STRENGTH TRAINING AND EXERCISE PRESCRIPTION FOR REHABILITATION PROFESSIONALS

AN EVIDENCE-BASED, THERAPEUTIC EXERCISE TEXTBOOK

JENNA A. MATTERA

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Strength Training and Exercise Prescription for Rehabilitation Professionals is a modern, evidence-based, therapeutic exercise textbook written for clinicians, by a clinician. The content aims to fill any gaps in exercise knowledge and truly highlights the application and integration of progressive resistance training into the rehabilitation setting. This book delivers a vast, well-researched exercise library and provides sound guidance on developing a comprehensive exercise program, including exercise selection, prescription, and dosing for any individual.

Strength Training and Exercise Prescription for Rehabilitation Professionals details a variety of progressions and regressions that allow a primary movement pattern – the squat, deadlift, bridge, push, pull, and carry – to be performed by individuals of all ages, body types, and experience levels. It considers specific factors that apply to injured populations, like pain, phase of healing, pre-requisite range of motion, and strength requirements. The exercise chapters feature many pieces of resistance training equipment, but also explain how to perform and modify bodyweight exercises to achieve the desired training effect, as access to equipment often varies. High-quality images are paired with step-by-step, written explanations, and valuable coaching cues aim to aid instruction and execution. In addition, it also highlights current evidence for rehabilitation of specific diagnoses, including Anterior Cruciate Ligament (ACL) reconstruction, lower back pain, patella, and Achilles tendinopathy.

This textbook is an excellent resource for both new clinicians and seasoned professionals who desire concise, factual guidance and reference to support the development of their rehabilitative exercise programs. It would be a worthwhile addition to the curriculum of any physical therapy, chiropractic, or athletic training program, but is also appropriate for anyone that may interact closely with rehabilitation clinicians, like strength and conditioning coaches, personal trainers, exercise physiologists, and other fitness professionals with one common goal: improve quality of care and maximize patient outcomes through exercise.

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ABOUT THE AUTHOR

I will never forget the day that I told my father I was going to pursue a path in physical therapy. He asked me one simple question: "Do you think you're smart enough for that?" It was not meant in a negative or condescending way; he was just genuinely asking how confident I was in my ability to achieve that goal. And rightfully so: I entered undergraduate college as a political science and pre-law major, and had always gravitated more toward the humanities as opposed to the sciences. Still, to his question, I replied, "Yes, I believe so." He nodded in acceptance.

I graduated cum laude from the University of Massachusetts at Amherst in 2012 with a bachelor of science dual-degree in kinesiology and sport management from the Isenberg School of Business. I received my doctorate of physical therapy from the University of Massachusetts at Lowell in 2016.

I started my career in outpatient physical therapy clinics, where I developed a solid manual therapy skill set and worked with a wide variety of orthopedic and neurological conditions. I earned certifications in vestibular rehabilitation, functional dry needling, and a Certified Strength and Conditioning Specialist (CSCS) designation from the National Strength and Conditioning Association (NSCA). I consider myself a well-rounded therapist who has since worked in multiple settings, including outpatient, acute care, home care, and has developed extensive experience with personal training. In 2021, I opened my own private practice, Mattera Physical Therapy, in Boston while still working full time as a senior physical therapist at a community hospital. I have also enjoyed working in additional roles as a clinical instructor to doctoral students, an adjunct faculty member for a physical therapy assistant program, and guest lecturer for my alma mater's doctoral program. I thrive when I am busy and feel fulfilled when most would feel overwhelmed. It may seem as though my career has had many offshoots but, to me, all of these different spokes tie everything together and have had countless benefits personally and professionally.

Aside from my work and authorship, I enjoy weightlifting and Brazilian jiu-jitsu. I pride myself on the fact that I am still an athlete at 34 years old… but more importantly, I am an athlete with the knowledge and training to understand how to work with other athletes and active adults. My hobbies and personal experiences have immeasurably shaped my practice. When I am not at work, in the gym, or on the mats, I enjoy many of life's simple pleasures like petting every possible dog (including my own dog, Rocko) and traveling.

After more than eight years in clinical practice in multiple settings, some experience in academia, ten-plus years as a strength-minded personal trainer, and, most recently, a published author, I can now say with the utmost certainty, "Yes, Dad, I *am* smart enough for that."

PREFACE

Strength Training and Exercise Prescription for Rehabilitation Professionals is the book I wish I had in school: a modern, evidence-based, therapeutic exercise textbook written for clinicians, by a clinician.

Exercise is one of the primary treatments we use in our practice, but deserves greater focus inside the classroom. There is a need to increase the understanding and application of exercise, specifically resistance training, in rehabilitation education. Students who don't enter a professional program with a strong exercise background or do not secure top-tier clinical affiliations will be expected to learn the skills of exercise selection, prescription, and dosing, but often lack concise, factual guidance and reference. As a result, it is not uncommon for many new clinicians to express a lack of confidence in their knowledge in these areas. Even clinicians with years of hands-on experience may benefit from further education on well researched, contemporary exercises, and how to integrate them into the rehabilitation setting using traditional strength training principles. This book aims to fill any gaps in exercise education and to serve as a sound classroom resource.

Strength Training and Exercise Prescription for Rehabilitation Professionals is packed with current, high-quality scientific evidence, paired with clinical experience. It highlights the importance of providing an appropriate training stress via progressive overload principles, how to design a rehabilitation program, and how to train in the presence of pain. The exercise chapters are strategically organized: squat, hinge, and bridge exercises are grouped by movement pattern because they are foundational movements that activate many muscle groups. Each of these exercises has many variations that require similar technique, set-up, and coaching cues. The remainder of the exercises are delineated by muscle group to improve ease of navigation through the exercise library. The exercises included range from basic to advanced and take into account differing access to equipment. This book supports the use of strength training equipment (e.g. barbells, kettlebells, and specialized machines) or the use of dumbbells, bands, and even simple bodyweight to achieve the desired training effect. The aim is to provide different ways to accomplish the same goal and allow a primary movement pattern to be performed by any individual through various progressions and regressions. This is important in the rehabilitation setting because, despite a similar diagnosis, very few patients can be treated exactly the same and will require individualized programming and coaching that respects their level of mobility, body type, experience level, strength, pain, and goals. This book also highlights the best current evidence for rehabilitation and exercise selection for specific diagnoses and patient populations, including ACL reconstruction, lower back pain, and tendinopathies.

This new textbook is not intended to take the place of other staple therapeutic exercise textbooks, but rather to be a complement that provides greater depth regarding developing a comprehensive therapeutic exercise program for any individual. The quality and quantity of this exercise library alone is far superior to any competing book on the market. It would be an excellent addition to the curriculum of any physical therapy, chiropractic, or athletic training program, but is also appropriate for strength and conditioning coaches, personal trainers, exercise physiologists, and other fitness professionals that may interact closely with rehabilitation clinicians.

This book will serve a critical role in teaching students, new graduates, and even seasoned professionals proven methods to improve quality of care and maximize patient outcomes through exercise.

Dr. Jenna A. Mattera, PT, DPT, CSCS

ACKNOWLEDGMENTS

This book would not be possible without the outstanding knowledge, guidance, and sometimes patience that was provided to me by my professors, mentors, managers, and clinical instructors.

A few special mentions: My undergraduate professor Barry Braun, PhD, whose course sparked my interest in the health and wellness field and who encouraged me to pursue a career in physical therapy; JoAnn Moriarty-Baron, DPT, my neurological physical therapy professor – I idolize her for her knowledge, wit, and clinical expertise – who helped me fully believe in myself, what I am capable of as a clinician, and played a large role in helping me connect with a publishing company that also believes in me like she did; Michele Fox, DPT, my graduate clinical education coordinator, who continues to give me a platform by inviting me back to my alma mater each year to educate on the topics of strength training and exercise prescription; and Andy McLarky, PT of Soul Physical Therapy, my former manager and mentor, who significantly shaped my clinical practice and strength-forward treatment style.

To the owners of Soul Physical Therapy in Beverly, MA, Boston Physical Therapy and Wellness in Winchester, MA, and Boston Underground Strength Training in Waltham, MA: many thanks for generously donating your clinics, space, and equipment for the exercise photos featured throughout this book. Also, thank you to the equally amazing and talented Tamara Hanley of Tamara Merri Photography for capturing and producing photos. She is a creative force.

Lastly, this book, my successes, and growth in both life and my career would not be possible without the unwavering support of my friends and family members. Many of these individuals are pictured in the exercise chapters, including my mother, aunt, and uncles. My sister, Alexis Silberberg, completed all the preliminary edits of this entire text multiple times over. My father and brother – educators with a combined 50 years of classroom experience – understand and have instilled in me the value of a good book; for listening to, inspiring, and challenging me, you all have my lifelong gratitude.

CHAPTER 1

PRINCIPLES OF PROGRESSIVE OVERLOAD

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GENERAL ADAPTATION SYNDROME (GAS)

The human body is an amazing thing. Of the approximately eight billion living people on the planet, each one is unique, yet most share the ability to adapt to their environments, navigate inherent stressors, and rebound appropriately. General adaptation syndrome is the body's response to the physical stress of exercise. Following exercise, the body enters an alarm phase where normal homeostasis is disrupted and there may be a short-term decline in performance capacity as a result of muscle soreness, fatigue, or even pain. With an appropriate level of stress, the body will either return to its baseline level (adaptation phase) or perform at a higher level (supercompensation phase). Over-training will occur if the stress is too great and may lead to a long-term reduction in performance capacity or injury.[1] The sequence of events is depicted below (Figure 1–1).

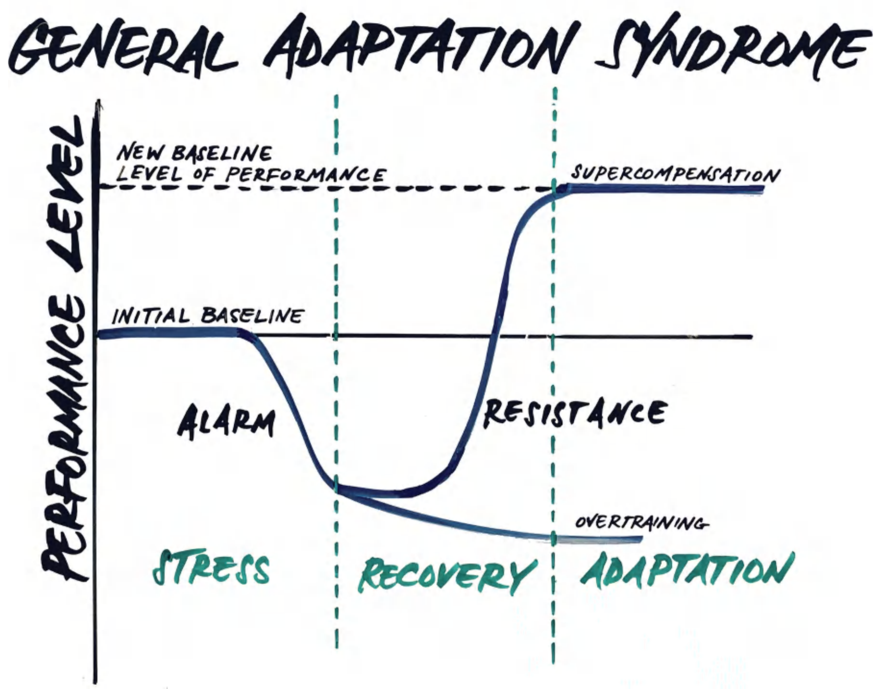

Figure 1-1 *General adaptation syndrome diagram*

PERIODIZATION AND PROGRESSIVE OVERLOAD

Change is created by continuously adapting to achieve desired results. If you're dissatisfied with something in your life, will you continue doing all the same things, expecting the situation to improve on its own, or will you analyze the issue and take action to remedy it? General adaptation syndrome is a perfect example of this. Strength and conditioning coaches work tirelessly to develop training programs that will drive performance above baseline levels. If we do not provide adequate training stress, we will not reach a new level of performance capacity. This is accomplished via progressive overload – the gradual increase in training stress over time. Progressive overload is accomplished through periodization, the calculated manipulation of training variables (load, volume, exercise selection, order, tempo, rest periods, etc.) to achieve a specific goal. The most common periodization schemes used are linear, non-linear, and block.

Linear periodization focuses on improving one goal at a time using predictable changes in volume and load over the course of at least three months. Load will typically start low and change with an inverse relationship to volume. Non-linear periodization, as its name suggests, is quite the opposite. Daily, weekly, or bi-weekly changes in volume and load allow multiple training goals to be addressed over a similar time frame and can also promote increased neuromuscular adaptation and recovery time. Block periodization consists of three different training phases, each lasting two to four weeks in duration, followed by a deload phase at 50% one repetition maximum upon completion. The one repetition maximum (1RM) is the load that can be lifted during one maximal effort trial and allows the number of repetitions at a certain weight for a submaximal lift to be easily determined. During the accumulation phase of the block, loads are set at 50–70% of 1RM.[1] Load increases to 70–90% during the transmutation phase, and greater than 90% during the realization phase.[1] The application of each method of periodization to rehabilitation program design is explained in detail in the next chapter.

There is no evidence that one model of periodization is superior, but periodized programs are more successful for maximal strength gains compared to programs designed without periodization in mind.[2,3] In the rehabilitation setting, non-linear and block periodization, or a combination of the two, are commonly used for program development. Improving muscle strength, size, endurance, or power all require slightly different training methods, which are detailed below (Table 1–1). The step-by-step progression from muscle endurance to power training does not need to occur for every patient. For example, a post-surgical patient with some degree of muscle atrophy whose daily living and recreation activities do not require maximal strength and power will likely benefit most from improving a muscle's ability to function and grow through muscle endurance and hypertrophy. An athlete whose primary goal is to return to sport at a high level will likely require progression into the strength and power phases to maximize their ability to generate force using higher loads and velocities. The literature also suggests patterns to allow better understanding of how to manipulate training variables to accomplish specific goals.

Table 1-1 *Training for a specific goal – muscle endurance, hypertrophy, strength, or power. Adapted from Baechle and Earle[1], and Cormie et al.[4, 5]*

	Repetitions	*Sets*	*% of 1RM*	*Rest*
Endurance	15+	2–3	50–70%	<30 seconds
Hypertrophy	8–12	4–6	70–80%	30–90 seconds
Strength	4–6	2–5	80–90%	2–5 min
Power	1–3	3–5	0–30% (e.g. plyometric and ballistic exercises) 80% (e.g. clean and snatch) >90% for maximal power, but lower velocity (e.g. deadlift, bench, squat)	3–5 min

MUSCLE ENDURANCE

Muscle endurance is a muscle's ability to contract repeatedly under load for an increased duration of time. Endurance training is very well understood and requires high-repetition training at low percentages of 1RM, even as low as 30%.[6] Improving muscular endurance is important if your sport, job, hobbies, or daily living activities require repeated contractions under submaximal or low loads, which most do. Think of a construction worker swinging a hammer, a custodian mopping the floor, or a tennis player during a back-and-forth match. These are all repetitive motions that, with improved muscular endurance, may become easier and more sustainable. High-repetition training may be beneficial in the rehabilitation setting to manage pain, build movement tolerance, overall stamina, and to recover from higher intensity training days.

MUSCLE STRENGTH

Muscle strength is a muscle's ability to produce force and is usually measured during a 1RM effort. Training load matters the most for strength training. High load training (greater than 60% of 1RM) has been proven superior to low load training to stimulate maximal strength gains.[7–14] Although strength gains have been observed initially while using low load training, these findings may be due to neurological adaptations and have been shown to plateau in the long-term.[13,15] High load training certainly has a place in rehabilitation programs, especially for athletes, weightlifters, parents of young children, and those that have other physically demanding careers (laborers, first responders, etc.). Training loads in the four to six repetition maximum range will still target muscle strength, but may decrease risk of injury compared to using one repetition maximum training.

MUSCLE HYPERTROPHY

The primary goal of muscle hypertrophy training is to improve muscle mass (size) by increasing the cross-sectional area of the muscle fibers. Training volume and lifting at or near failure are far more important than repetition range and amount of load used if the aim is to increase muscle size. Muscle hypertrophy appears to have a dose-response relationship with training volume.[9,14,16–18] This means that training a muscle at a greater frequency, either by using a greater number of sets or training days per week, resulted in increased muscle hypertrophy.[9,14,16,18–21] In general, using at least ten sets per week per muscle group is recommended for muscle growth,[11,17,20] but the intensity at which the exercise is performed can vary greatly. A recent systematic review by Baz-Valle et al.[22] supports increasing volume to 12–20 sets per week, which appeared more effective than lower volume training (less than 12 sets per week) for enhancing muscle hypertrophy of the quadriceps and biceps. Specific muscle groups, like the triceps, benefited from even higher volume at greater than 20 sets per week.[22] Significant changes in muscle hypertrophy occur when using both high and low training loads.[8–13,15,23,24] Although it has been determined that training to muscle failure is not required to induce muscle hypertrophy,[11,25–29] it can be beneficial when utilizing lower loads or when working with individuals that have a greater amount of training experience.[11,13,15,24,26] Hypertrophy training is used frequently in rehabilitation programming to improve muscle cross-sectional area, which may be lost due to injury and disuse.

MUSCLE POWER

Power training improves a muscle group(s) ability to produce maximal force and velocity. This is accomplished via weight training, ballistic, or plyometric exercises that mimic the metabolic demands of the desired activity, primarily sport. A significant level of strength must be achieved prior to power training, as strength is essential for generating maximal power.[5] Peak power production varies widely based on the type of exercise and load used. Power is maximized at 0% (bodyweight) for the jump squat, 30% 1RM for ballistic bench press throw, and up to 80% 1RM for traditional power based weightlifting exercises, like clean and snatch variations.[5] As load increases, it becomes more difficult to generate velocity, so it may be beneficial to train power movements at both light and heavy loads to maximize adaptations along the force-velocity curve,[4, 5] as illustrated below (Figure 1–2). Maximal strength development and power training can be successfully implemented in rehabilitation programs and may be an essential part of return to sport training for some individuals. However, it is of utmost importance to improve tissue capacity and strength first before progressing to power activities.

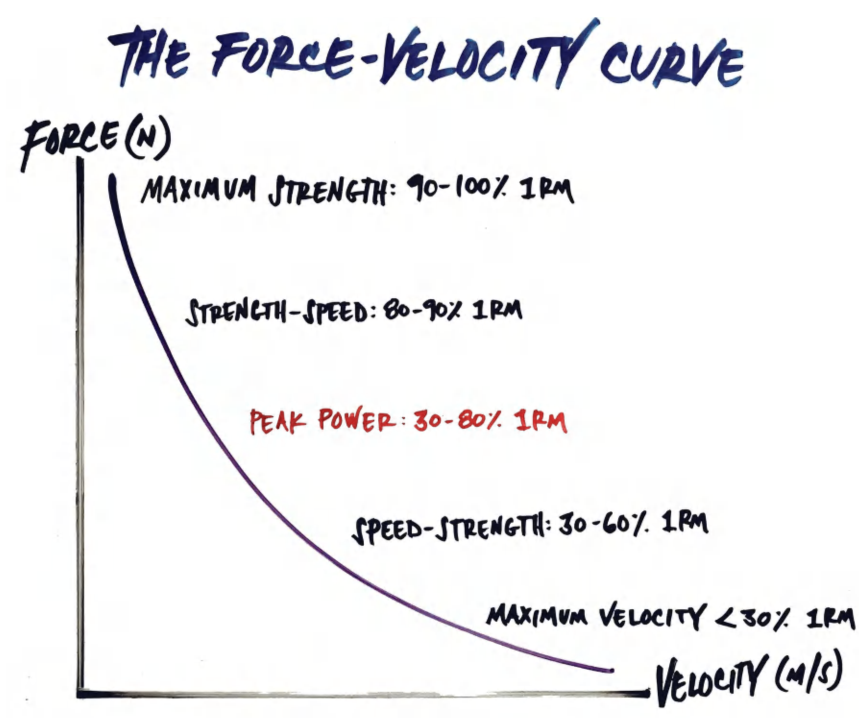

Figure 1-2 *Force-velocity curve*

CLINICAL SIGNIFICANCE OF SELECTING THE APPROPRIATE EXERCISE DOSE

Improving muscle strength and size are primary training goals of athletes and bodybuilders, but are just as important for older adults – a population at high risk of developing sarcopenia. Sarcopenia is the decline in skeletal muscle mass with age; it can begin as early as age 35 and contribute to impaired functional capacity and frailty among the afflicted. There are many potential causes, but physical activity is one that our profession has the ability to modify.[30] To build muscle mass, muscle protein synthesis must exceed protein breakdown. Muscle protein synthesis and exercise-induced muscle hypertrophy occurs when a loading stimulus activates anabolic pathways, thus increasing the number of contractile components and sarcomeres within a muscle.[31] Older adults respond to resistance training quite favorably, especially at higher intensities or 70–80% of their 1RM, which falls into the hypertrophy training range.[32] It is also important to note that continuing resistance training beyond the initial cycle is crucial to help retain muscle mass and prevent muscle atrophy. A study by Mertz et al.[33] observed statistically significant increases in muscle strength and hypertrophy after both light and heavy resistance training protocols, but a decrease in muscle cross-sectional area was evident when resistance training ceased for a period of six months. Those that continued resistance training, however, appeared to preserve their muscle mass.[33]

Despite the research that supports the use of periodization and progressive overload, many rehabilitation professionals often put less emphasis on these fundamental principles than their strength coach counterparts. This has not gone unnoticed. The act of prescribing under-dosed training programs is now under scrutiny by the American Physical Therapy Association. The 2014 "Choosing Wisely" initiative proposes new standards to establish baseline levels of strength: use an exercise dose that is "physiologically adequate" for strength gains, and match frequency, intensity, and duration of exercise to abilities and goals of the individual. The lack of knowledge or understanding among rehab professionals on how to implement these concepts into a clinical setting is imperative to address. While it is understandable that some professionals may not know how to implement this in a clinical setting, they are just that: professionals. Professionals can use their knowledge and training to adapt their methods and achieve the desired results.

A SIMPLE CLINICAL REPETITION MAXIMUM TEST

Falvey et al.[32] propose two simple methods to gauge 70–80% of one repetition maximum and establish baseline levels of strength in a clinical setting.

1. Select a weight that produces muscle fatigue and failure at 8 to 12 repetitions. This can be determined by an individual's subjective report of failure or objective failure, like form breakdown.
2. Use a rating of perceived exertion (RPE), a subjective scale of effort, of 15–17 on the 6–20 Borg scale, which equates to work classified as being "hard" to "very hard."

Falvey et al.[32] piggyback on the research of Eston and Evans[34] who validate use of the Borg scale and RPE method (Figure 1–3) for accurate one repetition maximum prediction, despite it being a subjective scale. These findings remain consistent among both trained and untrained individuals. If a formal RPE scale is difficult for an individual to fully understand, another strategy would be to instruct the patient to stop when they have about two repetitions in reserve, meaning that they could only perform two more repetitions prior to failure. The actual weight or load, tempo at which the exercise is performed, or a designated pause may be adjusted or added accordingly to induce muscle fatigue and approach failure at 8 to 12 repetitions. A 1RM chart (Table 1–2) can be used for comparison or the load may be entered into an online repetition maximum calculator, such as the one found on the National Academy of Sports Medicine website, to gauge which weight to use for higher and lower repetition training if indicated.

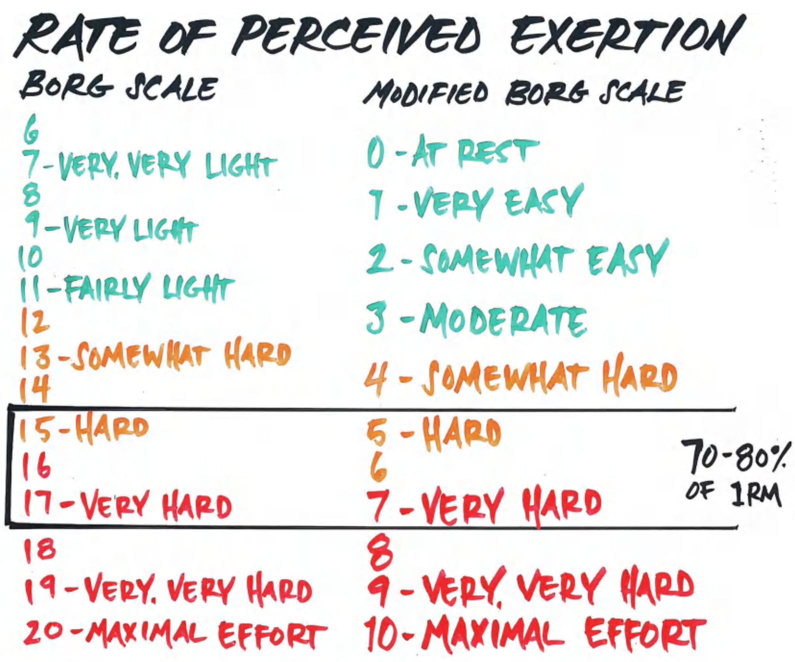

Figure 1-3 *RPE using the Borg and Modified Borg scales*

Table 1-2 *Repetition maximum and percentage of training load used*

Repetitions	***1***	***2***	***4***	***6***	***8***	***10***	***12***
% 1RM	100%	95%	90%	85%	80%	75%	70%
Weight in pounds (lb)	10	9.5	9	8.5	8	7.5	7
	20	19	18	17	16	15	14
	30	28.5	27	25.5	24	22.5	21
	40	38	36	34	32	30	28
	50	47.5	45	42.5	40	37.5	35
	60	57	54	51	48	45	42
	70	66.5	63	59.5	56	52.5	49
	80	76	72	68	64	60	56
	90	85.5	81	76.5	72	67.5	63
	100	95	90	85	80	75	70

FURTHER APPLICATION OF PERIODIZATION PRINCIPLES IN A CLINICAL SETTING

In the rehabilitation setting, we cannot focus exclusively on load and often need to approach resistance training with a handful of different strategies to accomplish the same goal. Simply adding extra weight may not be successful for someone who physically or emotionally is not ready for that challenge. Increasing load may cause pain, significant form breakdown, or may be counterproductive to the specific injury or the stage of tissue healing. An individual may also have fear or beliefs related to exercise, which increasing load may trigger.

Table 1-3 *Change the training focus with methods other than increasing load*

Increase load	*Change tempo*	*Add a pause*
20 lbs 8 repetitions	10 lbs with tempo 4:1:1* 10 repetitions	10 lbs with 3-second pause 12 repetitions
Assume that the individual now reports a rate of perceived exertion of 16/20 or 6/10 (between hard and very hard) after each adjustment. **4-second eccentric, 1-second hold, 1-second concentric*		

Three different scenarios to shift the training focus from muscle endurance to muscle hypertrophy are detailed (Table 1–3); only one requires altering the load. Assume that an individual initially performs 20 repetitions of a 10-pound goblet squat until reported and observed muscle fatigue.

A recent randomized controlled trial by Plotkin et al.[35] also supports the idea of progressive overload without increasing the actual weight used. The study compares two different training programs that include four sets of each exercise (back squat, leg extension, standing, and seated calf raise) performed twice a week for eight weeks. After establishing a 10RM load, the first program increases load and keeps repetition range constant at 8–12 while the second program increases repetitions until muscle failure, but keeps the load constant at the initial 10RM load. Increasing repetition range while keeping load constant produced similar increases in lower body muscle mass, 1RM strength (back squat), and leg extension muscle endurance compared to just increasing the weight.[35]

PAIN MONITORING MODEL

The focus of the next chapter is how to develop a comprehensive rehabilitation program. In order to implement and progress these programs successfully, transparency and education are vital. Many individuals have emotions, beliefs, and behaviors related to pain, injury, and activity. The more the individual understands how the methods being employed will produce the desired results, the more likely it is for them to be an active participant in their recovery journey. Therefore, when designing and modifying an exercise program, pain education, pain monitoring, loads management, and creativity are all key factors. A painful stimulus activates nociceptors that carry signals to the spinal cord and eventually to the brain where pain is realized and perceived by an individual. Pain does not always equal injury of a specific tissue structure. Pain is complex and shaped by experiences, a fact that is supported by current literature. A systematic review by Brinjikji et al.[36] supports that a high proportion of individuals with no pain have degeneration on their spinal imaging; conversely, studies by Bishop et al.[37] and George et al.[38] demonstrate a high correlation of fear of pain to post-exercise pain and muscle soreness. Since pain does not equal injury, feeling "stuff" while training is okay if it is maintained at an acceptable level. Use of the pain monitoring model proposed by Silbernagel et al.,[39] allows individuals to train if the pain rating is less than 5/10 on a 0–10 scale. Pain should not progressively increase throughout, should not be worse by the end of session, and symptoms should not worsen or should subside over a 24–48-hour period. A visual description of the pain monitoring model is provided below (Figure 1–4). When using this model, individuals with Achilles tendinopathy were able to continue running and exercise did not negatively affect outcomes when compared to rest (no running or jumping) for the first six weeks, as long as symptoms were monitored.[39] For this model to work, you must be willing to manipulate load, volume, range of motion, or change the movement pattern all together to alter pain and stay under the threshold. Educate, listen, and adjust based on patient response.

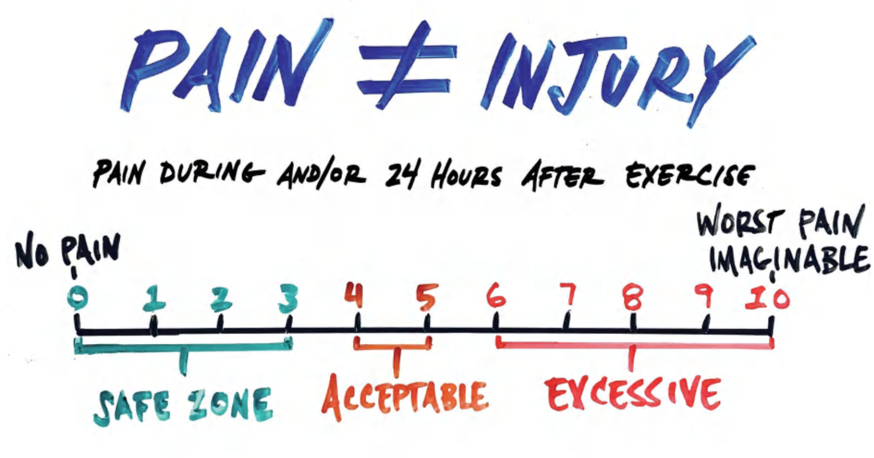

Figure 1-4 *Pain monitoring model*

CHAPTER 2

BASIC PROGRAM DESIGN

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BASIC REHABILITATION PROGRAM COMPONENTS

A solid rehabilitation program should focus on basic, foundational movement patterns: squat, hinge, push, pull, and carry. These movements mimic the majority of functional activities, activities of daily living, job duties, and recreational activities that an individual must perform. One to two bilateral, multi-joint movements can serve as the core, supplemented by accessory movements including single-joint, single-limb, and static or dynamic stabilization exercises (Table 2–1). Exercises should take place in multiple planes of movement, frontal, sagittal, and transverse (Figure 2–1), and force should also be exerted in many directions, vertical, horizontal, medial, lateral, forward, backward. This allows greater specificity with exercise selection, the ability to train in positions that mimic the demands of activities or sport, but may also take an individual out of their usual patterns and strategically train alternate planes of motion. For example, hockey players are heavily biased to moving side to side or in the frontal plane; although they need to be strong and dynamic in this plane, they would also benefit from performing sagittal plane exercises (forward and reverse lunges, skater squats, etc.) and should focus on directing force in a horizontal direction, potentially with bridges and hip thrusts, to improve "sprint" speed. This can help prevent overuse of specific muscle groups and promote overall joint health.

An exercise program can immediately follow manual therapy or be preceded by one to three targeted warm-up activities that may emphasize mobility, stability, or dynamic movement, based on need. Warm-up exercises can be loaded or unloaded. Each program should focus on an individual's strengths, weaknesses, and aberrant movement patterns, with respect to their condition, progressive overload, and periodization, as already stressed in the previous chapter. Unsurprisingly, there are no clear guidelines for designing rehabilitation programs, and periodized programs for injured individuals have not been widely studied.

Table 2-1 *Types of stability exercises, adapted from O'Sullivan and Schmitz*[40]

Anti-movement stability	Maintain the body in the desired position and resist movement in a specific direction while the limbs are not moving. Planks and some dead bug variations are considered anti-movement stability exercises.
Dynamic stability	Maintain the body in the desired position and resist movement in a specific direction when the body needs to shift weight or when the limbs are in motion. Planks and dead bugs with limb movements, chops, lifts, crawling, and carries are considered dynamic stability exercises. It is possible for a dynamic stability exercise to have an anti-movement component. For example, in addition to stabilizing for the movement in the upper extremities during the press-out exercise (see page 412, 417), the body must also resist rotation of the trunk (anti-rotation) toward the direction of the resistance.

Reiman and Lorenz[41] propose using three phases of exercise during rehabilitation: (1.) immediate phase to develop muscle endurance, reduce pain and inflammation; (2.) intermediate phase to continue the tissue healing process through muscle hypertrophy and strength, progressing from lower to higher intensity; and (3.) advanced phase for continued development of strength, power training, agility, and return to sport activities. They use criteria instead of time frames in order to progress to the next phase, which may include pain reduction, gains in range of motion, strength, and form maintenance during exercises. Lorenz et al.[42] propose longer-term (12+ week) linear and non-linear programs following anterior cruciate ligament (ACL) rehabilitation that allow transition from endurance to power phases. While either would be appropriate for ACL rehabilitation, many individuals who suffer from other conditions are not in supervised rehabilitative care for 12–24+ weeks. Programs that develop over a shorter period may be more appropriate for the general population and follow a normal rehabilitation timeline, typically 6–10 weeks. In combination with sound clinical judgment, the following plans can serve as initial templates for program development, guide clinical decision making, and create a plan of care. As you continue to learn and gain experience, you will begin to construct and adapt your own protocols in order to make them effective to suit the unique needs of each individual.

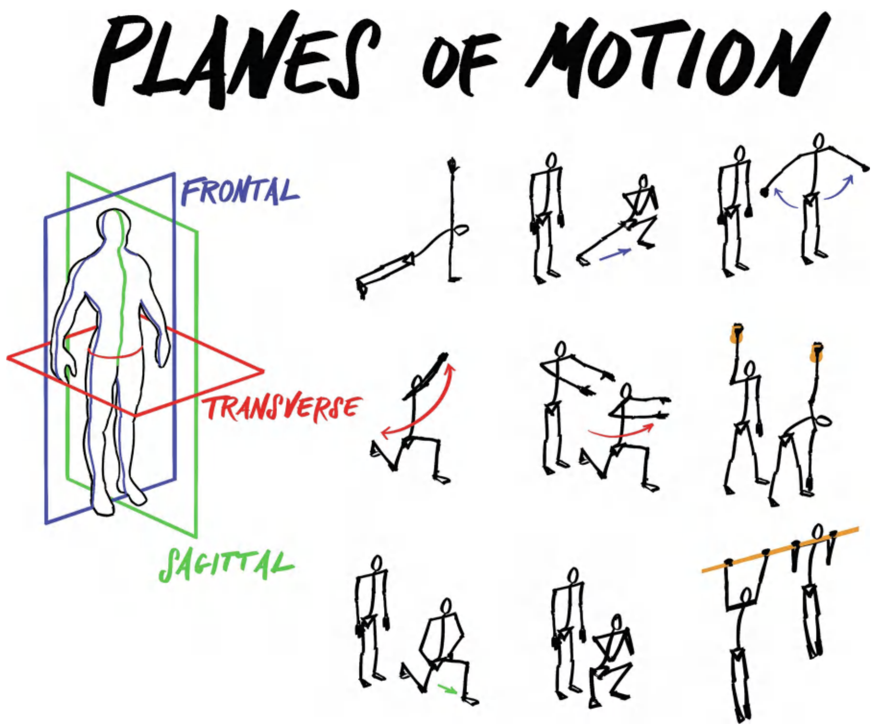

Figure 2-1 *Planes of motion – (A) The top row are frontal plane movements from left to right (high plank, lateral lunge, lateral raise); (B) The middle row are transverse plane movements from left to right (half kneeling chop/lift, lunge with trunk rotation, kettlebell windmill). On the bottom row are sagittal plane movements from left to right (forward lunge, squat, pull-up)*

LINEAR PERIODIZATION

Linear periodization can be very advantageous for beginners to allow advancement of training loads while building the proper foundation, experience, and confidence to eventually progress outside of the clinical setting. The program parameters will change less frequently, which makes it easy to learn and implement based on the predictable nature of load and volume fluctuations. This ten-week program (Table 2–2) will focus on muscle endurance and hypertrophy. It falls a bit short of a true three-to-four-month cycle that is typical of linear periodization, but can prepare for an eventual transition to a home exercise or gym program for continued maintenance or strength and power phases, if indicated.

Table 2-2 *Linear periodization, ten-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The individual will perform the same workout on both days*

Linear periodization: Ten weeks, two days per week of exercise				
Week	Load as % of 1 Rep Max	Set 1	Set 2	Set 3
1	60–65%	15	15	20
2	60–65%	15	15	20
3	65–70%	15	15	12
4	70–75%	12	12	10
5	70–75%	12	12	10
6	70–75%	12	12	10
7	75–80%	10	10	8
8	75–80%	10	10	8
9	80–85%	8	8	6
10	80–85%	8	8	6

NON-LINEAR PERIODIZATION

There are often peaks and valleys throughout the rehabilitation process and different goals may need to be addressed on a day-to-day basis. Daily changes in volume, load, and overall intensity that occur with non-linear periodization (Table 2–3) may be ideal for the rehabilitation setting. This approach may allow for increased recovery time and flexibility when issues arise throughout the course of treatment (think: fluctuations in pain, response to training, schedule changes, missed days of therapy, etc.).

Table 2-3 *Non-linear periodization, six-to-eight-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional and one day per week outside of the clinic as a home exercise or gym program*

Non-linear periodization: Eight weeks, three days per week of exercise						
Week	Day 1		Day 2		Day 3	
1	Endurance	2 × 15	Hypertrophy	3–4 × 12	Endurance	2 × 20
2	Hypertrophy	3–4 × 12	Endurance	2 × 15	Hypertrophy	3–4 × 10
3	Hypertrophy	3–4 × 10	Strength	5 × 6	Hypertrophy	3–4 × 8
4	Hypertrophy	3–4 × 8	Strength	5 × 6	Endurance	2 × 20
5	Strength	5 × 5	Hypertrophy	3–4 × 8	Strength	5 × 5
6	Strength	4 × 4	Power (low intensity)	5 × 3-5	Strength	4 × 4
An additional two weeks can be completed in-person and supervised, independently upon discharge, or during a two-week hiatus prior to discharge to ensure readiness to self-manage.						
7	Hypertrophy	3 × 7	Strength	5 × 5	Hypertrophy	3 × 7
8	Power	3 × 3	Strength	4 × 4	Hypertrophy	4 × 8

BLOCK PERIODIZATION

Block periodization follows the "consecutive development" model similar to linear periodization, but allows for increased variability in the duration of each phase.[43] The accumulation phase focuses on the development of the basics, building tissue capacity, and can be compared to the endurance phase of traditional models. It can be much shorter, as seen below (Table 2–4) for well-trained individuals or can be adjusted to a longer duration for beginners, but will set the stage for the rest of the recovery process. In the rehabilitation setting, we generally spend the most time in the transmutation phase developing adequate levels of muscle hypertrophy and strength to return to full, pain-free activity; we can adjust the duration of this phase based on the patient's response. The realization phase represents the return to maximal effort sport, specific activities, and power, which is followed by a short-duration deload phase – a well-deserved break to aid in recovery from competition level intensity.[43]

Table 2-4 *Block periodization, nine-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The accumulation phase is two weeks at 50–70% of 1RM; the transmutation phase is four weeks at 70–90% of 1RM; the realization phase is two weeks at 90% or greater 1RM; and the deload phase is one week at 50% or less 1RM*

Block periodization: Nine weeks, two days per week of exercise				
	Week	Day 1	Day 2	% 1 Rep Max
Accumulation	1	2 × 20	2 × 20	60%
	2	3 × 15	3 × 15	65%
Transmutation	3	4 × 12	4 × 10	70–75%
	4	4 × 10	4 × 8	75–80%
	5	4 × 8	4 × 6	80–85%
	6	4 × 6	4 × 5	85–90%
Realization	7	3 × 4	3 × 4	90%
	8	5 × 2	5 × 2	95%
Deload	9	3 × 8–10	3 × 8–10	50% or less

REST PERIODS

Timed rest periods aim to allow adequate recovery between sets and may be better adhered to when their mechanisms are understood by both the clinician and client. After a set of resistance training, a rest period will allow removal of byproducts, restoration of blood flow, oxygen, phosphocreatine stores, pH, and membrane potential that will allow the muscle in question to contract again under similar conditions of the first set.[44] Multiple studies have observed similar improvements in muscular hypertrophy using either long (two and a half to three minutes) versus short (one minute) rest intervals.[21,45] Schoenfiend et al.[46] also observed greater improvements in muscle hypertrophy using long (three minutes) versus short (one minute) rest intervals in a group of experienced, resistance trained individuals with load adjusted and when training to muscle failure. Any post-exercise hormonal changes, like increased growth hormone, testosterone, cortisol, and insulin-like growth factor are no different in the long-term when using long or short rest intervals.[45,47]

Table 2-5 *Appropriate rest periods to use based on desired training goal*

Training Goal	***Rest Period (between sets)***
Endurance	≤30 seconds for trained individuals ≤90 seconds for untrained individuals May need to progressively lower weight to maintain repetition range between sets
Hypertrophy	1–3 minutes Lower rest once repetition ranges can be maintained between sets Can lower resistance to extend sets to failure (drop sets) and maintain intensity over multiple sets
Strength	3 minutes is ideal to maintain training intensity 4 minutes for heavy, grip-related exercises (deadlifts, shrugs)
Power	2–3-minute rest breaks 2–4 minutes for plyometrics <30 sec will not allow for restoration of phosphocreatine stores >6 minutes will take away from neural excitation

Adapted from Williardson,[44] Longo,[21] Buresh et al.[45] and Schoenfiend et al.[46]

SUPERSETS

Supersets or agonist-antagonist paired set training can increase training efficiency by training alternate muscle groups immediately following the other without need for a structured rest break.[48] Supersets can allow more direct time spent with each individual, more to be accomplished within a single session or to induce greater training fatigue, but their actual application to mechanisms of strength and power development are not well understood.[49] It is beneficial to develop a method to label exercises for supersets (Table 2–6). The first letter or number serves to designate the superset and the second designates the order in which the exercises are performed. For example, the exercise "A1" will be performed, followed by "A2," at which point the individual will cycle back to "A1" and continue this process until each exercise is completed for the designated number of sets before moving onto the "B" exercises. Examples of how to structure lower (Table 2–7) and upper body (Table 2–8) supersets are detailed below. Alternatively, it would also be appropriate to pair upper and lower bod exercises together during superset training if the goal is to perform a total-body routine.

Table 2-6 *Two different options for labeling supersets*

Option 1	***Option 2***
A1	1A
A2	1B
B1	2A
B2	2B
C1	3A
C2	3B

Table 2-7 *Examples of lower body super sets. (A) The first column details the compound movement focus (squat, hinge, or bridge); (B) The second column provides a category that each movement pattern will fall into. For example, "double-leg squat" can be any variation of a double-leg squat, which will be covered in detail in Chapter 4; (C) The third column provides a specific exercise that fits into the movement pattern category listed in column two*

Lower body superset	A1 Double-leg squat	A1 Kettlebell squat
(Squat focus)	A2 Anti-movement stability	A2 Dead bug hold
	B1 Single-leg quadriceps	B1 Single-leg box squat
	B2 Single-leg glute/hamstring	B2 Single-leg bridge
	C1 Hip abductor	C1 Side plank clamshells
	C2 Dynamic stability/Locomotion	C2 Bear crawls
Lower body superset	A1 Double-leg hinge	A1 Kettlebell deadlift
(Hinge focus)	A2 Anti-movement stability	A2 High plank shoulder taps
	B1 Hip abductor	B1 Double-band lateral walks
	B2 Single-leg glute/hamstring	B2 Rear foot elevated split squat (RFESS)
	C1 Single-leg glute/hamstring	C1 Single-leg deadlift
	C2 Single-leg quadriceps/locomotion	C2 Sled pull
Lower body superset	A1 Double-leg bridge	A1 Barbell bridge
(Bridge focus)	A2 Anti-movement stabilization	A2 Bear plank
	B1 Single-leg glute/hamstring	B1 Foot elevated single-leg bridge
	B2 Hip abductor	B2 Side-lying hip abduction
	C1 Single-leg quadriceps	C1 Lateral lunge
	C2 Dynamic stability/locomotion	C2 Farmer's carry

Table 2-8 *Examples of upper body super sets. (A) The first column details the compound movement focus (push or pull); (B) The second column provides a category that each movement pattern will fall into. For example, "double-arm pull" can be any variation of a row or pull-up, which will be covered in detail in Chapter 9. (C) The third column provides a specific exercise that fits into the movement pattern category listed in column two*

Upper body superset	A1 Double-arm pull	A1 Seated cable row
(Pull focus)	A2 Dynamic stability	A2 Reverse bear crawl
	B1 Single-arm pull	B1 Single-arm high row
	B2 Single-arm press	B2 Landmine press
	C1 Accessory shoulder exercise	C1 Face pulls
	C2 Accessory exercise for shoulder/forearm/core	C2 Horizontal abduction with press
Upper body superset	A1 Double-arm press	A1 Floor press
(Push focus)	A2 Dynamic stability	A2 High plank shoulder taps
	B1 Double-arm pull	B1 Suspension strap row
	B2 Single-arm press	B2 Bottoms up kettlebell press
	C1 Accessory shoulder exercise	C1 Straight-arm pulldown
	C2 Accessory exercise for shoulder/forearm/core	C2 Band pull apart

TEMPO

Tempo, the prescribed speed at which portions of the exercise are performed, and pause training may be beneficial for developing controlled movement patterns, focusing on weak points, and increasing difficulty without adding weight – all of which are very important in the rehabilitation setting. A slower tempo will increase time under tension, the amount of time under which the muscle must work, and therefore may cause a muscle to fatigue faster compared to repetitions performed at a faster velocity with the same weight.[50] Increased time under tension, specifically during the eccentric portion of an exercise, can produce greater levels of muscle ischemia, hypoxia, therefore promoting muscle hypertrophy.[31] The tempo is dictated by four phases of the movement pattern: eccentric, pause at the end of eccentric, concentric, pause at the top. For example, a squat with a four-second lowering phase, two-second pause at maximal depth, a concentric phase performed as fast as possible, and one-second pause at the top would be written as 4:2:0:1. Higher intensity, normal speed training is ideal for gains in muscle hypertrophy and strength,[51] but tempo training with a lighter load can be used to stimulate a hypertrophic response when heavy loads are contraindicated. In a randomized controlled trial by Tanimoto et al.,[52] use of a medium tempo (3:1:3:0) with a light load (50% 1RM) was just as effective as using a fast tempo (1:0:1:1) with a heavy load (80–90% 1RM) to stimulate hypertrophy. A similar increase in muscle cross-sectional area was also observed between groups utilizing slow (3:0:10:0), low load (40–60% 1RM) and fast tempo (1–2:0:1–2:0), high load (80–85% 1RM). However, slow tempo, low load resistance training produced a significant hypertrophic response compared to fast tempo, low load training.[51]

DROP SETS

Drop sets are performed by continuing a set with a lower load to prolong repeated contractions, increase time under tension, and to train until muscle failure. This level of muscle fatigue can be beneficial to enhance muscle growth due to increased metabolic stress and hormonal response. Drop sets help increase training volume, may promote increased muscle cross-sectional area and activation of type I fibers, but studies have not been able to prove a statistically significant advantage of drop sets compared to regular training.[9,53] Loads are usually reduced by about 20% each set, but there are no clear-cut guidelines.[54] Similar to supersets, drop sets can improve efficiency and decrease training time due to the onset of muscle fatigue. They produce a burning sensation and a feeling of complete muscle exhaustion, even when training at very light loads. Drop sets may be useful toward the end of a training session, as they are very taxing on the muscle group that is targeted. An example of drop set training for the biceps is detailed below (Table 2–9).

Table 2-9 *Drop set training. In this example, the initial weight is set at about 75% or 1RM, or a weight that can be managed for ten repetitions. The weight is reduced by about 20–25% for each drop set with the aim of performing ten repetitions with the lower weight without a designated rest period*

Exercise: Bicep curls

Repetitions: 10 repetitions

Sets: Four total working sets; 1 regular set plus 3 drop sets

Rest: None or minimal rest in between sets

Set 1 (primary working set)	Set 2 (drop set)	Set 3 (drop set)	Set 4 (drop set)
20 lbs	15 lbs	10 lbs	5 lbs

NON-PERIODIZED VS. PERIODIZED PROGRAMS

Let's compare non-periodized programs to progressive linear, non-linear, and block program designs. In the non-periodized programs, sets and repetitions remain constant and difficulty is progressed by arbitrary

LOWER BACK REHABILITATION

Table 2-10 *Non-periodized lower back rehabilitation, 10-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The individual will perform the same workout on both days*

Non-periodized: Lower back rehabilitation, ten weeks, two days per week			
Weeks 1–5		Weeks 5–10	
Pelvic tilt	1 × 20	Pelvic tilts	1 × 20
Transverse abdominis brace	1 × 10	Transverse abdominis brace with marching	2 × 10 each leg
Glute set	1 × 10	Bridges with ball adduction	3 × 10
Bridges	3 × 10	Bridges with band	3 × 10
Ball adduction	10 × 10 second hold	Clamshell	2 × 10
Double knees to chest	3 × 10 second hold	Bird dogs	2 × 10
Bird dogs	2 × 10 each	Squats with resistance band above knees	2 × 10
Passive stretching (30 seconds each): hamstrings, quadriceps, piriformis, hip flexors, calf			

Table 2-11 *Linear periodization for lower back rehabilitation, 10-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The individual will perform the same workout on both days. Rest periods are not needed or should be minimal, as all the exercises are performed as supersets*

Linear periodization: Lower back rehabilitation, ten weeks, two days per week			
Week 1	Weeks 2–3	Weeks 4–8	Weeks 9–10
60–65% 1RM	***60–65% 1RM***	***70–80% 1RM***	***80–85% 1RM***
A1: *Anti-movement stability* Dead bug hold 3 x 10–30 seconds A2: *Double-leg squat* Bodyweight box squat 2 × 15–20 B1 *Anti-movement stability* Bear plank 3 × 10–30 seconds B2 *Upper back mobility* Side-lying thoracic rotation 2 × 8 each side	A1 *Anti-movement stability* Dead bug hold 3 x 10–30 seconds A2 *Double-leg squat* Kettlebell box squat 2 × 10–12 B1 *Anti-movement stability* Bear plank 3 × 10–30 seconds B2 *Upper back mobility* Side-lying thoracic rotation 2 × 8 each side C1 *Hip abductor/ Anti-movement stability* Side plank 3 × 10–30 seconds each side C2 *Double-leg hinge/Dynamic stability* Hinge pulldowns 2 × 15–20	A1 *Dynamic stability* Dead bug alternating limbs 4 × 8–10 A2 *Double-leg squat* Kettlebell tempo squat 4 × 8–12 B1 *Dynamic stability* High plank shoulder tap 5 × 8–10 each side B2 *Double-leg hinge* Kettlebell deadlift 4 × 8–12 C1 *Hip abductor/dynamic stability* Side plank clamshell 4 × 8–12 each side C2 *Upper back mobility (with load)* Lunge thoracic rotation with kettlebell 3 × 8–12 each side	A1 *Dynamic stability* Half-kneeling chop/lift 4 × 6–8 A2 *Double-leg squat* Kettlebell squat 4 × 6–8 B1 *Double-leg hinge* Trap bar deadlift 4 × 6–8 B2 *Dynamic stability* Bear crawls 3 × 10–15 ft C1 *Hip abductor/dynamic stability* Side-plank lift (super clam) 4 × 6–8 each side C2 *Single-arm pull (to reinforce upper back mobility)* Single-arm row with rotation 4 × 6–8

amounts of resistance; there are no defined rest breaks or other means to increase difficulty (supersets, drop sets, tempo changes, etc.) and there is little to no change in exercise selection over its course. In the periodized programs, however, appropriate changes to load, sets, repetitions, and exercises will be made, as they should be for optimal outcomes.

EXERCISE SELECTION AND CLINICAL DECISION MAKING

The early stages of this periodized lower back rehabilitation program focus on developing static stability and mobility in order to progress to more advanced weight-bearing exercises, like loaded squats and deadlifts, as well as accessory exercises, like hip and upper back strengthening. Though we will not dissect the program in its entirety, it is important to understand the reasoning behind the transition from one exercise variation to the next. Core stability exercises, like the dead bug (see page 410), are first initiated using a static hold to reinforce understanding of the contraction, monitor for pain, and challenge endurance prior to initiating dynamic limb or body movements, which will make the exercise more difficult. In addition, transition to an alternate weight-bearing posture, like half kneeling, will narrow the support base (e.g. back in contact with floor versus foot and knee in contact with floor) which makes the exercise more difficult. Similarly, for the deadlift progression, the hinge pull down aims to enhance trunk rigidity, dynamic stability, and latissimus dorsi activation, which is meant to carry-over to the kettlebell deadlift and hexagonal (trap) bar deadlift where increased weight may be lifted.

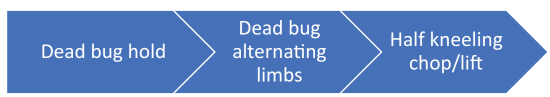

Figure 2-2 *Abdominal exercise progression; from left to right, least difficult to most difficult*

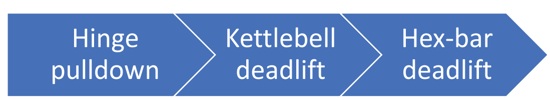

Figure 2-3 *Deadlift progression; from left to right, least difficult to most difficult*

KNEE ARTHRITIS REHABILITATION

Table 2-12 *Non-periodized knee arthritis rehabilitation, eight-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The individual will perform the same workout on both days*

Non-periodized: Knee arthritis rehabilitation, eight weeks, two days per week	
Weeks 1–8	
Quad sets	10 × 10 seconds
Hamstring set	10 × 10 seconds
Short arc quad	3 × 10
Long arc quad	3 × 10
Straight leg raise	3 × 10
Bridges with band or ball adduction	2 × 10
Clamshells	2 × 10
Mini squats	2 × 10
Passive stretching (30 seconds each): quadriceps, hamstrings, illiotobial band, piriformis, calf	

Table 2-13 *Non-linear knee arthritis rehabilitation, six-to-eight-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional and one day per week outside of the clinic as a home exercise or gym program. The weights used for the home exercise or gym program will be determined by those used during the in-clinic sessions*

Non-linear periodization: Knee arthritis rehabilitation, six to eight weeks, three days per week			
	Day 1	***Day 2***	***Day 3: Home Exercise Program***
Week 1	Endurance | ***65–70% 1RM*** A1 *Double-leg squat* Door frame squats 2 × 15 A2 *Anti-movement stability* Dead bug hold 2 × 10, 30 seconds B1 *Single-leg quadriceps* Straight-leg raise with eccentric lowering 2 × 15 B2 *Hip abductor* Clamshells 2 × 15 with 2-second hold C1 *Double-leg hinge* Dowel hinges 3 × 5 with 5-second hold	Hypertrophy | ***75% 1RM*** A1 *Double-leg squat* Spanish squat 3 × 12 A2 *Double-leg bridge* Dumbbell Bridge 4 × 12 B1 *Hip abductor* Clamshells with eccentric 3 × 12 B2 *Double-leg hinge* Regular (stiff leg) deadlift with band 3 × 12 C1 *Single-leg quadriceps* Kettlebell knee extensions 4 × 12 C2 *Double-leg hamstring* Seated hamstring curls 4 × 12	A1 *Double-leg squat* Door frame squats 2 × 15 A2 *Anti-movement stability* Dead bug hold 2 × 10, 30 seconds B1 *Double-leg bridge* Dumbbell bridge 4 × 12 B2 *Hip abductor* Clamshells with 2 second hold 2 × 15 C1 *Single-leg quadriceps* Straight-leg raise with eccentric lowering 2 × 15
Week 2	Hypertrophy | ***75% 1RM*** Repeat: Week 1, Day 2	Endurance | ***65–70% 1RM*** A1 *Double-leg squat* Suspension strap assisted squats 2 × 15 A2 *Anti-movement stability* Dead bug hold 2 × 10, 30 seconds	A1 *Double-leg squat* Door frame squat eccentric with unassisted concentric 3 × 10 A2 *Anti-movement stability* Dead bug hold 2 × 10, 30 seconds
		B1 *Single or double-leg quadriceps* Terminal knee extension (band or plank) 2 × 15 B2 *Hip abductor* Side-lying hip abduction 2 × 15 each C1 *Double-leg hinge* Dowel hinges with band resistance at waist 2 × 15 C2 *Single-leg quadriceps* Single-leg running man 2 × 15 each	B1 *Double-leg bridge* Dumbbell bridge 4 × 10 B2 *Single or double-leg quadriceps* Terminal knee extension 2 × 15 C1 *Single-leg quadriceps* Single-leg running man 2 × 15 each

(*Continued*)

Table 2-13 *Continued*

Non-linear periodization: Knee arthritis rehabilitation, six to eight weeks, three days per week			
	Day 1	***Day 2***	***Day 3: Home Exercise Program***
Week 3	Hypertrophy | ***75% 1RM*** A1 *Double-leg squat* Spanish squat 4 × 10 A2 *Double-leg bridge* Barbell bridge 4 × 10 B1 *Double-leg hinge* Kettlebell deadlift 3 × 10 B2 *Hip abductor* Lateral toe taps 4 × 10 C1 *Single-leg quadriceps* Kettlebell knee extensions 4 × 10 C2 *Single or double-leg hamstrings* Seated hamstring curls 4 × 10	Hypertrophy | ***75–80% 1RM*** A1 *Double-leg squat* Kettlebell box squat 3 × 8 A2 *Single-leg bridge* Single-leg dumbbell bridge 3 × 10 B1 *Single-leg quadriceps* Split squat 4 × 8 B2 *Single-leg glute/Dynamic stability* Modified plantigrade hip extensions 4 × 10 each C1 *Single-leg hinge* Split-stance deadlift 4 × 8 C2 *Single-leg quadriceps* Lateral lunge 3 × 8	A1 *Double-leg squat* Spanish squat 3 × 10 A2 *Anti-movement stability* Dead bug hold 3 × 10, 30 seconds B1 *Single-leg bridge* Single-leg dumbbell bridge 4 × 10 B2 *Hip abductor* Lateral toe taps 4 × 10 C1 *Hip abductor* Side-lying hip abduction 2 × 15
Week 4	Hypertrophy | ***80% 1RM*** A1 *Single-leg squat* Single-leg or staggered-stance eccentric squat 4 × 8 A2 *Double-leg hinge* Kettlebell deadlift 3 × 8 B1 *Double-leg bridge* Barbell bridge 4 × 8 B2 *Single-leg quadriceps* Split squat 4 × 8 C1 *Single-leg quadriceps* Kettlebell knee extensions 4 × 8 C2 *Double or single-leg hamstrings* Eccentric hamstring curls on physioball 4 × 8	Strength | ***85% 1RM*** A1 *Double-leg squat* Kettlebell box squat 5 × 6 A2 *Single-leg bridge* Single-leg dumbbell bridge 5 × 5 B1 *Dynamic stability* Plank hip extensions 5 × 6 each B2 *Hip abductor* Clamshells with 5 second hold and eccentric 5 × 6 C1 *Hip abductor* Double-banded lateral and backward walks	A1 *Double-leg squat* Kettlebell box squat 4 × 8 A2 *Dynamic stability* Plank hip extensions 5 × 6 each B1 *Single-leg bridge* Single-leg dumbbell bridge 4 × 8 B2 *Hip abductor* Double-banded lateral and backward walks

Table 2-13 *Continued*

Non-linear periodization: Knee arthritis rehabilitation, six to eight weeks, three days per week			
	Day 1	***Day 2***	***Day 3: Home Exercise Program***
Week 5	Strength | ***85–90% 1RM*** A1 *Single-leg squat* Single-leg or staggered-stance eccentric squat 5 × 5 A2 *Double-leg hinge* Kettlebell deadlift 5 × 5 B1 *Double-leg bridge* Barbell bridge 5 × 5	Hypertrophy | ***80% 1RM*** A1 *Double-leg glute* Dumbbell hip thrust 3 × 8 A2 *Single-leg quadriceps* Lateral lunge 4 × 8 B1 *Single-leg hinge* Split-stance deadlift 4 × 8	A1 *Double-leg squat* Kettlebell box squat 5 × 5 A2 *Double-leg hinge* Kettlebell deadlift 5 × 5 B1 *Single-leg quadriceps* Lateral lunge 3 × 8
	B2 *Single-leg quadriceps* Split squat 5 × 5 C1 *Hip abductor/Dynamic stability* Super clam 3 × 6 C2 *Hip adductor/Anti-movement stability* Modified Copenhagen plank 3 × 10 seconds each	B2 *Single-leg quadriceps* Forward step up 3 × 8 C1 *Hip abductor* Gluteus medius wall lean 4 × 8	B2 *Hip abductor/dynamic stability* Super clam 3 × 6 C1 *Single-leg hinge* Split-stance deadlift 4 × 8
Week 6	Plyometrics A1 Medicine ball slams 3 × 5 A2 Mini skater hop 3 × 5 each side B1 Light skips 3 × 20 ft	Hypertrophy | ***80% 1RM*** A1 *Double-leg glute* Dumbbell hip thrust 4 × 8 A2 *Single-leg hinge* Single-leg deadlift 3 × 8	A1 *Double-leg squat* Kettlebell box squat 4 × 4 A2 *Double-leg hinge* Kettlebell deadlift 4 × 4
	B2 Double-leg small height depth jump 3 × 5 C1 Single-leg step off 3 × 5 D1 Spanish squat isometric holds 3 × 45 seconds, 1 minute rest in between	B1 *Single-leg squat* Single-leg or staggered-stance squat 4 × 8 B2 *Single-leg bridge* Single-leg dumbbell bridge 4 × 8 C1 *Hip abductor* Gluteus medius wall lean 4 × 8	B1 *Double-leg bridge* Barbell bridge 4 × 4 B2 *Single-leg quadriceps* Split squat 4 × 4 C1 *Hip abductor/Dynamic stability* Super clam 3 × 6 C2 *Hip adductor/Anti-movement stability* Modified Copenhagen plank 3 x 10 seconds each
The next two weeks are completed by the patient post-discharge (or during a two-week hiatus from in-person rehabilitation prior to discharge). Week 6 is used as a guide for the remaining two weeks. The home exercise or gym program routine from week 6 is considered the "strength" day			
Week 7	Plyometric	Strength | ***85–90% 1RM***	Hypertrophy | ***80% 1RM***
Week 8	Hypertrophy | ***80% 1RM***	Strength | ***85–90% 1RM***	Plyometric

EXERCISE SELECTION AND CLINICAL DECISION MAKING

The door frame squat (see page 42) uses upper extremity support to decrease demand on the lower body muscles, achieve greater, pain-free range of motion and promotes a more upright trunk posture. Progression to the Spanish squat (see page 46) removes upper body assistance, which will require increased contribution from the lower body muscles. The band behind the knees now provides the added support to help maintain an upright trunk, assists the eccentric phase, but challenges terminal knee extension on the concentric phase. The band also encourages a more vertical shin angle, which may help build quadricep strength with less anterior knee pain. Progression to the box squat (see page 50) uses the box as a counterbalance, which may help an individual to continue to learn and load the squat technique, reduce balance demands, decrease time under tension, and develop the requisite level of strength and endurance that is required for more advanced variations. The individual must now, however, focus on controlling their trunk angle and may require increased anterior knee translation (knees over toes) compared to the door frame or Spanish squat. In this program, the staggered stance squat is considered the most difficult variation, as it requires modified single-leg loading. This exercise may not be able to be loaded as heavily due to increased balance demands, but may limit compensation from the opposite extremity in order to build strength and muscle mass symmetrically.

Figure 2-4 *Squat progression; from left to right, least difficult to most difficult*

SHOULDER REHABILITATION

Table 2-14 *Non-periodized shoulder rehabilitation, nine-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The individual will perform the same workout on both days*

Non-periodized: Shoulder rehabilitation, nine weeks, two days per week			
Weeks 1–4		***Weeks 5–9***	
Seated scapular retractions	2 × 20	I, T, Y	2 × 10, all conditions
Shoulder pendulums	2 × 10	Supine serratus press	2 × 10
Shoulder pulley flexion and abduction	1 × 20	Rows	2 × 10
	3 × 10	Standing shoulder ER/IR with band	3 × 10
Dowel shoulder flexion, abduction, ER/IR	2 × 10, all conditions	Front raises	2 × 10
Shoulder isometrics	10 × 10 second hold	Standing scaption	2 × 10
Side-lying shoulder ER	2 × 10	Bilateral shoulder extension with resistance band	2 × 10
Rows	2 × 10		

Table 2-15 *Block periodization shoulder rehabilitation, nine-week program. This program is meant to be completed two days per week, in-person, and supervised by a rehabilitation professional. The accumulation phase is two weeks at 50–70% of 1RM; the transmutation phase is four weeks at 70–90% of 1RM; the realization phase is two weeks at 90% or greater 1RM; and the deload phase aims to decrease total training intensity and volume*

Block periodization: Shoulder rehabilitation, nine weeks, two days per week			
	Week	***Day 1***	***Day 2***
Accumulation	1 ***60% 1RM***	*Upper back* Prone shoulder extension 2 × 20 *Double arm pull* Supine dumbbell pullovers 2 × 20 *Rotator cuff* Side-lying shoulder ER 2 × 20 *Upper back mobility* Side-lying thoracic rotation 2 × 20	*Double arm pull* Seated rows 2 × 20 *Upper back mobility* Thoracic extensions 2 × 20 *Rotator cuff* Tall kneeling 45-degree shoulder extensions 2 × 20 *Single-arm elevation*
		Dynamic stability Quadruped shoulder taps 2 × 20	Side-lying shoulder flexion 2 × 20 *Rotator cuff* Shoulder ER end range liftoffs 1 × 10–15 each
	2 ***65% 1RM***	*Upper back/Rotator cuff* Prone shoulder extension 2 × 15 *Double arm pull* Supine dumbbell pullovers 2 × 15 *Rotator cuff* Side-lying shoulder ER 2 × 15 *Upper back mobility* Side-lying thoracic rotation 2 × 15 *Double-arm push* Quadruped serratus push up 2 × 15 *Double-arm pull* Seated rows 2 × 15 *Rotator cuff* Side-lying shoulder horizontal abduction 2 × 15	*Double arm pull* Neutral grip high row 2 × 15 *Double-arm elevation* Shoulder scaption with mini band 2 × 15 *Rotator cuff* Tall kneeling 45-degree shoulder extensions 2 × 15 *Double arm-press/elevation* *Double-arm press* Serratus wall slides 2 × 15 *Rotator cuff* Shoulder ER/IR walkouts (arm at side or in scapular plane) 2 × 15

(*Continued*)

Table 2-15 Continued

Block periodization: Shoulder rehabilitation, nine weeks, two days per week			
	Week	***Day 1***	***Day 2***
Transmutation	3 ***70–75% 1RM***	*Double-arm pull* Face pull 4 × 12 *Single-arm pull* Single-arm row with thoracic rotation 4 × 12 *Rotator cuff* Side-lying shoulder ER 4 × 12 *Static stability* Bear plank 4 × 15–30 sec *Rotator cuff* Side-lying shoulder horizontal abduction eccentrics 4 × 12	*Double arm-pull* Neutral grip high row 4 × 10 *Single-arm press* Landmine press 4 × 10 *Double arm-pull* Hinge straight-arm pulldowns 4 × 10 *Double-arm press* Serratus wall slide with lift-off 4 × 10 *Rotator cuff* Shoulder ER/IR walkouts with eccentric (scapular plane and/or 90 degrees) 4 × 10
	4 ***75–80% 1RM***	*Double-arm pull* Face Pull 4 × 10 *Single-arm pull* Single-arm row with thoracic rotation 4 × 10 *Rotator cuff* Prone external rotation 4 × 10 *Dynamic stability* Reverse bear crawl 4 × 10 *Single-arm press* Alternating floor press 4 × 10	*Double-arm pull* Neutral grip high row 4 × 8 *Single-arm press* Landmine press 4 × 8 *Double-arm pull* Hinge straight-arm pulldowns 4 × 8 *Dynamic stability* High plank shoulder taps from elevated surface 4 × 8 *Rotator cuff* Shoulder ER/IR 90/90 with band 4 × 8–10
	5 ***80–85% 1RM***	*Double-arm pull* Face pull 4 × 8 *Single-arm pull* Single-arm row with thoracic rotation 4 × 8	*Double-arm pull* Neutral grip high row 4 × 8 *Single-arm press* Landmine press 4 × 8

Table 2-15 *Continued*

Block periodization: Shoulder rehabilitation, nine weeks, two days per week			
	Week	***Day 1***	***Day 2***
		Rotator cuff Prone external rotation 4 × 8 *Dynamic stability* Reverse bear crawl 4 × 10 *Single-arm press* Alternating Floor Press 4 × 8	*Double-arm pull* Hinge straight-arm pulldowns 4 × 8 *Dynamic stability* High plank shoulder taps from elevated surface 4 × 8 *Rotator cuff* Shoulder ER/IR 90/90 with band 4 × 8
	6 ***85–90% 1RM***	*Double-arm pull* Face pull 4 x 6 *Rotator cuff* Prone external rotation 4 × 6–8 *Single-arm pull* Single-arm row with thoracic rotation 4 × 6 High plank thoracic rotations 4 × 6 *Double-arm pull* Chest supported rear delt raises 4 × 6–8 *Double-arm press* Alternating floor chest press 4 × 6	*Double-arm pull* Wide-grip high row or lat pulldown 4 x 5 *Double-arm pull* Hinge straight-arm pulldowns 4 × 5, 2 second hold *Single-arm press* Landmine press 4 × 5 *Dynamic stability* High plank kettlebell pull throughs 4 × 5 each *Rotator cuff* Shoulder ER/IR 90/90 with band 4 × 5–6
Realization	7 ***90% 1RM***	*Double-arm pull* Incline row 4 × 4 *Rotator cuff* Prone shoulder ER reactive ball drops 4 × 4–6 *Single-arm pull* Single-arm row with thoracic rotation (speed) 3 × 4 *Dynamic stability* High plank step walk-over 3 × 4 each direction *Double-arm press* Floor chest press 3 × 4	*Double-arm pull* Wide-grip high row or lat pulldown 3 × 4 *Double-arm pull* Overhead med ball slam 3 × 4 *Single-arm press* Landmine press (speed) 3 × 4 *Single-arm press/Dynamic stability* Overhead carry 3 × for distance *Dynamic stability* High plank kettlebell pull throughs 3 × 4 each

(*Continued*)

***Table 2-15** Continued*

Block periodization: Shoulder rehabilitation, nine weeks, two days per week			
	Week	***Day 1***	***Day 2***
	8 ***95% 1RM***	*Double-arm pull* Incline row 5 × 2–3 *Single-arm pull* Single-arm row with thoracic rotation (speed) 5 × 3 *Double-arm press* Medicine ball chest pass to floor 5 × 3 *Double-arm press* Floor chest press 5 × 2–3 *Dynamic stability* Farmer's carry 3 × for distance	*Double-arm pull* Wide-grip high row or lat pulldown 5 × 2 *Double-arm pull* Overhead med ball slam 5 × 3 *Single-arm press* Landmine press (speed) 5 × 2 *Double-arm press* Push press 5 × 2–3 *Dynamic stability* High plank thoracic rotations 3 × 4–6 each side
Deload	9 ***50% 1RM***	*Double-arm pull* Face pull 2–3 × 10 *Rotator cuff* Prone external rotation 2–3 × 10 *Double-arm pull* Seated cable row 2–3 × 10 *Double-arm pull* Chest-supported rear delt raise 2–3 × 10 *Single-arm press* Alternating floor press 2–3 × 10	*Double-arm pull* Wide-grip high row or lat pulldown 2–3 × 10 *Single-arm press* Landmine press 2–3 × 8 *Double-arm pull* Hinge straight-arm pulldowns 2–3 × 10 *Rotator cuff* Shoulder ER/IR 90/90 with band 2–3 × 10 *Double-arm pull* Horizontal abduction with band 2–3 × 10

EXERCISE SELECTION AND CLINICAL DECISION MAKING

Prone shoulder extensions (see page 288) and seated rows (see page 302) aim to teach scapular motor control and require the involved muscles to contract against gravity or resistance with the goals of improving muscle activation and endurance. External rotation performed at 90° against gravity (see page 352) demands high levels of muscle activation about the rotator cuff and posterior deltoid,[55] requires movement in the transverse plane, which can be considered a progression from a sagittal plane pull. Face pulls (see page 335) are performed using resistance bands or a cable column and thus can offer additional loading capability for the deltoids and external rotators. The trunk muscles must also participate during the face pull to help the torso remain erect. External rotation performed at 90° of shoulder flexion and abduction (see page 349) is also performed in the upright position, but requires a greater degree of shoulder external rotation range of motion compared to the face pull. This exercise is performed unilaterally, with the aim of further isolating the muscles in the posterior rotator cuff in a position that mimics functional or sport-specific activities, like throwing or catching a ball.

Figure 2-5 *Scapular motor control and external rotation progression; from left to right, least difficult to most difficult*

Overhead pressing or front raises that require a long lever against gravity may be difficult in the presence of shoulder pain or limited shoulder motion. The supine dumbbell pullover (see page 284) uses gravity and eccentric lowering to create a loaded stretch to improve overhead shoulder range of motion. The side-lying position during flexion (see page 353) is a gravity minimized position, but may require increased contraction from the posterior shoulder girdle to maintain the arm above the horizontal throughout the exercise, which may enhance shoulder stability and strength. The landmine press (see page 320) transitions the pressing movement to a modified overhead position to build strength in a pain-free range of motion. Progression to the overhead carry aims to enhance overhead shoulder stability using the natural perturbation of the gait cycle and overhead muscle endurance prior to concentric-eccentric pressing with the injured extremity. Due to the stability requirements, a lighter weight should be used compared to other overhead pressing exercises. The final exercise in the progression, the push-press (see page 324), uses the pressing power of the deltoid, assistance from the rotator cuff,[55,56] and lower body muscles[57,58] to reinforce the newly acquired range of motion, overhead stability, strength, and power.

Figure 2-6 *Shoulder flexion and overhead press progression; from left to right, least difficult to most difficult*

To be clear: These templates are just a guide. You will be far more successful if you learn the general concepts and then apply them to a wide variety of situations and different populations. Learn from these examples, then put your knowledge into practice. You do not need to take every individual through three separate cycles of endurance, strength, hypertrophy, and power. The programs here are designed with respect to strengths, weaknesses, and goals but you must be willing to be flexible and pivot. The exercises will be described in greater detail in the remaining chapters, which will add greater context to the selection and clinical decision making process. Start small with just a few exercises and work your way up. Starting with ten exercises as opposed to a simpler approach will make it much more difficult to determine what exercises are supporting or hindering progress.

CHAPTER 3

INTRODUCTION TO STABILIZATION

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The transverse abdominis, internal obliques, external obliques, rectus abdominis, intercostals, and latissimus dorsi all share direct or indirect fascial or tendon attachments to the spine, pelvis, and rib cage. There are two common methods used to activate the abdominal muscles: hollowing and bracing. Abdominal hollowing is the act of drawing the belly button in toward the spine to activate the transverse abdominis (TA), the deepest abdominal stabilizer. Abdominal hollowing and TA motor control exercises can have excellent utility during neuromuscular re-education and initial core stabilization training, but may have limited carryover to higher level lifting tasks. Abdominal bracing creates spinal stiffness and intra-abdominal pressure by actively contracting all the above listed muscles, which may allow the spine to sustain greater compression loads and prevent tissue injury.[59–61] An activation sequence, as described below, may promote deeper understanding, improved motor control, skill development, and acquisition of the abdominal bracing strategy.

THE DIAPHRAGM

First and foremost, the mechanisms of respiration are complex and well beyond the scope of this book and are presented on a very superficial level. If greater detail is desired, any work by professionals such as Ron Hruska, Pavel Kolar, and Mary Massery may be a good start.

The diaphragm is a muscle that is located below the lungs that supports breathing. Though both the lungs and diaphragm help to sustain human life, they operate quite differently. The lungs function via passive airflow and a vacuum system, while the diaphragm is innervated by spinal nerves C3–6. When taking a breath in, the lungs and rib cage expand and the diaphragm descends into the thoracic cavity to make space for the inflated lungs, while the opposite occurs during exhalation. As the diaphragm rises into the thoracic cavity during forced exhalation, the abdominal muscles contract harder to compress the abdominal viscera, increase intra-abdominal pressure, depress the rib cage, and further promote air exiting the lungs.[62–64]

When bracing for lifting, diaphragm breathing is very important, as it tends to keep the rib cage more centered over the pelvis. This helps maintain an optimal zone of apposition (ZOA), i.e. the dome shape of the diaphragm, which is important to promote efficient air flow, muscle activation, and posture.[64] Diaphragm breathing allows the rib cage to expand laterally, increases activation of the abdominal muscles, prevents hyperinflation of the lungs and the use of accessory muscles for breathing.[64] If the diaphragm is unable to move in its normal manner, this may decrease its ability to contribute to spinal stiffness and force production.[61] For example, if the rib cage expands more superior and anterior (as it does with chest breathing), abdominal muscles may become less active during respiration and the dome of the diaphragm will flatten, making it more difficult to expel air from the lungs.[64] The best way to describe a sub-optimal ZOA is by visualizing someone with a barrel chest and anterior pelvic tilt.

BREATHING AND BRACING SEQUENCE

INITIAL ASSESSMENT: CHEST OR STOMACH BREATHING?

- Start in a hook-lying position with one hand on the stomach and the other on the chest
- Take a breath in and notice which hand rises first and has the greatest excursion

More activity and excursion of the chest (top hand) (Figure 3–1) indicates that most of the inhalation is driven from the lungs, while a greater amount of stomach breathing (bottom hand) (Figure 3–2) is driven by the diaphragm.

Figure 3-1 *Chest breathing*

Figure 3-2 *Diaphragm breathing*

CUE BREATHING WITH THE DIAPHRAGM

If the initial assessment reveals a tendency to breathe into the chest and difficulty with diaphragm breathing, this pattern can be trained with appropriate cues and practice.

- Use the same hand placement as the assessment (Figures 3–1, 3–2) or place the hands in a "c" grip around the lower rib cage (Figure 3–3)
- Take a deep breath in through the nose, attempt to breathe air into the stomach to make the stomach rise greater than the chest and expand the rib cage laterally, as pictured (Figures 3–2, 3–3)
- Purse the lips, blow slowly and forcefully out through the mouth until there is no air left to expel
- Perform for sets of 5–10 repetitions each for retraining

RIB DEPRESSION

Rib depression is the act of drawing the rib cage inferiorly toward the pelvis and inward toward the deep abdominal stabilizers using an exhalation and/or the abdominal muscles. The ribs articulate with the spine at the costovertebral joint and serve as an attachment point for many of the abdominal and trunk muscles. Anatomically, it would make sense that the rib cage's position plays a vital role in spinal position and abdominal stabilization. Take a moment to breathe deeply into the chest and feel what happens. The lumbar spine automatically extends and the abdominals are lengthened. Not only is it difficult to contract the abdominals effectively in this position, but it places increased demand on the lumbar erectors.

- Place the hands on either side of the base of the rib cage
- Perform diaphragm breathing as detailed above
- During exhalation, focus on drawing the base of the rib cage down toward the pelvis
- Feel the abdominals tighten and the lower back flatten to the floor or table

Figure 3-3 *Hands placed at the lower rib cage during the breath in. This allows the individual to find the base of the ribs to feel the difference between rib elevation and flare versus lateral rib cage expansion during the inhalation and to gauge rib depression during the exhalation*

Figure 3-4 *Forceful exhalation with rib cage depression. The hands placed at the lower rib cage allow the individual to feel the hands (and base of the rib cage) traveling down and in toward the pelvic bones*

BRACE WHILE BREATHING

The first two steps teach how to assume the position, but the third ensures it can be maintained while breathing, which may help with exercise and lifting tasks.

- Perform diaphragm breathing with rib depression as described above
- Following a maximal exhalation, brace the abdominals to maintain rib depression
- Take 5–10 small breaths in and out while maintaining this position

An exercise that will require maintenance of this position, like a dead bug variation (see page 410) or a glute bridge (see page 106) may be a good follow-up activity. If the aim is to consciously contract the abdominals prior to and during the movement (whether during a dedicated core stabilization exercise or a multi-joint exercise, like a squat), an individual needs to feel the muscles they are trying to contract and know how to contract them on command, in any position.

CHAPTER 4

SQUAT

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We squat all day long – in and out of office chairs, on and off the toilet, to pick up the dog and to play with children – so it is safe to say it is an important exercise to master. The squat is a compound movement that activates many muscle groups in the lower extremities, particularly the hip and knee extensors.[65]

There are a few common misconceptions about squat form and execution that should be addressed. Contrary to popular belief, deep squats are not bad for you.[66] Shear forces at the knee joint actually decrease as the knee flexion angle increases. Although compressive forces increase with greater amounts of knee flexion, the contact area of cartilage and joints also increases. This allows force to be distributed more evenly throughout the knee joint surface and is thought to have a stabilizing effect.[66,67] Full-range squats may also be more advantageous for increasing muscle mass, particularly in the gluteus maximus and adductors, and may improve 1RM to a greater extent than partial squats.[68] There is no direct evidence that deep squats have a negative effect on knee health, so it is reasonable to perform squats at different depths if appropriate for each individual.

Allowing the knees to translate forward, past the toes, is also not necessarily bad for the knee joint and depends on an individual's diagnosis, phase of healing, goal of the squat, and available range of motion. Increased forward knee translation reduces forward trunk flexion,[69–72] hip torque,[72] lower back torque, and shear force.[69–72] So, advancing the knees beyond the toes may be an appropriate strategy to train around pain if an individual has a lower back issue or if the goal is to maximize focus on the quadricep muscles.[72] However, if an individual is suffering from acute patella tendinopathy and anterior knee pain, it may be best to limit forward translation in the short-term to reduce severity of symptoms and work on load management.

The ideal squat form is different for everyone depending on their anatomy, available range of motion, strength, and injury (if applicable). There are numerous squat variations, which should allow anyone to learn their preferred method and progressively load the squat pattern. Different variations are also compared in greater detail at the end of this chapter (Figure 4–77)(Table 4–1). Keep in mind, there are many ways to train around knee and back pain during the squat, knees-over-toes, squatting to a deep level is not bad if performed correctly, and the barbell back squat does not have to be included in every training program. Taking the time to assess and program the optimal squat variation on a case-by-case basis is essential for patient satisfaction and successful outcomes in both the short and long term.

BASIC SQUAT GUIDELINES

1. Ensure proper foot contact

The feet should remain firmly planted to the floor throughout the entire movement. Decreased foot contact may increase balance demands and require other muscles to compensate to maintain stability of the lower extremities and trunk. Signs of impaired foot contact include the toes elevating from the floor (Figure 4–1) and the ankles caving inwards (Figure 4–2).

Figure 4-1 *Toes elevating from the floor*

Figure 4-2 *Ankles caving inward*

2. Adjust stance width and degree of foot rotation as needed for comfort and form maintenance

Figure 4-3 *Normal, hip-width stance*

Figure 4-4 *Narrow stance*

Figure 4-5 *Wide stance*

3. Create a rigid torso and maintain a neutral spine

Use the abdominal bracing strategies learned in Chapter 3 and engage the latissimus dorsi by pulling down on the barbell if performing a back squat or contracting the upper back muscles by retracting and depressing the shoulder blades if performing another squat variation.

Figure 4-6 *Neutral spine*

Figure 4-7 *Overly lordotic spine*

Figure 4-8 *Overly flexed spine*

4. Ensure the patella remains in line with the middle of the foot (toes 2–4)

Figure 4-9 *Appropriate tracking*

Figure 4-10 *Knees caving inward (valgus). This may place a greater stress on the medial knee joint[73] and may be due to poor foot contact, impaired ankle mobility, glute length, posterior hip capsule mobility, and/or lateral hip and posterior chain muscle weakness*

Figure 4-11 *Knees bowing outward (varus). This may place a greater stress on the lateral knee[73] and ankle joints and may present in the presence of poor foot contact (ability to load the first toe), impaired ankle mobility, balance, and/or adductor muscle weakness*

5. Allow the knees to travel past the toes if desired
6. Use the cues "sit back," "shift your hips back," and/or "sit down" appropriately

The cues "sit back" or "shift the hips back" are often used to promote a posterior weight shift and to discourage excessive anterior knee translation by using a greater amount of hip and forward trunk flexion (Figure 4–12). The cue "sit down" is often used to encourage a more upright trunk and increased knee flexion to descend to depth (Figure 4–13). Utilize the cue that produces the desired movement pattern and allows an individual to understand the technique.

Figure 4-12 *Forward trunk shift and increased hip flexion with decreased anterior knee translation*

Figure 4-13 *Upright trunk with increased knee flexion and anterior knee translation*

ASSISTED SQUATS

Assisted squats use upper extremity assistance to decrease the balance and eccentric demands required during a regular, unassisted squat. Assisted squats may aid in the development of pain-free range of motion and comfort descending to maximal depth (e.g. use of door frame or suspension straps). To increase difficulty, use the upper extremity assistance to control the eccentric portion, but let go at maximal depth and perform the stand without support. A weighted vest can also be used with any of these exercises for an additional challenge.

DOOR FRAME SQUAT

- Stand at least one foot away from the door frame
- Grasp the door frame with both hands (Figure 4–14)
- Slowly "walk" the hands down the door frame (Figure 4–15) and descend to maximal, pain-free depth (Figure 4–15)
- Use the hands to walk back up the door frame to return to the starting position


Figure 4-14 Door frame squat start position


Figure 4-15 Door frame squat mid-range


Figure 4-16 Door frame squat maximal depth

SUSPENSION STRAP BOX SQUAT

- Stand with minimal to moderate tension on the suspension straps (Figure 4–17)
- Shift the hips back or sit down while using the upper extremities to control the descent into the squat
- Pause once seated on the box, but do not let the trunk shift backward (Figure 4–18)
- Initiate the stand from the legs rather than pulling with the upper extremities and use assistance from the straps only as needed


Figure 4-17 Suspension strap box squat start position


Figure 4-18 Suspension strap box squat at maximal depth

SUSPENSION STRAP SQUAT

Figure 4-19 *Suspension strap squat start position*

Figure 4-20 *Suspension strap squat at maximal depth*

SUSPENSION STRAP SINGLE-LEG BOX SQUAT

- Stand with minimal to moderate tension on the suspension straps
- Stand on the target leg and hover the opposite leg from the floor (Figure 4–21)
- Use the upper extremities to aid descent into squat and do not let the trunk shift backward once seated
- Initiate the stand from the target leg rather than pulling with the upper extremities (Figure 4–22)

Figure 4-21 *Suspension strap single-leg box squat start position*

Figure 4-22 *Suspension strap single-leg box squat at maximal depth*

SUSPENSION STRAP SINGLE-LEG SQUAT

Figure 4-23 *Suspension strap single-leg squat start position*

Figure 4-24 *Suspension strap single-leg squat at maximal depth*

HATFIELD SQUAT

The Hatfield squat uses the upper extremities for balance and/or assistance during both the eccentric and concentric phases as needed. It is performed using bodyweight, a weighted vest, belt (see belt squats, page 67), or safety squat bar (see page 66). Many weight racks have attachment points for pins or specialized hand grips, but this can also be performed by grasping any secure surface between chest to shoulder height with both hands.

- Stand at an arm's length or less from the handgrips and grasp with each hand (Figure 4–25)
- If using a safety squat bar, secure the load to the back by angling the handles of the bar down
- Sit down into the squat
- Utilize the arms to assist the lowering phase and to rise from depth as needed (Figure 4–26)

Figure 4-25 *Hatfield squat start position*

Figure 4-26 *Hatfield squat at maximal depth*

UNASSISTED SQUATS

SPANISH SQUAT

There are many factors that can affect the ability to load a regular squat, such as pain in the knees or back, inability to sit back to balance the knee/hip/torso angle, and ankle mobility, among other things. The Spanish squat uses a band positioned behind the knees to allow an upright trunk and greater range of motion by increasing comfort and sense of security when sitting down into a squat. These factors may increase quadriceps loading ability to allow greater muscle hypertrophy, while simultaneously decreasing anterior knee "stress" and associated pain. The Spanish squat is a progression from the terminal knee extension with a band (see page 183) and a regression from a sissy squat (see page 69) or hack squat. A small case series by Rio et al.[74] investigated the use of isometric Spanish squats during an in-season training program. They found that performing the Spanish squat with a 30-second hold time for five repetitions significantly reduced patella tendon pain, but did not use a control group or sham procedure. Nonetheless, this may allow loading of the quadriceps in a functional, weight-bearing posture when other movements are not tolerated. The Spanish squat also produced a greater degree of muscle activation in the rectus femoris at 100%

maximal voluntary isometric contraction (MVIC) and vastus lateralis at 70% MVIC, compared to other exercises, like regular squats and wall squats.[75]

- Position the band behind the knee at a point of comfort between the knee joint line and the top portion of the gastric-soleus muscle
- Step back until there is maximum tension on the band and secure the feet to the floor (Figure 4–27)
- Lean back and allow the band to accept the body's weight
- Descend into a squat with the goal of keeping the trunk as upright as possible (Figure 4–28)
- The shins should remain relatively vertical and the knees stay well behind the toes
- Use the quadriceps to extend the knees and pull the body to upright from maximal depth
- Don't come to a full stand; this allows increased time under tension for the quadriceps throughout the movement (Figure 4–29)

Figure 4-27 *Spanish squat start position*

Figure 4-28 *Spanish squat maximal depth*

Figure 4-29 *Spanish squat end position*

BODYWEIGHT SQUAT

This squat uses only bodyweight for resistance and can be performed with different hand positions to improve balance, upper back activation, and trunk rigidity.

- "W" position engages the upper back for stability and prevents excessive lumbar flexion (Figure 4–30)
- Holding the arms forward acts as a counterbalance, but is not very tactical for loading (Figure 4–31)
- The goblet or prayer position engages the upper back for stability (somewhat) and prepares to hold a load (Figure 4–32)

Figure 4-30 *Bodyweight squat with upper extremities in "W" position*

Figure 4-31 *Bodyweight squat with upper extremities extended forward for counterbalance*

Figure 4-32 *Bodyweight squat with upper extremities in goblet or prayer position*

GOBLET SQUAT

The goblet squat is performed with a front-loaded weight that acts as a counterbalance and encourages descending to maximal depth. A dumbbell (Figure 4–34) or kettlebell held either right side up (Figure 4–36) or upside down (Figure 4–37) can be used interchangeably. Performing this exercise with the heels elevated (Figure 4–35) aims to reduce ankle dorsiflexion demands, which may allow increased knee flexion angle and squat depth to further load the quadriceps and/or anterior knee. Elevating the heels may also correct common squat faults, like excessive spinal flexion at greater depths. Instead of holding a weight, the goblet squat can also be performed while wearing a weighted vest.

- Secure the feet to the floor
- Create a rigid torso using a combination of abdominal bracing, rib depression, and upper back activation
- Sit down into the squat as if trying to bring the elbows to the inside of the knees
- The front-loaded weight will keep the trunk more erect throughout the movement
- Squeeze abdominals, glutes, and quadriceps to power up to the upright position

Figure 4-33 *Goblet squat start position*

Figure 4-34 *Goblet squat maximal depth*

Figure 4-35 *Goblet squat with feet elevated on plate at maximal depth*

Figure 4-36 *Goblet squat with kettlebell right side up at maximal depth*

Figure 4-37 *Goblet squat with kettlebell upside down at maximal depth*

KETTLEBELL FRONT SQUATS

Kettlebell front squats use a modified grip that may allow an individual to train around wrist pain or mobility deficits that may occur in the barbell front squat (see page 63).

Figure 4-38 *Kettlebell front squat start position*

Figure 4-39 *Kettlebell front squat at maximal depth*

- Rest the kettlebell on the lower portion of the upper arm or crease of the elbows (Figure 4–38)
- Grasp and position the handle just medially to the front of the shoulder
- Keep the wrists straight (fists pointing toward midline) and elbows high (level with the wrists)
- Secure the feet to the floor
- Create a rigid torso using a combination of abdominal bracing and rib depression
- Retract and depress the shoulders in order to enhance stability of the upper back to maintain an upright trunk
- The remainder of the exercise is performed with the same technique as the regular goblet squat

BOX SQUAT

From a performance perspective, box squats can help consistently reach desired depth with each repetition, enhance the stretch reflex, and power production from having to explode off the box. Westside Barbell, a renowned weightlifting gym, trains many squat world record holders using only box squats between competitions in order to take advantage of these benefits.[76] Box squats can be performed with posterior or front-loaded weight via barbell. In the event a barbell is not appropriate for a particular patient, a box squat with a dumbbell (Figure 4–40,

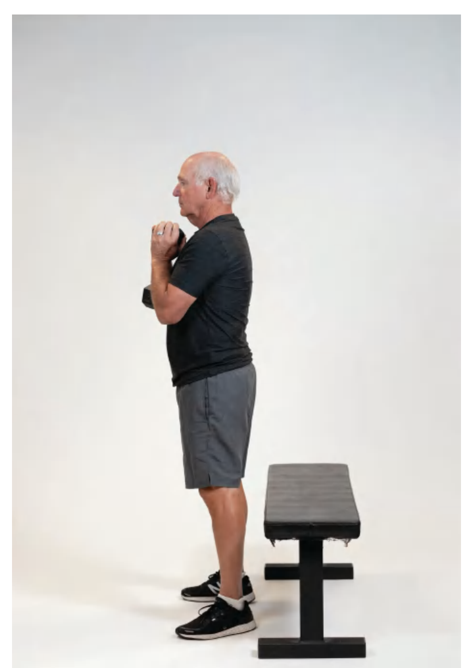

Figure 4-40 *Box squat with dumbbell start position*

4–41), kettlebell, or weighted vest are all alternative forms of load. The technique for barbell squats is detailed in the "advanced squat variations" section of this chapter (see page 60), which educates on the appropriate barbell set-up.

Swinton et al.[77] examined the biomechanics of the box, traditional, and powerlifting squats with a barbell in a comparative study. The box squat generates decreased anterior knee translation, as the center of mass is displaced more posteriorly. Interestingly, there are also decreased peak extension moments at the spine and hips. This means that by using the box as a counterbalance, the subjects were able to keep a more upright torso while also shifting their weight back. The rate of force development is also much higher during the box squat due to the ability to explode off the box.[77]

Figure 4-41 *Box squat with dumbbell at maximal depth*

- Secure the feet to the floor
- Create a rigid torso using a combination of abdominal bracing, rib depression, and upper back activation
- Sit down until contact with the box is made
- Keep a rigid trunk and briefly pause on the box (Figure 4–41)
- Do not change trunk angle while on the box
- Use a combination of foot and hip drive (glute contraction) to explode up off the box

LANDMINE SQUAT

Landmine squats may help to promote body awareness, posterior weight shift, and an upright torso while descending into a squat. One end of the barbell is anchored with a landmine attachment or to the corner of a wall and the opposite end sits on the chest around the level of the sternum. If an individual attempts to shift the trunk too far forward, the bar continues to press into the chest and becomes uncomfortable. Fortunately, the body usually prefers the path of least resistance and therefore this exercise may be useful for those who have a difficult time learning the squat pattern and do not respond to traditional coaching cues.

- Stand at an angle with the feet further away from the bar than the chest
- Grasp the bar with both hands like a cup and rest it on the sternum (Figure 4–42)
- Secure the feet to the floor
- Brace abdominals and descend into a squat, allowing the bar to guide the posterior weight shift and descent
- Squeeze abdominals, glutes, and quadriceps to propel the body back to the upright position

Figure 4-42 *Landmine squat start position*

Figure 4-43 *Landmine squat at maximal depth*

WALL SQUATS

The wall provides support and allows the trunk to remain fully erect, instead of translating forward during the squat. The reduced trunk angle promotes minimal lower back and hip torque while shifting the focus to the anterior chain. The support from the wall also eliminates many of the stability demands and ankle dorsiflexion requirements of regular squats. Wall squats can be performed with both legs (Figures 4–44, 4–45), a staggered stance (Figures 4–46, 4–47), or with one leg (Figures 4–48, 4–49).

- Lean into the wall so that the back is flat against it
- Walk the feet out until they are at a comfortable distance and width
- Slide down the wall until at maximal, pain-free depth
- Drive through the whole foot to return to upright

Figure 4-44 Wall squat start position

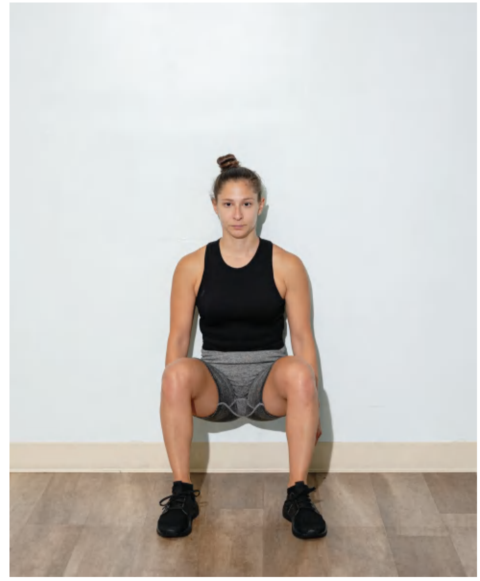

Figure 4-45 Wall squat at maximal depth

WALL SQUAT HOLD

Wall squat holds are an isometric variation that can be appropriate for pain reduction, establishing a pain threshold, and/or to enhance muscle endurance. Isometric holds can be performed through the range to load the quadriceps at different degrees of knee flexion.

STAGGERED STANCE WALL SQUAT

Staggered stance wall squats will bias one leg, but are not as challenging as a true single-leg squat because the support of the wall reduces strength and balance demands.

Figure 4-46 Staggered stance wall squat start position

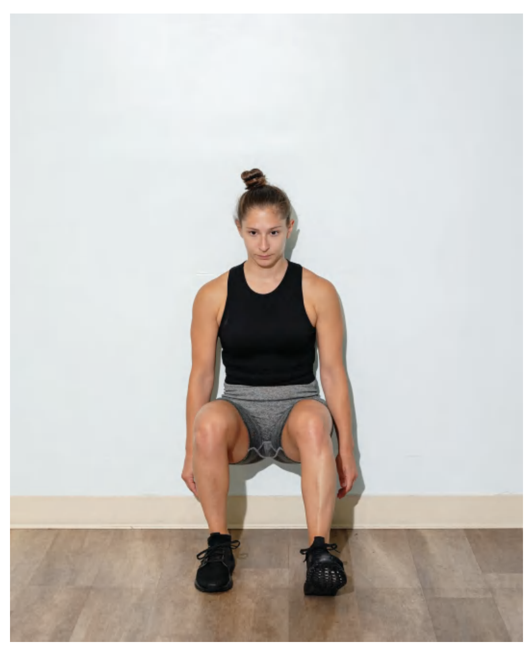

Figure 4-47 Staggered stance wall squat at maximal depth

SINGLE-LEG WALL SQUAT

Figure 4-48 *Single-leg wall squat start position*

Figure 4-49 *Single-leg wall squat at maximal depth*

SINGLE-LEG SQUATS

The single-leg squat has a variety of applications in lower body training. It generates greater than 50% and up to 92% MVIC for the gluteus medius and maximus[78–80] and activates the quadriceps to a greater extent than the hamstrings.[78] A recent systematic review by Moore et al.,[81] examined the gluteus medius exclusively and found at least moderate to high levels of muscle activation from 39% to 92% MVIC across all studies. When compared to other exercises, like split squats and rear foot elevated split squats (RFESS), the single-leg squat activates the gluteus medius to a greater extent.[78,82] A recent study by Collings et al.[83] determined that the single-leg squat generates higher levels of peak force for the gluteus medius when compared to other common hip rehabilitation exercises, like side-lying hip abduction, split squats, or hip hikes and similar levels of peak force compared to side planks and single-leg deadlifts, which appears in agreement with the existing body of research. Single-leg squats also produce greater ground reaction force, velocity, and achieve similar muscle activation to bilateral squats even when using lighter loads.[84] A single-leg squat limb symmetry index (LSI) of less than 90% can also be predictive of deficits in knee extensor strength and readiness to return to sport.[85] Though highly specific, the single-leg squat is not the most sensitive test and should not be the sole measure for quadricep strength and return-to-play.[85] LSI and return-to-play criteria are discussed in greater detail in Chapter 11.

STAGGERED STANCE BOX SQUAT

Performing the single-leg squat to a box provides a cue for depth and counterbalance, which is important since balance can be a limiting factor to single-leg loading. The box may allow an individual to improve stability and ability to power up from maximal depth prior to progressing to an unsupported variation, while the staggered stance (Figures 4–50, 4–51) and light contact of the opposite limb with the floor increases the base of support. The height of the box can be raised or lowered to decrease or increase difficulty respectively.

- Stagger the feet with the target leg posterior
- Weight is placed through only the heel of the anterior leg for balance
- Sit down until able to tap or lightly rest on the box, but do not change the trunk angle by shifting backward
- Propel primarily through the target leg to stand

Figure 4-50 *Staggered stance box squat start position*

Figure 4-51 *Staggered stance box squat at maximal depth*

SINGLE-LEG BOX SQUAT

- Stand on the target leg with the opposite leg straight and positioned in front
- Bend the knee, sit down, and allow the trunk to travel forward as needed
- The knee should remain in line with the middle to outside of the foot
- The arms can be used as a counterbalance or held close to the chest (prayer position)
- Tap or lightly rest on the box, but do not change the trunk angle by shifting backward
- Propel through the target leg to stand

Figure 4-52 *Single-leg box squat start position*

Figure 4-53 *Single-leg box squat at maximal depth*

SKATER SQUAT

The skater squat combines the movement patterns of the lunge and single-leg squat. The non-weight-bearing leg is positioned behind, compared to single-leg squats where it is usually in front. Though there is not any direct research available on the skater squat, the research surrounding the positioning of the non-weight-bearing leg during a single-leg squat is interesting. Positioning the non-weight-bearing limb at 0° hip flexion (the starting point for the skater squat shown in Figure 4–54) during a single-leg squat appears to promote a greater knee extension moment and rectus femoris activation compared to positioning the limb anteriorly, which produces greater hamstring activation.[86,87]

- Start in a single-leg stance
- Bend one knee, which will function as the rear leg
- Bend the front knee to descend into a squat, extend the hip of the rear leg and lower the knee to the floor
- Hover the rear knee just above the floor or a cushioned pad (Figure 4–55)
- The arms should be positioned out in front for counterbalance

Figure 4-54 Skater squat start position

Figure 4-55 Skater squat at maximal depth

DECLINE SQUATS

The decline squat elevates the heels in relation to the toes using a footplate (Figure 4–56). This reduces the amount of ankle dorsiflexion needed and encourages a greater degree of knee flexion. A decline between 16–24° promotes greater forward translation of the knee over the toe and increases maximum patellar tendon force up to 40% compared to a traditional single-leg squat. Greater than 60° of knee flexion may shift forces from the patellar tendon to the patellofemoral joint,[88,89] but greater flexion angles are not contraindicated in the absence of pain.

DOUBLE-LEG DECLINE SQUATS

- Position both feet on the footplate
- Sit down to descend into a squat
- Allow the knees to travel forward to maximal pain-free depth during the descent (Figure 4–57)
- Return to full upright to briefly take tension off the quadriceps or remain in a slight knee bend at the top to increase time under tension

Figure 4-56 *Double-leg decline squat start position*

Figure 4-57 *Double-leg decline squat at maximal depth*

ECCENTRIC SINGLE-LEG DECLINE SQUATS

- Stand on the footplate with the target leg
- The opposite leg is held straight and positioned in front (Figure 4–58)
- Sit down to descend into a squat using only the target leg (Figure 4–59)
- At maximal depth, place the opposite leg back on the footplate and push up with both legs (Figure 4–60)

Figure 4-58 *Eccentric single-leg decline squat start position*

Figure 4-59 *Eccentric single-leg decline squat at maximal depth*

Figure 4-60 *The leg is placed back on the footplate in order to perform the concentric portion with both legs*

SINGLE-LEG DECLINE SQUATS

- Perform using the same set-up and initial instructions as the eccentric decline squats
- At maximum depth, do not place the opposite leg back on the footplate and propel upward using only the target leg

Figure 4-61 *Single-leg decline squat start position*

Figure 4-62 *Single-leg decline squat at maximal depth*

ADVANCED SQUAT VARIATIONS

The barbell back squat is an advanced exercise. There are many other exercises that may promote lower body strength without the need for spinal loading and may be more appropriate for establishing baseline levels of strength for beginners. For athletes, powerlifters, CrossFit, and any other individual who chooses to live life under the bar, however, this is an essential movement pattern. The basic squat guidelines explained at the beginning of this chapter still apply here, but many additional details must be considered to properly execute the back squat, which include, but are not limited to, bar position, stance, back muscle activation, and depth.

BAR POSITION

Low bar back squats: The bar is positioned about 2–3 inches below C7 on the upper thoracic spine (Figure 4–63).

- Increased forward trunk lean and hip flexion angle[90,91]
- Decreased knee flexion and ankle dorsiflexion range of motion requirements[92]
- Performed with a wider stance[93]
- May be preferred for posterior chain activation[91,92] due to increased hip extension moment[91]
- May promote lifting heavier loads due to shifting some of the work to the posterior chain[90]
- May be more beneficial than high bar squat for those dealing with knee issues

Figure 4-63 *Low bar back squat bar position*

High bar back squats: The bar is positioned just below C7 on the trapezius "shelf." (Figure 4–64)

- More upright trunk and decreased hip flexion angle[90,91]
- Increased knee flexion and ankle dorsiflexion range of motion requirements[92]
- May be preferred for quadricep activation[91,94] due to increased knee extension moment[91]
- Better replicates the bottom catch position for the snatch or power clean[93]
- May be more beneficial than low bar squat for those dealing with lower back or hip issues

Figure 4-64 *High bar back squat bar position*

FOOT WIDTH AND POSITION

Optimal position is based on comfort and biomechanics – simply, the orientation that allows the greatest pain-free depth while maintaining spinal position. A bodyweight squat assessment and range of motion measurements for the hips and ankles is a practical strategy and should provide a good starting point for the foot position.

- Increased hip external rotation and adductor mobility may favor a wider stance squat
- Increased hip internal rotation and decreased adductor mobility may favor a narrow squat stance
- Bony anatomy also dictates squat depth, but varies greatly between individuals
- Do not force a stance that is uncomfortable

UPPER BACK ACTIVATION AND BRACING

The barbell needs to sit on a stable and strong upper back. The act of pulling down on the bar as if driving the elbows into the lateral ribs engages the latissimus dorsi, middle trapezius, and rhomboids through their respective muscle actions (shoulder extension, scapular depression and retraction). This may also help activate the abdominals via rib cage depression (Figure 4–66). Less movement of the bar on the upper back will allow a more controlled descent into the squat and will help prevent compensatory strategies from the lumbar region or lower extremities. Diaphragmatic breathing and abdominal bracing, as described in Chapter 3, may prevent abdominal hollowing and rib cage flare (Figure 4–65), which can affect spinal position and hip range of motion.

Figure 4-65 *Rib cage elevation, lumbar extension, with poor abdominal bracing strategy*

Figure 4-66 *Rib cage depression, lumbar neutral, with good abdominal bracing strategy*

DEPTH

Squat to the greatest pain-free depth before a significant increase in lower spine flexion, known as the "butt wink," as pictured (Figure 4–68). At this point, the spine will transition from neutral to a posterior pelvic tilt. Adjust foot position, squat width, and bar position to determine effects on spinal flexion and squat depth. Remember, deep squats are not bad, but you need to respect what ranges of motion the body owns and operates in. For example, if an individual only has 90° of active and passive knee flexion, the body will need to compensate at the hip, spine, ankles, etc. to achieve a depth greater than 90°. It is also important to descend to a depth that allows equal weight-bearing on both legs. The body may shift away from the involved side in the presence of pain, impaired range of motion or strength in the ankle, knee, or hip on that side (Figure 4–69). If this occurs, a lateral shift correction can be performed using a band with resistance that pulls them away from the involved side (Figure 4–70). This corrective mechanism will cue the individual to pull back against the resistance of the band in order to load the involved side.

Figure 4-67 *Normal squat pattern. Maintenance of neutral spine at maximal depth*

Figure 4-68 *Lower lumbar spine "butt wink" at maximal depth*

Figure 4-69 *Lateral shift to the right. The body is shifting away from and is not appropriately loading the left leg (involved side)*

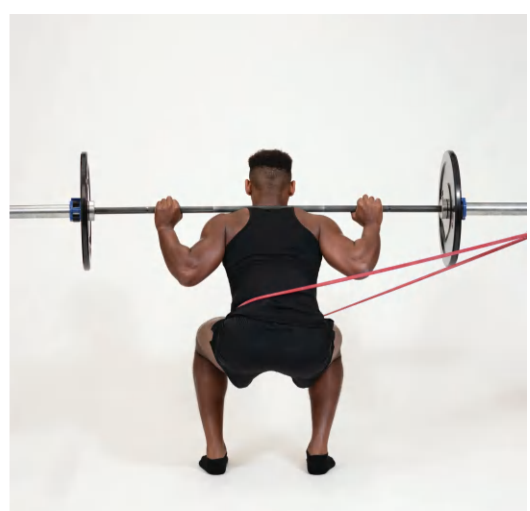

Figure 4-70 *Lateral shift correction. A band is placed around the hips to cue loading the left side*

BARBELL BACK SQUATS

- Select the appropriate stance and secure the feet to the floor
- Take a deep breath in through the nose to fill the stomach with air
- During the breath out, grip the bar and pull down as if pulling the elbows into the rib cage and brace the abdominals
- Initiate the descent by sitting down or shifting the hips backward
- Bend the knees until the maximal pain-free depth
- Drive through the feet while contracting the glutes and quadriceps to transition to the full upright position

Figure 4-71 *Barbell back squat start position*

Figure 4-72 *Barbell back squat at maximal depth*

BARBELL FRONT SQUATS

There is no evidence to support that front squats activate the quadriceps or anterior chain musculature better than back squats, but both variations have different prerequisites with respect to mobility. Barbell front squats can be very challenging because the barbell rests across the clavicle and front of the shoulder, which may be uncomfortable for some individuals. They also require large amounts of wrist extension and ankle mobility. Elevating the heels on plates and using different grip options for the barbell may reduce the amount of ankle and wrist mobility requirements if an individual has deficits in these areas. Front squats do not require as much hip flexion or shoulder external rotation range of motion as back squats, so they may be preferred by those with hip impingement or shoulder injuries. Front squats also generate less compressive forces at the knee compared to back squats,[70,71] so those with cartilage injuries or osteoarthritis may find them more comfortable to perform. Though not well studied, there is also support that front squats also generate less lumbar spine torque and sheer force compared to back squats due to the upright trunk posture, which could make them a worthwhile substitution for someone recovering from a back injury.[95–97]

Front squats have been studied to have positive effects on 3RM squat strength, vertical jump height, horizontal jump, and appear to have carry-over to 3RM hip thrust (see page 160) strength.[98] In a randomized controlled study by Contreras et al.,[98] the front squat significantly improved 3RM squat strength and vertical jump height to a greater extent than hip thrusts, likely because the force vector during front squats is vertical while the hip thrust is horizontal. Hip thrusts had better utility than front squats for improving sprint speed.[98] Therefore, front squats appear to be an appropriate exercise to build strength and maximize jump height.

WRIST STRAP GRIP FRONT SQUAT

Wrist straps decrease the need for wrist extension mobility, promote increased bar security, elbow height, and decrease the pressure of the bar on the clavicle and shoulders.

- Rest the bar across the clavicle and anterior deltoids
- Place the straps where the front of the shoulders contact the bar
- Grasp the straps with the thumbs pointing toward the shoulders and chest
- Pull up on the straps to take the slack out and until the thumbs point down
- Adjust the position of the straps as needed for comfort
- Take a deep breath in through the nose to fill the stomach with air
- During the breath out, pull the rib cage down and brace the abdominals
- Sit down to initiate the descent
- Allow the knees to translate forward during the descent
- Maintain the elbow height throughout the movement to keep the upper back muscles engaged and trunk erect

Figure 4-73 *Barbell front squat, wrist strap grip start position*

Figure 4-74 *Barbell front squat, wrist strap grip at maximal depth*

REGULAR GRIP FRONT SQUAT

- Rest the bar across the clavicle and anterior deltoids
- The hands should be at or just outside of the midpoint of the front of the shoulder
- The bar is held mainly by fingers 2–4 with the wrists maximally extended and the tips of the elbows pointed up at or slightly above shoulder height (Figure 4–75)
- The remainder of the sequence is the same as the wrist strap grip front squat

Figure 4-75 *Barbell front squat, regular grip start position*

GENIE GRIP FRONT SQUAT

The genie grip is likely appropriate for individuals with less wrist extension mobility or those that have difficulty keeping the elbows up throughout the movement due to impaired shoulder range of motion or upper back strength. At lighter loads, the genie grip may be a good substitute for the regular grip, but at heavier loads it may become difficult to secure the bar and prevent it from rolling forward.

- Rest the bar across the clavicle and anterior deltoids
- Cross the arms, create an "X" with the forearms across the bar and rest each hand on the opposite shoulder with the palm facing down (Figure 4–76)
- The remainder of the sequence is the same as the regular grip front squat

Figure 4-76 *Barbell front squat, genie grip start position*

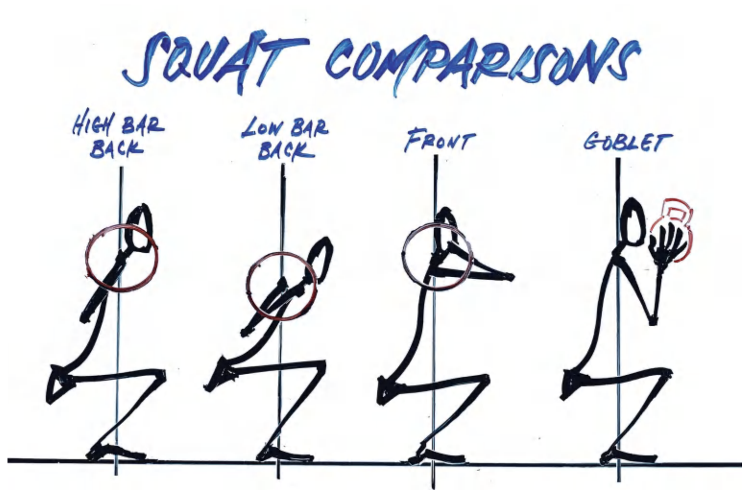

Figure 4-77 *Comparison of four common squat variations – high bar, low bar, front, and goblet squats. The image provides a visual of how trunk displacement, hip, knee, and ankle range of motion should change based on where the load is located*

Table 4-1 *Comparison of three common squat variations – the back, front, and goblet squats*

Which squat variation is most appropriate? *Consider load, training level, injuries, anatomy, and goals*		
Back Squat	***Front Squat***	***Goblet Squat***
High load Intermediate to advanced training level *Prerequisites:* Good hip mobility Good shoulder external rotation mobility *Goals:* Strength, powerlifting, athletics	Moderate-high load Intermediate to advanced training level *Prerequisites:* Good wrist mobility Good ankle mobility *Goals:* Strength, powerlifting, Olympic lifting, CrossFit	Low load Novice training level *Prerequisites:* Basic range of motion of hips, knees, and ankles *Goals:* General muscle endurance, strength, and hypertrophy; improve range of motion under load and learn to balance center of mass

SAFETY BAR SQUATS

Many individuals lack the requisite shoulder mobility to comfortably perform barbell squats and can have difficulty securing a regular barbell in place. In addition, the barbell on the neck or upper back can also be painful or uncomfortable. In these cases, the safety bar, which is a "U" shape design with handles and extra padding, may be a valuable piece of equipment. One support rests on the back of the neck and the other two across the front of each shoulder (Figure 4–78). The handles in the front are used to secure the bar. Use of a

Figure 4-78 *Safety bar squat start position*

Figure 4-79 *Safety bar squat at maximal depth*

safety squat bar promotes increased upright torso position decreased hip extensor torque, upper trapezius, abdominal, hamstring, vastus lateralis, and gastrocnemius muscle activation compared to a regular back squat.[99,100] These differences in muscle activation may have been observed because participants were able to lift heavier loads when performing the barbell back squat compared to the safety squat.[90,99,100]

- The mechanics for the safety bar squat are very similar to the back squat, as the load is still positioned across the back
- Pulling down on the handles will allow some latissimus dorsi and upper back engagement, which will make the bar feel more secure

BELT SQUATS

Belt squats distribute the load to the hips, so there is decreased spinal loading or involvement of the upper body to secure the weight. Belt squats are usually programmed by strength and conditioning coaches that really understand their unique utility, but are less often utilized in the rehabilitation setting. Belt squats have been found to produce the same amount of quadricep and hamstring muscle activation,[101–103] but less lumbar erector and abdominal muscle activation compared to back squats.[102] They also produce either the same[103] or less glute medius and maximus muscle activation compared to back squats.[101, 102] Therefore, belt squats may be a good alternative to barbell or other loaded squats if the goal is to train the lower extremities while also reducing muscle activation and stress on the low back and/or abdominals. Accessory exercises to target the hip muscles may be good additions to a training program that uses belt squats. Belt squats can be performed with a specialized piece of equipment or freestanding with a tricep belt, steps or risers, and free weight, plate, or landmine attachment. The free weight (Figure 4–80) and landmine setups (Figure 4–82) are easiest to replicate in a clinical setting.

FREE WEIGHT BELT SQUATS

- Equipment: two risers, a tricep belt, weighted plates, or a kettlebell
- Have the patient climb up onto the risers and don the belt
- Loop the chain from the tricep belt around the weight and let it hang between the legs
- Descend into a squat and allow the weight to travel between the risers toward the floor
- To decrease the difficulty, rest the hands on the thighs or perform with upper extremity assistance like the hatfield squat (see page 45), as both of which may improve stability
- For the purpose of safety, add the weight after climbing up onto the risers and remove it prior to stepping down from the risers

Figure 4-80 *Free weight belt squat start position*

Figure 4-81 *Free weight belt squat at maximal depth*

LANDMINE BELT SQUATS

The landmine method decreases the stability demands of a free weight belt squat, as the barbell does not oscillate and move around as much as the free weights. It can be performed with risers (as pictured) or without depending on the desired range of motion.

- Straddle the end of the barbell and loop the chain from the tricep belt around it
- Descend into a squat and allow the barbell to travel between the legs toward the floor
- If adding weight to the barbell, use smaller plates to maximize range of motion

Figure 4-82 *Free weight belt squat start position*

Figure 4-83 *Free weight belt squat at maximal depth*

STRADDLE SQUATS

Similar to the belt squat, straddle squats use a load that travels between the legs and remains close to the midline of the body, which decreases lower back torque. Risers must be used to increase available range of motion.

- Adopt a stance wider than hip width
- Grasp a dumbbell or kettlebell with both hands
- Descend into a squat and allow the weight to travel between the legs toward the floor
- The trajectory of the weight should be straight down
- Keep the trunk relatively erect throughout the movement

Figure 4-84 *Free weight belt squat start position*

Figure 4-85 *Free weight belt squat at maximal depth*

SISSY SQUATS

Sissy squats are designed to load the quadriceps maximally and reduce contribution from other muscle groups. Traditional sissy squats are somewhat controversial due to increased loading of the anterior knee and may be too difficult or contraindicated for the majority of patients, but modified variations may be quite useful to load the quadriceps and anterior knee.

MODIFIED SISSY WALL SQUATS

- Elevate the heels on the wall or heel wedges (Figure 4–86)
- Allow the knees to travel forward over the toes during the descent and let the back slide down the wall
- Range of motion will be limited only by knee flexion and ankle mobility, as the hip angle stays constant throughout the movement
- At maximal, pain-free depth, think about contracting the quadriceps and extending the knees to return to upright
- Do not come to a full stand at the top to keep constant tension on the quadriceps

Figure 4-86 *Modified sissy wall squat foot position*

Figure 4-87 *Modified sissy wall squat start position*

Figure 4-88 *Modified sissy wall squat at maximal depth*

SISSY BARBELL SQUAT

The use of a barbell pad on a racked barbell or smith machine (Figure 4–89) acts as a counterbalance for the legs to allow the feet to remain fully grounded. The stationary bar and pad also provides leverage, as the back of the lower legs can be driven into the pad to allow the quadriceps to pull the body to an upright position from depth. There is minimal hip and trunk flexion, so the majority of the range of motion comes from knee flexion. This set-up is easy to replicate in a clinic, especially in the absence of a sissy squat machine, which is not commonly found in physical therapy clinics or many commercial gyms.

- Secure the feet to the floor by planting them, or by using two weighted plates in front of the feet
- Rest the back of the lower legs on the barbell pad, which should fall right at the top of the calf and below the knee joint
- Lean back into the barbell pad and allow it to accept the body's weight
- Sit down into a squat by bending the knees and allow the back of the knees to bend over the pad
- Once at maximal, pain-free depth, continue to drive the back of the legs into the pad and use the quadriceps to "pull" the body back to upright
- Do not come to a full stand at the top to keep constant tension on the quadriceps

Figure 4-89 *Sissy barbell squat start position*

Figure 4-90 *Sissy barbell squat at maximal depth*

TRADITIONAL SISSY SQUAT

This is an advanced exercise and a simple visual of the movement may induce knee pain in some individuals. Traditional sissy squats, however, can be used for return to sport and activity for those with the requisite mobility, training level, and who perform activities that demand excessive anterior knee translation. This movement pattern is quite similar to some of the mechanics found in dance as well as the mount position and some takedown variations in Brazilian jiu-jitsu.

- Begin with heels elevated and weight through the balls of the feet
- Keep the torso in a straight line from the head to the knees
- As the knees bend and travel forward toward the floor, the torso travels backward
- Push through the feet and contract the quadriceps to propel back to upright, all while keeping the torso straight
- It is important to not bend at the hip at any point throughout the movement
- These can be performed next to a bench, in front or inside of a squat rack for balance and upper extremity support

Figure 4-91 *Traditional sissy squat start position*

Figure 4-92 *Traditional sissy squat at maximal depth*

CHAPTER 5

HINGE

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The hinge pattern teaches hip and spine dissociation, lumbo-pelvic motor control, and how to pick things up and put them down with control and intent. Deadlifts target the posterior chain muscles, including the erector spinae, gluteus maximus, and hamstrings, but have also been observed to activate the quadriceps to a significant extent.[104] Deadlifts are not bad for the lower back, despite the stigma surrounding them. When performed correctly, deadlifts can play a crucial role in lower back health and have been proven to have positive effects on pain, quality of life, and back extensor endurance. High-load training (i.e. deadlifts) may be just as effective as low-load motor control exercises for pain, muscle strength, and endurance.[105–107] Individuals that have lower pain levels (less than 60 mm on the visual analog scale) and who have already developed some back extension endurance as measured by greater than 60 seconds on the Beiring Sorensen test (see page 114) may be more appropriate for deadlift training than those who have not.[108]

To an untrained eye, the squat and deadlift can be mistaken for very similar exercises. Biomechanically, the deadlift requires a greater degree of hip flexion and decreased knee flexion angle compared to the squat[109,110] (Figure 5–1). As a result, deadlifts may be more optimal to target the hip extensors.[109] A good hinge pattern may reduce low back torque and compression via activation of the trunk extensors during lifting tasks[59] and will place the spine and posterior chain in an optimal position to lift. It may also allow trunk musculature and supportive spine structures to learn to share the load with the glutes and hamstrings. The deadlift and squat produce similar improvements in maximal strength and jump height, but remain true to the principle of specificity, as those in the deadlift group improved their 1RM deadlift greater than their 1RM squat and vice-versa.[111] As a result, deadlifts may be best if the goal is to improve ability to lift loads from the floor.

Rehabilitation professionals should feel confident prescribing and coaching hinge patterns to beginners and advanced lifters to treat current and prevent future injuries. The different deadlift variations throughout this chapter provide ample opportunities for the movement pattern to match the experience level, body type, and injury of each individual (Figure 5–80)(Table 5–1).

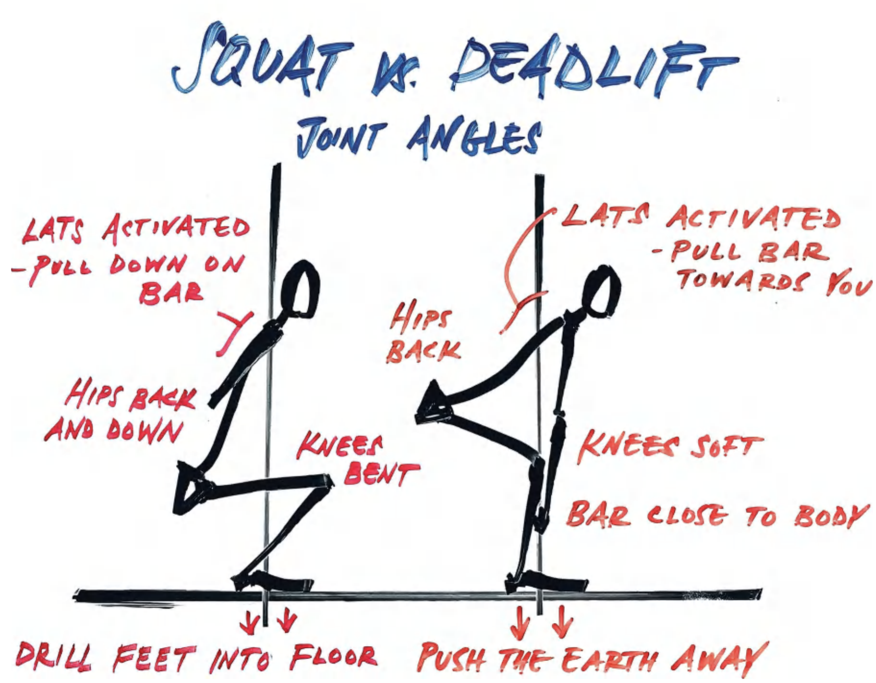

Figure 5-1 *Comparison of squat and deadlift form with respect to trunk, hip, and knee angles, as well as closed-chain ankle dorsiflexion range of motion*

HINGE TRAINING FOR BEGINNERS

There are many exercises that may allow beginners to optimize movement capacity and build a foundation of strength and endurance in order to progress safely to more advanced variations. Specifically, the dowel hinge, hinge pulldown, band Romanian deadlift, and kneeling hinge aim to teach crucial components of the deadlift, including the hips back motion, maintaining spinal position, and keeping the load close to the body.

DOWEL HINGE

The dowel hinge teaches many crucial components of the hinge, including how to shift the hips back and allow the trunk to travel forward using the dowel, PVC pipe, etc. as a counterbalance. It can also help mobilize the hamstrings and serve as a warm-up exercise prior to lifting.

- Stand with the feet hip-width apart
- Secure the feet to the floor
- Grasp the dowel with both hands at about shoulder height
- Keep knees soft and unlocked
- Push the dowel away and reach the hips backward as the arms and trunk travel forward
- The knee angle should stay relatively constant throughout the movement
- The goal is to bend from the hips to feel a stretch on the underside of the glutes and proximal hamstrings
- The spine should stay relatively neutral without any excessive flexion or extension
- Tighten the glutes and pull the dowel back toward the body to return to upright

Figure 5-2 *Dowel hinge start position*

Figure 5-3 *Dowel hinge at end-range*

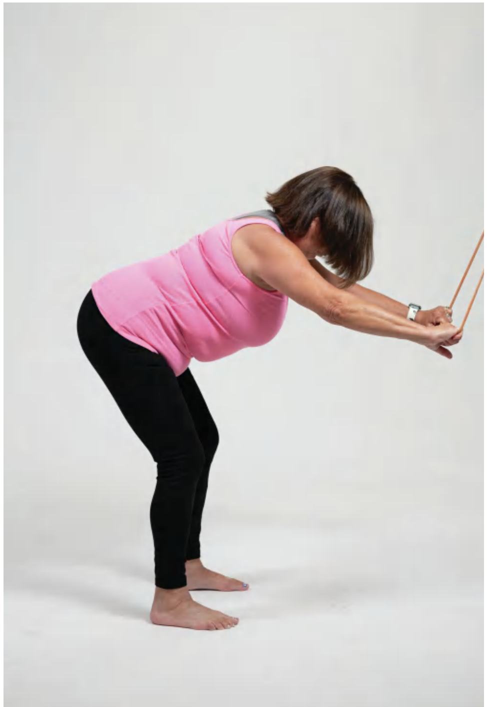

Figure 5-4 *Hinge pull down with band start position*

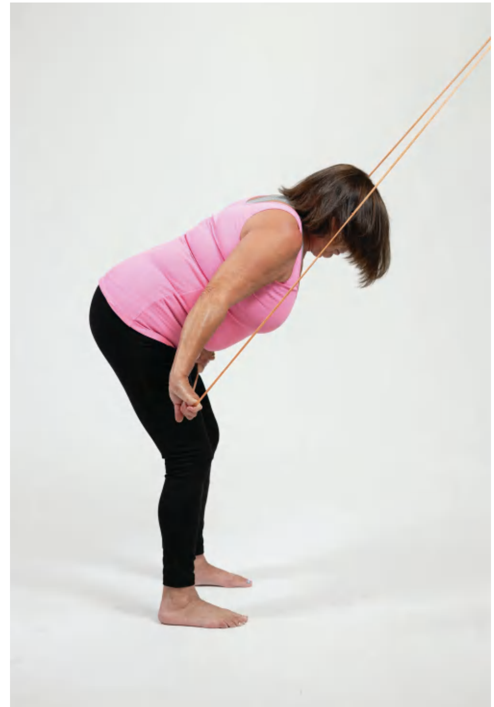

Figure 5-5 *Hinge pull down at end-range*

HINGE PULLDOWN

The hinge pulldown promotes stability via abdominal and latissimus dorsi engagement. Engaging these muscles properly prior to deadlifting may improve lifting efficiency and prevent loss of spinal position, especially during the "pull" phase of the deadlift movement.

- Stand with the feet hip-width apart and knees soft
- Grasp the band with both hands
- Reach the hips backward as the arms and trunk travel forward
- Tighten the abdominals and pull the ribcage down
- Keep the arms straight and pull the band down toward the sides
- The goal is to maintain a stable position in your back throughout the movement

BAND ROMANIAN DEADLIFT (RDL)

The band RDL forces latissimus dorsi engagement by resisting the constant pull of a resistance band that is attached to the load (or hands if performing without weight). The goal is to keep the load close to the body, which may encourage stability and form maintenance through the entire movement.

- Stand with the feet hip-width apart and knees soft
- Pull the band to the thighs
- Reach the hips back and allow the trunk to travel forward
- Keep band contact with the legs as the hands slide down the thighs

- The knee angle should remain relatively constant
- A good stopping point is right below the knee
- Contract the glutes and abdominals hard to propel back to upright
- Grasp a kettlebell in each hand for an additional challenge

Figure 5-6 *Band RDL start position*

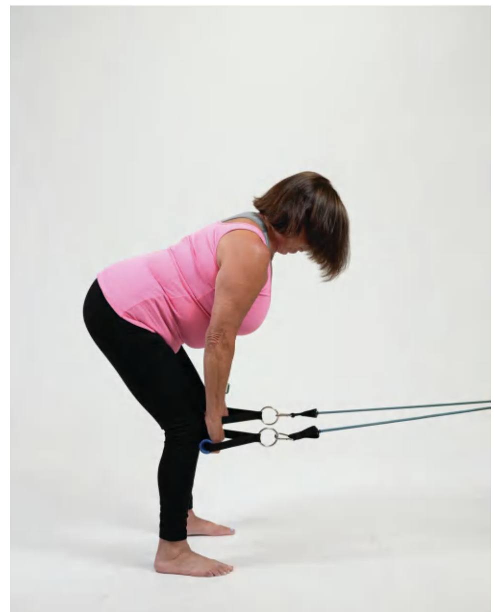

Figure 5-7 *Band RDL at end-range*

KNEELING HINGE

Sometimes, individuals will have increased difficulty with hinge or deadlift patterns from standing for a variety of reasons. Standing exercises have more degrees of freedom and increased stability requirements compared to tall kneeling exercises. Hamstring mobility and balance demands are greatly reduced when the exercise is regressed to the floor. The kneeling hinge may allow greater focus on spine mechanics, glute, and abdominal activation for the novice lifter.

- Clasp the hands together and place them against the chest
- Engage the abdominals and pull the rib cage down
- Activate the latissimus dorsi by pressing the hands into the chest, pulling the arms down and slightly backward
- Shift the hips back and allow the trunk to travel forward
- Contract the glutes hard and drive the hips forward to return to upright
- For those with excessive lumbar extension, cue performing a posterior pelvic tilt at end-range

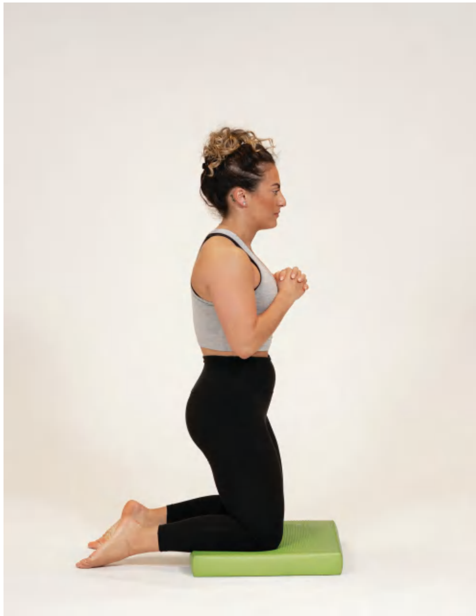

Figure 5-8 *Kneeling hinge start position*

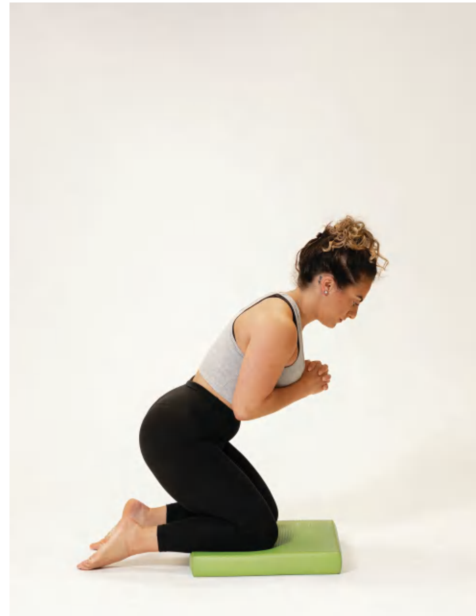

Figure 5-9 *Kneeling hinge at end-range*

BAND-RESISTED KNEELING HINGE

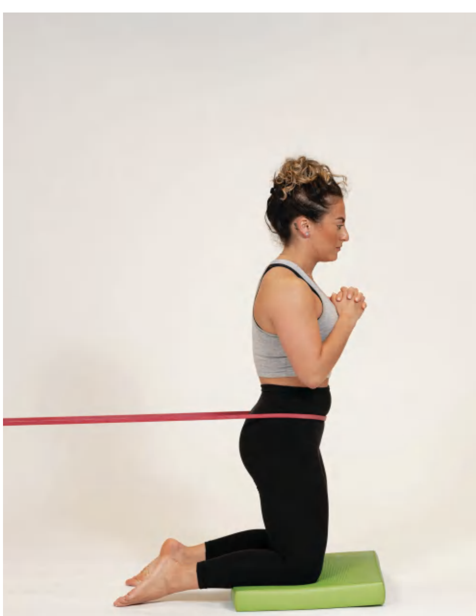

Figure 5-10 *Kneeling hinge with band start position*

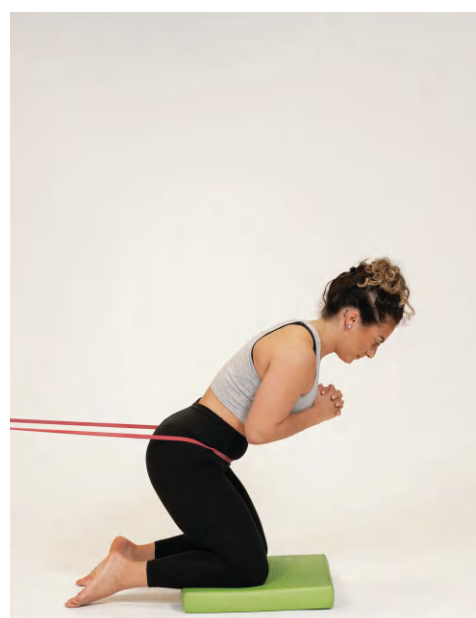

Figure 5-11 *Kneeling hinge with band at end-range*

KETTLEBELL DEADLIFTS

Lifting a weight from the floor can be very challenging, so it may be easier to break down the movement pattern into separate exercises to ensure readiness, skill acquisition, and success. The addition of a box will decrease the distance the weight needs to travel and will reduce the required range of motion at multiple joints, most notably in the back and hamstrings. The initial set-up is the same for all four exercises and is detailed below.

- Position the feet on either side of the box with the kettlebell between the shoelaces (Figure 5–12)
- Reach the hips back and slide the hands down the thighs (Figure 5–13)
- Allow the trunk to travel forward
  - There should be a 1:1 hips back to trunk forward ratio
- The knees are slightly bent, but knee flexion angle does not increase significantly throughout
- Cue not to reach for the kettlebell, but to slide the hands down the legs until the hands are at the level of the handle
- Grasp the kettlebell and imagine ripping the handle apart (Figure 5–14)
- Retract the shoulder blades and imagine pulling backward with the arms in order to activate the latissimus dorsi and upper back (Figure 5–14)
- Engage the abdominals and pull the rib cage down to avoid low back hyperextension and rib flare

Figure 5-12 *Kettlebell deadlift start position*

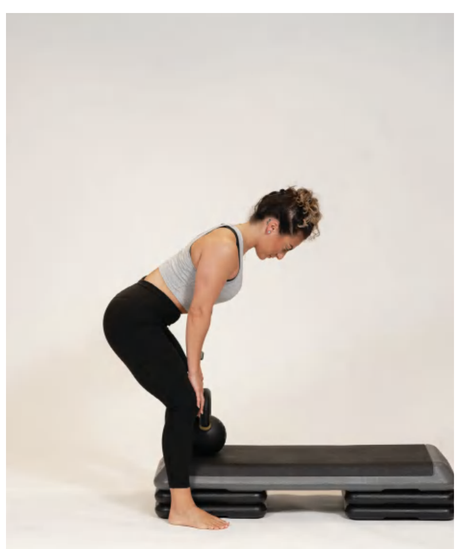

Figure 5-13 *Begin the hinge by sliding the hands down the thighs instead of reaching for the weight*

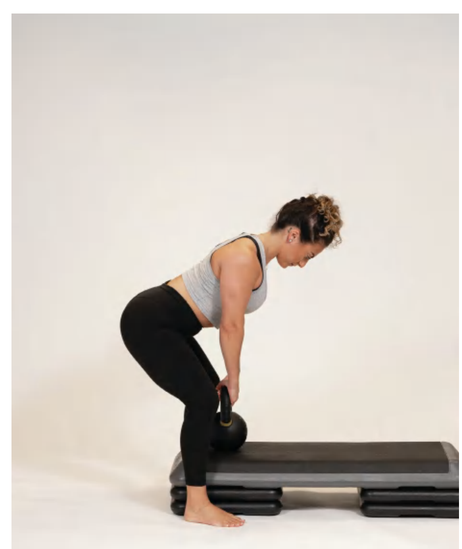

Figure 5-14 *Stabilize in the bottom position by activating the upper back and abdominals prior to initiating the pull*

KETTLEBELL ISOMETRIC DEADLIFT FROM BOX

Two common faults that are observed during the deadlift are loss of tension in the upper back (rounding) and the hips rising before the torso during the initial pull. Isometric deadlifts from a box promote mastering the starting set-up and pull position. Isometric deadlifts are very safe to perform, as there is no change in muscle length or joint angle, and can provide a significant training effect when performed with high effort. The kettlebell should be significantly heavier than any weight an individual would normally use for this lift, as the goal is not to actually pick it up off the box.

- Perform the sequence as detailed above in order to achieve the appropriate position and grasp the kettlebell (Figure 5–14)
- Pull up on the kettlebell with the goal of irradiating whole body tension via a strong grip, upper back, and abdominal muscle activation, but do not aim to lift the weight
- Take small breaths while maintaining the position to avoid continuous Valsalva
- Place the load on the floor to increase range of motion and difficulty

KETTLEBELL CONCENTRIC DEADLIFT FROM BOX

Apart from the initial pull, form breakdown also occurs during the lowering or eccentric phase. Excessive flexion of the lumbar and thoracic spine are observed if an individual leads with the weight instead of the hips during the descent. This often results in the load traveling away from the body, which increases the lever arm and torque on the lower back. The lowering phase can be eliminated in the short-term to prioritize concentric strength and to reduce additional stress on the spine and soft tissues.

- The chest and torso should rise before the hips as the weight is lifted from the box
- Drive down through the feet, contract the glutes, and drive the hips forward
- Keep the rib cage stacked over the pelvis and don’t hyperextend the low back at the top of the movement
- Another individual will take the kettlebell and reset it on the box in preparation for the next repetition

Figure 5-15 *Kettlebell deadlift from box start position*

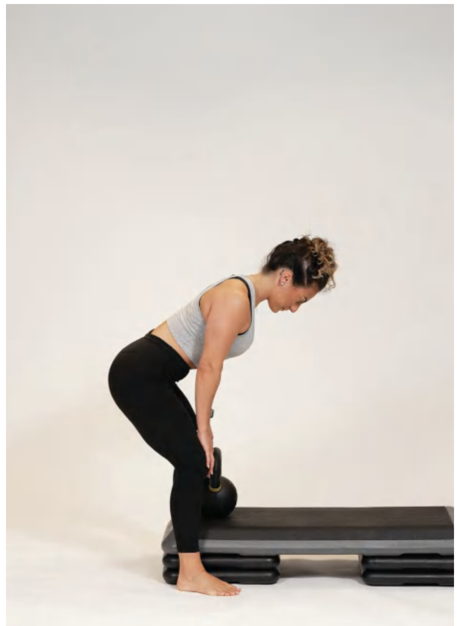

Figure 5-16 *Kettlebell deadlift from box initial hinge*

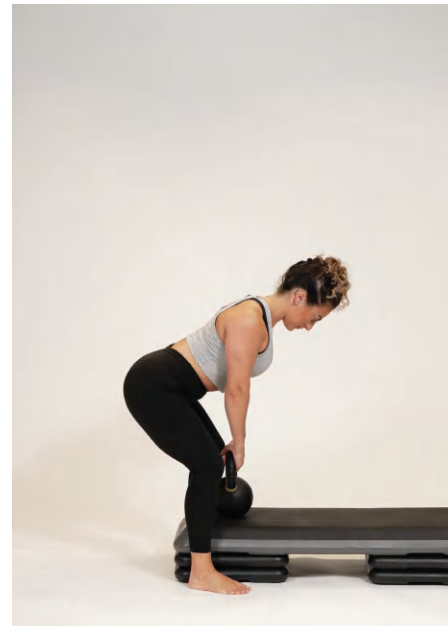

Figure 5-17 *Kettlebell deadlift from box at end-range prior to the pull*

KETTLEBELL DEADLIFT FROM BOX

Many individuals with increased thoracic kyphosis or poor hamstring mobility have difficulty achieving a good pull position when lifting from the floor and may compensate by flexing the spine. The kettlebell deadlift from a box will reduce the range of motion that the weight must travel and serves as an entry point for loading both the concentric and eccentric portions of the deadlift across all patient populations.

- Perform the concentric portion of the deadlift as detailed above
- Shift the hips backward and lower the weight to the box as if trying to place it between the feet
- Lowering the weight should be driven from the hips back motion and not by reaching the weight to the floor

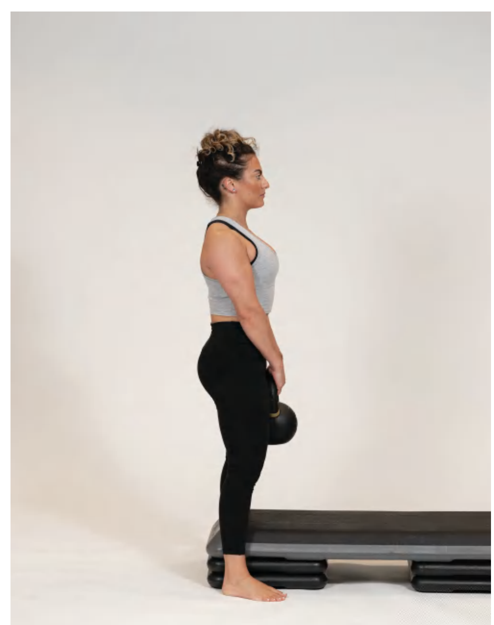

Figure 5-18 *Kettlebell deadlift from box at end-range of the concentric pull phase*

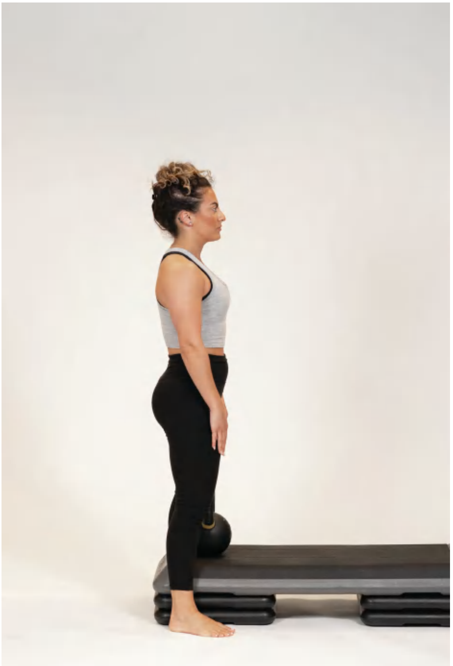

Figure 5-19 *Kettlebell deadlift from box start position*

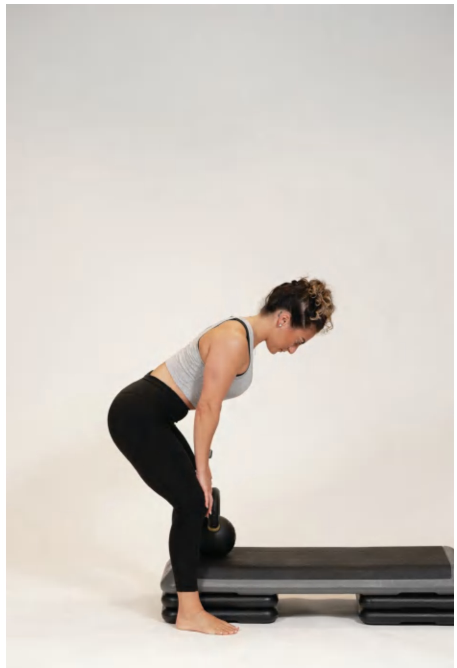

Figure 5-20 *Kettlebell deadlift from box initial hinge*

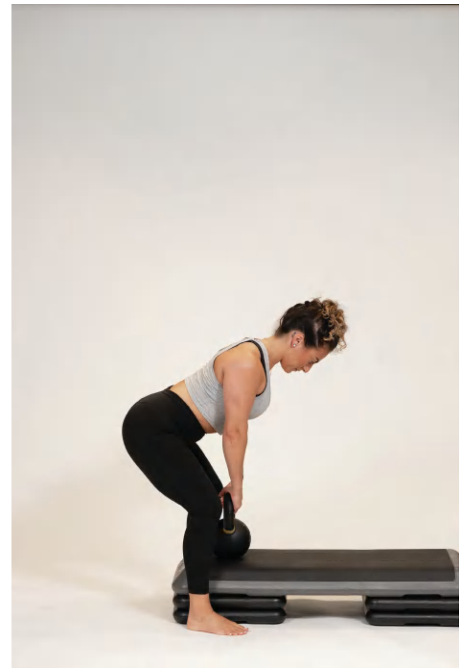

Figure 5-21 *Kettlebell deadlift from box at end-range prior to the pull*

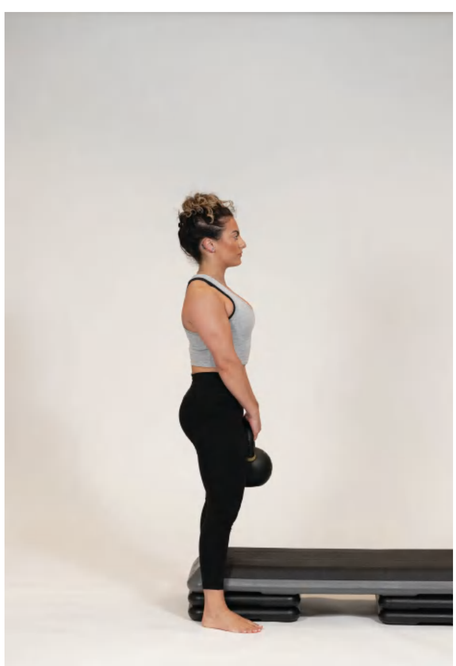

Figure 5-22 *Kettlebell deadlift from box at end-range of the concentric pull phase*

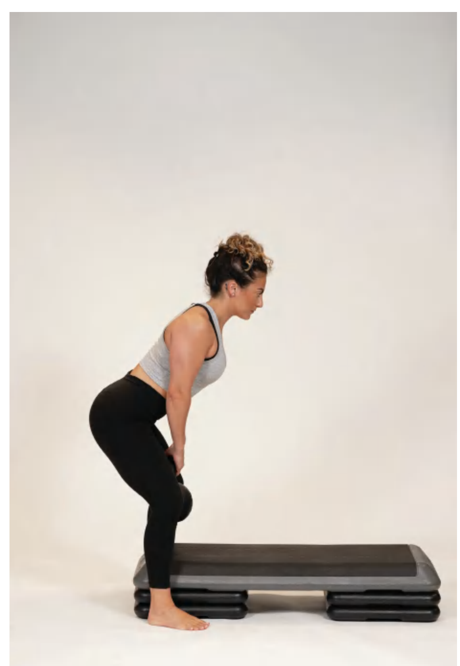

Figure 5-23 *Controlled lowering of weight back down to box (halfway point) with the path of the kettlebell traveling back between the laces or mid-foot*

KETTLEBELL DEADLIFT FROM FLOOR

It is appropriate to progress to the floor once a good pull position is achieved from the box and the individual understands how to properly lower the weight. The same technique as above will be used, less the box.

Figure 5-24 *Start position*

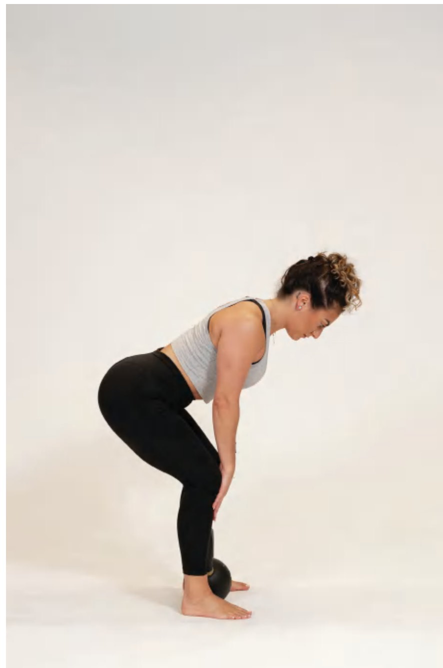

Figure 5-25 *Sliding hands down the thighs to initiate the hinge*

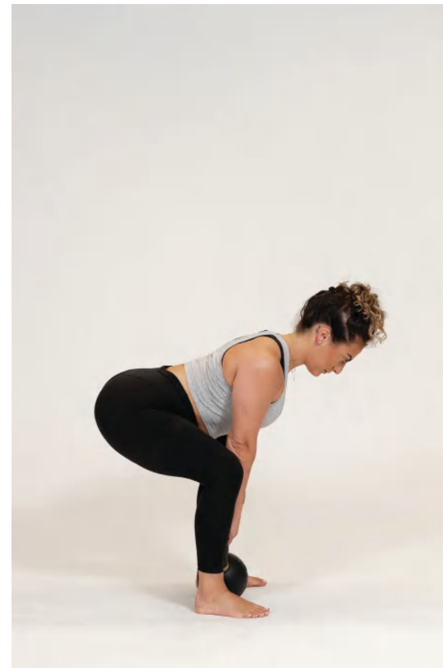

Figure 5-26 *End-range prior to pull phase*

Figure 5-27 *End-range of concentric pull*

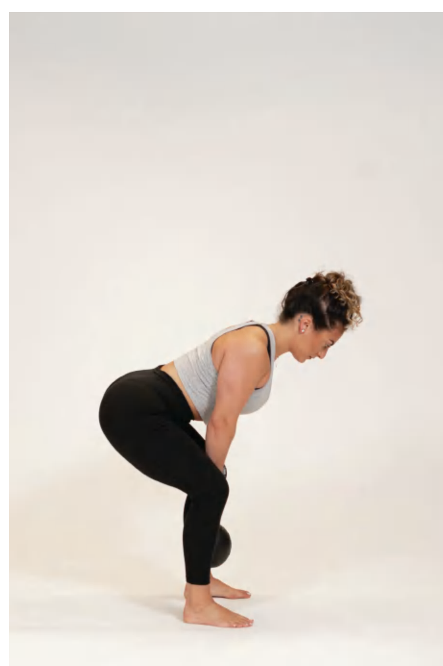

Figure 5-28 *Controlled lowering of weight back down to floor*

Figure 5-29 *Deadlift fault – excessive knee flexion*

Figure 5-30 *Deadlift fault – forward trunk flexion when attempting to reach for the weight*

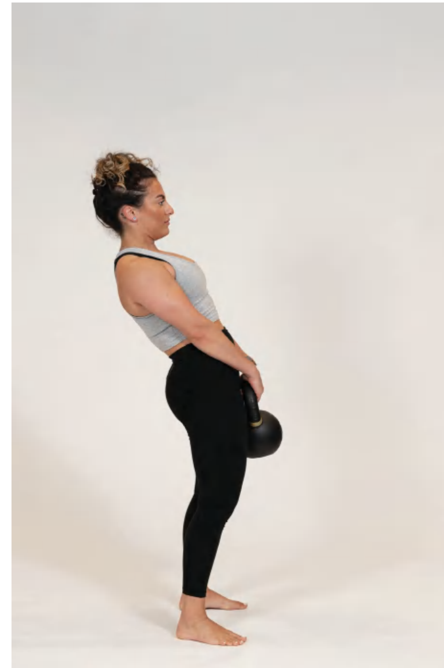

Figure 5-31 *Deadlift fault – hyperextension at end-range*

OTHER DEADLIFT AND HINGE VARIATIONS

SUITCASE DEADLIFT

The suitcase deadlift aims to target both posterior chain and lateral core strength. It mimics patterns that are performed daily, like carrying a heavy bag, suitcase, or even groceries.

- Perform a regular deadlift pattern while holding the weight only on one side
- Let the weight slide down the leg as the hips shift backward
- Place it on the floor next to the foot on the same side
- Drive down through the feet, contract the glutes, and push the hips forward to return to upright
- Can be performed from a riser (elevated on box, bench, step, etc.) as needed


Figure 5-32 *Start position*

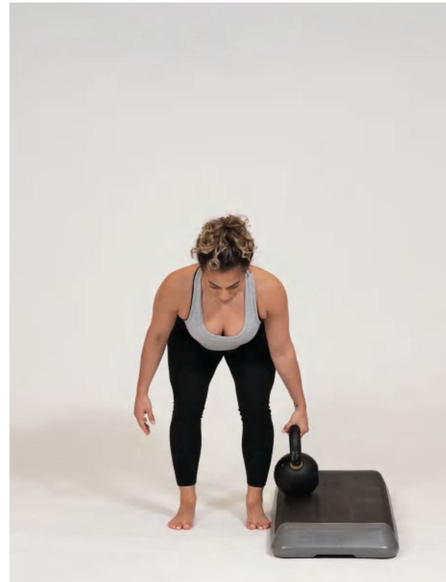
Figure 5-33 *End-range prior to pull phase*

STANDING BAND-RESISTED DEADLIFT

Band resistance at the hips may enhance glute activation and provide a means to load the hinge pattern when an individual is unable to grasp a weight due to hand or other upper extremity issues. The band also helps guide the hips posteriorly during the hinge.

- Engage the abdominals and pull the rib cage down
- Reach the hips back, slide the hands down the thighs and allow the trunk to travel forward by bending at the hips
- The knee angle should remain relatively constant
- Contract the glutes and drive the hips forward to return to upright


Figure 5-34 *End-range of hinge, prior to forward propulsion*

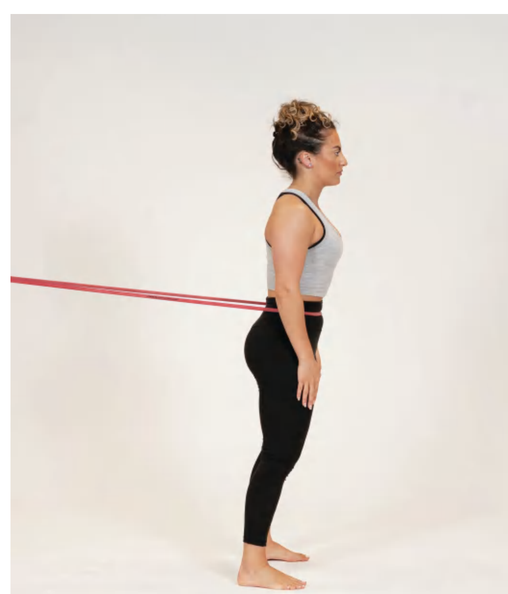
Figure 5-35 *End position*

PULL THROUGH

The pull through changes the angle at which the load is oriented, as the line of pull of the resistance is posterior versus down and in the direction of gravity, as experienced during the barbell or dumbbell RDL (see page 101). As a result, there is reduced muscle activation in the lumbar erectors and hamstrings, but comparable activation of the gluteus maximus compared to the RDL.[112] Therefore, the pull through may be an appropriate hinge pattern to train the gluteus maximus while reducing stress on the lower back muscles if recovering from injury.

- Stand with the feet shoulder-width apart
- Secure the feet to the floor
- Grasp a band or tricep rope between the legs
- Reach the hips back and allow the trunk to travel forward as the arms are pulled backward between the legs by the resistance
- The cable or band will actually assist with pulling the body into proper hinge form
- The knee angle should remain relatively constant
- Contract the glutes and drive the hips forward to return to upright

Figure 5-36 *End-range of hinge, prior to forward propulsion*

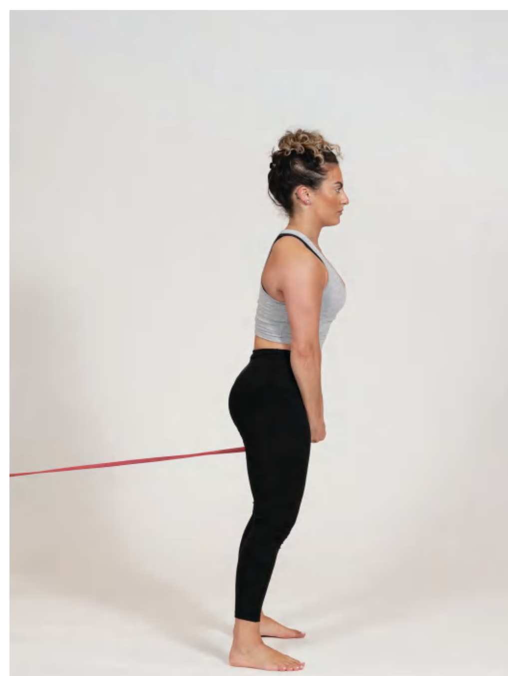

Figure 5-37 *End position*

ASSISTED OR MODIFIED SINGLE-LEG HINGE VARIATIONS

Single-leg loading is very important, especially when addressing unilateral injuries. Training one leg at a time will promote increased rotatory stability, lateral hip strength, and may help correct muscle imbalances. It is, however, sometimes difficult for individuals to perform single-leg hinge exercises due to balance or strength issues. Assisted single-leg exercises may allow an individual to establish the requisite level of single-leg stability and strength necessary to transition to a more challenging variation.

STAGGERED-STANCE DEADLIFTS

Staggered-stance, "kickstand" or "B-stance" deadlifts reduce balance demands associated with traditional single-leg deadlift exercises, but can bias shifting the load to one limb more than the other. Due to decreased balance demands, they can often be loaded heavier than a single-leg deadlift.

- Stand in a split stance with the target leg about 8–12 inches in front of the other
- The majority of the weight should be on the front foot throughout the movement
- The back foot provides stability by weight bearing through the toes, hence the "kickstand" term
- Engage the abdominals and pull the rib cage down
- Shift the hips backward and allow the trunk to travel forward as if sitting back into the hip of the front leg
- The hands (and weights if loaded) should slide down the side of the thighs toward the floor
- A stretch should be felt deep in the glute and proximal hamstring muscles
- The angle of the front knee should remain relatively constant or increase only slightly
- Do not let the front knee straighten out, as this will shift weight off the front foot
- Contract the glutes and drive the hips forward to return to upright

Figure 5-38 *Start position*

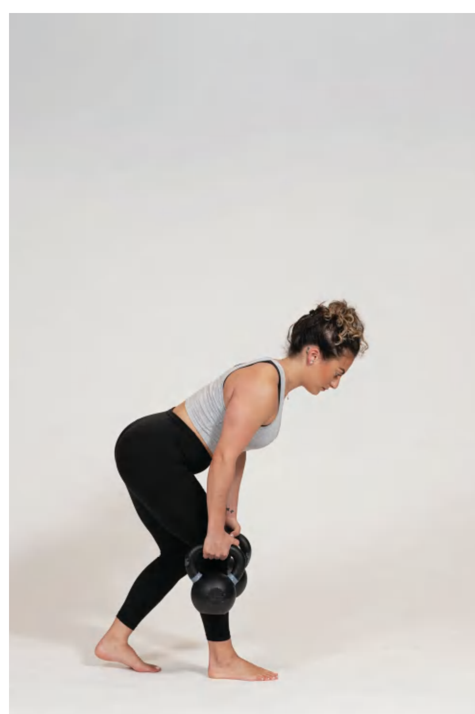

Figure 5-39 *End-range of hinge, prior to forward propulsion*

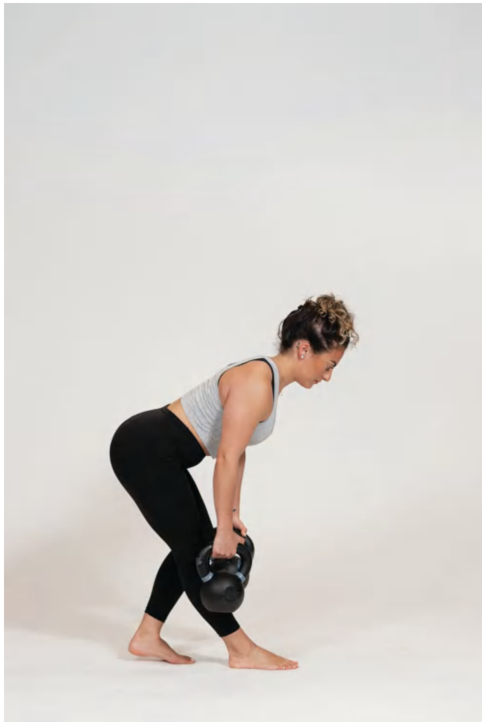

Figure 5-40 *Staggered-stance deadlift fault – shifting weight off of the front leg*

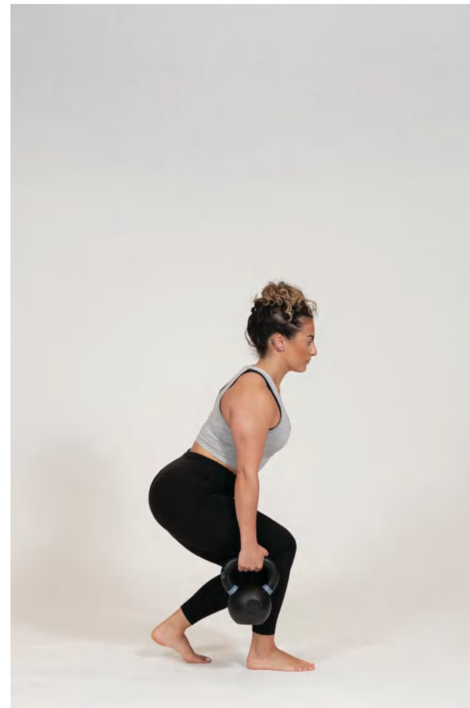

Figure 5-41 *Staggered-stance deadlift fault – excessive knee flexion into a lunge pattern decreases the ability of the hips to shift posteriorly*

REAR FOOT ELEVATED SINGLE-LEG DEADLIFT (RFE SLDL)

The RFE SLDL is similar to the staggered-stance deadlift, but the balance demands are slightly greater. Elevating the rear leg will allow increased single-leg loading and aims to further challenge both the posterior chain and hip abductors of the stance leg.

- Elevate the rear foot on a box, bench, RFE rack attachment, etc.
- Maintain good foot contact and a soft knee on the front leg
- Bend from the hip (not the knee) to allow the trunk to travel forward as if sitting back into the hip of the front leg
- Without pushing off the back leg, contract the glutes, and drive the hips forward to return to upright

Figure 5-42 *Start position*

Figure 5-43 *End-range of hinge, prior to forward propulsion*

BENCH SLIDE SINGLE-LEG DEADLIFT (SLDL)

The upper extremity support on the bench or box provides increased tactile and kinesthetic awareness, acts as a guide for the trunk to travel forward, reduces core stability and balance demands.

- Place the hand on the top of an incline bench, box, or high mat
- Use the upper extremity support to slide the hand forward
- Hinge at the hips and reach the rear leg back

Figure 5-44 *Start position*

Figure 5-45 *End-range of hinge*

SINGLE-LEG DEADLIFTS (SLDL)

The single-leg deadlift targets the hamstrings, gluteus maximus, hip abductors, single-leg, and rotatory trunk stability. It generates high levels of peak force for the entire gluteal complex: gluteus maximus, medius, and minimus.[83] The SLDL activates the gluteus medius to a greater extent at 68% MVIC during combined concentric and eccentric action, compared to 48% MVIC during the conventional deadlift.[113]
It is a difficult exercise to master due to significant balance and stability demands, but modified variations mentioned throughout this chapter can allow an individual to train this movement pattern.

TRADITIONAL SLDL

- Ensure contact of the entire foot with the floor (especially the first toe) throughout the entire movement
- Engage the abdominals and pull the rib cage down
- Keep a soft knee on the stance leg
- Bend at the hip and reach the rear leg back and up, as if trying to create length through the leg and torso
- The rear leg should move in line with the torso
- As the trunk comes forward, keep the front of the pelvis facing the floor
- Turning the rear foot inward can help keep the pelvis level if it tends to open toward the side of the moving leg
- Contract the glutes and drive the hips forward to return to upright

Figure 5-46 *Start position*

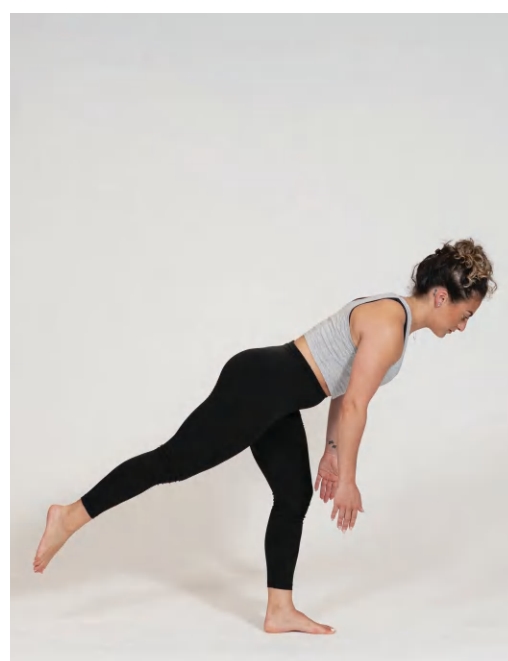

Figure 5-47 *End-range of hinge*

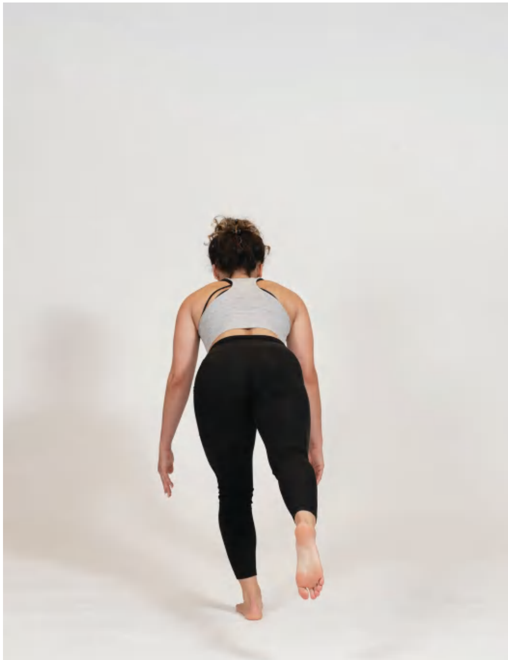

Figure 5-48 *Maintains a level pelvis at end-range*

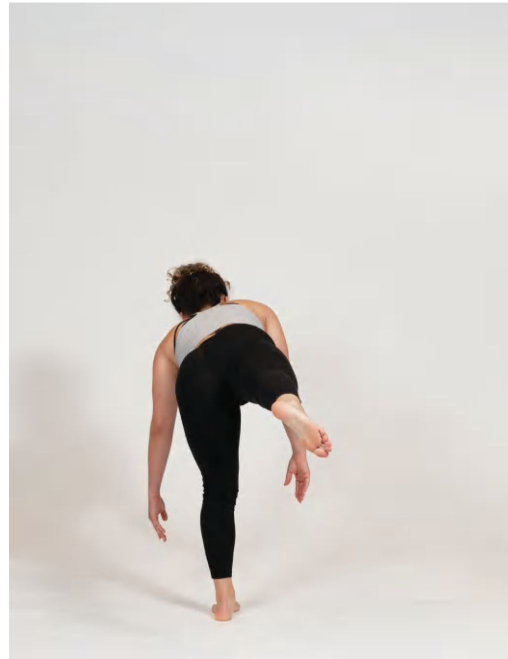

Figure 5-49 *SLDL fault – opening up at the produces excessive trunk and hip rotation and limits ability to maintain a level pelvis*

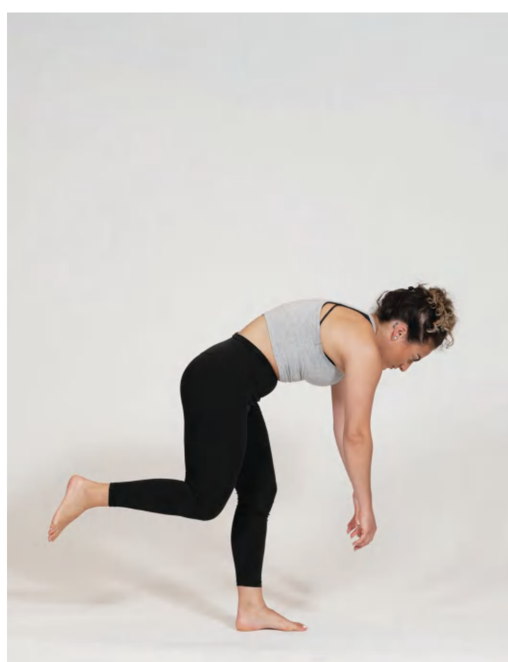

Figure 5-50 *SLDL fault – forward trunk flexion*

FOAM ROLLER SLDL

The foam roller may enhance stability through an isometric contraction of the upper and lower extremity. The pressure exerted into the foam roller by the extremities may help to further engage the abdominals, keep the pelvis level, discourage spine segmentation, and excessive forward trunk flexion.

- Position the foam roller on the top of the foot of the rear leg
- Place the hand on that side on top of the roller
- Extend the arm out straight and create tension by pressing into the roller with the arm and leg
- Hinge at the hips and reach the rear leg back while maintaining pressure into the roller
- Contract the glutes and drive the hips forward to return to upright

Figure 5-51 *Start position*

Figure 5-52 *End-rage of hinge*

SLDL TOE TAPS

Instead of allowing the rear leg to travel up toward the ceiling, it will travel backward to tap the toes on the floor to maintain balance. The hip hinge range of motion will be drastically reduced, as the leg extends further behind versus up and the trunk is less horizontal, but this may be used to improve balance and build confidence before progressing the range of motion.

- Keep the knee of the stance leg soft
- Hinge at the hips and allow the trunk to travel forward in order to extend the rear leg backward
- Tap the toes of the rear leg to the floor behind
- Contract the glutes and drive the hips forward to return to upright

Figure 5-53 *Start position*

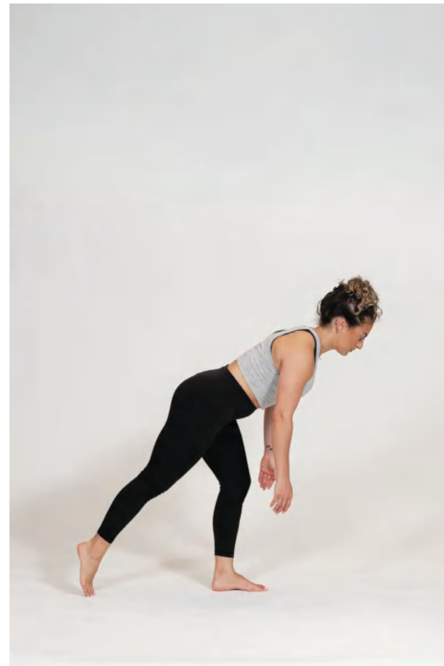

Figure 5-54 *End-range of hinge. Rear foot taps floor for balance, which limits range of motion at the hip and trunk*

RUNNING MAN SLDL

The "running man" SLDL incorporates reciprocal limb movement and dynamic balance while replicating patterns commonly observed during walking or running, but the increased forward trunk translation shifts some of the focus to the posterior chain.

- Start in single-leg stance with the contralateral hip in flexion
- The flexed hip and opposite arm remain paired throughout the movement
- Hinge at the hips and allow the moving leg and opposite arm to extend backward as the trunk travels forward

Figure 5-55 *Start position*

Figure 5-56 *End-range of hinge. Note the reciprocal arm and leg movement*

ADVANCED DEADLIFT VARIATIONS

RACK PULL

The rack pull is a modified height barbell deadlift, named for the fact that it is usually performed on the safety bars inside of a squat rack, but can be performed from a different raised height set-up as pictured. Rack pulls, may be extremely useful if pulling from the floor causes form breakdown or exacerbates symptoms. Consider the rack pull as the barbell version of the kettlebell deadlift from a box (see page 79).

- Elevate the barbell on crash bars, stacked plates, or blocks
- Position the shoelaces under the bar with feet between hip-and shoulder-width apart
- The bar should be in contact with the shins
- Slide the hands down the thighs, reach the hips backward, and allow the trunk to travel forward
- Once the hands can touch the bar, grip the bar with the hands outside of the legs
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades to activate the upper back and pull the bar toward the body to activate the latissimus dorsi
- Drive down through the feet, contract the glutes, and push the hips forward to return to upright
- The hips and shoulders should rise at the same rate
- The goal is to keep the bar as close as possible to the body
- Let the bar slide back down the thighs and rest on the elevated surface

Figure 5-57 *Start position*

Figure 5-58 *End-range of hinge prior to pull phase*

Figure 5-59 *End-range of the concentric pull phase*

Figure 5-60 *Controlled lowering of bar back down to rack or risers*

RACK PULL ISOMETRICS

Similar to kettlebell isometric holds (see page 80), rack pull isometrics can be used to create total body tension to increase neural drive, promote proper muscle engagement, and to strengthen the initial pull position. They can be performed at different ranges of motion, which can address weak points during the lift. They may provide a significant training effect for an individual who can't currently load the deadlift due to injury.

- Use an excessively heavy load that would make it extremely difficult or impossible to lift
- Perform the initial set-up for the rack pull, as detailed above
- Pull up on the bar (without the goal of actually lifting it) while maintaining tension through the abdominals and upper back
- Do not let the hips or chest rise excessively

HEXAGONAL (TRAP) BAR DEADLIFT

The hexagonal bar deadlift allows increased quadricep activation, less lumbar shear forces,[114–116] and produces greater peak force, allowing loads to be lifted at greater velocities compared to the conventional deadlift.[115,117] The torso angle during the hexagonal bar deadlift is more upright and the hands grip the bar from the side, instead of in front as observed with the barbell deadlift. This may explain the ability to lift heavier loads at faster speeds, as the load is higher from the floor with less range of motion required to reach upright. It may also be easier for those with limited hamstring or thoracic extension mobility to assume the start position of the hexagonal bar deadlift compared to the conventional deadlift. It is important to note that despite increased quadricep activation and upright torso angle, the hexagonal bar deadlift still produces a high level of gluteus maximus activation, at greater than 60% MVIC.[118]

- Stand inside the hexagonal bar and secure the feet to the floor
- Reach the hips back and slide the hands down the outside of the thighs until able to reach the handles
- The knees will bend slightly more and the torso is less forward compared to a conventional deadlift, due to the position of the handles
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades and pull back on the handles to activate the upper back, latissimus dorsi, and to take up any slack
- Drive down through the feet and contract the glutes to propel the hips forward to return to upright
- Shift the hips posteriorly and lower the weight back to the floor

Figure 5-61 *Start position*

Figure 5-62 *End-rage of hinge prior to pull phase*

Figure 5-63 *End-range of concentric pull phase*

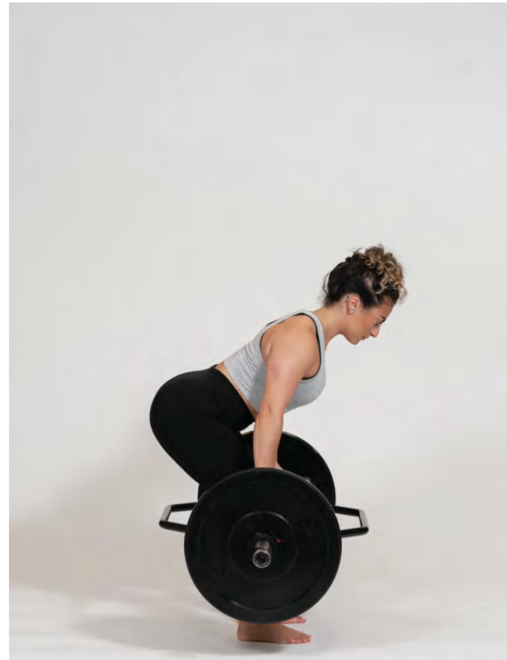

Figure 5-64 *Controlled lowering of bar back down to floor*

CONVENTIONAL DEADLIFT

The conventional deadlift requires a narrow stance and horizontal torso angle. It creates increased demands on lower back erector spinae and hamstrings.[116] It produces increased activation of the hamstrings and erectors compared to the hexagonal bar deadlift,[115] increased erector activation compared to the single-leg deadlift,[113] increased gluteus maximus and rectus femoris activation compared to the Romanian deadlift (RDL).[119] This variation is best if the goal is to target the lower back, but may be a more difficult position for a taller individual with a longer torso angle[120] or someone with mobility restrictions to assume.

- Position the feet hip-width apart and shoelaces under the bar
- Secure the feet to the floor
- Reach the hips back and allow the trunk to travel forward while sliding the hands down the outside of the thighs
- The knees will bend slightly to allow the hands to reach the bar
- Grasp the bar outside of the lower legs
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades and pull the bar toward the body to activate the upper back and latissimus dorsi
- Due to the horizontal torso angle, the shoulders should be in front of the bar at the beginning of the pull position
- Pull up on the bar while maintaining tension through the abdominals and upper back
- During the pull, the shoulders rise before the hips and the bar should graze the front of the legs

- Drive down through the feet, contract the glutes, and push the hips forward into the bar to return to upright
- Reach the hips back and keep the shoulders well over the bar as it slides back down the thighs
- The goal is to keep the bar as close as possible to the body throughout the entire movement

Figure 5-65 *Start position*

Figure 5-66 *End-range of hinge prior to pull phase*

Figure 5-67 *End-range of concentric pull*

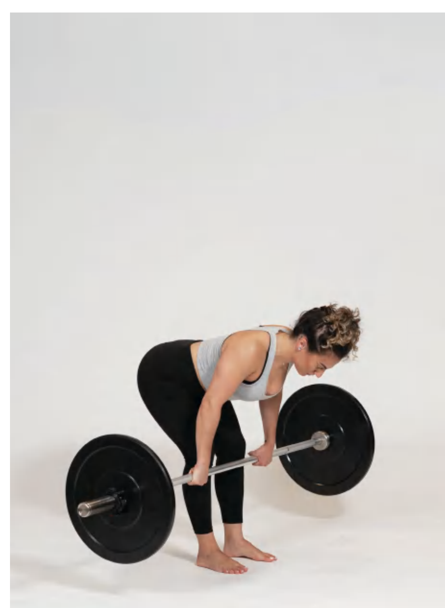

Figure 5-68 *Controlled lowering of bar back down to floor*

Figure 5-69 *Conventional deadlift fault – excessive knee flexion or squatting to reach the weight*

Figure 5-70 *Conventional deadlift fault – hips rise before chest when initiating the pull*

Figure 5-71 *Conventional deadlift fault – excessive flexion to reach the bar or lack of tension in the latissimus dorsi and upper back prior to initiating the pull, which results in spinal flexion during the pull phase*

Figure 5-72 *Conventional deadlift fault – impaired abdominal bracing mechanism (lumbar lordosis and rib flare)*

Figure 5-73 *Conventional deadlift fault – hyperextension at end-range*

SUMO DEADLIFT

The sumo deadlift is performed with a wide stance, upright torso angle, and the upper extremities grip the bar on the inside of the lower legs, which differs from the conventional deadlift set-up. It requires a large amount of hip mobility, particularly in external rotation. Similar to the hexagonal bar deadlift, it may also decrease lower back shear force and promote increased activation of the quadriceps.[114,121]

- Adopt a wide stance with the feet turned out and shoelaces under the bar
- Slide the hands down the inside of the thighs and drive the knees out until able to grip the bar
- The knees should line up with the middle of the foot and remain behind or just on top of the bar
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades to activate the upper back and pull the bar into the body to activate the latissimus dorsi
- Pull any remaining slack out of the bar by dropping the hips down slightly
- The shoulders should now be stacked directly over or behind the bar
- The hips remain higher than the knees
- During the pull, the shoulders rise before the hips
- Drive down through the feet, contract the glutes and quadriceps, and push the hips forward into the bar to return to upright
- Reach the hips back and keep the shoulders stacked over the bar as it slides back down the thighs

Figure 5-74 *End-range of hinge prior to pull phase*

Figure 5-75 *End-range of concentric pull phase*

ROMANIAN DEADLIFT (RDL)

The Romanian, also known as the "stiff-leg" deadlift or RDL, is performed with a reduced knee flexion angle and constant tension on the hamstrings throughout the movement, as the load is not placed on the floor in between each repetition. As a result, it requires a great degree of grip, upper and lower back strength and endurance to maintain form and spinal stiffness over repeated contractions. The RDL produces a similar level of muscle activation in the gluteus maximus compared to the barbell hip thrust (see page 160) and appears to be a better exercise to train the hip extensors compared to the squat.[65] It requires high levels of muscle activation in the lumbar erectors,[112] likely due to the biomechanics of the movement, constant tension, and pull of gravity, so it must be programmed with caution in those recovering from a lower back injury. It can be performed with a barbell or dumbbells.

- Position the feet hip-to shoulder-width apart and secure the feet to the floor
- Hold a barbell or two dumbbells against the thighs
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades to activate the upper back and pull the bar into the body to activate the latissimus dorsi
- Keep the knees soft, shins vertical, with the knee angle relatively constant throughout
- Reach the hips back and let the barbell or dumbbells slide down the front of the thighs
- Keep the bar or dumbbells in contact with the legs throughout the entire movement
- A good stopping point is right below the knee at the patella tendon
- Contract the glutes and drive the hips forward to return to upright

Figure 5-76 *Start position*

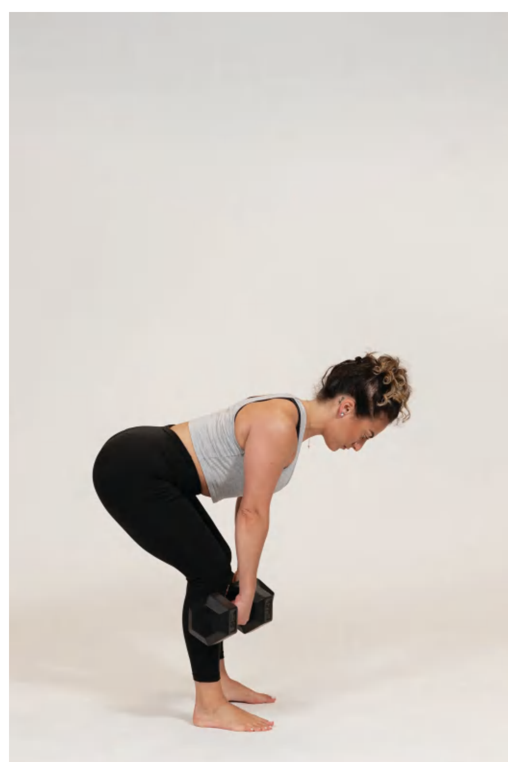

Figure 5-77 *End-range of hinge. Lower weights between the level of the patella tendon and upper shin*

STRADDLE LIFT

The straddle lift is similar to the straddle squat (see page 69), but like many hinge-based exercises, it requires a more horizontal torso angle. The risers allow increased range of motion, which may produce greater time under tension and stretch on the posterior chain.

- Stand with each foot on a step, box, or other riser
- Adopt a wide stance with the feet turned out
- Hold a kettlebell or dumbbell between the legs
- Engage the abdominals and pull the rib cage down
- Retract the shoulder blades to activate the upper back and engage the latissimus dorsi by isometrically pulling the weight apart
- Reach the hips back, allow the knees to bend, and lower the weight between the shoe laces
- The shoulders should be over the weight and the torso is more horizontal compared to the straddle squat, but the knees flex to a greater extent than other deadlift variations

Figure 5-78 *Start position*

Figure 5-79 *End-range of hinge. Note the position of the weight traveling behind the shoulders, between the legs, and toward the middle of the feet, not in front*

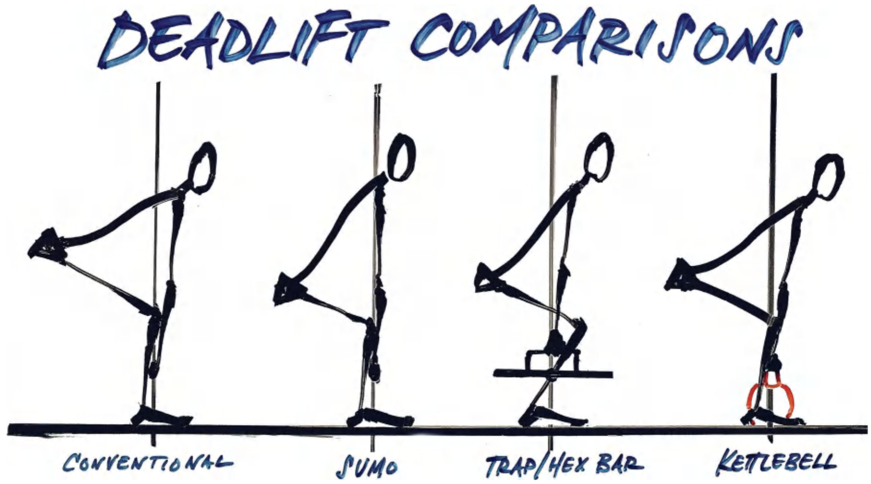

Figure 5-80 *Comparisons of four common deadlift variations – conventional, sumo, hexagonal bar, and kettlebell. The image provides a visual of how trunk displacement, hip, knee, and ankle range of motion should change based on the width of the grip, stance, and where the load is located*

Table 5-1 *Comparison of four common deadlift variations – the conventional, sumo, hexagonal bar, and kettlebell deadlift*

Which deadlift variation is most appropriate? ***Consider load, training level, injuries, anatomy, and goals***			
Conventional deadlift	***Sumo deadlift***	***Hexagonal bar deadlift***	***Kettlebell deadlift***
High load Intermediate to advanced training level *Prerequisites:* Good hamstring and upper back extension mobility, shorter height *Goal:* Strength, powerlifting, athletics	High-medium load Intermediate to advanced training level *Prerequisites:* Good hip mobility *Goal:* Strength, powerlifting, athletics	Low load Novice training level *Prerequisites:* Basic range of motion of hips, knees, and ankles *Goal:* Strength, power	Low to moderate load Novice training level *Prerequisites:* Adequate hamstring and upper back extension mobility to maintain spinal position in the initial pull position *Goal:* General muscle endurance, strength, and hypertrophy; complete usual daily lifting tasks

CHAPTER 6

BRIDGE

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The bridge targets large muscle groups of the posterior chain and is easy to load heavy and pain-free if desired. It has a wide range of applications to daily activities, like repositioning in bed, and various athletic movements. Brazilian jiu-jitsu and wrestling are "bridge-heavy" sports, just to name a few. Horizontal force production exercises, like the bridge, have also been linked to increased sprint performance[98,122,123] which make them a worthwhile addition to programs for runners or other athletes. When performed correctly, the bridge helps train the glutes and hamstrings to extend the hips versus the lower back. It may allow an individual to focus on actively feeling the glutes contract before progressing to higher level terminal hip extension exercises, like the squat, hip thrust, or deadlift. Increased knee angle of 135° (compared to 90°) during the bridge is associated with decreased hamstring and erector spinae activation.[124,125] Therefore, greater knee flexion angles should be used if the goal is to target the gluteus maximus. Decreased knee flexion angles promote increased activation of the hamstrings (semimembranosus and biceps femoris). The bridge will also put less strain on the semitendinosus compared to leg curls when recovering from a hamstring injury or hamstring tendon surgical graft.[124] The following sequence for the bodyweight glute bridge can be applied to all variations in this chapter.

BRIDGE TRAINING FOR BEGINNERS

BODYWEIGHT GLUTE BRIDGE

- Find a comfortable foot position (hip-width, wide, or narrow)
- Weight-bearing through the heels (versus the entire foot) may help keep the feet planted, reduce sliding forward, and drive posterior chain activation
- Engage the abdominals and pull the rib cage down
- Contract the glutes before lifting the hips and maintain this contraction during hip extension
- Push through the feet and drive the hips up
- Perform a posterior pelvic tilt at end-range (terminal hip extension)
- Avoid extending at the lower back to gain additional range of motion (Figure 6–3)
- End-range holds of 2–10 seconds aim to maximize isometric glute contraction at end-range, stability, and build a solid foundation to progress to loaded variations

Figure 6-1 *Start position*

Figure 6-2 *End position. Achieves terminal hip extension without compensation*

Figure 6-3 *Bridge fault – though subtle, note the excessive hyperextension through the lumbar spine to compensate for terminal hip extension*

DUMBBELL GLUTE BRIDGE

Knee-banded bridges are used primarily to cue hip abduction. Ideally, the load should be placed in a position to challenge terminal hip extension if the goal is to target the gluteus maximus.

- Place a dumbbell across the front of the hips, resting on the hip bones
- A foam pad, folded mat, or towel can be used to minimize pressure

Figure 6-4 *Dumbbell glute bridge start position*

Figure 6-5 *Dumbbell glute bridge end position. Note: the position of the weight will challenge terminal hip extension*

BRIDGE WITH BAND ABOVE KNEES

The band cues hip abduction and external rotation to enhance glute activation.

BRIDGE WITH BAND ABOVE AND BELOW KNEES

The addition of a second band below the knees has the potential to promote increased muscle activation, as distal band placement has been shown to increase gluteus medius activation during other exercises, like lateral band walks (see page 142). However, there are no present studies that make this comparison with band placement during the bridge.

Figure 6-6 *Bridge with band above knees end position*

Figure 6-7 *Bridge with band above and below knees end position*

BRIDGE WITH BALL ADDUCTION

An isometric ball squeeze during the bridge promotes co-contraction of adductors and glutes to enhance pelvic stability.

- Place the ball between the knees and squeeze hard using the inner thighs
- Maintain the contraction as the hips lift
- Use a medium-sized compliant ball or low-weight medicine ball for beginners
- Use a large, weighted slam ball to increase difficulty

Figure 6-8 *Bridge with ball adduction end position*

BALL BETWEEN KNEES WITH ALTERNATING LEG EXTENSION

Removing the support of one extremity challenges rotary stability while promoting single-leg loading.

- Perform a double-leg bridge with ball adduction as detailed and pictured above (Figure 6–8)
- At the top of the movement, maintain the adductor contraction against the ball and extend one knee straight out
- Maintain a level pelvis and do not allow the hip to drop on the side that the leg is extending

Figure 6-9 *Bridge with ball adduction and alternating leg extension*

BARBELL GLUTE BRIDGE

The barbell glute bridge produces greater peak (>129% MVIC) and mean (>65% MVIC) muscle Electromyography (EMG) activity in both the upper and lower fibers of the gluteus maximus when compared to the barbell hip thrust (see page 160).[126] This may be due in part to the fact that greater loads can be lifted during the barbell glute bridge compared to the hip thrust, though the difference in training load observed between subjects during this specific study by Kennedy et al.[126] was not significant. The start position of the glute bridge is very stable with the back supported fully by the floor and may be easier for some to adopt compared to other glute dominant exercises, like the hip thrust. The barbell glute bridge also generates relatively high levels of muscle EMG activity in the gluteus medius and hamstrings.[126] The barbell bridge is a primary, compound exercise that can be used when the goal is to maximize load to maintain or build lower body hypertrophy and strength. It may also be good to use as a substitute when other exercises like squats and/or deadlifts are sensitive or contraindicated.

- Load a barbell with bumper plates and a barbell pad
- Start in the hook-lying position with the feet under the bar
- Extend the legs under the bar, roll the barbell onto the hips, then bend the knees back up
- Place the feet together on the floor, then walk them apart to achieve an even foot position
- For novice lifters, it is helpful to bring the barbell down to a dead stop after each repetition to reinforce the abdominal bracing and glute contraction
- Advanced lifters can progress to a tap and go method to allow increased repetitions/load

Figure 6-10 Barbell glute bridge start position

Figure 6-11 Barbell glute bridge end position

SINGLE AND MODIFIED SINGLE-LEG BRIDGE VARIATIONS

STAGGER-STANCE BRIDGE

The stagger-stance bridge is similar to its squat (see page 55) and deadlift (see page 87) namesakes. It will bias strengthening one leg, but with less stability demands compared to a true single-leg bridge. It can be performed with a dumbbell or a barbell.

- Adopt a staggered stance with the target leg closest to the torso
- The weight of the far leg should be on the heel
- The weight of the foot of the target leg can be on the entire foot (flat) or on the heel
- Contract the glutes and drive through the target leg to lift the hips
- Very little weight should be transmitted through the far leg

Figure 6-12 Stagger-stance bridge start position

Figure 6-13 Stagger-stance bridge end position

SINGLE-LEG BRIDGE

- The target leg is in contact with the floor (weight through the entire foot or heel) and the opposite leg is bent up to 90° or greater of hip flexion
- Contract the glutes and drive through the target leg to lift the hips
- Keep the hips level

Figure 6-14 *Single-leg bridge start position*

Figure 6-15 *Single-leg bridge end position*

FEET-ELEVATED BRIDGES

Elevating the feet increases the range of motion to put greater tension on the glutes and proximal hamstrings.

FEET-ELEVATED BRIDGE ON WALL

- Start in supine with the feet in contact with the wall
- Position the knees and hips at a 90° angle
- Engage the abdominals and pull the rib cage down
- Contract the glutes prior to lifting the hips and maintain until at end-range
- Drive the hips up as if trying to pull down on the wall with the heels

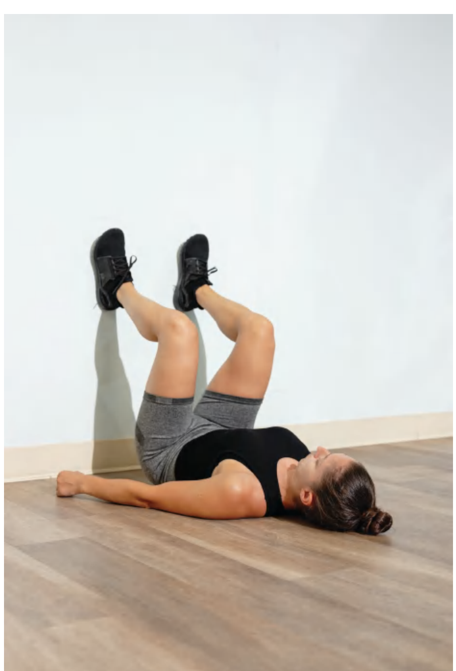

Figure 6-16 Feet-elevated bridge on wall start *position*

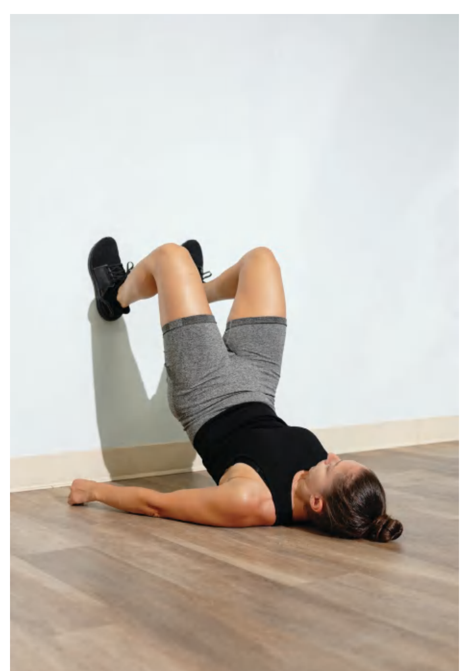

Figure 6-17 Feet-elevated bridge on wall end *position*

FEET-ELEVATED BRIDGE ON BENCH

- Start in supine with heels on a bench, box, etc.
- Position the knees and hips at a 90° angle
- Engage the abdominals and pull the rib cage down
- Contract the glutes prior to lifting the hips and maintain until at end-range
- Drive the heels down to lift the hips up

Figure 6-18 *Feet-elevated bridge on bench start position*

Figure 6-19 *Feet-elevated bridge on bench end position*

SINGLE-LEG FOOT-ELEVATED BRIDGE

Figure 6-20 *Single-leg foot-elevated bridge start position*

Figure 6-21 *Single-leg foot-elevated bridge end position*

FEET AND SHOULDER-ELEVATED DEFICIT BRIDGE

The addition of a deficit allows even more range of motion and greater stretch on the posterior chain during the eccentric portion of the contraction that it must then overcome to complete the concentric portion.

- Set-up two benches 2–3 feet away from each other
- Position the edge of the one bench at or just below the inferior angle of the scapula and the heels on the opposite bench

- Engage the abdominals and pull the rib cage down
- Create a stretch on the glutes and hamstrings by letting the hips drop down between the benches
- Drive the heels down into the bench, contract the glutes, and use leverage through the shoulder blades to push the hips up

Figure 6-22 *Feet and shoulder-elevated deficit bridge start position*

Figure 6-23 *Feet and shoulder-elevated deficit bridge end position*

FEET AND SHOULDER-ELEVATED SINGLE-LEG DEFICIT BRIDGE

Figure 6-24 *Feet and shoulder-elevated single-leg deficit bridge start position*

Figure 6-25 *Feet and shoulder-elevated single-leg deficit bridge end position*

CHAPTER 7

LOWER BACK AND GLUTES

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LOWER BACK

There are three key muscle groups of the lower back: (1.) erector spinae (large paraspinal extensors); (2.) quadratus lumborum; and (3.) multifidus (spinal stabilizer). These muscles function to keep the trunk erect (extension), side bend (lateral flexion), and stabilize against rotatory forces. The gluteal complex is also made up of three muscles: the gluteus medius, maximus, and minimus. They connect with the lower back via thoracolumbar fascia and attachment sites on the spine and pelvis. Like the erectors, the glutes also function to keep the trunk erect by extending the hips (gluteus maximus). Additional actions include abducting and rotating the hip and keeping the pelvis level when standing on one leg (gluteus medius and minimus).

When we look at the posterior chain, the lower back, and gluteal muscles occupy a large amount of surface area. As previously discussed, these muscles share deep, broad connections through their many attachment sites and fascia. They create many lines of pull from the shoulders and upper back all the way down to the feet. In a standing position, the feet will point out automatically if the glutes are isometrically contracted due to their function as an external rotator of the hip. Therefore, progressively loading the posterior chain is imperative to combat lower back pain and other musculoskeletal issues. A strong, robust lower back and gluteal region will create a strong base and is likely to help the body move better overall. If these muscles are not strong and resilient, they may often feel painful or tight, and other structures will need to share the work of their day-to-day functions. The ability to produce force and power through the hips may decrease the effort required by the low back and other surrounding tissues to hold the body upright and can help distribute load appropriately to other areas of the body in order to prevent compensatory patterns during activity.

ISOMETRIC LOWER BACK EXTENSIONS

The following isometric exercises use the floor, a table, physioball, or glute hamstring developer (GHD) exercises resembling the Biering-Sorensen Test, a timed test for trunk extension endurance. An isometric hold time of less than 176 seconds is a predictor of low back pain and is proven to have excellent test-retest, interrater and intrarater reliability, predictive, and construct validity for the low back pain population. This test also has a minimal detectable change (MDC) of 24.1 seconds for individuals with low back pain and 48.8 seconds for those without.[127] This can be used as an objective measure for goal setting and to monitor progress.

PRONE LUMBAR EXTENSION

Lower back exercises don't need to be overly complicated. The prone extension, also known as the "Superman," generates 81% and 77% of MVIC for the lonissimus thoracis (erector spinae) and the lumbar multifidus, respectively.[128] A study by McGill et al.,[129] also confirms high extensor muscle activity using the superman, greater than 60% MVIC for thoracic extensors, greater than 50% MVIC for lumbar extensors and multifidus. Compressive forces on the lumbar spine, however, are also very high at greater than 4,000 N.[129] The spine is resilient and this exercise may be appropriate for an individual who needs to develop their lumbar extensors, but the benefits of the exercise may not outweigh the potential negative effects for specific populations (e.g. facet joint irritation, spondylolisthesis, spinal stenosis, etc.) and there may be better-suited exercises for these populations.

- Start on the stomach with the knees extended, shoulders flexed overhead, elbows straight with the arms resting on the floor or table
- Contract the abdominals, glutes, extend the upper and lower back to simultaneously lift the arms, chest, and legs from the floor
- The abdomen remains in contact with the floor throughout

TABLE OR PHYSIOBALL LOWER BACK PLANK

- Isometric activation of the low back extensors can serve as a starting point to train basic muscle endurance, promote stability, and increase blood flow to the posterior chain, especially when these structures are sensitive and can't be loaded heavy or through a significant range of motion
- Position the hip crease or ASIS on the edge of a table/mat or physioball
    - To decrease difficulty, position the belly button at the edge
- The legs must be anchored by a heavy dumbbell, a strap, or manually by another individual
- Contract the abdominals, glutes, and extend the low back to maintain the trunk parallel with the edge of the mat or ball
- Hold for a duration that induces muscle fatigue, does not produce a significant increase in pain and/or and as long as spinal flexion can be resisted
- The hands can be positioned at the sides, in a "W" position, or on the head/neck

Figure 7-1 *Static hold using table and stabilizing strap*

Figure 7-2 *Static hold using physioball and dumbbells to stabilize the feet. A wall, or a wall in addition to dumbbells, would be the most stable set-up for the feet*

GLUTE HAMSTRING DEVELOPER (GHD) LOWER BACK PLANK

This exercise requires a specialized piece of equipment (GHD), but allows the feet to be anchored and has a large, cushioned pad for the hips to rest on. During this exercise, maximal hip extension torque is achieved in the fully-extended position, so the isometric variation will require the hip extensors to work extremely hard to maintain the position.[130]

- Anchor the feet on the footplate with the pads in contact with the back of the ankles
- Extend the knees straight
- The hip crease or ASIS should rest between the bulkiest portion and edge of the pad with the rest of the torso suspended over the edge of the pad

Figure 7-3 *Static hold using GHD pads and footplate to secure the legs*

LUMBAR HYPEREXTENSIONS

The "traditional" hyperextension is a straight leg-hip extension exercise that targets the glutes, erectors, and hamstrings.[131] This exercise generates high hip extension torques at relatively low loads that are constant throughout the entire range of motion.[130] It activates the lateral hamstring to a similar[131] or greater[132] degree compared to the reverse hyperextension (see page 126), but is considered a lower-intensity exercise when compared to the reverse hyperextension for posterior chain activation.[131] However, this could make the hyperextension a good lead-up exercise if the goal is to progress to the reverse hyperextension.

PHYSIOBALL HYPEREXTENSION

The physioball hyperextension incorporates both concentric and eccentric muscle action with minimal equipment and a simple set-up. Performing the exercise on the ball will limit the amount of available range of motion and hip torque compared to the 45° hyperextension,[130] which makes this a great exercise for beginners or those that are flexion sensitive. Still, it generates greater than 50% MVIC for the longissimus thoracis and lumbar multifidus.[128]

- Position the hip crease or ASIS on the edge of the physioball
- Ideally, this exercise is performed with the bottoms of the feet in contact with a wall and further anchored by heavy dumbbells, but in lieu of a wall just the dumbbells can be used
- Let the trunk flex forward over the ball
- Extend the low back and contract the glutes to extend the hips and trunk

Figure 7-4 *Physioball hyperextension start position*

Figure 7-5 *Physioball hyperextension end position*

GHD HYPEREXTENSION

The GHD places the trunk at a full horizontal 180° at full hip extension, which will increase difficulty at the top of the movement with respect to hip torque.[130]

- Anchor the feet on the footplate with the pads in contact with the back of the ankles
- Extend the knees straight
- The hip crease or ASIS should rest between the bulkiest portion and edge of the pad with the rest of the torso suspended over the edge of the pad

- Contract the abdominals, glutes, and extend the low back to maintain the trunk parallel with the edge of the mat or ball
- Let the trunk flex forward over the pad
- Extend the low back and contract the glutes to extend the hips and trunk back to the start position
- The hands can be positioned at the sides, on the chest, or in a "W" position

Figure 7-6 *GHD hyperextension start position*

Figure 7-7 *GHD hyperextension end position*

TABLE HYPEREXTENSION

Hyperextensions performed over the edge of a table generate close to 70% MVIC for the longissimus thoracis and lumbar multifidus.[128]

- Position the hip crease or ASIS on the edge of a table or mat
- The legs must be anchored by a strap or manually by another individual
- Contract the abdominals, glutes, and extend the low back to maintain the trunk parallel with the edge of the mat or ball
- Let the trunk flex forward over the edge of the table
- Extend the low back and contract the glutes to extend the hips and trunk back to the start position
- The hands can be positioned at the sides, in a "W" position, or on the head/neck

Figure 7-8 *Table hyperextension start position*

Figure 7-9 *Table hyperextension end position*

45° HYPEREXTENSIONS

The 45° hyperextension decreases the trunk angle against gravity by 15° and shortens the range of motion, so it is easier to perform than the traditional hyperextension. The technique used during the exercise is important and the degree of hyperextension depends on the goal: a more rounded back or neutral spine position may target the glutes greater than the erectors and may be best for sensitive individuals. A moderate amount of hyperextension may effectively target the erectors but is unlikely to aggravate the facet joints. A large amount of hyperextension may be appropriate for flexion sensitive individuals or if attempting to develop more of a lumbar curvature.

Figure 7-10 *Erector focus 45° hyperextension start position*

DOUBLE-LEG 45° HYPEREXTENSION

Erector focus

1. Hinge at the hips

- Secure the legs on the footplates with the pads in contact with the back of the ankles
- Adopt a narrow stance with the feet pointing forward
- The pelvic bone should be resting on the pad with the crease of the pad just below the ASIS
- Bend at the hips to hinge the torso forward
- Keep the lower back straight (in line with the shoulders throughout the movement) without defaulting into lumbar flexion
- To return to upright, focus on activating the erectors to lift and extend back to upright with slight lumbar extension at the top of the movement

2. Increased forward trunk flexion for erector stretch

- Position the edge of the pad a bit higher (at a comfortable
  point between the ASIS and belly button) to allow increased

- lumbar flexion and stretch on the erectors as you bend forward over the pad
- Activate the erectors to lift and extend back to upright with slight lumbar extension at the top of the movement

Figure 7-11 *Erector focus 45° hyperextension end position. The lumbar curvature at the top is pronounced, but not excessive*

NEUTRAL SPINE FOCUS

- Rest the pelvic bone on the pad, hinge forward over the pad, keeping the spine relatively straight
- Drive the hips into the pad, contract the glutes, and perform a posterior pelvic tilt
- Use the glutes to pull the trunk to upright

Figure 7-12 *Neutral spine 45° hyperextension start position*

Figure 7-13 *Neutral spine 45° hyperextension end position. The lumbar spine is in neutral at the top*

GLUTE FOCUS

- Rounding the upper back will allow increased glute activation due to decreased range of motion and less demand on the erectors
- The lower back muscles will be less likely to fatigue, which can increase time under tension for the glutes
- Let the trunk flex forward over the pad to allow the upper back to relax and flex maximally
- Clasp the hands in a fist, rest them under the chin or on the chest, and pull the arms down and into the torso to lock in the flexed position of the upper back
- Drive the hips into the pad, contract the glutes, and perform a pelvic tilt to pull to upright
- The low back remains in neutral with no additional extension
- There is a very small range of motion compared to the other variations

Figure 7-14 *Glute focus 45° hyperextension start position*

Figure 7-15 *Glute focus 45° hyperextension end position. The upper back remains rounded with at the top to limit lumbar extension range of motion so the glutes are required to function as the primary extensors*

WHAT ABOUT THE FOOT POSITION?

- Adjusting the foot position may help isolate specific muscles
- A wider stance with the feet turned out will produce greater hip external rotation, one of the functions of the gluteal muscles
- A normal to narrow stance may be most ideal for erector or hamstring focused training due to decreased degree of hip external rotation

WEIGHTED 45° HYPEREXTENSION

- Add the weight at chest level or under the chin and keep it close to the body to reduce low back torque
- Keeping the weight at chest level will also increase demands on the glutes due to a longer lever arm

Figure 7-16 *Weighted 45° hyperextension start position*

Figure 7-17 *Weighted 45° hyperextension end position*

SINGLE-LEG 45° HYPEREXTENSION

The initial set-up for this exercise is key!

- If the pad has an open space in the middle, move all the way over toward one side if it is wide enough
- If the pad is narrow or slants inward, place a folded mat or foam pad over it so that there is no opening, as this will help increase stability
- Position the working leg on the footplate and anchor it with the back of the calf in contact with the lower pad
- The top leg is bent with the top of the foot suspended in the air or lightly resting on the top of the lower pad
- Perform the exercise with the same with the same instruction as the double-leg hyperextension using the technique (erector, neutral spine, or glute focus) that will address the muscles you are trying to target

Figure 7-18 *Single-leg 45° hyperextension start position*

Figure 7-19 *Single-leg 45° hyperextension end position*

REVERSE HYPEREXTENSIONS

The reverse hyperextension is an open-chain hip extension exercise that aims to build lower back strength without axial loading[133] and improve spine health through range of motion,[134] but is often underutilized by most in the rehabilitation setting. The concentric motion engages the glutes, hamstrings, and lumbar erectors,[131,133,134] while the eccentric portion acts as a loaded stretch to the soft tissues.[132,134] It is an open-chain exercise and the position of the load closer to the feet creates a longer lever arm for the lower back,[131] so it is unsurprising that the reverse hyperextension generates increased low back moment and less lumbar flexion range of motion than the hyperextension[132] and activates the lumbar erectors and gluteus maximus to a similar[132] or greater[131] extent. Also, the open-chain reverse hyperextension produces a significant increase in muscle activation of the gluteus maximus and hamstrings compared to the closed-chain RDL.[112] Similar to the glute hamstring developer (GHD), the reverse hyperextension machine is a specialized piece of equipment, but the exercise can be executed in the clinical setting with a modified set-up. Heavier loads of 100% and 150% bodyweight induce a greater degree of hip and lumbar flexion than a 50% bodyweight load.[133] Westside Barbell, a renowned weightlifting gym, recommends performing the reverse hyperextension for both strength with a load of 50% of 1RM for four sets of ten repetitions and "restoration" with a load of 25% of 1RM for two to three sets of 15 repetitions.[134]

- Rest the hip crease across the front of the pad
- Engage the latissimus dorsi by pulling against the hand grips or the sides of the pad
- Contract the abdominals and glutes to lift the legs and extend the low back
- Let the legs lower in a controlled fashion about halfway, then completely relax

The neck should extend as the low back extends and flex as it flexes, if comfortable, otherwise it can remain in neutral

Figure 7-20 *Reverse hyperextension start position. The lower back is relaxed and should be able to relax and traction at the end of the lowering phase*

Figure 7-21 *Reverse hyperextension end position. The lumbar erectors are engaged, but the lower back is not aggressively extended under load*

BENCH-REVERSE HYPEREXTENSION

- Rest the hip crease across the edge of the bench
- Lock in the latissimus dorsi by pulling against the sides of the bench
- Contract the abdominals and glutes to lift the legs and extend the low back
- Leg position
    - Straight (range of motion is limited by height of the bench and the floor)
    - Knees flexed (will allow additional hip flexion range, hamstrings will be actively insufficient for increased glute activation)
    - Knees flexed with hip external rotation (increased glute activation)

Figure 7-22 *Straight leg bench-reverse hyperextension start position*

Figure 7-23 *Straight leg bench-reverse hyperextension end position*

Figure 7-24 *Knees flexed bench-reverse hyperextension start position*

Figure 7-25 *Knees flexed bench-reverse hyperextension end position*

Figure 7-26 *Knees flexed with hip external rotation start position*

Figure 7-27 *Knee flexed with and hip external rotation end position*

PHYSIOBALL REVERSE HYPEREXTENSION

Similar to the physioball hyperextension, using the physioball will decrease available range of motion and may be an ideal set-up for beginners or those sensitive to increased range of motion. Using only the weight of the legs, this exercise generates greater than 50% MVIC for the longissimus thoracis and 49% MVIC for the lumbar multifidus.[128]

- Rest the pelvis over the ball
- Stabilize the torso using one of two methods:
  1. Rest the forearms on the floor in front of the ball, clasp the hands together, and pull the elbows toward the hips (isometric) to activate the latissimus dorsi
  2. Hold onto something sturdy positioned in front of the ball (bench, legs of a mat/table, squat rack, etc.)
- Contract the abdominals and glutes to lift the legs and extend the low back
- The legs can be straight or bent, similar to the bench-reverse hyperextension

Figure 7-28 *Physioball reverse hyperextension start position*

Figure 7-29 *Physioball reverse hyperextension end position*

HIGH MAT REVERSE HYPEREXTENSION

A high mat will allow increased range of motion where the legs can come to a dead hang, promoting some degree of spinal flexion, decompression, and greater stretch on the posterior chain soft tissues. In the clinic, use plyometric boxes, an elevated plinth or massage table adjusted to their maximum height. A counter island also works well for an at-home variation. This is performed with the same technique as the traditional reverse hyperextension machine, but instead of grasping the handles, the upper half is secured by grasping the sides of the mat, table or other surface.

Figure 7-30 *High mat reverse hyperextension start position*

Figure 7-31 *High mat reverse hyperextension end position*

GHD REVERSE HYPEREXTENSION

Similar to the high mat reverse hyperextension, the use of the GHD will allow increased range of motion and it mimics the set-up of the traditional reverse hyperextension machine. The amount of cushion provided by the pad on the front of the pelvis also makes this set-up very comfortable.

45° REVERSE HYPEREXTENSION

The 45° hyperextension machine is a more common piece of equipment to find in a commercial gym and is less expensive (and more spatially efficient) to purchase for a clinic compared to a reverse hyperextension or GHD. The only potential downside is that the head will be inverted, which may be an uncomfortable set-up for some individuals.

- Rest the hip crease on the pad and invert the head toward the foot plates
- The pad should be positioned high enough so that the feet can clear the floor (or at least come close)
- Secure the hands on the footplates and pull them toward the chest to engage the latissimus dorsi
- Contract the abdominals, glutes, and lift the legs to extend the low back

Figure 7-32 *45° reverse hyperextension start position*

Figure 7-33 *45° reverse hyperextension end position*

GLUTEAL COMPLEX

According to Bret Contreras,[135] a strength coach who specializes in lower body training, the glutes can be broken up into two parts: upper and lower. The hip abductors (glute medius and minimus) and upper portion of the gluteus maximus are the upper glutes and the lower portion of the gluteus maximus makes up the lower glutes. Frontal and transverse plane hip abduction exercises like side-lying abduction, band walks, or seated hip abduction target the upper glutes. Sagittal plane exercises, including lunges, squats, and deadlifts, target the lower glutes. Rotatory hip external rotation, back extensions, bridges, and hip thrusts target both the upper and lower glutes.[135] Hip abductor and external rotator strength has been associated with better performance during jumping and landing tasks,[136,137] decreased pain, and improved functional outcomes of those with anterior knee pain[138,139] as well as increased single-limb stance time and walking distance following total knee replacement.[140] There are other accessory muscles that also assist with hip external rotation, like the piriformis (if the hip is positioned below 90° of flexion), quadratus femoris, superior and inferior gemelli, and obturator internus, and hip internal rotation, like the tensor fascia lata (TFL), piriformis (if the hip is positioned above 90° of flexion) and adductor muscles. Many of these muscle groups are addressed in either this chapter or Chapter 8.

HIP EXTERNAL ROTATION

HOOK-LYING EXTERNAL ROTATION ISOMETRIC

- Externally rotate the target hip to the desired range of motion
- Use the arms or manual resistance of another individual to apply resistance with the sole focus on maintaining the position
- If available, a squat rack or another heavily anchored piece of equipment can be used to provide resistance instead of the upper extremities

Figure 7-34 *Use of the hand to resist external rotation force*

SEATED EXTERNAL ROTATION ISOMETRIC

- Sit on an elevated surface (high mat, bench, plyometric box, etc.)
- Externally rotate the target hip by bringing the ankle up and in as the knee moves outward
- To target the beginning and mid-range of motion, use a small-to-medium sized ball between the feet or resistance by the opposite leg
- To target the end-range of motion, use self-resistance, manual resistance of another individual, or an anchored strap
- Meet the resistance provided to maintain the position of the leg

Figure 7-35 *Use of a ball between the feet*

Figure 7-36 *Use of an anchored strap*

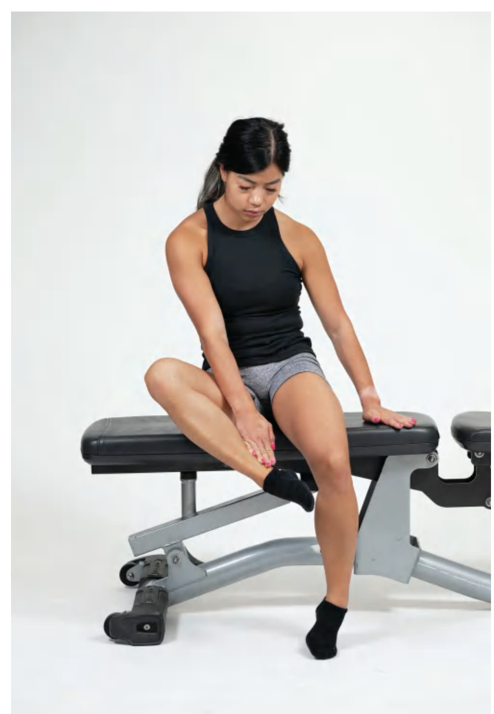

Figure 7-37 *Manual resistance*

SIDE-LYING EXTERNAL ROTATION ISOMETRIC

- The bottom leg is the target leg
- Lift the lower leg, but keep the upper thigh in contact with the floor or table
- Provide self-resistance using the opposite hand or manual resistance by another individual
- Meet the resistance provided to maintain the position of the leg

Figure 7-38 *Side-lying external rotation isometric with manual resistance*

QUADRUPED EXTERNAL ROTATION ISOMETRIC

- Contract the abdominals to stabilize the spine and pelvis
- Lift the target leg out to the side, and slightly rotate the knee backward to allow for increased hip external rotation versus hip abduction
- Use a physioball or the wall for resistance

Figure 7-39 *Use of a squat rack for resistance*

STANDING EXTERNAL ROTATION ISOMETRIC

- Stand next to a door frame, wall, or squat rack
- Use a counterbalance in the arm opposite of the target leg, like a dowel or PVC pipe if needed for balance
- Lift the hip into flexion and rotate to the desired range of motion
- Rotate the hip out into the door frame, wall, squat rack, etc.

Figure 7-40 *Use of a squat rack for resistance*

SUPINE EXTERNAL ROTATION

- Attach a band or cable strap to the ankle (or higher on the lower leg to decrease difficulty) and anchor it to a stable surface
- Flex the target hip to 90°
- The opposite leg can be straight or bent with the foot on the floor to stabilize the pelvis/lower back
- Tighten the abdominals
- Externally rotate the target hip by bringing the lower leg inward as the knee moves outward
- Avoid additional hip flexion or adduction

Figure 7-41 *Supine external rotation start position*

Figure 7-42 *Supine external rotation end position*

SEATED EXTERNAL ROTATION

- Attach a band or cable strap to the ankle (or higher on the lower leg to decrease difficulty) and anchor it to a stable surface
- Externally rotate the target hip by bringing the ankle up and in as the knee moves outward
- Avoid additional hip flexion or adduction

Figure 7-43 *Seated external rotation start position*

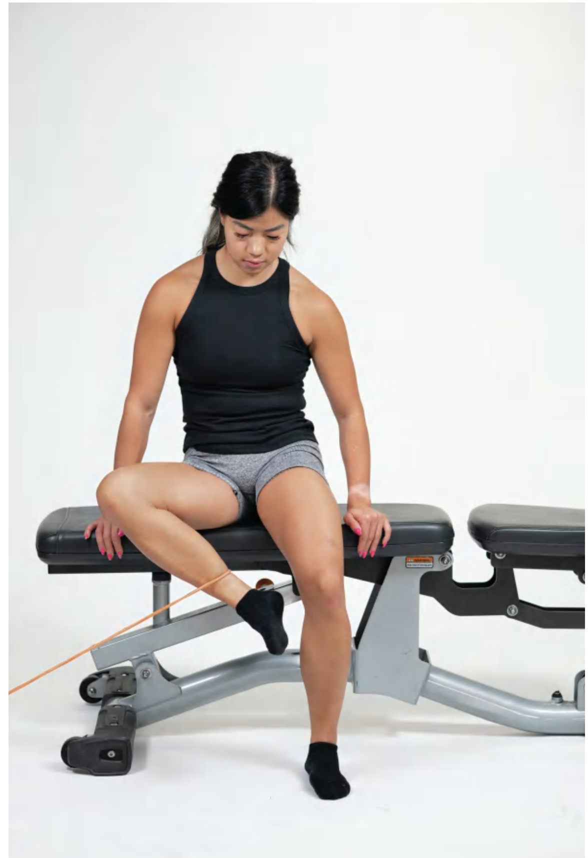

Figure 7-44 *Seated external rotation end position*

SIDE-LYING EXTERNAL ROTATION

- Lift the lower leg up and inward toward midline, but keep the upper thigh in contact with the table
- Load the external rotators eccentrically during the lowering phase by using the increased range of motion available for the hip to internally rotate beyond the edge of the mat
- To increase difficulty, anchor a band at floor level using a heavy weight and attach it to the ankle

Figure 7-45 *Side-lying external rotation start position*

Figure 7-46 *Side-lying external rotation end position*

QUADRUPED EXTERNAL ROTATION "FIRE HYDRANT"

- Contract the abdominals to keep the hips level and externally rotate the target hip up and out to the side
- Turn the knee slightly backward and ankle forward to promote gereater hip external rotation versus abduction
- Place a resistance band above the knees to increase the difficulty

Figure 7-47 *Quadruped external rotation start position*

Figure 7-48 *Quadruped external rotation end position*

STANDING EXTERNAL ROTATION

- Attach a band or cable strap to the lower leg at mid-calf (or above the knee to decrease difficulty)
- Grasp the cable column, squat rack, or another counterbalance
  in the arm on the same side as the stance leg, like a dowel or PVC pipe

- Raise the target leg to 90° hip flexion
- Externally rotate the target hip as if "opening it up" to the side and pivot on the stance leg
- As the target leg returns to midline, again pivot on the stance leg to allow internal rotation past midline during the eccentric phase if comfortable

Figure 7-49 *Standing external rotation start position*

Figure 7-50 *Standing external rotation end position*

HIP ABDUCTION

SIDE-LYING HIP ABDUCTION

Side-lying hip abduction produces high levels of gluteus medius activation between 44–80% MVIC[79–81] and moderate-high gluteus minimus activation between 38–44%,[81] which means it may be effectively used to increase hip abductor strength if loaded correctly. A non-weight-bearing exercise, like side-lying hip abduction, may also prepare an individual for weight-bearing exercises that may require increased frontal plane stability and hip abductor strength that they do not currently possess. The lower extremity positioning and eccentric control are both crucial components to maximizing gluteus medius versus hip flexor and TFL activation during this exercise.

- Start on one side with the target leg on top
- The target knee is straight with the bottom knee bent

- Tighten the abdominals and do not let the top hip roll backward during the movement
- Rotate the foot inward and lift the leg up (away from midline) and slightly backward
- Rotating the foot down and inward will increase activation of the gluteus medius, while turning it up toward the ceiling will increase activation of the hip flexors and TFL[141]
- Add an ankle weight, a band above the knees or at the ankle to increase difficulty

Figure 7-51 *Side-lying hip abduction start position*

Figure 7-52 *Side-lying hip abduction end position. The foot is turned down and in to maintain the hip in internal rotation*

Figure 7-53 *Hip abduction fault – external rotation of the foot and hip will shift focus away from the gluteus medius*

Figure 7-54 *Use of band resistance below the knee in absence of an ankle weight*

SIDE-LYING HIP ABDUCTION WITH EXTRA RANGE

Increasing the range of motion below neutral will promote greater eccentric load and time under tension on the hip abductors.

Figure 7-55 *Extra range start position*

Figure 7-56 *Extra range end position. The higher surface (bench, table, etc.) allows the leg to travel below the horizontal*

STANDING HIP ABDUCTION

Standing hip abduction targets both the stance leg via single-leg loading and the moving leg via frontal plane hip abduction. There is some variability in MVIC, between 40–80% MVIC,[81,141,142] but this still equates to at least moderate-high levels of muscle activity. Standing hip abduction, however, may be easier to perform than more advanced weight-bearing exercises like the single-leg squat, single-leg deadlift, and step-up variations that activate the gluteus medius in a similar range.[79,80,143] Ankle weights, a cable column, resistance band tubing, or a mini band may be used for resistance.

- Grasp the cable column, squat rack, or another counterbalance like a dowel or PVC pipe
- Keep the knee of the stance leg soft, the pelvis level, and lift the moving leg out to the side
- Keep the foot of the moving leg turned inward
- If using a cable column or band tubing, position the stance leg in front of the tubing to avoid it rubbing against the front of the shin throughout the movement

Figure 7-57 *Standing hip abduction start position. Use of a PVC pipe for counterbalance*

Figure 7-58 *Standing hip abduction end position. Foot and hip remains internally rotated*

GLUTEUS MEDIUS WALL LEAN (ISOMETRIC HIP ABDUCTION)

Single-leg exercises can be difficult for a variety of reasons, including balance and pelvic stability. The isometric force of one leg against a door frame or another stable surface provides an additional point of contact to reduce balance demands and allows increased activation of the hip abductors on the opposite stance leg. It may be used as a lead-up exercise to a single-leg squat or deadlift. It is also useful to enhance single-leg loading capability on a limb that does not have the requisite strength to perform other exercises or that may be sensitive to an increased range of motion.

- Stand next to a door frame, squat rack, or wall
- Keep a soft knee on the target (stance) leg furthest from the door frame, squat rack, or wall
- Flex the knee of the opposite leg no more than 90°
- Drive the outside of the flexed knee into the squat rack as if trying to lift the hip up and out to the side
- The lateral hip of the stance leg should activate
- For an additional challenge, place a physioball or medicine ball between the flexed leg and the squat rack
- Maintain an isometric hold at end-range or perform small range single-leg squat or hinge motion with the stance leg to increase difficulty (Figure 7-60)

Figure 7-59 *Gluteus medius wall lean start position*

Figure 7-60 *Gluteus medius wall lean end position*

BAND WALKS

Like clamshells and side-lying hip abduction, band walks are commonly prescribed in the rehabilitation setting, but their effectiveness may be limited by set-up and execution. The lateral band walk generates 30–60% MVIC,[79,142,143] but gluteus medius activation is enhanced with distal band placement at the feet or ankles and with the feet and the feet in neutral, as opposed to externally rotated.[142,144] All of the following exercises should be performed in an athletic stance with vertical tibias.

Band at ankles:

- Adopt a stance that allows moderate tension to be placed on the band
- Push off the trail leg to take a step (instead of "reaching" with the lead leg)
- Avoid turning the feet out
- The entire foot of the lead leg should contact the ground, including the heel
- Keep knees in line with the toes and do not let them cave in

Band at knees:

- Can be placed just above or just below the knees
- Use the placement that maximizes the sensation of lateral hip activation
- A band at the feet enhances gluteus medius activation, further involves ankle muscles and foot intrinsics
- Double-banded walks are performed with two bands (hence the name). Bands are placed above the knees and either just below the knees, at the ankles, or around the feet

Figure 7-61 *Band at ankles*

Figure 7-62 *Band below knees*

Figure 7-63 *Band at feet*

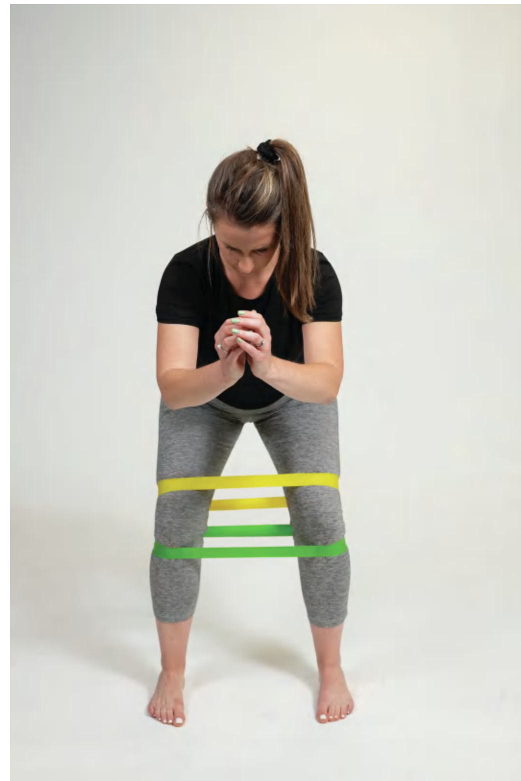

Figure 7-64 *Double-banded*

SEATED HIP ABDUCTION

Seated hip abduction produces relatively high levels of muscle activation (50–80% MVIC) when performed with a machine, though there is very little data for comparison.[142] Leverage makes it difficult to perform this exercise with heavy weight, so in order to increase exertion, drop sets or high-repetition training with lower weight may be used.

- Plant the feet on the footrests of the hip abductor machine or floor
- Drive the knees out against the machine or band placed above the knees
- Lean forward to increase the amount of stretch on the gluteus maximus
- Lean back to open up space in the hip joint if there is any anterior hip discomfort

SIDE PLANKS

Side planks can help build strength of the gluteus medius, minimus, obliques, and may also improve pelvic stability. They yield a high amount of gluteus medius activation greater than 80% MVIC[143] and generate high peak forces for the gluteus medius and minimus similar to those observed during the single-leg squat and single-leg deadlift.[83] They can be difficult to perform due to increased weight-bearing requirements on the shoulder girdle. When performed with the legs straight, they also demand a great deal of stability from both the knees and ankles. Add a resistance band at the hips during side plank exercises to provide an additional challenge to hip abductors, extensors, and abdominal muscles.

HIGH MAT OR BENCH SIDE PLANK

Performing the side plank from a high mat or bench will decrease the difficulty by reducing the angle and demand placed by gravity. Instead of positioning parallel to the floor, the body can be angled 20–60° from the floor, depending on the height of the surface used.

HIGH MAT PLANK WITH ELBOW FLEXED

- Position the elbow directly under the shoulder
- Position the bottom leg behind the top leg in a staggered stance to increase the base of support (less difficult) or stack the ankles on top of each other (more difficult)
- Contract the abdominals and pull the rib cage down to avoid lumbar spine hyperextension
- Drive the sides of the feet down into the floor to lift the hips up and forward
- Attempt to keep the body in a straight line
- The hips should not rotate forward, backward, or sink down

Figure 7-65 *High mat plank with elbow bent*

HIGH MAT PLANK WITH ELBOW STRAIGHT

- Extending the arm straight will demand more from the shoulder girdle and abdominal stabilizers

Figure 7-66 *High mat plank with elbow straight*

BENCH PLANK WITH ELBOW FLEXED

Figure 7-67 *Bench plank with elbow bent*

BENCH PLANK WITH ELBOW STRAIGHT

Figure 7-68 *Bench plank with elbow straight*

SIDE PLANK WITH KNEES FLEXED

There are fewer degrees of freedom when this exercise is performed with the knees bent and it can eliminate discomfort on the knees, ankles, and shoulder that may occur with the legs straight. Driving the bottom knee into the floor to initiate the lift-off may help enhance activation of the hip abductors on the weight-bearing bottom leg.

- Position the elbow directly under the shoulder
- Bend the knees and position the legs so that the knees line up with the middle of the forearm (about 30° of hip flexion)
- Tighten the abdominals and pull the rib cage down
- Drive the outside of the lower leg into the floor to lift the hips up and forward
- Muscle activation should be appreciated in the lateral hip of the bottom leg

Figure 7-69 *Side plank with knees bent start position*

Figure 7-70 *Side plank with knees bent end position*

SIDE PLANK WITH HIP ABDUCTION

- Perform a side plank with the bottom knee bent and top knee straight
- Rotate the foot inward and lift the top leg up (away from midline) and slightly backward

Figure 7-71 *Side plank with hip abduction start position*

Figure 7-72 *Top leg remains straight*

Figure 7-73 *Hip abduction is performed with top leg. Foot and hip of top leg remain internally rotated or neutral*

SIDE PLANK KNEES STRAIGHT

- Position the elbow directly under the shoulder
- Tighten the abdominals and pull the rib cage down
- Drive through the outside of the foot of the bottom leg to lift the hips up and forward

Figure 7-74 *Side plank with knees straight end position*

CLAMSHELLS

Muscle activation during the clamshell ranges from low to high across multiple studies, but is less overall during the clamshell when compared to side-lying hip abduction.[79,81,141,143] However, the gluteus medius-to-TFL activation ratio is actually higher during the clamshell,[145] so it may be a useful exercise if the goal is to limit TFL muscle activity. The clamshell may also be a better exercise for beginners or those with impaired loading capacity compared to exercises that generate a higher level of muscle activity. The clamshell may be considered a fundamental exercise to teach isolated movement of the hip (femur) on the pelvis. Maximal gluteus medius activation is achieved with the hip flexed to 60° and pelvis in a neutral position instead of rotated forward or backward.[146] A resistance band may be added above the knees to increase difficulty during most clamshell exercises.

TRADITIONAL CLAMSHELL

- Position the hips between 30–60° of flexion
- The knees should flex enough to set the feet in line with the glutes
- Contract the abdominals
- Keep the ankles together, but lift the top knee up and back
- Maintain a neutral pelvis throughout and do not let the hips roll backward at end-range

Figure 7-75 *Clamshell start position*

Figure 7-76 *Clamshell end position*

Figure 7-77 *Clamshell fault – hips do not remain stacked with excessive posterior hip and lower back rotation*

CLAMSHELL WITH EXTENSION AND INTERNAL ROTATION

Internal rotation and extension of the top leg during the clamshell generates high gluteus medius muscle activation at 77% MVIC.[143]

- Position the hips at 45° of flexion and knees bent
- Lift the top leg until it is parallel to the ground and extend the hip backward
- Maintain this position and internally rotate the hip (lift the ankle toward the ceiling)

Figure 7-78 *Top leg is lifted into hip abduction and slight extension*

Figure 7-79 *Internal rotation of top hip while maintaining abduction and extension*

SIDE PLANK CLAMSHELL

- Perform a side plank with knees bent (see page 146)
- Maintain the plank as you lift the top knee up and back while keeping the ankles together
- Do not let the hips drop, roll backward, or hyperextend the lumbar spine

Figure 7-80 *Start position in side plank*

Figure 7-81 *Clamshell from side plank*

SIDE PLANK LIFT

- Perform a side plank with knees bent
- Lift the top leg up and back while keeping the foot in line with the knee

Figure 7-82 *Start position in side plank clamshell*

Figure 7-83 *The ankles separate as the top leg elevates*

HIP ABDUCTION WITH DYNAMIC BALANCE

SLDL ROTATION

The single-leg deadlift rotation or "hip airplane" combines the hinge pattern with pelvis on femur rotation to target the hip rotators.

- Perform a single-leg deadlift (see page 90) to the desired range of motion
- Rotate the torso and pelvis as one to "open" then "close" the hip

Figure 7-84 *Single-leg deadlift*

Figure 7-85 *The trunk and pelvis do not segment and rotate as one unit*

SLDL ROTATION UPPER EXTREMITY ASSISTED

- Hold on to a door frame or squat rack with the arms outstretched
- Perform a single-leg deadlift
- Use the upper extremities to aid balance and assist with rotating the torso and pelvis together

Figure 7-86 *Assisted single-leg deadlift*

Figure 7-87 *Use of bench for balance support during rotation*

LATERAL TOE TAPS

- Place a band around the ankles
- Keep a soft knee on the stance leg
- Reach the opposite leg out to the side and backward
- Tap the toe on the floor for balance

Figure 7-88 *Start with gentle tension on the band*

Figure 7-89 *Position of the stance leg and trunk is maintained against dynamic, resisted movement of the opposite extremity*

HIP BAND CIRCLES

- Place a band around the ankles
- Keep a soft knee on the stance leg
- Reach the opposite leg forward
- Maintain tension on the band as you draw a half circle clockwise, then counter clockwise with the band

Figure 7-90 *Leg forward at start of clockwise motion (12:00)*

Figure 7-91 Leg positioned *laterally (3:00)*

Figure 7-92 *Leg positioned backward (6:00); all motions completed in a smooth, arc type motion with constant band tension*

GLUTE FOCUS LUNGES AND STEP-UPS

Lunge and step-up patterns performed with a forward trunk lean will increase hip flexion range of motion and stretch on the posterior chain, similar to low bar back squats and deadlifts. Lunge patterns can be loaded bilaterally or unilaterally (in the arm opposite of the forward leg) to enhance gluteus medius activation.

SPLIT SQUAT

Split squats produce significant levels of peak force in both the gluteus maximus and medius.[83]

- Stand with the feet staggered at a comfortable distance with the target leg in front
- Lean forward at the trunk slightly
- Bend the back knee to descend into a lunge
- Adjust the trunk angle to feel a stretch on the glute of the forward leg
- Return to upright by driving through the front foot

Figure 7-93 *Glute focus split squat start position*

Figure 7-94 *The trunk is positioned forward, rather than upright at end-range*

REAR FOOT ELEVATED SPLIT SQUAT (RFESS)

Elevating the rear leg will enhance single-leg loading capacity, but maintaining contact with the foot support will reduce balance demands. The RFESS offers similar muscle activation of the gluteus maximus and quadriceps compared to other exercises, like back squats, split squats,[147] and single-leg squats,[78] but provide increased activation of the hamstrings, particularly the biceps femoris.[147] The RFESS has a greater hip extension moment than the back squat[148,149] and can also activate lower body muscles to the same extent as back squats, but when using half the load,[147] which may have particular significance with respect to rehabilitation training.

- Rest the back foot on a bench, specialized single-leg squat stand, roller attachment on a decline bench, 45° hyperextension, or squat rack
- Position the front foot at a comfortable distance away from the rear foot
- Lean forward at the trunk
- Bend the back knee to descend into a lunge
- The back knee should travel down and slightly posterior in order to remain in line with the trunk

Figure 7-95 *RFESS start position*

Figure 7-96 *The trunk is positioned forward, rather than upright at end-range with weight through the front foot*

SUSPENSION STRAP REVERSE LUNGE

Reverse lunges limit forward momentum which, in addition to the forward trunk angle, shifts the focus to the posterior chain.

- Grasp the suspension straps and take a large step backward
- Lean forward at the trunk
- Bend the back knee to descend into a lunge
- Use the suspension straps to reduce balance demands and decrease difficulty of the eccentric contraction
- Use the straps to pull back to upright if necessary

Figure 7-97 *Suspension strap reverse lunge start position*

Figure 7-98 *The trunk is positioned forward, rather than upright at end-range*

REVERSE LUNGE

- Take a large step backward
- Lean forward at the trunk
- Bend the back knee to descend into a lunge
- Drive through the front leg to return to upright

Figure 7-99 *Reverse lunge start position*

Figure 7-100 *Step backward*

Figure 7-101 *The trunk travels forward during the descent to load the front leg*

HIGH BOX STEP-UP

A step-up to a high box requires a large amount of hip flexion, greater stretch on the gluteus maximus and adductors and is a much more hip-dominant move than a traditional step-up.

- Place the foot up on a high box (20–30 inches)
- Lean forward and drive through the heel to propel to upright
- Try to control the descent
- Stand next to a squat rack, post, or door frame for balance if needed

Figure 7-102 *High box step-up start position*

Figure 7-103 *High box step-up end position*

CROSSOVER STEP-UP

Crossover step-ups effectively target the gluteal complex, generating 76% MVIC of the gluteus medius and 124% of the gluteus maximus.[150] The concentric action is initiated in a large range of femoral adduction with the gluteus medius on stretch and therefore requires a large amount of gluteus medius activation to abduct the hip.

- Stand to the side of the step
- Bring the far leg across the body, in front of the opposite leg, and place the whole foot on the step
- Shift the torso forward slightly to feel a slight stretch on the glute
- Push through the entire foot and contract the glute hard to propel the body upward onto the step
- Lift the trail leg into hip flexion
- To descend, slightly lean the trunk forward
- Reach the trail or moving leg behind the target, planted leg
- Bend the knee and lower until the trail leg contacts the floor

Figure 7-104 *Crossover step-up start position*

Figure 7-105 *Single-leg balance in contralateral hip flexion to increase demand on the gluteus medius of the stance leg*

Figure 7-106 *Controlled eccentric phase to create additional stretch on the glute*

HIP THRUSTS

The barbell hip thrust produces very high gluteus maximus activation at greater than 70% MVIC[118] and greater activation compared to barbell squats and deadlifts.[65,151–153] The addition of hip thrusts into a lower body training program has been shown to increase muscle thickness of the gluteus maximus compared to a control group.[154] Therefore, it can be used as both a primary and an accessory lift for glute and lower body training. It is often easier to move heavier loads with the hip thrust versus squats or deadlifts, especially for someone with a sensitive lower back. Exercises that produce horizontal force, like the hip thrust, are highly associated with the acceleration phase of sprinting[123] and have been proven to enhance both sprint and vertical jump performance,[98,122,155] which make them an excellent exercise to consider when designing programs for athletes or any individual with the goal of increasing lower body power. Hip thrusts are also a superior exercise to barbell squats if the goal is to develop greater sprint speed.[156]

There are five key areas of focus to ensure proper set-up and execution of the hip thrust:

Bench height:

- 12–16 inches (or higher for an individual with a very long torso)

- A standard weightlifting bench is too high for most individuals and will promote hyperextension of the low back to reach end-range
- The bench should be lined up with the bottom of the shoulder blades

Head position:

- The neck should remain flexed with the chin tucked
- Gaze should be at the knees versus the ceiling throughout the movement

Knee angle:

- A vertical shin angle (90° of knee flexion) or greater will enhance gluteus maximus activation by rendering the hamstrings actively insufficient[157]
- Similar to the bridge, positioning the feet farther away will shift some of the load to the hamstrings[157]

Foot position:

- A wider stance with the feet externally rotated (rotational hip thrust) will increase gluteus maximus activation[157]
- The feet can also face straight ahead for comfort

Terminal hip extension:

- Contract the abdominals, pull the rib cage down and perform a posterior pelvic tilt at end-range to avoid hyperextension of the lumbar spine

The information above was adapted from Bret Contreras' online article: "How to Hip Thrust."[158]

Figure 7-107 *Increased knee flexion and vertical shin angle for glute focus*

Figure 7-108 *Decreased knee flexion for hamstring focus*

Figure 7-109 *Terminal hip extension at end-range*

Figure 7-110 *Lumbar hyperextension at end-range has the potential to irritate the lumbar facet joints or a stenotic spine and is not recommended, especially under load*

DOUBLE-LEG BODYWEIGHT HIP THRUST

- Sit on the floor in front of the bench
- Position the bottom of the shoulder blades on the edge of the bench
- Tuck the chin and flex the neck so the gaze is at the knees
- Position the feet at a comfortable distance away from the glutes (try for 90° of knee flexion, but this is difficult to gauge until the his are in neutral)
- Tighten the abdominals and pull the rib cage down
- Drive the hips up toward the ceiling, contract the glutes, and perform a posterior pelvic tilt at end-range
- Re-adjust the shoulder and/or foot position at the top of the first repetition if necessary
- Lower the hips without letting the upper back slide down the bench
- The glutes should remain elevated from the floor in between each repetition to increase time under tension
- The arms can be outstretched across the bench, tucked close to the body, or elbows slightly pointed out with the triceps against the edge of the bench

Figure 7-111 *Bodyweight hip thrust start position*

Figure 7-112 *Bodyweight hip thrust end position*

DUMBBELL HIP THRUST

- Place a dumbbell across the front of the hips with cushion support (towel, foam pad, etc.)

Figure 7-113 *The dumbbell is secured in place with the upper extremities*

Figure 7-114 *Dumbbell hip thrust end position*

DOUBLE-BAND HIP THRUST

- Place bands above and below the knees to maximize hip abduction and external rotation
- Push the thighs out into the bands while contracting the glutes during the concentric phase

Figure 7-115 *Double-band hip thrust start position*

Figure 7-116 *Double-band hip thrust end position*

BARBELL HIP THRUST

- Roll the barbell onto the front of the hips (use a foam pad for comfort)
- Grasp the barbell with both hands using an overhand grip and pull the bar into the hips
- Elbows should be slightly pointed out with the triceps against the edge of the bench
- Otherwise, perform with the same sequence as the bodyweight hip thrust
- Bring the plates to the floor (dead stop) to reset after each repetition or keep them elevated from the floor in between each repetition to increase time under tension

Figure 7-117 *Barbell hip thrust start position*

Figure 7-118 *Barbell hip thrust end position*

SINGLE-LEG AND MODIFIED SINGLE-LEG HIP THRUSTS

STAGGERED-STANCE BODYWEIGHT HIP THRUST

Similar to the staggered-stance deadlift or RFESS, using this stance during the hip thrust will allow increased loading to one leg, but will reduce balance demands.

- The knee of the target leg remains flexed to 90° with the foot flat
- The opposite leg will be positioned in front of the foot of the target leg with weight on the heel
- Drive through the target leg with only light weight (enough for balance) resting on the opposite heel

Figure 7-119 *Staggered-stance bodyweight hip thrust start position*

Figure 7-120 *Staggered-stance bodyweight hip thrust end position*

STAGGERED-STANCE DUMBBELL HIP THRUST

Figure 7-121 *Staggered-stance dumbbell hip thrust start position*

Figure 7-122 *Staggered-stance dumbbell hip thrust end position*

STAGGERED-STANCE BARBELL HIP THRUST

Figure 7-123 *Staggered-stance barbell hip thrust start position*

Figure 7-124 *Staggered-stance barbell hip thrust end position*

SINGLE-LEG HIP THRUSTS

Single-leg hip thrusts generate very large levels of peak force for the gluteus maximus and greater gluteus maximus compared to medius and minimus activation.[83] This may be an appropriate exercise to target the gluteus maximus while limiting contribution of the medius and minimus. Single-leg hip thrusts also generate similar levels of peak force for the gluteus maximis as other exercises, like the split squat, single-leg deadlift, and single-leg squat.[83]

- Single-leg bodyweight hip thrust
- Flex the knee of the target leg to 90° with the foot flat on the floor
- Position the opposite leg in 90° of hip flexion
- The arms should be outstretched across the bench to increase the base of support and balance
- Tighten the abdominals and pull the rib cage down
- Drive the hips up toward the ceiling, contract the glutes, and perform a posterior pelvic tilt at end-range
- Keep the pelvis level throughout and do not allow one hip to drop

Figure 7-125 *Single-leg hip thrust start position*

Figure 7-126 *Single-leg hip thrust end position*

SINGLE-LEG DUMBBELL HIP THRUST

- Place a dumbbell across the front of the target hip
- Secure the dumbbell with a hand throughout

Figure 7-127 *The dumbbell is secured in place with the upper extremities*

SINGLE-LEG LANDMINE HIP THRUST

The single-leg hip thrust is difficult to load heavy with an unstable, free-weight dumbbell resting on the front of the hip. The landmine set-up enhances stability via an anchor point (landmine attachment, corner of a wall, or between two plates), as shown, and therefore allows use of heavier loads.

- Add desired weight and rest the end of the barbell across the front of the hip
- Otherwise, perform with the same sequence as the single-leg hip thrust

Figure 7-128 *Landmine hip thrust start position*

Figure 7-129 *Landmine hip thrust end position*

HIP EXTENSION

MODIFIED PLANTIGRADE KICKBACK

- Rest the upper body on a table or high mat with the pelvis at the edge
- The knee of the stance leg should remain soft
- Engage the abdominals
- Bend the target knee to 90°
- Kick up and back
- To ensure true hip extension, do not extend the low back at end-range
- This exercise can be performed with bodyweight or a band above the knees
- For an additional challenge, perform a hold at end-range (10–30 seconds)

Figure 7-130 *Modified plantigrade kickback start position*

Figure 7-131 *Modified plantigrade kickback end position*

QUADRUPED GLUTE KICKBACK

Quadruped kickbacks induce a low-moderate level of EMG excitation at 32% MVIC for the target leg and 24% for the stance leg.[159]

- Engage the abdominals
- Kick the target leg up and back
- Maintain a level pelvis and avoid excessive lumbar extension
- For an additional challenge, place a band above knees or add an ankle weight for resistance

Figure 7-132 *Quadruped kickback start position*

Figure 7-133 *Quadruped kickback end position. The hip is extended, but the lumbar spine remains neutral at end-range*

MODIFIED PLANTIGRADE EXTENSION

- Rest the upper body on a table or high mat with the pelvis at the edge
- The stance leg can be positioned two different ways:
  1. Soft knee with the foot in contact with the floor (53% MVIC)[159]
  2. Knee bent and rested on chair or bench (66% MVIC)[159]
- Engage the abdominals
- Contract the glute and kick the target leg up and back
- To ensure true hip extension, do not extend the low back at end-range
- An ankle weight or band at the ankles may be used for resistance

Figure 7-134 *Modified plantigrade hip extension start position*

Figure 7-135 *Modified plantigrade hip extension end position*

Figure 7-136 *Stance knee on bench start position*

Figure 7-137 *Stance knee on bench end position*

STANDING CABLE HIP EXTENSION

- Face the cable column and secure the hands either on the column or handles (if available)
- Hinge forward at the hips until the trunk is close to horizontal
- Engage the abdominals
- Kick the target leg up and back
- To increase time under tension:
  1. Do not bring the target leg all the way back to the ground after each repetition
  2. Perform pulsing repetitions at the last quarter range of motion

Figure 7-138 *Standing cable hip extension start position. Use of PVC pipe for bilateral arm support and to support forward trunk lean in order to increase range of motion*

Figure 7-139 *Standing cable hip extension end position. The hip is extended, but the lumbar spine does not extend excessively and the pelvis remains square to the floor*

QUADRUPED HIP EXTENSION EXTRA RANGE

- Set-up on a high mat, table, or plyometric box with the target leg off the edge
- Engage the abdominals to maintain stability at the lumbar spine and pelvis
- Kick the target leg up and back
- Lower until the hip is at a 90° angle, which will create a stretch on the glute

Figure 7-140 *Quadruped hip extension start position. Use of the bench allows extra range into hip flexion for an additional stretch on the glute*

Figure 7-141 *Quadruped hip extension end position*

PLANK HIP EXTENSION

The plank hip extension is a very simple exercise that requires no equipment or external load, but generates a high level of muscle activity for the gluteus maximus at 106% MVIC.[143] Due to single-leg loading, there is also increased demand on the gluteus medius of the opposite extremity at 75% MVIC[143] and the quadriceps to maintain knee extension.

- Start in a forearm plank position
- Engage the abdominals and isometrically pull the elbows toward the pelvis
- Lift the target leg off the ground and flex the knee to 90°
- Contract the glute of the target leg and extend the hip (kick the heel toward the ceiling)
- To ensure true hip extension, do not extend the low back at end-range

Figure 7-142 *Plank hip extension start position*

Figure 7-143 *Plank hip extension end position. Maintain a level pelvis during extension*

CHAPTER 8

LOWER BODY

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The past four chapters have covered some major ground already with respect to lower body training, but there are many other exercises for the lower body that can serve as both primary and accessory lifts. Many of the lower body exercises included will produce some activation of the gluteal complex, but this chapter focuses on exercises that will better target the hip flexors, quadriceps, hamstrings, adductors, gastrocnemius, soleus, and smaller, albeit important, muscles of the lower leg (peroneals, anterior, and posterior tibialis). Strength and resiliency of lower body musculature is important even for the most physically-capable individuals and is vital to maintain as we age in order to maximize quality of life.

HIP FLEXORS

The hip flexor muscles – the iliopsoas and rectus femoris – are somewhat misunderstood. This may be due in part to Janda's lower crossed system, which labels the hip flexors as a culprit for postural issues, like anterior pelvic tilt and lumbar lordosis. As a result, a large emphasis is often put on stretching the hip flexors to resolve issues with anterior hip, groin, and lower back pain. Muscles that are tight (or that feel tight) don't always need to be stretched, like the hip flexors and hamstrings. If the desired results are not achieved with stretching exercises, it may be worthwhile shifting the focus from stretching to strengthening. Pain relief and adaptive muscle lengthening can often be achieved by progressively loading the target issue.

HIP FLEXOR ISOMETRICS SEATED

- Sit in a chair with both feet planted on the floor
- Lift the target hip into flexion
- Maintain the height of the leg while resisting a downward force applied by the hands

Figure 8-1 *Hip flexor isometric hold*

PSOAS MARCH SUPINE

The psoas march combines isometric hip flexor strengthening of the stable leg, eccentric lengthening of the moving leg, and core stabilization, all of which are important when trying to address issues like anterior hip or groin pain.

- Place a mini band around the feet (light resistance)
- Bend both hips and knees to 90°
- Engage the abdominals, pull the rib cage down, and maintain contact with the lower back to the floor throughout the exercise

- Maintain the position of the stationary leg in 90° of hip flexion
- Push against the band with the moving leg to extend the knee
- Alternate legs with each repetition

Figure 8-2 *Psoas march supine start position*

Figure 8-3 *Psoas march supine end position. The stationary leg maintains an isometric contraction while the opposite leg lengthens*

PSOAS MARCH BENCH BRIDGE

- Place a mini band around the feet
- Position the heels on a bench, chair, or plyometric box
- Engage the abdominals and pull the rib cage down
- Contract the glutes and drive the hips up until the body is in a straight line
- Keep the heel of the stationary leg in contact with the bench
- Pull the knee of the moving leg toward the chest
- Do not let the hips drop

Figure 8-4 *Psoas march bench bridge start position in a straight-leg bridge*

Figure 8-5 *Psoas march bench bridge end position. Hip height and a level pelvis is maintained when removing the support of one leg, which also challenges the abdominals and hip extensors of the stationary leg*

PSOAS MARCH STANDING

- Place a mini band around the feet
- Keep the band anchored to the floor using the stance leg
- Drive the target leg up into hip flexion
- Alternate legs with each repetition

Figure 8-6 *Psoas march standing start position*

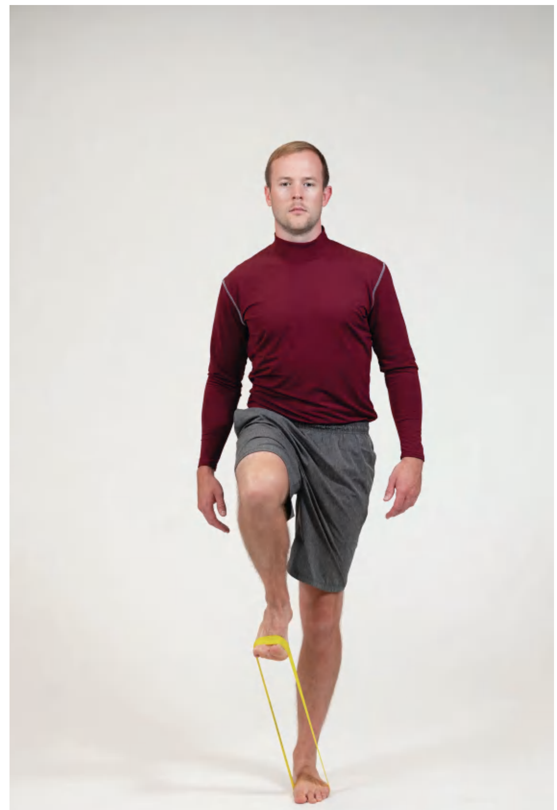

Figure 8-7 *Psoas march standing end position. Maintain a level pelvis and avoid laterally flexing the trunk to one side in single-leg stance*

CABLE HIP FLEXION

- Attach an ankle strap to the target leg and cable column
- Use a bench, dowel, or other means of upper extremity support for balance
- Lift the target hip into flexion
- Keep the weight of the body in a slight forward lean to prevent loss of balance backward

Figure 8-8 *Cable hip flexion start position*

Figure 8-9 *Cable hip flexion end position*

STANDING HIP FLEXION WITH ANKLE WEIGHT

- Secure an ankle weight to the target leg
- Lift the target leg up into hip flexion
- Complete all repetitions on one side prior to switching legs

Figure 8-10 *Standing hip flexion with ankle weight start position*

Figure 8-11 *Standing hip flexion with ankle weight end position. Maintain a level pelvis and avoid laterally flexing the trunk to one side in single-leg stance*

BEAR CRAWLS WITH BAND

- Place a mini band above the knees
- Push through the arms and balls of the feet to lift the knees from the floor
- "Step" forward with one arm, followed by the opposite leg
- Repeat on the opposite side for a reciprocal crawling motion

Figure 8-12 *Bear crawl start position in bear plank*

Figure 8-13 *Continue the alternating arm and leg reciprocal motion. The band provides resistance into hip flexion for the forward leg*

HANGING KNEE RAISES

- Hang from a pull-up bar
- Engage the abdominals
- Drive the knees up toward the chest to at least 90° of hip flexion
- This exercise can be performed bilaterally or unilaterally, with or without ankle weights

Figure 8-14 Hanging knee raise start position

Figure 8-15 Hanging knee raise end position (hip flexion concentric motion)

DEAD BUG WITH ECCENTRIC HIP FLEXION FROM BENCH

- Position the legs in 90° hip and knee flexion
- Contract the abdominals and pull the rib cage down
- Slowly lower one leg off the bench
- The goal is to control the lowering phase and achieve at least neutral hip extension while maintaining the lower back flat on the bench

Figure 8-16 Start position in a dead bug hold

Figure 8-17 Eccentric hip flexion. The bench allows a greater range of motion during the eccentric portion

QUADRICEPS

There are four muscles in the quadricep group: the rectus femoris, vastus medialis, lateralis, and intermedius. The rectus femoris spans two joints (the hip and knee) while the other three muscles function solely at the knee joint. The quadriceps primarily act to extend the knee, but the rectus femoris acts as a synergist to hip flexion. Knee extension range of motion and strength are important to promote normal lower extremity biomechanics and to achieve maximal quadriceps muscle activation. Loss of knee extension post-operatively after ACL reconstruction is a predictive factor in the development of osteoarthritis and lower subjective scores at long-term follow-up.[160–162] Unsurprisingly, individuals with knee osteoarthritis have reduced lower body muscle mass, decreased peak knee extension torque and relative peak knee extension, so restoring knee range of motion and developing knee extension strength should be used as both a preventive measure and a treatment for arthritis.[163] Exercise prescriptions that are limited to quadricep sets and straight-leg raises are unlikely to promote progressive overload, muscle hypertrophy, or strength gains of the quadriceps in the middle to later phases of the rehabilitation process.

Isolated knee extension exercises appear to have a different effect on muscle growth when compared to compound exercises and are very important for regaining quadricep strength, especially unilateral exercises. Open-chain knee extensions increase the size of the rectus femoris to a significantly greater extent than squats, while squats proved to be a better exercise to grow the vastus lateralis.[164] Less than 90% limb symmetry index (LSI) with respect to quadricep strength is a predictor of reinjury after ACL reconstruction[165] and additional research also recommends at least 80% limb symmetry before progressing to plyometric exercises.[166] Open-chain knee extension exercises stress the patellofemoral joint most at full extension, so you can target the end-range or mid-range (90–40°) based on the desired amount of patellofemoral and ACL stress.[167] LSI is usually tested by an isometric or isokinetic leg extension contraction.

Muscle activation of the rectus femoris was also observed to be higher during leg extensions when compared to the leg press.[168] A randomized controlled trial by Stien et al.[169] also highlights the importance of training specificity by comparing leg extensions to the leg press exercise. A significant increase in a 6RM of the leg extension was observed in the group that performed leg extension training compared to those that performed leg press. The opposite finding was observed in the 6RM leg press group when compared to the leg extension group.[169] Therefore, if considering the principles of specificity and this research study, if an individual never performs the open-chain knee extension exercise that would mimic the testing procedure, it seems plausible that there may be some deficiency.

A well-designed rehabilitation program should include both open- and closed-chain exercises. Open-chain exercises may make it more difficult to compensate with other muscle groups, while closed-chain exercises better mimic daily functional activities. Which one is better? That's to be seen, as available evidence does not support that open-chain exercises are undoubtedly superior to closed-chain exercises. With respect to quadricep training, however, there is much more to it than simply prescribing endless amounts of quadricep sets and straight-leg raises. Please do not misunderstand: these are very good exercises but we must be honest with *why* we are using them. The goals of these exercises should be to restore full knee extension and promote muscle re-education, especially when increased loading would be contraindicated (i.e., immediately post-operatively or in the setting of severely impaired static and dynamic control in standing).

QUADRICEP ACTIVATION AND TERMINAL KNEE EXTENSION FOR BEGINNERS

QUADRICEP SETS

- Can be performed in multiple positions: supine, reclined, or long sitting
- Focus on contracting the quadriceps while attempting to flatten the back of the knee onto the mat, bed, etc.
- Hold the contraction for a full ten seconds
- The heel will slightly lift from the surface if the knee achieves hyperextension

STRAIGHT-LEG RAISES

- Start in a supine position with the target leg straight and opposite knee bent
- Perform a quadricep set to fully straighten the knee
- Maintain knee extension and lift the leg to a maximum of six inches
  - A smaller range of motion may limit contribution of the hip flexors and allow a focus on the quadriceps throughout the exercise
- Slowly lower the leg without allowing the knee to bend
- "Extension lag" occurs when the knee bends during the concentric or eccentric action
  - To correct this, alter the range of motion, perform assisted, or use alternative exercises until able to maintain extension throughout
- Add resistance via ankle weights

PRONE TERMINAL KNEE EXTENSION (TKE)

The prone TKE is a closed-chain knee extension exercise that uses the force of the toes into the table or floor, essentially trying to push the surface away, in order to enhance knee extension and the intensity of the isometric contraction at end-range.

- Lay on the stomach with the toes in contact with the floor or table
- Drive the toes into the surface, as if trying to kick it away, and contract the quadriceps to extend the knee

Figure 8-18 *Prone TKE start position*

Figure 8-19 *Prone TKE end position*

PLANK

The plank is most often used to develop abdominal muscle strength, but can also be effective for loading the quadriceps. It is simply a bodyweight loaded terminal knee extension if focus on contracting the quadriceps and maintaining knee extension throughout is prioritized.

- Assume the plank position – elbows bent and positioned directly under the shoulders, abdominals tight, pelvis posteriorly tilted, and weight through the balls of the feet
- Contract the quadriceps by straightening the knees
- To increase difficulty:
  - Shift the weight back and forth between each leg
  - Shift weight onto one leg and lift the toes of the opposite leg from the floor

Figure 8-20 *Plank position*

PLANK TKE

- Assume the high plank position
- Bend the knees toward the floor
- Contract the quadriceps to straighten the knees

Figure 8-21 *Plank TKE start position*

Figure 8-22 *Plank TKE end position*

STANDING TKE

- Attach a band behind the target knee
- Stand in a staggered stance with the target leg slightly posterior
- Let the target knee translate forward
- Contract the quadricep and pull the knee backward against the band into full extension

Figure 8-23 *Standing TKE start position*

Figure 8-24 *Standing TKE end position*

KNEE EXTENSION ISOMETRICS

Knee extension isometrics are best used for pain reduction, especially when loading the tissue in a different manner isn't tolerated (i.e., tendinopathy) or would be detrimental to the healing process (i.e., muscle tear).

- Kick into the wall using a comfortable amount of force
- This exercise be performed at multiple angles of knee flexion to target the quadricep

Figure 8-25 *Knee extension isometric kick into an immovable surface*

PLATE KICKS

Plate kicks can be performed as an isometric or concentric exercise depending on the goal. To perform isometrically, use a heavy plate or stacked plates that will be difficult to move. To perform concentrically, simply use a lighter plate.

- Start in the desired amount of knee flexion
- Drive the foot into the edge of the plate, as if trying to kick the plate away

Figure 8-26 *Isometric plate kick*

PHYSIOBALL KNEE EXTENSIONS OR "LEG PRESS"

- Place a physio ball between the foot and a wall with the knee in 90° of flexion
- Press the foot into the ball and contract the quadricep until the knee is at or close to full extension without hyperextending

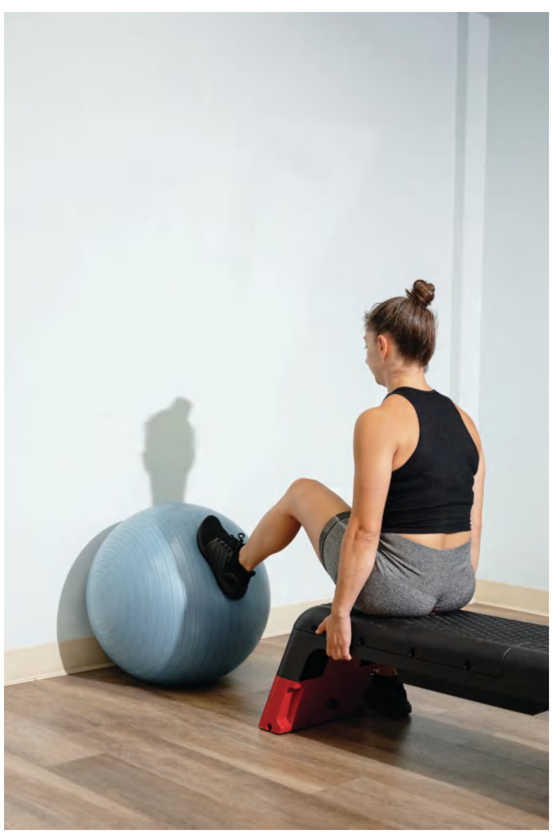

Figure 8-27 *Physioball knee extension start position*

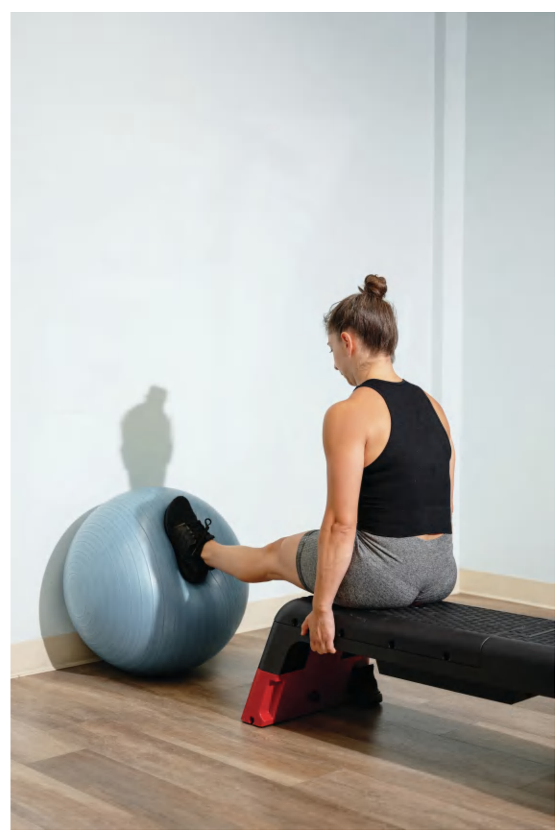

Figure 8-28 *Physioball knee extension end position*

ADVANCED QUADRICEP ACTIVATION AND TERMINAL KNEE EXTENSION

SINGLE-LEG PLANK TKE

- Start in a full plank position
- Lift one leg off the floor and maintain the target leg straight
- Bend the target knee toward the floor
- Contract the quadricep to straighten the knee while maintaining the opposite leg off the floor

Figure 8-29 *Single-leg plank TKE start position*

Figure 8-30 *Single-leg plank TKE with the target knee flexed*

HIGH PLANK TKE

- Assume high plank position – elbows extended and hands positioned directly under the shoulders
- Bend the knees until flexed at 90° and positioned directly under the hips (bear plank position, see page 413)
- Contract the quadriceps to straighten the knees and transition back to high plank
- Do not let the hips rise or fall throughout the movement

Figure 8-31 *Start and end position in high plank with quadriceps contracted*

Figure 8-32 *Knee flexion to bear plank position*

HIGH PLANK SINGLE-LEG TKE

Figure 8-33 *High plank single-leg TKE start position*

Figure 8-34 *High plank single-leg TKE end position with quadricep contracted*

FEET-ELEVATED KNEE EXTENSIONS

Elevating the feet allows increased range of motion and time under tension on the quadriceps.

- Assume high plank position with the feet elevated on a bench or box
- From high plank, bend the knees to a comfortable degree of flexion (Figure 8–35)
- Drive through the toes and contract the quadriceps to straighten the knees
- Allow the hips to rise up toward the ceiling during the knee extension, as pictured (Figure 8–36), in order to increase the range of motion during the lowering phase
- To increase difficulty, secure a light super band behind the knees which is anchored under the palms and looped around the thumbs

Figure 8-35 *Feet-elevated knee extension start position (after flexing the knees from high plank)*

Figure 8-36 *Feet-elevated knee extension end position*

Figure 8-37 Start position with resistance band

Figure 8-38 End position with resistance band

SINGLE-LEG FOOT ELEVATED KNEE EXTENSION

- Can be performed with band resistance using the same set-up as Figure 8–37 and 8–38 or without band resistance (Figures 8–39, 8–40).

Figure 8-39 Single-leg foot elevated knee extension start position (after flexing the knee from high plank)

Figure 8-40 Single-leg foot elevated knee extension end position

REVERSE NORDIC CURLS

The reverse Nordic exercise trains the quadriceps eccentrically using a bodyweight load. There is limited research available on the reverse Nordic, but it did produce significant increases in muscle fascicle length, thickness, pennation angle, and cross-sectional area in a small group of subjects. These properties may allow the quadricep to not only be more flexible, but also operate with greater strength and power.[170]

- Start in a tall kneeling position with the trunk upright
- Slowly lean the trunk backward without bending at the hip
- Bend only at the knees while keeping the rest of the trunk in a straight line
- Use the quadriceps or an upper body support to pull the body back to upright
- To decrease difficulty, secure a band around the torso to assist both the eccentric and concentric portions

Figure 8-41 *Reverse Nordic curl start position*

Figure 8-42 *Eccentric knee flexion with maintenance of hip extension*

KNEE EXTENSION (OPEN-CHAIN)

KNEE EXTENSION WITH CABLE OR BAND

Many clinics lack an actual knee extension machine. Luckily, there's no disadvantage to keeping it simple. Knee extensions performed with a band generate higher MVIC for the quadriceps (98% for vastus medialis and 89% for vastus lateralis) compared to knee extensions performed with a machine (73% for vastus medialis and 72% for vastus lateralis).[171]

- Sit on a bench or plyometric box with a resistance band or cable attached from behind at the ankle
- Place a towel roll under the knee to create a slight incline and increased knee range of motion

- Kick up until the knee reaches full extension
- The lockout should be controlled and not aggressively hyperextended
- Let the knee flex slightly beyond the box or bench

Figure 8-43 *Cable knee extension start position in flexion. The cable travels under the box in order to create a straight line of pull*

Figure 8-44 *Cable knee extension end position*

KETTLEBELL KNEE EXTENSIONS

The set-up for the kettlebell knee extension is simple and it requires minimal equipment. It is a great alternative for individuals who don't have access to a leg extension machine or have a difficult time finding the right fit in a machine due to their size. It can also provide a dual strengthening effect for the tibialis anterior.

- Sit on a bench, plyometric box, high mat, etc.
- Place a towel roll under the knee to create a slight incline and increased knee range of motion
- Loop the kettlebell handle around the toes
- Kick up until the knee reaches full extension
- The lockout should be controlled and not aggressively hyperextended

Figure 8-45 *Kettlebell knee extension start position in knee flexion*

Figure 8-46 *Kettlebell knee extension end position*

KNEE EXTENSION MACHINE OR BENCH

The knee extension machine or bench can be used for isometric, bilateral, and unilateral training. The initial set-up on the machine is pretty much the same for each variation, but the execution is a bit different. Isolated knee extension exercises may provide significant benefit compared to compound movements for quadricep muscle hypertrophy. A randomized control trial by Zabaleta-Korta et al.[164] found that all regions of the rectus femoris increased their cross-sectional area after performing leg extensions, while smith machine squats only increased cross-sectional area of the central vastus lateralis muscle.

- If using a knee extension machine, position yourself in the machine so the knee joint lines up with hinge of the moving arm and the pad on the lower quarter of the shin
- If using a knee extension bench (Figure 8–47), slide forward or backward on the bench until the pad on the lower quarter of the shin

KNEE EXTENSION ISOMETRIC WITH MACHINE OR BENCH

- If using a knee extension machine, set the moving arm in position to target the desired angle of knee flexion/extension
- If using a knee extension bench, perform at 90° unless the bench has an adjustable moving arm
- Set the weight high enough that you can't overpower it
- Kick up into the pad (Figure 8–47)

CONCENTRIC DOUBLE-LEG KNEE EXTENSION WITH MACHINE OR BENCH

- Contract the quadriceps to extend the knee to end-range without forcefully hyperextending
- Lower under control

Figure 8-47 *Knee extension start position*

Figure 8-48 *Knee extension end position*

ECCENTRIC DOUBLE-LEG KNEE EXTENSION WITH MACHINE OR BENCH

- Slowly lower at a designated tempo (e.g. three, five, or ten second eccentric)
- Eccentrics are especially useful when the concentric motion causes pain or if the goals are to increase control and time under tension

CONCENTRIC SINGLE-LEG EXTENSION WITH MACHINE OR BENCH

Figure 8-49 *Single-leg knee extension start position*

Figure 8-50 *Single-leg knee extension end position*

ECCENTRIC SINGLE-LEG (UP TWO, DOWN ONE) KNEE EXTENSION WITH MACHINE OR BENCH

- Kick up using both legs
- Remove one leg and allow the target leg to slowly lower the weight
- Set the weight light enough that it can be managed by the single extremity during the lowering phase

Figure 8-51 *Concentric knee extension with both legs*

Figure 8-52 *Eccentric knee extension with one leg*

KNEE EXTENSION (CLOSED-CHAIN)

REVERSE SLED DRAGS

Sled drags are an inconspicuous closed-chain knee extension exercise and can be versatile depending on the goal. Heavy weight is appropriate for building muscle, while lighter weights can be used for conditioning.

- Grasp the hand grips and step back to take the slack out
- Lean the torso backward
- Take a step backward and maintain the weight on the forefoot of the rear leg
- Drive through forefoot to extend the rear knee, while taking a step backward with the opposite foot to drag the sled in reverse
- Focusing on contracting the quadriceps to extend the knee

Figure 8-53 *Reverse sled drag start position*

Figure 8-54 *Step back*

Figure 8-55 *Rear leg drives forward into knee extension*

LEG PRESS

Traditional squats are more effective than the leg press if the goals are to activate the quadriceps[171] and maximize strength gains.[172] Like the squat, the leg press is a closed-chain exercise, but has fewer degrees of freedom and stability demands. The leg press may be a good option when attempting to train around pain, for those with balance difficulty, or other injuries that prevent an individual from performing squats and other closed-chain exercises. The leg press activates the quadricep muscles (vastus medialis, lateralis, and rectus femoris) greater than the hamstring muscles,[173, 174] generates less hamstring activation when compared to squats, and less ACL stress compared to leg extensions.[175] Quadricep muscle EMG activity is greater when the leg press is performed in an increased angle of knee flexion with peak activity at 90°.[173, 174] The MVIC of the vastus medialis and lateralis is between 70–80% when performed from zero to between 60–100° knee flexion. It can reach 120–140% when performing the leg press from 100–80°. There is also a high level of quadricep activation, which surpasses 100% MVIC, when the leg press is performed from 60–40° and 80–60°.[173, 174, 176] Muscle activation also tends to increase with exercise intensity and a greater percentage of 1RM.[173, 174] Quadricep muscle activation decreases as the knee reaches full extension, which is typical of closed-chain exercises,[173–175] so it may be best to utilize time under tension (stopping prior to full knee extension) in the ranges of motion listed above to maximize quadricep activation.

The jury is still out on foot placement during the leg press. Individuals with osteoarthritis may benefit from an internally rotated foot position to decrease pain and improve function. Increasing tibial internal rotation may modify kinematics that are typical of osteoarthritis including knee varus, tibial external rotation, which may reduce medial knee stress.[177] For conditions other than knee osteoarthritis, the majority of studies

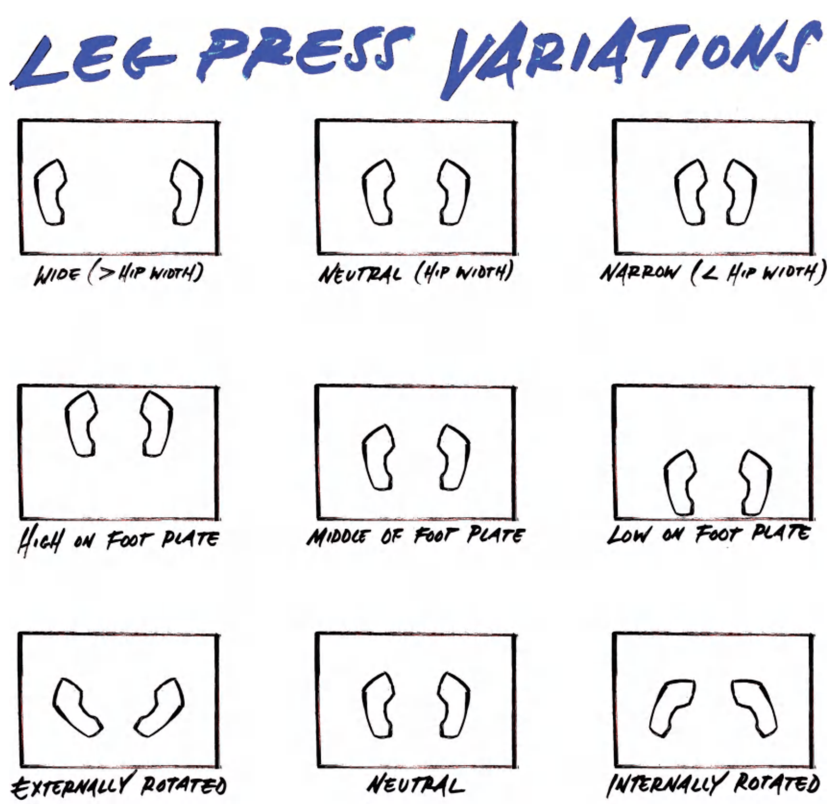

Figure 8-56 *Example of the wide variety of stance width and foot placement that may be used during the leg press. It is important to select the width and foot orientation that is most comfortable and allows an individual to feel the target muscle activate maximally*

support using the most comfortable stance, as modifying stance width and foot rotation has not been consistently proven to provide any additional benefit with respect to muscle activation.[173, 174, 178, 179]

INCLINE LEG PRESS

- Set the feet at the desired width and orientation
- Position the seat and footplate such that the knees start in 60–100° of flexion
- Drive through the feet to push the footplate up and away from the body
- Stop prior to full knee extension to maintain tension on the quadriceps
- Lower back to the start

LEG PRESS WITH BALL BETWEEN KNEES

Hip adduction performed during the leg press has been proven to increase activation of the adductors.[180] In theory, it could also increase VMO to VL ratio and provide greater co-contraction about the knee.[180–182] However, this remains a theory, as it is not well supported by high-quality scientific evidence. If there is pain during a regular leg press at a particular range of motion, try using an adductor squeeze. If it minimizes the pain, accept the phenomenon and use this variation to induce a training stimulus until the ball is no longer needed. If it does not work, focus on modifying the range of motion, foot position, stance, etc.

- Place a ball between the knees and squeeze the ball to produce a strong isometric contraction of the adductors
- Maintain this contraction and drive through the feet to push the footplate up and away from the body
- Stop prior to full knee extension to maintain tension on the quadriceps
- Lower back to the start and release the adductor squeeze

SINGLE-LEG PRESS

The single-leg press generates a moderate to high level of muscle activity in the VMO at 40% MVIC. This is higher than other unilateral weight-bearing exercises like step-ups, step-downs, and almost double that of non-weight-bearing exercises like straight-leg raises.[178] The greatest benefit of single-leg compared to double-leg press is lack of compensation from the strong side. As a result, the initial weight for this exercise should start at least 50% less than the weight used for both legs and can be adjusted up or down from there.

QUAD-FOCUS LUNGES AND STEP-UPS

Lunges can also be a very sensitive exercise in the presence of anterior knee pain. Attention must be given to exercise selection, progression, and load based on symptoms and desired outcome. Upright lunges allow loading of the quadriceps and patellar tendon, which can have excellent utility for patellar tendon rehabilitation. Split squats activate the quadriceps to a greater extent than the single-leg squat. Forward lunges require increased deceleration, knee joint sheer force, and generate increased patellar tendon stress when the knee translates forward beyond the toes compared to reverse lunges.[183] Forward and/or walking lunges should be prescribed if the goal is to increase patellar tendon stress and load to the anterior knee. Reverse lunges are optimal if the goal is to train the quadriceps with less knee joint flexion.[184] Isometric lunge variations allow loading the tissues and training the pattern without having to work in an uncomfortable range of motion. It is also possible to bias the gluteus medius by holding a weight in the arm contralateral to the forward leg.[185]

SUSPENSION STRAP OR DOOR FRAME LUNGES

- Grasp the suspension straps, the lip of the door frame, or a squat rack for upper body support
- Step one leg backward to a comfortable distance with weight through the ball of the foot
- Initiate the descent by bending the rear knee
- Use the upper extremities to control the lowering phase
- Unlike the glute-focused reverse lunge, the trunk should remain relatively erect
- Drive through both feet to return to upright
- This exercise can be performed statically (split squat) or stepping back and returning to upright with each repetition (reverse)

Figure 8-57 *Suspension strap lunge start position*

Figure 8-58 *Suspension strap lunge end position*

Figure 8-59 *Use of a squat rack to perform "door frame" lunge*

Figure 8-60 *The upper body assists the descent*

ISOMETRIC STEP LUNGE

- Placing the front foot on a step increases the available range of motion for the rear leg
- Place one foot up on a step or box
- Step the opposite leg backward
- Bend the rear knee
- Focus on maintaining a static hold for ten seconds or more
- This exercise can be performed as a "mini lunge" with a reduced range of motion
- This exercise can also be performed concentric-eccentric with the step acting to increase available range of motion into rear knee flexion, as the rear knee is further from the ground than if performed on a level surface

Figure 8-61 *Isometric step lunge start position*

Figure 8-62 *Isometric step lunge end position*

REVERSE LUNGE

- Step one leg backward to a comfortable distance with weight through the ball of the foot
- Initiate the descent by bending the rear knee
- Unlike the glute-focused reverse lunge, the trunk should remain relatively erect
- Drive through both feet, but with emphasis on the rear foot to return to upright
- Bring the rear foot forward to meet the front foot and repeat

Figure 8-63 *Reverse lunge start position*

Figure 8-64 *Step backward*

Figure 8-65 *Bend the rear knee*

SPLIT SQUAT

- Use the same set-up as the reverse lunge
- Initiate the descent by bending the rear knee, return to upright, and repeat
- Maintain the split stance throughout the exercise without returning to the start point

Figure 8-66 *Start position in a split stance*

Figure 8-67 *Bend the rear knee*

FORWARD LUNGE

- Take a step forward
- Bend the back knee to descend into a lunge
- Allow the front knee to translate forward to increase knee flexion or keep the tibia vertical to decrease anterior knee stress
- Keep the trunk erect
- Drive through the front foot to propel the body back to the start point

WALKING LUNGES

Walking lunges are forward lunges performed in succession with alternating legs. They require increased dynamic stability, can allow increased loading to the lower extremities and time under tension.

Figure 8-68 *Step one leg forward*

Figure 8-69 *Forward lunge start position*

Figure 8-70 *Bend the rear knee*

FORWARD TO REVERSE LUNGE

Similar to walking lunges, forward to reverse lunges increase time under tension and metabolic stress.

- Perform a forward lunge
- Return to upright and immediately transition into a reverse lunge
- Select one leg to be the “stationary leg” and the other to be the “moving leg” for all repetitions
- Repeat for desired number of repetitions, then perform on the opposite side

LATERAL LUNGE

Lateral lunges yield greater knee extension joint moment and require increased ankle mobility compared to forward lunges.[186] They can act both as a quadricep building exercise and as an active mobility drill for the adductors and ankle complex. For frontal-plane athletes, like skiers, hockey, and tennis players, lateral lunges may help develop mobility, strength, and explosive power. Many of the activities we do daily are in the sagittal plane: walking, stair climbing, sitting down, and standing up, etc., so these can be a useful exercise to transition out of that plane.

- Stand with the feet together
- Take a large step out to one side (this is the target leg)
- Shift the hips back, flex the knee, and sit down into that side
- The opposite leg should remain straight
- Drive the target leg away from the floor to return to the start point
- Hold a dumbbell or kettlebell against the chest or in each arm

UPPER EXTREMITY ASSISTED LATERAL LUNGE

Similar to door frame squats and suspension strap-assisted exercises, this variation allows increased range of motion due to decreased stability demands and upper body support.

Figure 8-71 *Lateral lunge start position*

Figure 8-72 *Lateral lunge end position*

- Grasp a door frame, squat rack, incline bench, or the edge of a high mat
- Stand with a wide stance and the feet slightly turned out
- Use the assistance from the upper extremities to shift the hips back, flex one knee, and sit down into that side
- The flexed knee should track over the middle of the foot
- The opposite leg should remain straight

Figure 8-73 *Assisted lateral lunge start position*

Figure 8-74 *Assisted lateral lunge end position*

ALTERNATING LATERAL LUNGE

- Stand with a wide stance and the feet slightly turned out (Figure 8–73)
- Shift the hips back, flex one knee and sit down into that side (Figure 8–74)
- The opposite leg should remain straight

- Return to upright and repeat to the opposite side
- Hold a dumbbell or kettlebell against the chest or in each arm if desired

BAND-RESISTED LATERAL LUNGE

Band resistance is placed around the waist, which will challenge the eccentric and assist the concentric motion.

Figure 8-75 *Band resistance at the waist*

LATERAL POWER LUNGE

- Stand on one leg with the opposite (target) leg in hip flexion
- Reach the foot of the flexed hip out laterally and to the floor
- Perform a lateral lunge to that side
- Drive the target leg away from the floor and propel the hip back up into flexion

Figure 8-76 *Lateral power lunge start position*

Figure 8-77 *Lateral power lunge end position*

COSSACK LUNGE

- Stand with a wide stance and the feet slightly turned out
- Shift the weight onto one leg and descend into a maximal depth squat
- Keep the opposite knee straight and allow the hip to rotate externally with the foot facing the ceiling and weight through the heel
- The trunk should remain as erect as possible throughout

Figure 8-78 *Cossack lunge start position*

Figure 8-79 *Cossack lunge end position*

STEP-UP

- Push the foot down through the step as if trying to drive the head toward the ceiling
  - The trajectory should be straight up
  - Do not initiate by driving the knee forward or pushing off the back foot
- Slowly lower down by bending the knee and reaching the trail leg behind
  - Limit inward or outward motion of the knee
  - Maintain a level pelvis
- Hold on to a rail or another support for balance, if needed
- Weights can be held in both hands or on the opposite side of the target leg
- Holding a weight on the same side as the target leg will decrease demands on the hip abductors and can be used to decrease difficulty
- Placing a band around the back of the knee may decrease anterior knee pain and challenge terminal knee extension during this exercise

Figure 8-80 *Step-up start position*

Figure 8-81 *Step-up end position*

RUNNER STEP-UP

The runner step combines push-off, loading in stance, and reciprocal arm movement. Therefore, it can be used as a lead-up exercise to running and plyometrics. The repetitive push-off and time under tension create a substantial quadricep burn and can be used for lower extremity muscle endurance.

- Position the target leg on a step
- Hinge at the hips and lean the trunk forward
- In order to mimic the reciprocal arm and leg motion or running, the arm opposite the target leg should be positioned forward with the other behind
- Push the foot down through the step to extend the knee and drive the opposite hip up into flexion
- The arms switch in unison with the leg drive
- The trunk should remain in a forward lean as the body travels up and forward then down and back
- There should be a bend in the knee throughout
- Repeat at a rapid pace for 20–30 repetitions

Figure 8-82 *Runner step-up start position*

Figure 8-83 *Runner step-up end position. Note the reciprocal arm and leg movement*

LATERAL STEP-UP/DOWN

Lateral step-ups and step-downs generate the highest levels of muscle activation in the vastus medialis, rectus femoris, vastus lateralis, and gluteus medius, in that order.[150, 187] They also contribute to greater activation of the rectus femoris compared to forward and crossover step-ups.[150]

- Position the target leg on the edge of a step or plyometric box
- Shift the hips back, down, and bend the knee to lower the opposite heel toward the floor
- Keep the pelvis level
  - Actively reaching the heel toward the floor will cause the hip to drop (Figure 8–86)
- The heel may tap the floor or remain suspended to increase difficulty
- Push through the entire foot, contract the quadricep to extend the knee and return to upright


Figure 8-84 *Lateral step down start position*


Figure 8-85 *Lateral step down controlled lowering*

FORWARD STEP DOWN

The forward step down mimics a very important activity – walking down stairs. Descending stairs requires anterior translation of the knees over the toes, eccentric control of the quadriceps, and closed-chain ankle dorsiflexion mobility. It can be a sensitive activity for many individuals with anterior knee pain. A reduced height step will limit range of motion and potentially pain. Progress toward a normal height step once load tolerance is achieved.


Figure 8-86 *Lateral step down fault – "reaching" down with outside leg results in hip drop on that side and hip hike on the contralateral stance leg*

- Stand with both feet on a step
- Keep the target foot planted and reach the opposite leg forward
- Bend the target knee, allowing the knee to translate forward toward the toes
  - The knee should remain in line with the fourth and fifth toes
  - Limit excessive inward or outward motion of the knee beyond this point
- Attempt to tap the heel of the opposite leg on the floor
- Drive through the front part of the foot and contract the quad of the target leg to return to upright
- Place a band around the back of the knee to assist the eccentric portion, which may decrease anterior knee pain, and challenge terminal knee extension during the concentric portion of the exercise

Figure 8-87 *Forward step down start position*

Figure 8-88 *Forward step down eccentric. Note, the knee must translate forward over the toes*

HAMSTRINGS

There are three muscles in the hamstring muscle group: the biceps femoris, semitendinosus, and semimembranosus. These muscles span two joints, act to extend the hip, and flex the knee. They also play a crucial role in running and sprint performance, particularly during the late swing phase due to the high eccentric load placed on the hamstrings.[188–192] Hamstring-focused resistance training is very important. When compared to uninjured runners, recently injured runners demonstrate impaired eccentric and concentric hamstring strength.[193] An decreased hamstring-to-quadricep (H:Q) activation ratio is considered to be a risk factor for ACL injury due to increased forward translation of the tibia and impaired knee stability. A ratio of 0.6 or greater, indicating that the hamstrings, and quadriceps better co-activate, may decrease the risk of ACL and hamstring injuries.[194] How to actually measure H:Q ratio is well beyond the scope of this book, but how to go about improving the strength of the hamstrings is something that is addressed in great detail. Deadlifts, bridges, and their many variations will effectively target the hamstrings, but they are not the only exercises to effectively activate the muscles of the posterior thigh.

NORDIC HAMSTRING CURLS

Nordic hamstring curls (NHC) are arguably the gold standard for hamstring training and injury prevention. There is a wealth of high-quality scientific research dedicated to this simple exercise. They have the potential to improve hamstring strength and sprint performance[195, 196] and Level 1 evidence supports the ability of the NHC to consistently reduce hamstring injuries by over 50%[197–199] and recurrent injuries by up to 85% – truly an outstanding finding.[198]

Nordic curls are performed with the lower legs anchored to a dedicated Nordic machine, partner, barbell, etc. The hamstrings must work eccentrically to lower the torso from an upright position toward the floor. The protocol that is often used for the NHC (Table 8–1) is based on a randomized trial by Mjølsnes et al.[200] Though effective, compliance with this protocol can sometimes be poor due to increased frequency of up to three sessions per week and duration of ten weeks. Whyte et al.[201] conducted a randomized trial of a four-week NHC protocol (Table 8–2) that produced significant strength gains up to 19% and similar strength gains when compared to the previously mentioned study. Lower volume Nordic curl training consistently demonstrates similar effects on strength and muscle length as high-volume protocols[202] and may be more applicable to a clinical setting. Strength gains have also been maintained in the long-term at three-month follow-up after a four-week protocol[196], which may further support their incorporation into both off-season and pre-season training programs for athletes.

Table 8-1 *Ten-week NHC protocol adapted from Mjølsnes et al.*[200]

Ten-week NHC protocol			
Week	Sessions per week	Sets × reps	Total reps per week
1	1	2 × 5	10
2	2	2 × 6	24
3	3	3 × 6–8	54–72
4	3	3 × 8–10	72–90
5–10	3	3 sets, 12/10/8 reps	270

Table 8-2 *Four-week NHC protocol adapted from Whyte et al.*[201]

Four-week NHC protocol			
Week	Sessions per week	Sets × reps	Total reps per week
1	2	2 × 6	24
2	2	3 × 6	36
3	2	4 × 8	64
4	2	4 × 10	80

NORDIC HAMSTRING CURLS

- Secure the feet against the footplate and lower legs against the pads
- Contract the glutes, abdominals, and pull the rib cage down to maintain a rigid trunk (Figure 8–89)
- Allow the knees to extend and the trunk to lean forward – the hips should not flex (Figure 8–90)
- When the trunk and legs can no longer control the descent, extend the arms out in front and let go of the contraction
- Allow the upper body to “catch” the fall and assist the chest to the floor in push-up position (Figure 8–93)
- Push the ground away to power back to upright
- The hamstrings should work minimally during the concentric portion

Figure 8-89 *Nordic start position*

Figure 8-90 *Controlled eccentric phase*

PARTNER-ASSISTED NORDIC HAMSTRING CURL

This variation of the Nordic curl can be performed without any equipment and only requires another individual to stabilize the lower legs throughout the exercise.

- Kneel on a foam pad or cushioned surface
- Another individual will secure the lower legs to the floor at the ankles or lower calves
- Perform with the same technique as the regular Nordic curl as explained above

Figure 8-91 *Partner-assisted Nordic start position*

Figure 8-92 *Partner-assisted controlled eccentric phase*

Figure 8-93 *The "catch" position*

NORDIC HAMSTRING CURL ISOMETRIC HOLD

- Secure the lower legs using one of the methods above
- Contract the glutes and abdominals, and pull the rib cage down to maintain a rigid trunk
- Allow the knees to extend and the trunk to fall forward
- Maintain the position for a period of 10–30 seconds
- Perform at different angles to develop strength and stability through the range of motion

DOWEL OR PHYSIOBALL-ASSISTED NORDIC HAMSTRING CURL

Assisted Nordic curls decrease eccentric demand. They are much easier to perform, so they can be used to train the pattern or can help load healing tissue in a less stressful manner.

- Control the descent using a dowel or PVC pipe, or by rolling a physioball with the upper extremities

Figure 8-94 *Dowel-assisted Nordic curl start position*

Figure 8-95 *Dowel-assissted Nordic curl end position*

Figure 8-96 *Physioball-assisted Nordic curl start position*

Figure 8-97 *Physioball-assisted Nordic curl end position*

BAND-ASSISTED NORDIC HAMSTRING CURL

- Loop a light resistance band around the neck
- Secure the band to the front of the chest with the hands by pulling down and engaging the latissimus dorsi
- The band will help control the descent

Figure 8-98 *Band-assisted Nordic curl start position*

Figure 8-99 *Band-assisted Nordic curl end position*

GHD HAMSTRING CURLS

The GHD looks very similar to the Nordic curl, but the placement of the pad shifts the fulcrum from the knee joint to the thigh; think of the GHD as a wheelbarrow and the NHC as a seesaw. The GHD is easier to perform since the fulcrum is closer to the load (weight of the trunk) and further from the effort (hamstrings) compared to the NHC. The GHD also requires increased focus on the concentric portion of the curl. The legs are used to pull the trunk back to upright instead of the arms pushing against the floor. This exercise can generate 98% MVIC for the hamstrings, which is greater than leg curls, stiff-legged deadlifts, and good mornings.[203] An EMG study by McAllister et al.[204] also concludes that GHD curls are the most effective exercise for maximizing concentric EMG activity of all three hamstring muscles compared to the leg curl, RDL, and good mornings. GHD curls also demand greater activation of the spinal erectors compared to the above listed exercises, so it may also be appropriate to incorporate for back strengthening.[204]

- Secure the feet against the footplate and lower legs against the pads
- The lower portion of the front thighs should contact the pad when the trunk is upright
- Adjust the pad to a distance where the hips are in front of the pad when the legs are straight
- Contract the glutes and abdominals, and pull the rib cage down to maintain a rigid trunk
- Allow the knees to extend and the trunk to fall forward
- At end-range, the trunk should be parallel with the ground (180° angle) or less to decrease difficulty
- Contract the hamstrings, glutes, and perform a leg curl to pull the trunk back to upright

Figure 8-100 *GHD curl start position*

Figure 8-101 *GHD curl controlled lowering. Unlike the Nordic curl, an active contraction of the hamstrings to curl the legs and trunk back up to the start position is performed*

HAMSTRING CURLS

PHYSIOBALL HAMSTRING CURLS

Physioball hamstring curls require minimal equipment and can be extremely challenging if performed correctly and at the right speed. They can be used to load the hamstrings eccentrically, with very long negatives of six to ten seconds in duration. Through the large body of research dedicated to NHC, eccentric training has been proven to increase hamstring strength and reduce risk of hamstring injuries. For individuals who may not be advanced enough to perform NHC or GHD curls, physioball hamstring curls may be a great alternative. There are fewer degrees of freedom for form breakdown and they are more stable due to consistent contact of the upper back (and hands if desired) with the floor.

Double-leg eccentric only hamstring curl:

- Start in bent-knee bridge
- Let the legs straighten in a controlled manner
- End in a straight-leg bridge
- Lower buttocks down to floor
- Curl the ball back in by flexing the knees and repeat

Figure 8-102 *Double-leg curl eccentric only start position*

Figure 8-103 *Double-leg curl eccentric only end position*

Single-leg eccentric only hamstring curl:

- Perform with the same technique as the double-leg eccentric curl as detailed above

Figure 8-104 *Single-leg curl eccentric only start position*

Figure 8-105 *Single-leg curl eccentric curl end position*

Double-leg concentric only hamstring curl:

- Start in a straight-leg bridge
- Curl the ball in toward the buttocks by flexing the knees
- Keep the hips high during the curl
- Lower buttocks down to floor
- Extend knees out and ball away and repeat

Figure 8-106 *Double-leg curl concentric only start position*

Figure 8-107 *Double-leg curl concentric curl end position*

Single-leg concentric only hamstring curl:

- Perform with the same technique as the double-leg concentric curl as detailed above

Double-leg combined concentric and eccentric:

- Combine the eccentric and concentric motions as detailed above

Single-leg combined concentric and eccentric:

- Combine the eccentric and concentric motions as detailed above

TOWEL OR SLIDER DISK CURL

- Start in a straight-leg bridge with towels or slider disks under the feet
- Curl the feet in by dragging the heels toward the buttocks and flexing the knees
- Reverse the sequence to perform the eccentric variation
- This exercise can be performed with both legs or one leg, as detailed above

Figure 8-108 *Towel or slider disk concentric curl start position*

Figure 8-109 *Towel or slider disk concentric curl end position*

SUSPENSION STRAP CURL

- Place the heels in a suspension strap system
- The straps should be taut enough to support the body's weight
- Start in a straight-leg bridge
- Curl the feet in toward the buttocks by flexing the knees
- Reverse the sequence to perform the eccentric variation
- This exercise can be performed with both legs or one leg, as detailed above

Figure 8-110 *Suspension strap concentric curl start position*

Figure 8-111 *Suspension strap concentric curl end position*

SEATED HAMSTRING CURLS

Seated curls and stiff-legged deadlifts produce nearly identical values of hamstring muscle EMG activity and both activate the hamstrings to a greater extent than back squats.[205] Stiff-legged deadlifts require a lot more technique and involve the lower back to a greater extent than seated leg curls. If unable to perform the deadlift because of lower back or upper extremity injuries, curls are an excellent exercise to maintain and continue to build hamstring strength.

SEATED HAMSTRING CURL WITH BAND

- Sit on a surface with an opening that will not restrict the degree of knee bend
- Anchor a band to a stable surface and loop it around the back of the ankles
- Use the arms gripping the sides of the seat or the hands to secure the legs down
- Bend the knees with the aim of curling the legs under the seat
- Do not let the hips flex (thighs lift from the seat) during the curl – use the hands to prevent the hip from rising if needed
- This exercise can be performed bilaterally or unilaterally (Figures 8–112 and 8–113)

Figure 8-112 *Seated curl start position*

Figure 8-113 *Seated curl end position. Note, the hip does not flex at end-range*

SEATED HAMSTRING CURL MACHINE

- Position the seat to line the knee joint up with the moving arm axis
- Secure the legs down using the pad
- Bend the knees with the aim of curling the legs under the seat
- This exercise can be performed bilaterally or unilaterally

PRONE DUMBBELL HAMSTRING CURL

- Lay on a flat bench with the edge of the bench above the knee
- Secure a dumbbell between the feet (this may require assistance)
- Slowly extend the knees until at a comfortable stopping point or just shy of full extension
- Flex the knees as if curling the feet up toward the buttocks
- If the lumbar spine is overly lordotic at rest or extends excessively throughout the exercise, place a rolled towel, pillow, or another small pad under the hips
- To decrease difficulty, use a decline bench with the entire thigh in contact with the bench

Figure 8-114 *Prone dumbbell curl start position*

Figure 8-115 *Prone dumbbell curl end position*

PRONE HAMSTRING CURL WITH BAND

- Anchor a band to a stable surface and loop it around the back of the ankles
- Flex the knees and curl the feet toward the buttocks
- Slowly extend the knees
- This exercise can be performed bilaterally (Figures 8–116 and 8–117) or unilaterally

Figure 8-116 *Prone band curl start position*

Figure 8-117 *Prone band curl end position*

PRONE HAMSTRING CURL MACHINE OR BENCH

In a randomized group design study by Kaminski et al.,[206] a six-week protocol of prone hamstring curl training increased hamstring strength relative to 1RM by 19.0% in the concentric training group and 28.8% in the eccentric training group. Training occurred two days per week, with two days of rest in between training days. There was no statistically significant change in the control group. These results lead us to believe that eccentric training can be even more effective than concentric training to develop concentric strength. The eccentric group also significantly increased eccentric isokinetic peak torque by up to 37%, which was not true for the concentric group.[206] The protocol is detailed below in Table 8–3.

- Adjust the machine to line the knee joint up with the moving arm axis
- The pad should contact the lower leg right above the Achilles

- The front of the pelvis should rest on the bench
- Place a rolled towel, barbell pad, or similar under the hips to prevent excessive lumbar extension if there is no crease in the bench or if the length of the bench doesn't fit the body's proportions
- Bend the knees with the aim of curling the pad and feet up toward the buttocks
- Attach a light resistance band to the pad to increase resistance on the concentric portion and/or to reduce eccentric load
- This exercise can be performed bilaterally or unilaterally

Figure 8-118 *Prone hamstring bench curl start position*

Figure 8-119 *Prone hamstring bench curl end position*

Figure 8-120 *Band resistance added to increase time under tension*

Table 8-3 *6-week prone hamstring curl protocol adapted from Kaminski et al.*[206]

Six-week prone hamstring curl protocol		
	Concentric	Eccentric
Warm-up	1 × 8 at 50% 1RM	
Working sets	2 × 8 at 80% 1RM	2 ×8 concentric load at 40% 1RM eccentric load at 100% 1RM
If able to complete both working sets of 8 repetitions without failure and RPE <8, 1RM value increased by 5.44 kg (12 lb) at the next training session The warm-up set was also adjusted using this value If not able to complete or RPE >8, load was maintained for the next session		

HAMSTRING TANTRUMS

Tantrums are used to train the hamstrings at a high velocity via rapid fire prone hamstring curls into a physioball, hence the name. The physioball requires the hamstrings to contract against resistance suddenly at end-range and to decelerate when contracting at a high velocity, which is a necessity during a quick change of direction or slowing down during a sprint.

- Start on the stomach with a physioball positioned on the back
- Hold the ball in place with the upper extremities or use the assistance of another individual
- In a rapid, alternating, kicking motion, bend the knees and drive the back of the lower leg into the ball
- Perform at a high speed and with as much force as possible
- Repetitions can be counted, timed, or performed until fatigue

Figure 8-121 *Hamstring tantrum start position*

Figure 8-122 *Legs alternate with rapid kicking motion*

Figure 8-123 *Secure the ball with the upper extremities if a partner is not available for assistance*

GOOD MORNINGS

Good mornings are technically a hinge-based movement, but they may have easily been lost among the many deadlift variations in the hinge chapter. Good mornings generate 43% MVIC for the hamstrings, which is similar to the value produced by stiff-legged deadlifts.[203] Muscle activation of both the hamstrings and erectors appears to increase proportionally to load during the good morning, but the stretch on the hamstrings tends to decline with respect to greater loads, likely due to increased knee flexion.[207] Therefore, it may be best to use lighter weight if the goal is to maximize range of motion and stretch on the hamstrings and heavier weight to increase muscle activation.

- Rest the barbell on the upper trapezius shelf (high bar back squat set-up, see page 60)
- If possible, use a safety bar to increase bar security and to decrease shoulder mobility requirements

- Position the feet shoulder-width apart
- Engage the abdominals
- Contract the latissimus dorsi by pulling down on the bar
- Bend at the hips to allow the hips to travel backward and trunk forward until parallel with the floor
- Extend and drive the hips forward to power back to upright
- Similar to the deadlift, do not hyperextend the low back at the top of the movement

Figure 8-124 *Safety bar good morning start position*

Figure 8-125 *Safety bar good morning end position. There is minimal knee flexion at end-range*

BAND GOOD MORNING

There may be less discomfort and hesitancy when performing the good morning if using bands, as they eliminate the need to place a barbell on the back or to externally rotate the shoulders. Light to medium resistance super band loops (or a combination of more than one) should be used.

- Loop the band around the back of the neck and anchor it with the feet
- Grasp the band(s) with the hands to anchor them
- Attempt to keep the bands as wide as possible around the shoulders and upper back so that they rest between the front and side of the shoulder

Figure 8-126 *Band good morning start position*

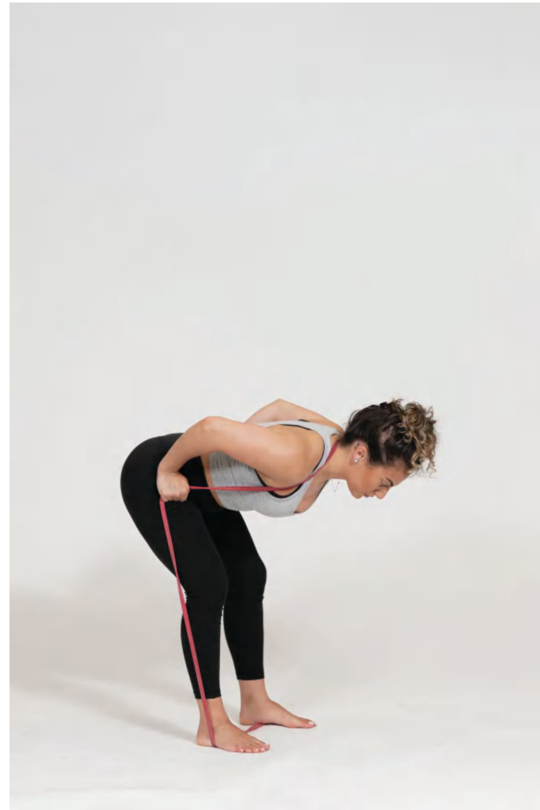

Figure 8-127 *Band good morning end position*

ADDUCTORS

There are three primary adductor namesake muscles: the adductor magnus, longus, and brevis. They are supported by the pectineus and gracilis. All of these muscles act to adduct, internally rotate, and flex (to some extent) the hip. The gracilis is the only muscle that spans two joints and also acts to rotate the knee inward. The adductor magnus can also act as a synergist to hip extension, due to its attachment point on the ischial tuberosity. The adductors play a crucial role in stabilizing the pelvis, producing rotational power through hip rotation, assisting with upward propulsion from the bottom of a squat or lateral propulsion during quick change of direction. Muscle strains of the adductor group (groin strain) are very common among athletes, particularly hockey and soccer players.[208–210] The adductor longus is most commonly injured during the transition from hip extension to flexion during a kicking motion or when the muscle is forced to contract under load in a lengthened state while reaching, jumping, and changing direction.[211, 212]

A moderate level of evidence supports previous groin injury, impaired adductor strength, and lack of sport-specific training as strong risk factors for adductor injury, particularly among those playing sports at a high level.[213] A randomized controlled trial by Hölmich et al.[214] found that the incidence of a groin strain doubles after sustaining a previous strain and triples at a higher level of athletic play in over 900 football players.[214] Normative values for adductor-to-abductor strength ratios were determined by two separate studies to be between 1.45–1.6 on the dominant limb and 1.25–1.45 on the non-dominant limb[215] and

0.9–1.4 in uninjured, professional soccer players[216]. Tyler et al.[217] concluded that professional ice hockey players with adduction to abduction strength ratios of less than 0.8 were 17 times more likely to sustain an in-season adductor injury. Thorborg et al.[218] further supported the 80% ratio and determined that hip adductor-to-abductor ratios can be 24% lower in athletes that have groin pain compared to those without pain. Individuals with adductor pain also demonstrate significantly less eccentric hip adductor strength in both the dominant and non-dominant legs compared to uninjured controls in an assessor blinded study.[219] Cohort studies have also determined that athletes with groin pain produced significantly less force during the adductor squeeze test using a sphygmomanometer device.[220, 221]

Detection of risk factors and interventions to reduce these said risk factors are important injury prevention strategies.[222] There is promising, though not particularly strong, research to support implementation of an exercise program to reduce the incidence of adductor injuries. Tyler et al.[223] demonstrated a statistically significant reduction in adductor strains from 3.2 strains to 0.71 strains per 1,000 game exposures by implementing a pre-season adductor strengthening program. Injuries sustained among those with adductor-to-abductor strength ratios less than 80% decreased from eight to three players, which was also a statistically significant finding.[223] A larger randomized controlled trial revealed a 31% reduction in groin strains within the exercise intervention group compared to the control, but this was not considered statistically significant.[214] The research on the use of Copenhagen planks (an adductor exercise) to reduce incidence of groin strains is actually quite strong and is detailed later in this chapter, so it is possible that these programs may have been more effective with the inclusion of this exercise.

ADDUCTOR ISOMETRICS

Bilateral adductor isometric exercises are helpful to teach individuals how to facilitate and feel the contraction of their adductors, and act as a starting point to loading injured tissue in a pain-free and safe manner.

HOOK-LYING MEDICINE BALL SQUEEZE

This exercise in all of its simplicity can generate greater than 100% MVIC of the adductor longus.[224]

- Place a ball between the knees
- A heavy slam ball or medicine ball will increase difficulty
- Contract the abdominals and pull the rib cage down
- Contract the adductors by squeezing the ball between the thighs, as if trying to crush it in half

Figure 8-128 *Hook-lying adductor squeeze*

BRIDGE WITH MEDICINE BALL SQUEEZE

See page 108.

BRIDGE WITH BALL BETWEEN KNEES, ALTERNATING LEG EXTENSION

See page 108.

WALL BRIDGE WITH MEDICINE BALL SQUEEZE

- Start on the back with the hips and knees flexed to 90° and feet on the wall
- Contract the abdominals and pull the rib cage down
- Squeeze the ball between the thighs
- Drive the heels down isometrically into the wall to lift the hips while maintaining the contraction against the ball

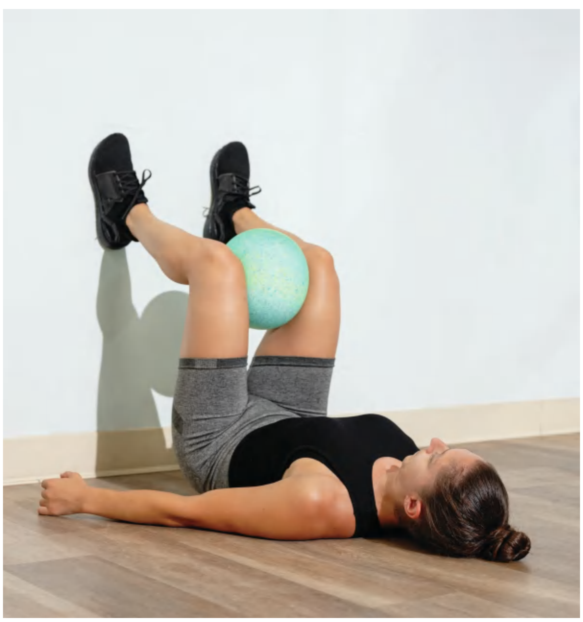

Figure 8-129 *Wall bridge start position*

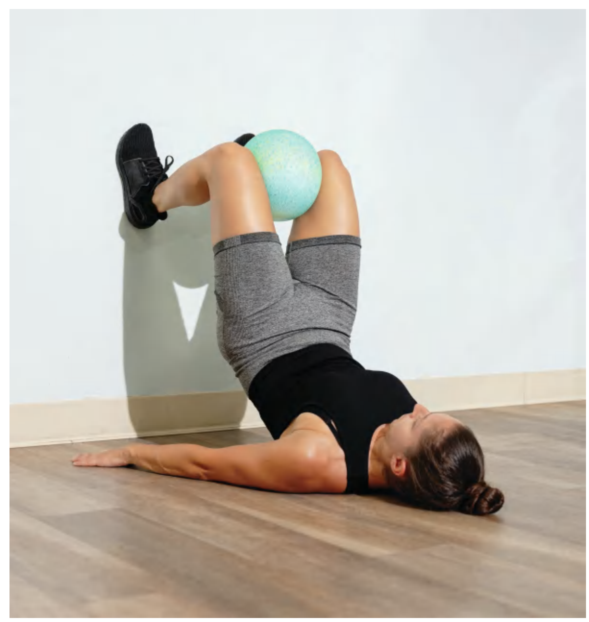

Figure 8-130 *Wall bridge end position*

WALL BRIDGE WITH ALTERNATING LEG EXTENSION

- Squeeze the ball between the thighs
- Drive the heels down isometrically into the wall to lift the hips
- Maintain the contraction of the thighs against the ball and extend one knee
- Alternate between flexion and extension of the knee, resting the foot back on the wall as needed
- Do not let the hips drop as the knee extends

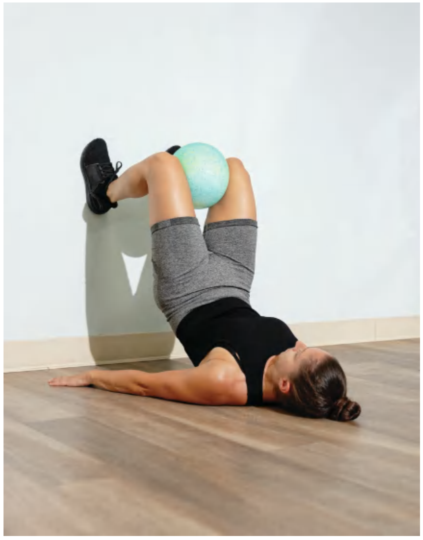

Figure 8-131 *Double-leg wall bridge*

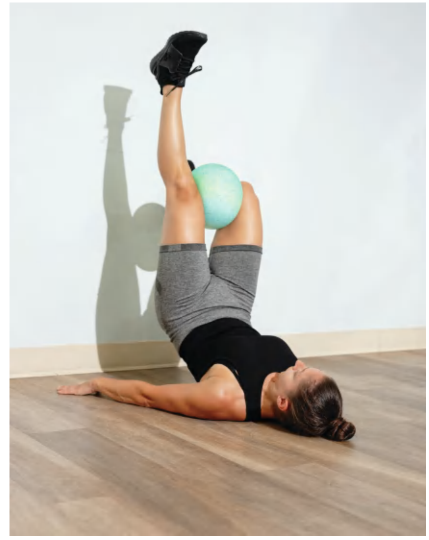

Figure 8-132 *Maintain adductor contraction during knee extension*

SEATED MEDICINE BALL SQUEEZE

- Sit on a chair or bench with the feet in contact with the floor
- Maintain an upright posture throughout the movement
- Contract the adductors by squeezing the ball between the thighs

TALL KNEELING MEDICINE BALL SQUEEZE

- Place a ball between the knees
- Contract the abdominals and pull the rib cage down
- Contract the adductors by squeezing the ball between the thighs, as if trying to crush it in half
- This exercise can be done in isolation or in conjunction with core stability exercises (chop, lift, Pallof press, etc.) or upper body pressing exercises

Figure 8-133 *Seated adductor squeeze with large, weighted medicine ball. The larger ball requires the adductors to work in a lengthened range*

Figure 8-134 *Tall kneeling adductor squeeze*

90/90 PHYSIOBALL SQUEEZE

The use of a physioball will require the adductors to contract at a lengthened range. It is a progression from the traditional medicine ball squeeze and can begin to prepare for the transition to eccentric loading. This set-up can also be utilized in conjunction with a variety of core stabilization exercises.

- Position the hips and knees at 90°
- Place a physioball between the thighs
- Contract the abdominals and pull the rib cage down
- Squeeze the ball between the thighs

Figure 8-135 *90/90 adductor squeeze with physioball*

CONCENTRIC SQUAT WITH ADDUCTOR ISOMETRIC

A lot of emphasis is placed on the abductors and driving the knees out during the squat, but the adductors are very important to help power to upright from full depth. Think about it from a biomechanical standpoint, where the hips are externally rotated and abducted at the bottom of the squat. The adductors will provide a co-contraction with the glutes to adduct the thighs while both work to extend the hips. This may be an extremely useful exercise for those attempting to lift maximal loads or elderly patients who simply have a difficult time standing from low chairs.

- Sit on a chair or bench with the feet in contact with the floor
- Contract the adductors by squeezing the ball between the thighs
- Lean the trunk slightly forward and contract the abdominals
- Power up from the seated position while maintaining the contraction against the ball
- Relax the adductors once in standing, remove the ball and sit under control

Figure 8-136 *Adductor isometric in bottom position of box squat*

Figure 8-137 *Concentric squat with adductor isometric end position*

BRIDGE WITH ISOMETRIC ADDUCTION (BAND RESISTANCE)

- Loop a resistance band just above the knee
- Position the body at a distance from the band to create the desired amount of tension
- Set-up to perform a double-leg bridge (see page 106) and extend the opposite knee
- Contract the adductors against the resistance of the band to maintain the leg in alignment with the hip (i.e., don't let the band pull the leg away from midline)

Figure 8-138 *Double-leg bridge with isometric adduction start position*

Figure 8-139 *Double-leg bridge with isometric adduction end position*

SINGLE-LEG BRIDGE WITH ISOMETRIC ADDUCTION (BAND RESISTANCE) SHORT AND LONG LEVER

- Loop a resistance band just above the knee (short lever, Figure 8–140) or at the ankle (long lever, Figure 8–142)
- Position the body at a distance from the band to create the desired amount of tension
- Set-up to perform a single-leg bridge (see page 109) and extend the opposite knee
- Contract the adductors against the resistance of the band to maintain the leg in alignment with the hip (i.e., don't let the band pull the leg away from midline)
- The long lever variation is more difficult, as the load is further from the adductor muscle attachment point on the thigh

Figure 8-140 *Single-leg bridge with isometric adduction, short lever start position*

Figure 8-141 *Single-leg bridge with isometric adduction, short lever end position*

Figure 8-142 *Single-leg bridge with isometric adduction, long lever start position*

Figure 8-143 *Single-leg bridge with isometric adduction, long lever end position*

SIDE-LYING ADDUCTION ISOMETRIC

The side-lying adductor isometric may be used to load healing tissue, but contracting unilaterally will prevent the non-injured or stronger side from taking over the bulk of the effort. It also may be used as a lead-up exercise for the Copenhagen plank. This exercise can be performed with a short lever (knee) or a long lever (lower leg). A higher surface will require the adductor to contract while elongated.

- Start in a side-lying position with the top leg on a stool or bench and the bottom leg bent
- Drive the top leg down into the surface and hold

Figure 8-144 *Side-lying adductor isometric*

COPENHAGEN PLANKS

Copenhagen plank variations can train both strength and endurance of the adductors. This is not for beginners – it is a difficult exercise. The Copenhagen plank generates over 100% MVIC of the adductor longus on the upper leg and 69% MVIC on the bottom leg.[224] Similar to the side-lying isometric exercise, it can be performed with both a short and long lever. The short lever variation may be useful for beginners, anyone with a previous knee pain (or pain in the knee while performing the long lever) or for non-athletes. Athletes who require recruitment of the adductors while exerting force distally (i.e., a soccer player kicking a ball) may have better carryover to sport with the long lever set-up.

The Copenhagen plank is to adductor training what the NHC is to hamstring training, or so it seems; the research is very strong. A randomized controlled trial by Ishoi et al.[225] demonstrated a 35.7% improvement in eccentric adductor strength using an eight-week Copenhagen plank training protocol. Haroy et al.[226] found a statistically significant increase in eccentric adductor strength of 8.9% compared to the control group when adding the Copenhagen plank to the pre-existing FIFA+ warm-up program for eight weeks. The training protocol used by Ishoi et al. includes a greater amount of sets and repetitions compared to Haroy et al., which may explain the additional strength gains. A smaller cohort study found similar improvements to Ishoi et al. with respect to improving eccentric adductor strength in professional football players using a progressive Copenhagen plank protocol. Eccentric adductor strength increased by 25% and hip adductor-to-abductor ratio increased by 10–12%, all of which were considered statistically significant. This protocol utilized time under tension via isometric holds (true planks) and gradually increased the level of difficulty via box height or a longer lever.[227] The protocols are detailed after the exercise variations (Tables 8-4, 8-5).

COPENHAGEN SHORT LEVER (KNEE BENT)

- Bend the knee and position the inside of the knee on a bench
- The elbow is bent and stacked under the shoulder
- Engage the abdominals
- Drive the top leg down into the bench to lift the hips up and forward
- The torso should remain in a straight line
- This can be performed up and down for repetitions (strength/hypertrophy) or using a hold (endurance)

Figure 8-145 *Copenhagen plank, knee bent start position*

Figure 8-146 *Copenhagen plank, knee bent end position*

COPENHAGEN LONG LEVER (KNEE STRAIGHT)

- Position the inside of the lower leg on a bench with the knee extended
- The elbow is bent and stacked under the shoulder
- Engage the abdominals
- Drive the top leg down into the bench to lift the hips up and forward
- The torso should remain in a straight line
- This can be performed up and down for repetitions (strength/hypertrophy) or using a hold (endurance)

Figure 8-147 *Copenhagen plank, knee straight start position*

Figure 8-148 *Copenhagen plank, knee straight end position*

COPENHAGEN PLANK PARTNER-ASSISTED

- A partner supports the upper leg by grasping at the knee joint and above the ankle
- Drive the top leg into the hands of the partner to lift the pelvis and lower leg
- Slowly lower the bottom leg, while allowing the pelvis to drop

Figure 8-149 *Copenhagen plank, partner-assisted start position*

Figure 8-150 *Copenhagen plank, partner-assisted end position*

COPENHAGEN PLANK WITH ADDUCTION OF BOTTOM LEG

- Perform a short or long lever Copenhagen plank (Figures 8–146, 8–148)
- Maintain the plank position with the bottom leg straight
- Lift the bottom leg up toward midline
- Press the lower part of the bottom leg up into the bench to further contract the adductors
- Lower just the the bottom leg down and repeat for repetitions

Figure 8-151 *Adduction of bottom leg during Copenhagen plank*

COPENHAGEN PLANK WITH HIP FLEXION OF BOTTOM LEG

- Perform a short or long lever Copenhagen plank as described
- Lift the bottom leg up toward midline with the knee straight
- Flex the knee and hip to 90° (or greater)
- Slowly extend the knee and hip back to 0° while maintaining the leg close to midline and parallel with the ground

Figure 8-152 *Hip flexion of bottom leg during Copenhagen plank*

Table 8-4 *Copenhagen plank protocol adapted from Ishoi et al.*[225]

Eight-Week Copenhagen plank protocol	
Number of weeks	8
Training sessions per week	2
Sets	Weeks 1–3: 2 Weeks 4–8: 3
Repetitions	Week 1: 6 Week 2: 8 Weeks 3–4: 10 Weeks 5–6: 12 Weeks 7–8: 15

Table 8-5 *Copenhagen plank protocol adapted from Haroy et al.*[226]

Eight-Week Copenhagen plank protocol	
Number of weeks	8
Training sessions per week	3
Sets	1
Repetitions	Beginner: 3–5 Intermediate: 7–10 Advanced: 12–15

Table 8-6 *Eight-week Copenhagen plank protocol adapted from Polglass et al.*[227]

Eight-week Copenhagen plank protocol					
Week	Training sessions per week	Sets	Repetitions	Time under tension	Level
1	2	2	6	20 seconds	30 cm box, short lever with lower knee on the ground for support
2	2	2	6		30 cm box, short lever with knees together
3	2	3	6		30 cm box, long lever with lower leg foot on the ground for support
4	2	3	8		30 cm box, long lever with legs together
5	2	3	8		Box at hip height, long lever with legs together
6	2	3	6	3-second concentric 3-second eccentric	Partner assisted
7	2	3	8		
8	2	3	10		

ADDUCTION (OPEN-CHAIN)

HOOK-LYING LONG LEVER ADDUCTION

- Start with the knees bent and position the target leg in 90° of hip flexion with the knee extended
- Slowly lower the leg out to the side and do not let the knee bend or hip externally rotate (Figure 8–153)
- A stretch should be felt on the inner thigh
- Adduct the leg toward midline (Figure 8–154)
- Perform with bodyweight, an ankle weight to challenge the eccentric phase, or with band resistance to challenge the concentric phase

Figure 8-153 *Hook-lying long lever hip adduction with adductors on stretch*

Figure 8-154 *Concentric hip adduction toward midline*

BRIDGE WITH LONG LEVER ADDUCTION

The addition of a bridge to the hook-lying variation will further challenge core and pelvic stability by maintaining the hips high and pelvis level throughout. It is performed with the same sequence as detailed above, but it is important to perform a bridge prior to initiating movement of the target leg.

Figure 8-155 *Bridge long lever hip adduction with adductors on stretch*

Figure 8-156 *Concentric hip adduction toward midline*

SIDE-LYING ADDUCTION

Side-lying abduction generates moderate-high levels of adductor muscle activity at greater than 60% MVIC.[224]

- Start on one side with the bottom (target) leg straight
- The top leg is bent with the hip flexed and the foot rested on the floor in front of the target leg
- Contract the adductor to lift the bottom leg up toward the ceiling

Figure 8-157 *Side-lying hip adduction start position*

Figure 8-158 *Side-lying hip adduction end position. Bottom leg is adducted toward midline*

STANDING ADDUCTION

Standing adduction with a resistance band generates over 100% MVIC of the adductor longus.[224] In addition to targeting the adductors, the standing position also activates the hip abductors of the stance leg and can greater challenge balance compared to supine or plank variations. A randomized controlled trial by Jensen et al.[228] utilized resistance band tubing to perform concentric, isometric, and eccentric hip adduction, which increased eccentric and isometric adductor strength by 30% and 14%, respectively. Eccentric strength gains were statistically significant at 14% greater in the training group compared to the control group, the latter of which did not do any adductor focused training and continued playing soccer as usual.[228] The full protocol is detailed below (Table 8–7).

- Grasp the cable column, squat rack, or another counterbalance like a dowel or PVC pipe
- Keep the knee of the stance leg soft and the pelvis level
- Bring the target (moving) leg in toward midline and across the body (if able)
- Keep the foot of the target leg facing forward
- A resistance band or cable column can be used

Figure 8-159 *Standing hip adduction start position. PVC pipe used for counterbalance*

Figure 8-160 *Standing hip adduction end position*

Table 8-7 *Standing hip adduction protocol adapted from Jensen et al.*[228]

Standing hip adduction protocol			
Weeks	Sets	Repetitions	Training sessions per week
1–2	3	15	2
3–6	3	10	3
7–8	3	8	3
3-second concentric phase 2-second isometric phase at end range 3-second eccentric phase			

SEATED ADDUCTION WITH RESISTANCE BAND

Seated adduction can be performed using either a resistance band or cable column in lieu of an adductor machine.

- Attach a band around the thigh and anchor it laterally and low to the ground
- Sit with the feet in contact with the ground
- There should be minimal-moderate tension on the band with the legs fully abducted
- Push the thighs together
- Slowly release the contraction and allow the thighs to abduct
- This can be performed unilaterally or bilaterally

Figure 8-161 *Seated adduction with resistance band start position*

Figure 8-162 *Seated adduction with resistance band end position*

ADDUCTOR MACHINE

The adductor machine generates almost 100% MVIC of the adductors.[224] It is found in most commercial gyms and some smaller training studios.

- Sit with the trunk upright, feet secured on the footplates, and legs abducted
- Push the thighs together as if trying to crush the pads between the knees

ADDUCTION (CLOSED-CHAIN)

ADDUCTOR SLIDE STANDING

The adductor slide mimics common movement patterns during sports, like sliding into home plate, skating, a dance split leap, or arabesque. It also resembles many unintentional and sometimes unfortunate movements, like slipping on water or ice. It generates 98% MVIC for the adductor longus of the target (moving) leg and 89% for the stance leg.[224]

- Place a small towel under the foot on a slide board or slick flooring
- Keep the stance knee soft
- Slide the target leg away from the body, keeping the toes facing forward (Figure 8–164)
- The trunk can remain fully erect or adopt a slight forward lean
- Allow the stance knee to bend to increase range of motion
- A stretch should be felt on the inner thigh of the moving leg
- Pull the target leg back toward midline and drive down through the stance leg to return to full upright

Figure 8-163 *Adductor slide standing start position*

Figure 8-164 *Adductor slide end position. The adductor is on stretch, prior to concentric contraction to return to start position*

ADDUCTOR SLIDE KNEELING

The kneeling component may reduce stability demands of the lower extremities and trunk while shifting the focus fully to the adductor stretch and contraction. A greater stretch will be felt on the outstretched leg, but the adductor of the stance leg must also contract concentrically from a lengthened range to bring the body back to upright.

- Start in tall kneeling on a slide board or slick flooring with both knees on the floor and the trunk upright
- Place a small towel or slider disk under one knee (moving leg)
- Slide the moving leg out to the side, away from the body (Figure 8–166)
- Keep the knee facing forward, as not to externally rotate the hip
- Pull the moving leg back toward midline and drive through the stance knee to adduct the leg in order to return to full upright

Figure 8-165 *Tall kneeling adductor slide start position*

Figure 8-166 *Tall kneeling adductor slide end position. The adductor is on stretch, prior to concentric contraction to return to start position*

CALF AND LOWER LEGS

The calf muscle complex is made up of the gastrocnemius (short head and long head), soleus, and plantaris. These muscles act to plantarflex the ankle, aid in propulsion, deceleration, and balance during the gait cycle. The gastrocnemius is a two-joint muscle with attachment sites at and below the knee joint. The soleus is deep to the gastroc, attaches below the knee and functions only at the ankle joint. These muscles blend together at the ankle and form the Achilles tendon. The largest plantar flexion moment and forces are generated by the gastrocnemius when the knee is extended and by the soleus when the knee is flexed.[229, 230]

Therefore, it is best to perform calf raise exercises with the knee straight to target the gastroc and knee bent to bias the soleus. Many of the exercise variations included in this chapter can be modified to target the soleus, simply by slightly flexing the knee. The soleus has been proven to generate large amounts of force (up to eight times bodyweight) compared to the gastrocnemius (three times bodyweight) and may be the optimal muscle to target when rehabilitating lower extremity injuries, like Achilles tendinopathy.[231] Foot position used during the calf raise will influence activation of a particular head of the gastrocnemius and allow for preferential muscle activation. The medial head of the gastrocnemius is best targeted with the feet positioned outward and the lateral head with the feet positioned inward.[232]

Strong risk factors for calf muscle injury are older age and previous calf muscle injury[233–235] The recovery process and time to return to play is greater in the presence of a connective tissue or aponeurosis injury (grade 2–3 strains) or when the mechanism of injury was a running related activity.[235–237] Unfortunately, plantarflexion strength and power appears to decline with age. When compared to their younger counterparts, older individuals generate 22–29% less power with the ankle plantarflexors and compensate with increased work of the hip extensors during walking.[238, 239] Kulmala et al.[238] also found a 25% reduction of propulsion force, plantar flexor moment, and up to a 41% reduction in ankle joint power during running in older male athletes. Plantarflexion strength is associated with better performance on standardized functional outcome measures, including the six-minute walk test (6MWT), timed up and go (TUG), ten repetition chair rise time, and ten-meter walk test in older adults.[240, 241] This research suggests that plantarflexor strength may play a crucial role in maintaining a higher level of mobility as we age.

When performing calf raises, think of the foot as a tripod with three main points of contact: the heel, the first toe, and the fifth toe. For all calf raise variants, it is extremely important to maintain the first toe's contact with the floor. As the heel lifts and one leg of the tripod is eliminated, weight must then be balanced between the other two points. The tendency, especially for those that lack first toe extension, is to roll onto the outside of the foot, which is essentially passive versus active inversion. This will limit the ability of the foot to function as a rigid lever, decreasing overall stability and the available surface area about which to transmit force. The cues "push up" or "propel" through the big toe and "drive the big toe into the floor" may help facilitate first toe push-off.

SEATED SOLEUS HOLDS

- Sit with the hips and knees bent to at least 90°
- Drive the ball of the foot and first toe into the floor to lift the heel
- Hold at end-range for an isometric contraction of at least ten seconds
- Use the hands or weight to apply resistance to the knee with force in a downward direction
- This exercise can be performed bilaterally or unilaterally

Figure 8-167 *Seated soleus isometric hold*

SEATED SOLEUS RAISE

- Place a kettlebell or dumbbell on the knee (unilateral), a barbell (bilateral) for resistance
  - A soleus raise machine can also be used if available
- Drive the ball of the foot and first toe into the floor to lift the heel
- Slowly lower down until the heel contacts the floor
- For extra range of motion, perform with the ball of the foot on a plate or small step and allow the heel to drop below neutral

Figure 8-168 *Seated soleus raise start position*

Figure 8-169 *Seated soleus raise end position*

SQUAT SOLEUS RAISE

- Descend into a full or partial squat
- Rise up onto the toes while keeping the knees bent
- Lower under control and repeat the raise for desired number of repetitions while maintaining the squat position

Figure 8-170 Squat soleus raise start position

Figure 8-171 Squat soleus raise end position

LUNGE SOLEUS RAISE

- Descend into a lunge
- Bend at the hip and lean the trunk forward to shift weight onto the front leg
- Rise onto the toes of the front foot while keeping the knees bent

Figure 8-172 Lunge soleus raise start position

Figure 8-173 Lunge soleus raise end position

Double-leg calf raises are an excellent alternative to single-leg calf raises (see page 245) for those with limited ability to perform single-leg calf raises, which may include older adults, individuals with medical conditions like peripheral vascular disease, neurological compromise, balance impairments, or lower body injury. As expected, loading of the Achilles tendon is less during bilateral compared to single-leg calf raises.[242] Normative values exist for the bilateral heel raise test (HRT), specifically maximal repetitions until fatigue, in a healthy population, though this study did not include individuals greater than 60 years old.[243] Normative values for double-leg calf raises are considered greater than those scoring in the 25th percentile for their age group and are listed in the table below. Andre et al.[244] proposed a new, standardized assessment method – the calf raise senior test (CRS) – to evaluate plantarflexion strength, measure physical activity and fitness in older adults. This test measures the maximal amount of calf raises performed in 30 seconds at a self-imposed repetition rate by individuals over 60. It demonstrates excellent validity and reliability across three separate studies. Higher scores are reflective of greater levels of plantarflexion strength via isometric and isokinetic strength testing, greater rate of force development, EMG muscle activation, physical activity level, physical fitness, and younger age.[244, 245] The inability to perform at least 38 repetitions (cut-off score) over a 30-second period suggests a significant reduction in plantarflexor strength. A minimal clinical important difference (MCID) of 3.5 repetitions and a minimal detectable change (MDC) of 4.6 repetitions were established for the CRS.[246]

Table 8-8 *Normative values (number of calf raises performed) for the bilateral heel raise test (HRT) by age group and gender. Adapted from Montiero et al.*[243]

Normative values for bilateral HRT		
Age	Male	Female
20–29	65	45.5
30–39	62.75	41.5
40–49	67.25	45
50–59	54	39.25

Table 8–9 *Objective measures for calf raise senior test (CRS) – cut-off score of 38 repetitions suggests a plantarflexion strength deficit; MDC; and MCID. Adapted from Andre et al.*[246]

Calf-raise senior test (CRS) objective data	
Cut-off score	38 repetitions
MDC	4.6 repetitions
MCID	3.5 repetitions

DOUBLE-LEG CALF RAISE WITH TENNIS BALL

A tennis ball between the heels forces push-off from the first toe and limits passive inversion (rolling out onto the lateral side of the foot). This can help limit compensation when actively training the gastrocnemius and posterior tibialis.

- Place a tennis ball between the heels
- Drive the balls of the feet and first toes into the floor to lift the heels
- Imagine pushing the head up into the ceiling to promote upward versus forward trajectory
- Weight can be added via a weight vest or weighted backpack

Figure 8-174 *Double-leg calf raise start position*

Figure 8-175 *Double-leg calf raise end position*

Figure 8-176 *Double-leg calf raise fault – passive inversion and increased weight distributed to the lateral side of the foot due to poor first toe push-off*

CALF RAISE WITH LEG PRESS

A leg press machine can be used to add load to both double and single-leg calf raises. In a study by Nunes et al.[232] (2020), calf raise training using a leg press machine induced hypertrophic gains measured by muscle thickness. The training program consisted of three sets of 20–25 repetitions for weeks one to three, and four sets in weeks four to nine, performed three times per week for nine weeks. A forward (neutral) foot position is used to target the two heads of the gastrocnemius equally, but an outward or inward orientation of the feet can respectively bias the medial or lateral heads.[232]

MODIFIED SINGLE-LEG CALF RAISE ON STEP

- Rest one leg up on a step
- Maintain the target leg on the floor and rise onto the toes
- The step is used for balance and to unload partial weight from the target leg to decrease difficulty

F:igure 8-177 *Modified single-leg calf raise start position*

Figure 8-178 *Rear foot push-off for modified single-leg loading*

ECCENTRIC (UP TWO, DOWN ONE) CALF RAISE

- Raising up on two legs eliminates single-leg concentric loading and trains eccentric single-leg loading on the descent
- Raise up on both feet
- At maximal height, lift one foot and lower under control using only the opposite leg

SINGLE-LEG CALF RAISE

The single-leg heel rise test is highly reliable with excellent test-retest ability.[247] The "normative" values have varied greatly since the poliomyelitis era with normal grades of just one to five full heel raises. In 1995, Lunsford and Perry[248] determined that 25 repetitions could be completed by both male and female participants and that this number should be met to achieve a grade of "normal." More current research has focused on establishing normative values by age group, but also demonstrated similar median values of 23–24 heel raises and highlight age, sex, and physical activity level as influencing factors.[247] Single-leg calf raises generate over 100% MVIC of the gastroc-soleus complex[249] and peak Achilles loading of three times body weight of an individual.[250] Single-leg heel raises are a great lead-up task to dynamic, multi-joint activities. They generate similar levels of Achilles tendon stress when compared to bilateral jumping and running, but less than half the amount of unilateral jumping.[242] It is essential to develop a large amount of load tolerance before progressing to plyometric activities and running, which result in peak loads greater than three times and over seven times bodyweight.[250]

- Drive through the first toe and forefoot to rise on one foot to desired height
- Lower under control

Figure 8-179 *Single-leg calf raise start position*

Figure 8-180 *Maximal height prior to lowering phase*

SINGLE-LEG CALF RAISE HOLDS

Holds performed at different points through the range of motion will help load the Achilles tendon and gastroc-soleus complex via an isometric contraction. This is particularly useful when the goal is to provide a training stress, but loading concentrically through the range or eccentrically is not tolerated. Insertional Achilles tendinopathies are usually exacerbated by increased range of motion or excessive stretch, so this may be an exercise to keep in mind when programming for this condition.

- Raise up on both feet to desired height
- Lift one foot and attempt to maintain height of the heel on the target leg (the leg that remains in contact with the floor)
- Hold for at least ten seconds
- Lower down using both feet

Table 8–10 *Normative data (number of calf raises performed) for single-leg calf raises by age group and gender. Adapted from Hebert-Losier et al.*[247]

Normative data for single-leg calf raises		
Age	Male	Female
20	37	30
30	33	27
40	28	25
50	24	22
60	19	19
70	15	16
80	10	14

DEFICIT CALF RAISE

Deficit calf raises will increase heel drop past the horizontal, which promotes greater range of motion into ankle dorsiflexion, which will provide a loaded stretch to the gastroc-soleus complex and Achilles tendon. The ability to push-off from a greater degree of ankle dorsiflexion is required during activities like running, sprinting, and ascending stairs or ladders. This exercise is may be beneficial for those with mid-portion Achilles tendinopathy and decreased calf flexibility to provide a loaded stretch to the calf and for strengthening, but should be avoided in those with insertional Achilles tendinopathy due to increased compressive force to the deep portion of the tendon insertion.[251] Designing a therapeutic exercise program to address mid-portion versus insertional Achilles tendinopathy is explained in greater detail in Chapter 11. This exercise can be performed with a tennis ball between the heels as detailed earlier in this chapter or without if the individual is able to maintain first toe contact with the floor throughout the movement.

- Position the forefoot on a small step, plate, or 2 × 4" piece of wood
- Raise up onto the toes
- Upon lowering, let the heels travel down past the edge of the step or other surface to provide a loaded stretch into ankle dorsiflexion
- This exercise can be performed bilaterally or unilaterally

Figure 8-181 *Deficit calf raise start and end position. Note the heel drop past neutral*

Figure 8-182 *Maximal height prior to lowering phase*

SINGLE-LEG CALF RAISE WITH BAND OR STRAP UNDER THE FIRST TOE

Placing a resistance band or strap under the first toe will encourage push-off from the first toe and discourage passive inversion (rolling out onto the lateral side of the foot), similar to using a ball between the heels. The band or strap acts as a useful tactile cue because it will dislodge from under the foot if first toe contact is lost. The benefit of this set-up over a ball between the heels is that it supports single-leg training to a greater extent.

- Place a resistance band or strap at or just anterior to the first metacarpal head
- Raise up onto the toes and maintain contact with the band

Figure 8-183 *Single-leg calf raise with strap start position*

Figure 8-184 *Single-leg calf raise with strap end position. The strap remains secure under the first toe*

ANKLE INVERSION AND EVERSION ISOMETRIC WITH BAND RESISTANCE

- Anchor a resistance band to a stable surface and loop it around the forefoot
- Step out to a point where there is minimal resistance on the band – this exercise is difficult even with light resistance!
- Use a dowel or PVC pipe in one hand for balance
- Position the ankle in slight inversion or eversion depending on which muscles are being targeted
- Raise the target leg up into hip flexion while maintaining the position of the foot, then slowly lower
- The band resistance will attempt to pull the foot in or out

Figure 8-185 *Inversion isometric start position*

Figure 8-186 *Inversion isometric end position*

Figure 8-187 *Eversion isometric start position*

Figure 8-188 *Eversion isometric end position*

ANKLE DORSIFLEXION ISOMETRIC

- Hang a kettlebell over the forefoot
- Dorsiflex the ankle and maintain
- This exercise can also be performed concentrically, but the range of motion must be limited on the descent to prevent the kettlebell from falling off

Figure 8-189 *Isometric ankle dorsiflexion with kettlebell*

SIDE-LYING ANKLE EVERSION WITH ECCENTRIC

- Start on one side with the target leg up
- Position the target ankle over the edge of the table, mat, bed, etc.
- Lift the ankle up and out into full eversion (toward the ceiling)
- Slowly lower into full inversion
- Use a resistance band or weighted resistance band to increase difficulty

Figure 8-190 *Side-lying ankle eversion against resistance*

Figure 8-191 *Side-lying eversion eccentric*

SLANT BOARD SINGLE-LEG BALANCE

Performing balance activities on a slant board places the ankle on some degree of incline or decline and requires the ankle to resist the range of motion in a certain direction. For example, if the outside of the ankle is parallel with the lower edge of the slant board, the ankle will have to work increasingly hard to resist inversion and supination of the ankle. This exercise mimics uneven surfaces that may be encountered during outdoor activity and can be very useful in end-stage ankle or knee rehabilitation.

- Position the foot on the slant board
- Keep the toes of the opposite leg in contact with the ground constantly or intermittently until there is enough stability to maintain full single-leg support
- Attempt to maintain stability without rolling onto the inside or outside of the ankle
- Do not drop the hip or side bend the trunk excessively

Figure 8-192 *Single-leg balance while resisting ankle eversion*

Figure 8-193 *Single-leg balance while resisting ankle inversion*

Figure 8-194 *Single-leg balance in ankle dorsiflexion*

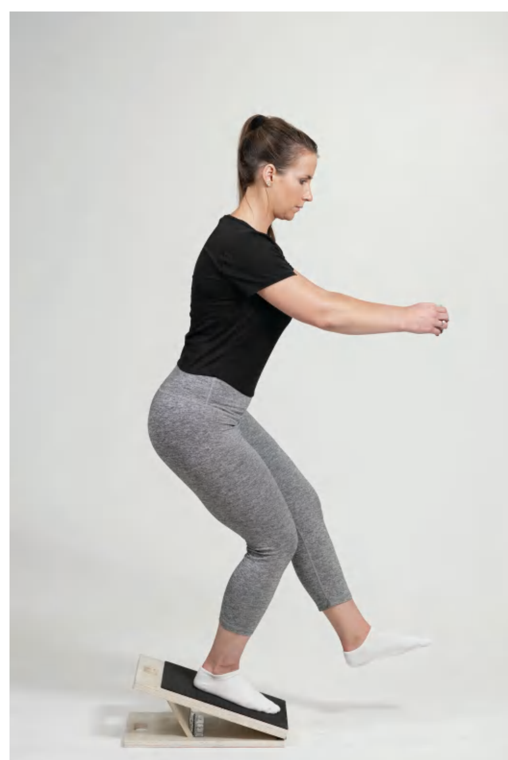

Figure 8-195 *Single-leg balance in ankle plantarflexion*

SINGLE-LEG WEIGHT PASS

- Stand in single-leg stance with the knee soft
- Hold a light weight in one hand
- Slowly reach across midline with the weight and pass it off to the opposite hand
- Repeat on the opposite side

Figure 8-196 *Single-leg weight pass start position*

Figure 8-197 *Weight crosses midline*

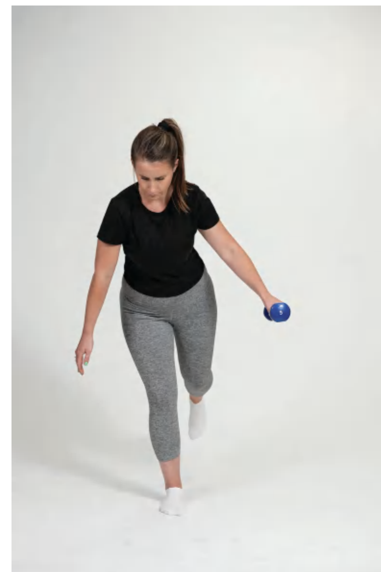

Figure 8-198 *Transition of weight to opposite hand*

SINGLE-LEG BALANCE OR DEADLIFT ON PLATES

This exercise targets the intrinsic foot muscles, which may be beneficial for runners, plantar fasciitis, and bunion rehabilitation. The single-leg deadlift (see page 90) is more difficult, as the stance leg must stabilize against dynamic movement of the opposite limb and trunk.

- Stand on two plates with one under the ball of the foot and the other at the heel
- The mid-foot has no support between the plates
- Perform a single-leg balance (less difficult) or single-leg deadlift (more difficult)

Figure 8-199 *Single-leg balance*

Figure 8-200 *Single-leg deadlift*

MINI BAND ARCH RAISE

- Place a mini band around both feet
- Step the feet apart to create tension on the band
- Perform an arch raise by drawing the base of the first toe toward the heel and tightening the glutes
- There should be a sensation of a foot "tripod" with contact maintained at three points (first toe, fifth toe, and heel)
- The arch raise should create a slight increase in tension on the band
- Allow the arches to collapse inward at a slow, controlled pace and repeat

Figure 8-201 *Mini band arch raise start position with tension on band*

Figure 8-202 *Mini band arch raise end position. Note, the hips and knees externally rotate following the arch raise*

LATERAL WALKS BAND AT FEET

See page 142.

BUNION BLASTER WALKS

The band set-up will pull the first toe into abduction and may help restore "tripod" function of the foot during weight-bearing.

- Place a mini band around the ankles
- Criss-cross the mini band and loop an end around the first toe of both feet
- Create tension on the band to pull the first toes away from midline
- Perform side steps, maintaining full foot contact, distance between the feet, and tension on the band throughout

Figure 8-203 *Orientation of band pulls the first toe into abduction*

MULTI-DIRECTIONAL ANKLE ISOMETRICS

The goal of this exercise is to promote stability and establish reactive control to change of direction about the ankle.

- Position the ankle over the edge of the table, mat, bed, etc.
- Place a mini band around the foot
- Position the foot in neutral and attempt to maintain neutral as another individual exerts force on the band in a 180° plane of motion
- The resistance on the band can be constant or varied throughout the exercise
- This exercise can also be performed in mid-range or end-range ankle dorsiflexion, plantarflexion, inversion, or eversion to challenge a specific range of motion or muscle group

Figure 8-204 *Ankle inversion isometric*

Figure 8-205 *Ankle dorsiflexion isometric*

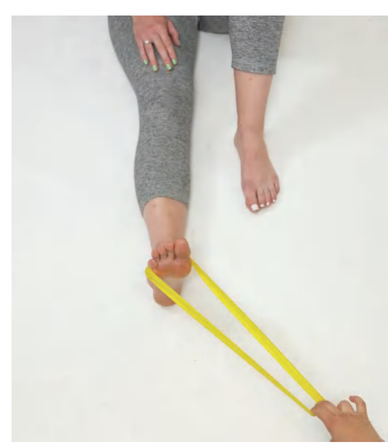

Figure 8-206 *Ankle eversion isometric*

CHAPTER 9

NECK, UPPER BODY, AND THORACIC REGION

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NECK

The anatomy of the neck is very complex, but can be simplified by separating muscles into three groups: flexors, extensors, and suboccipitals. The anterior neck houses the superficial cervical flexors (sternocleidomastoid, scalenes) and deep cervical flexors (longus colli, longus capitis). The posterior neck includes the upper trapezius and cervical extensors (splenius capitis, splenius cervicis, semispinalis, longissimus, and multifidus – listed from superficial to deep). In general, when acting bilaterally these muscles flex or extend the neck. Unilaterally, they promote lateral flexion and rotation. The upper trapezius acts primarily at the shoulder to drive upward rotation and elevation of the scapula. The suboccipital muscle group lies deep to the cervical extensors at the base of the skull. They are very small but important muscles that form a web of connections between the skull and the first two cervical vertebra to extend the occiput, laterally flex and rotate the upper cervical spine. The exercises in this chapter aim to advance beyond standard chin tucks and manual resisted cervical isometrics by introducing gravity resisted movements and resistance band loading to increase tolerance to mechanical strain and develop neuromuscular control. These exercises pair well with upper body resistance training, which will also be covered later in this chapter.

Unfortunately, neck pain plagues up to 70% of individuals at some point throughout life and has high rates of recurrence, chronicity, and associated disability. Females and those with prior history of neck pain are considered to have a higher risk of developing neck pain.[252,253] Neck pain can be atraumatic or caused by a motor vehicle accident, fall, high impact sports, etc. In absence of any red flag symptoms or neurological signs (bilateral extremity symptoms, myotomal weakness, gait disturbance, etc.), neck pain is usually treated conservatively with physical rehabilitation as a primary intervention.[252,253] According to the most recent clinical practice guidelines by Blanpied et al.,[252] the most rapid portion of the recovery process occurs six to 12 weeks after the initial injury or onset of pain. Education and exercise therapy are the primary treatment strategies for those at low risk of developing chronic issues. Patients with high pain levels, history of previous injury, and high initial levels of disability are considered at greater risk of developing chronic issues. They may benefit from a multimodal approach that includes exercise, education, and manual therapy. Strength and endurance exercises of the neck, upper back, and upper extremities are moderately supported by the literature followed by thoracic manipulation, cervical mobilization and manipulation.[252]

There is no high-quality evidence that details the optimal type of exercise to rehabilitate neck pain. Some studies have found no difference between resistance training and vaguely described general physical exercise[254,255] though the former may be more beneficial to reduce fear-avoidance behavior.[255] It is not possible to gain accurate conclusions from these results due to small sample sizes, questionable periodization methods, incomplete data, and poor participant adherence to training programs. Strength and endurance training of the neck and scapulothoracic regions appear to have similar positive effects on reducing pain and improving function,[252,256] but exercise protocols vary greatly throughout studies. Two randomized control studies demonstrate decreased pain levels and significant increases in maximal isometric neck strength using cervical isometrics, cervical and upper body concentric endurance exercises (15 or greater repetitions and under 70% one repetition maximum) with bodyweight, resistance bands, and dumbbells.[257,258]

Research that provides well-described progressive resistance training interventions appears to be quite favorable compared to regular physical activity and endurance training. A 20-week regimen of high-intensity strength training performed one to three times per week reduced neck pain intensity of industrial workers by 49% compared to just 17% in the control group (general physical activity). The exercise protocol consisted of dumbbell front raises, lateral raises, shrugs, reverse flies, and wrist extension. A non-linear periodization scheme was used to modify repetitions and load while working up to an intensity of 8–12 repetitions between 75% and 85% one repetition maximum using two to four sets per exercise.[259] Another randomized-controlled trial established a dose-response between the amount of exercise and pain relief using the same protocol. Maximal pain relief was achieved compared to lower dosage and control groups when using one to two weekly strength training sessions of at least 7.4 sets of periodized resistance training for 20 minutes.[260] As a profession, we would benefit from further research with larger sample sizes, less variability among treatment protocols and exercise selection. For now, we should remain confident in the existing body of evidence that consistently supports exercise as a treatment method for neck pain, as well as many other musculoskeletal conditions.

It is not uncommon to notice the position of the head migrate forward in relation to the rest of the body (cervical protraction) during activities like reading, texting, driving, or sitting at a computer. In this position, often dubbed "forward head posture," the lower cervical spine sits in flexion and the upper cervical spine in extension, which is a reversal of the normal anatomical position. It is not appropriate, however, to blame neck pain solely on poor posture. Forward head posture is not always associated with pain and is actually quite prevalent in an aging population, even in those completely asymptomatic of neck pain.[261] Neck pain is more prevalent in adults with forward head posture when compared to adults without forward head posture and adolescents.[262] Still, instead of harping on an individual to maintain one "ideal" static position, it may be better to promote variable postures via frequent changes in position, active breaks, and exercise.

CERVICAL RETRACTION

Cervical retraction (chin tuck) is often a staple exercise in any neck rehabilitation program. It pulls the head backward toward the center of gravity into a better resting neck posture of upper cervical flexion and lower cervical extension,[263] can play a role in restoring upper cervical mobility[264] and cervical nerve root decompression.[265] Repeated cervical retractions are utilized in the mechanical diagnosis of a suspected derangement and as a treatment strategy to centralize and alleviate neck pain.[263,265,266] It is usually performed seated or standing to replicate the positions in which we perform job functions or activities of daily living, but can also be performed in supine or quadruped and prone on elbows to increase difficulty via resistance against gravity. Cervical retractions and retractions with overpressure can be used for both range of motion and pain relief. Resisted retractions may be useful to utilize newly acquired range of motion and to strengthen at end ranges to maintain range of motion gains.

CERVICAL RETRACTION (CHIN TUCK)

- Perform in a seated, standing, or supine position
- Sit up tall with the feet in contact with the floor
- Retract the neck by pulling the head straight backward, as if pushing a button on the chin
- Do not allow the neck to extend (nose up) or flex (nose down) during the movement
- In the supine position or if standing up against a wall, the back of the head should gently glide up on the surface it is in contact with

RESISTED CERVICAL RETRACTION

- Place a resistance band behind the head above the base of the skull
- Create light to moderate tension on the band by pulling forward with the arms
- Pull the head straight backward into a chin tuck as described above
- Coaching cues: make a double chin, pull the chin straight back, act as if pressing a button on the chin

Figure 9-1 *Cervical retraction against resistance start position*

Figure 9-2 *Cervical retraction against resistance band*

DEEP CERVICAL FLEXORS

EMG studies have shown greater superficial flexor activity, reduced deep cervical flexor muscle activity, and craniocervical flexion range of motion in individuals with neck pain compared to those without pain.[267,268] Direct training of the deep cervical flexors can improve neuromuscular coordination by reducing activation of other anterior neck flexors (sternocleidomastoid and scalenes) during craniocervical flexion.[269] The craniocervical flexion test and deep neck flexor endurance test are two methods commonly used to assess the deep cervical flexors in a clinical setting.

SUPINE DEEP CERVICAL FLEXION

- Perform a chin tuck
- Maintain the chin tuck and perform a “nod” motion as if saying “yes”
- The back of the head should lift off the floor or mat slightly
- Focus on feeling the contraction in the deep cervical flexors just under the chin versus throughout the entirety of the anterior neck

Figure 9-3 *Deep cervical flexion start position in cervical retraction*

Figure 9-4 *Deep cervical flexion nod*

CRANIOCERVICAL FLEXION TEST

The craniocervical flexion test can assess for issues with neuromotor control, deep cervical flexor muscle endurance, and serve as an intervention for re-training.[267] It is executed using a biofeedback device just below the occiput with the goal of increasing the range of motion and pressure at each phase. In order to advance to the next phase, a 10-second isometric must be held without evidence of excessive superficial neck muscle compensation.[267,268] Pressures of 24–26 mmHg may be optimal for recruiting deep versus superficial flexors.[270] The use of the biofeedback device is more effective for improving cervical endurance and pain compared to training without the device.[271–273] The progression through each phase of the protocol is detailed below (Table 9–1). The craniocervical flexion test has been validated as a tool to assess deep neck flexor muscle activity with positive convergent validity, interrater and intrarater reliability supported by moderate level evidence. It has not been studied extensively or proven effective as an outcome measure.[274]

Table 9-1 *Craniocervical flexion test for deep cervical flexor muscle endurance. Progression to the next phase requires a ten-second isometric hold and maintenance of a specific measure of pressure on a biofeedback device. Adapted from Jull et al.*[267]

Craniocervical flexion test progression	
Phase	Pressure (mmHg)
1	22
2	24
3	26
4	28
5	30

DEEP NECK FLEXOR ENDURANCE TEST

The deep neck flexor endurance test is a two-centimeter head lift off a flat surface (while maintaining craniocervical flexion) that is held for time. The time is stopped when the chin begins to untuck. It can be used both as an assessment test and as an outcome measure for muscle endurance.[275] This clinical test, detailed by Grimmer et al.,[275] demonstrated high test-retest reliability. Further studies measured good intrarater[276] and moderate to good interrater reliability[276,277] for asymptomatic populations. Studies by Lourenço et al.[278] and Edmondston et al.,[279] examined populations symptomatic for neck pain and measured moderate interrater reliability with a minimal detectable change of 19.15 seconds and excellent intrarater reliability with minimal detectable change of 17 seconds, respectively. Males consistently demonstrated greater cervical flexor endurance compared to females in all of these studies.[278,279] There was some variability, however, in normative data, which is detailed below (Table 9–2).

Table 9-2 *Normative data (number of seconds the deep cervical flexor endurance test can be maintained) by age group and gender. The number of participants is the amount of subjects from each individual study from which the data was extracted. Adapted from Olson et al.[276], Domenech et al.[277] and Jarman et al.[280]*

Normative data for deep neck flexor endurance			
Age range (years)	Number of participants	Males	Females
20–35	27	25 seconds	20 seconds
20–80	126	39.1 seconds	29.3 seconds
14–22	81	35.57 seconds	31.86

OTHER NECK MUSCLE STRENGTHENING

MULTI-DIRECTIONAL CERVICAL ISOMETRICS

- Place a mini band around the forehead
- Maintain the neck in neutral (shoulders stacked, chin can be slightly tucked)
- Resist the band as it is moved by another individual in a clockwise then counterclockwise motion

Figure 9-5 *Multi-directional cervical isometrics band set-up*

Figure 9-6 *Left lateral flexion isometric*

Figure 9-7 *Flexion isometric*

Figure 9-8 *Right lateral flexion isometric*

SUPINE CERVICAL FLEXION ISOMETRIC

- Position the upper body at the edge of a mat or bench so the neck is unsupported
- Perform a chin tuck, slight nod (upper cervical flexion), then fully flex the neck by lifting the head up and forward
- Attempt to resist the downward pull of gravity

Figure 9-9 *Cervical retraction*

Figure 9-10 *Cervical flexion isometric*

PRONE CERVICAL EXTENSION ISOMETRIC HOLD

- Position the upper body at the edge of a mat or bench so the neck is unsupported
- Perform a slight chin tuck, but do not flex the neck, and lift the head up slightly to engage the extensors
- Attempt to resist the downward pull of gravity and maintain the neck in neutral to slight extension

Figure 9-11 *Cervical extension isometric*

SIDE-LYING LATERAL FLEXION HOLDS

- Start on one side with the upper body at the edge of a mat or bench so the neck is unsupported
- Position the neck in neutral with the eyes facing forward
- Attempt to resist the downward pull of gravity and maintain the neck parallel with the body

Figure 9-12 *Cervical lateral flexion isometric*

PRONE CERVICAL EXTENSION

- Extend the neck as if looking up toward the ceiling
- Slowly lower back to neutral by nodding the chin down, then allow the rest of the neck to follow
- Attempt to move one segment of the spine at a time, starting from the top

Figure 9-13 *Prone cervical extension start position*

Figure 9-14 *Prone cervical extension end position*

SUPINE CERVICAL FLEXION

- Perform a chin tuck, slight nod (upper cervical flexion)
- Continue to flex the neck by lifting the head up and forward
- Slowly lower back to neutral by lifting the chin first as if tipping the head back, then allow the rest of the neck to follow

Figure 9-15 *Supine cervical flexion start position*

Figure 9-16 *Supine cervical flexion at end range*

PRONE NECK CURLS

- Start in a maximal cervical flexion (a deep head hang with the chin to the chest)
- Lift the head to neutral (parallel with the body)
- Extend the neck (look up toward the ceiling)
- Slowly lower back to neutral by nodding the chin down, then fully flex the neck

Figure 9-18 *Prone cervical neutral*

Figure 9-17 *Prone cervical flexion*

Figure 9-19 *Prone cervical extension*

SUPINE HEAD HANG TO NECK CURL

- Start in maximal cervical extension (a deep head hang with the head tipped back)
- Perform a chin nod to begin curling the neck up and lift the head to neutral
- Continue to lift the head into full cervical flexion
- Slowly lower by lifting the chin first as if tipping the head back, then fully extend the neck

Figure 9-20 *Supine cervical extension*

Figure 9-21 *Supine cervical neutral*

Figure 9-22 *Supine cervical flexion*

SIDE-LYING LATERAL FLEXION

- Slowly lower the head down as if trying to touch the ear to the shoulder
- Laterally flex the neck and lift back up to neutral (parallel with the body)
- Continue to raise the neck up in the opposite direction as if trying to touch the opposite ear to the shoulder on the same side

Figure 9-23 *Side-lying lateral flexion start position*

Figure 9-24 *Side-lying lateral flexion neutral*

Figure 9-25 *Side-lying lateral flexion end position*

UPPER TRAPEZIUS

The upper trapezius is a largely misunderstood muscle that is often associated with neck and shoulder pain. The actions of the upper trapezius are scapular elevation and upward rotation, the latter of which is very important during overhead exercises to increase subacromial space and limit impingement. The upper trapezius, however, is rarely targeted in the overhead position. The overhead shrug activates the upper trapezius to a similar extent as regular shrugs, but can decrease activation of levator scapulae and rhomboids during the movement.[281] Exercises like barbell or dumbbell shrugs with the arms at the sides are much more common than overhead variations and are also appropriate to use to mobilize and strengthen the upper trapezius.

OVERHEAD BARBELL OR PVC SHRUG

- Rest the bar on the sternum and adjust the hands to a wide grip
- Press the bar or PVC pipe overhead
- Ideally, the arms should be in line with or slightly behind the ears
- Shrug the shoulders up and hold
- Depress the shoulders to lower the bar down to the overhead start position
- Prevent the bar from tipping excessively forward or backward on the way up or down

Figure 9-26 *Overhead PVC shrug start position*

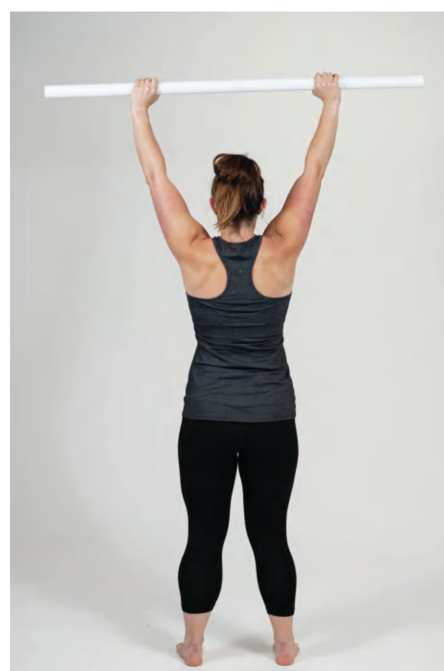

Figure 9-27 *Overhead PVC shrug end position*

OVERHEAD SHRUG

- Hold a kettlebell or small dumbbell overhead
- Keep the arm straight and shrug the shoulder up, as if reaching the weight toward the ceiling
- This exercise can be progressed to using a small weighted barbell, bottoms-up kettlebell or vertical dumbbell to increase shoulder stability
- This exercise can also be performed with a landmine set-up for someone that lacks overhead shoulder mobility

Figure 9-28 *Overhead dumbbell shrug start position*

Figure 9-29 *Overhead dumbbell shrug end position*

CHEST

The primary muscles of the chest are the pectoralis major and minor. The pectoralis major is separated into the upper, middle, and lower portions. The upper chest muscle has attachment points to the clavicle (clavicular head) while the middle and lower chest muscles attach to the sternum (sternal head). The clavicular head is active during shoulder flexion and serves as a synergist to the anterior deltoid. The sternal head performs more of the "traditional" pectoral functions: shoulder horizontal adduction, extension, adduction, and internal rotation. The pectoralis minor performs scapula anterior tilt, downward rotation, and may play a supporting role in respiration due to its attachment points on the rib cage.

Chest press variations are used to target the pectoral muscles, but the set-up may dictate the extent to which specific muscles are involved. The degree of incline on a bench matters if the goal is to bias a specific portion of the pectoralis major. Increasing the incline will promote greater muscle activation of the upper pectoral muscle and anterior deltoid[282] while decreasing muscle activation of the triceps.[283] At 30°, muscle activation of the upper pectoral and anterior deltoid are similar. At 45° and 60°, the activity of the upper pectoral is significantly less than the anterior deltoid, but remains greater than the medial and lower pectoral muscles.[282] A horizontal bench or 0° incline promotes greater muscle activation of the medial and lower pectoral muscle activation compared to performing on an incline.[282,284] A decline demonstrates no additional benefit for lower pectoral muscle activation.[284] The horizontal bench appears to activate all three pectoral muscles similarly.[282,284] To summarize:

- 0° incline (flat bench) is best for medial and lower pectoral muscle activation
- 30° incline is best for upper pectoral muscle activation
- 45° incline is best for anterior deltoid compared to pectoral muscle activation

It is also important to consider the position of the arms during pressing exercises like bench presses, dumbbell presses, and push-ups. If the pressing exercise is performed in the position of 90° of shoulder abduction with a wide grip or arm stance, these exercises may promote unnecessary stress to the anterior shoulder, especially if combined with increased shoulder extension and external rotation. Reducing anterior shoulder stress may be beneficial for individuals with anterior shoulder instability, osteolysis of the distal clavicle, pectoralis major muscle strains or partial tears,[285] biceps tendinopathy, or rotator cuff injury. A grip width of 1.5 times the distance between the acromion process of each shoulder (shoulder width) during the bench press increases shoulder torque by 1.5%. A narrow grip bench press produces less stress for the acromioclavicular joint, inferior glenohumeral ligament, and pectoralis major.[285] A grip width of less than 1.5 times the measured distance between the acromion processes can be used if the goal is to decrease shoulder abduction and extension.[285,286] This grip width will promote about 45° abduction of the shoulder during a closed-chain exercise, like a bench press or push-up.[285] It is also possible to position the shoulders at 45–60° abduction during free weight dumbbell presses by tucking the elbows slightly. The arms in relation to the trunk will resemble the shape of an arrow (at 45–60° of shoulder abduction) instead of the letter "T."

FREE WEIGHT PRESSING EXERCISES

FLOOR PRESS

The floor press may be used to limit upper extremity movement past the horizontal (neutral). This will decrease shoulder abduction, extension, eccentric demands and limit stress on the anterior shoulder, which can become aggravated with many of the conditions listed above. Shoulder extension past 0° is sometimes contraindicated during early phases of shoulder rehabilitation protocols. If an individual is unable to transition up and down from the floor, a wide, raised mat or table can be used.

- Start flat on the floor with the knees bent
- Position the weights at shoulder level with the elbows bent and shoulders at a 45–60° angle from the torso
- Press the weights up and together until positioned at eye level
- Avoid flaring the elbows out by allowing them to track slightly inward toward the body as the weights are lowered down toward the start position

Figure 9-30 *Floor press start position*

Figure 9-31 *Floor press end position*

FLAT BENCH DUMBBELL CHEST PRESS

- Position the weights at shoulder level with the elbows bent and shoulders at a 45–60° angle from the torso
- Press the weights up and together until positioned at eye level
- Depress and retract the shoulder blades together as the weights are lowered to activate shoulder stabilizers and prepare for a better push-off

Figure 9-32 *Flat bench chest press start position. Note the orientation of the dumbbells*

Figure 9-33 *Flat bench chest press end position*

FLAT BENCH DUMBBELL CHEST PRESS WITH ALTERNATING ARMS

Alternating arms may be beneficial to enhance shoulder stability and will require the trunk to resist rotatory movement. The stable arm is forced to maintain the weight overhead with the elbow extended while the moving arm creates a dynamic balance challenge. It may also induce greater muscle fatigue from holding the contralateral weight up in between each repetition.

- Position the weights at shoulder level with the elbows bent and shoulders at a 45–60° angle from the torso
- Press the weights up and together until positioned at eye level (Figure 9–32)
- Lower one weight, while the opposite elbow remains extended
- Alternate sides and lower the second weight when the opposite arm returns to upright

Figure 9-34 *Flat bench chest press alternating arms*

FLAT BENCH SINGLE-ARM DUMBBELL PRESS

This single-arm press variation is meant to challenge rotatory trunk stability. The only contact the body has with the support surface (bench) is the trunk and the weight in only one arm will offset the body's center of mass. To decrease difficulty, this can also be performed with the legs stabilized on a bench or the floor.

- Flex the hips and knees to 90° to eliminate foot contact with the floor
- Contract the abdominals and irradiate tension through the free arm
- Attempt to maintain trunk stability during both the press up and lowering of the weight

Figure 9-35 *Flat bench single-arm press start position*

Figure 9-36 *Flat bench single-arm press end position. The trunk and legs do not dissociate at end-range*

INCLINE BENCH DUMBBELL CHEST PRESS

- Position the bench accordingly to target the desired muscle group (pectorals versus anterior deltoid)
- Position the weights at shoulder level with the elbows bent and shoulders at a 45–60° angle from the torso
- Press the weights up until positioned at eye level
- Depress and retract the shoulder blades together as the weights are lowered

Figure 9-37 Incline press start position

Figure 9-38 Incline press end position

INCLINE BENCH DUMBBELL CHEST PRESS WITH ALTERNATING ARMS

- Position the weights at shoulder level with the elbows bent and shoulders at a 45–60° angle from the torso
- Press the weights up until positioned at eye level (Figure 9–37)
- Lower one weight, while the opposite elbow remains extended
- Alternate sides and lower the second weight when the opposite arm returns to upright

Figure 9-39 Incline press alternating arms

STRICT PRESS

- Start with the weights on the chest
- Press the two weighted portions of the dumbbell together (horizontal adduction) and maintain contact with the weights throughout the exercise
- Press up until the weights are at eye level
- Keep the elbows close to the body and retract the shoulder blades during the descent

Figure 9-40 *Strict press start position*

Figure 9-41 *Strict press end position*

KETTLEBELL BOTTOMS-UP CHEST PRESS

The weight of the kettlebell sitting above the handle may challenge dynamic and reactive shoulder stability due to the variable shifts in the weight's center of mass. To maintain the position of the weight, the forearm and wrist have to remain vertical, which will demand a co-contraction between the internal and external rotators. When comparing pressing exercises with stable and unstable loads, stable load training appears to elicit greater prime mover activation when using the same amount of weight.[287] It can be hypothesized that pressing with an unstable object may require greater stabilizer muscle activation to maintain alignment of the shoulder which may shift the focus away from the prime mover, but the previously mentioned study did not measure muscle activation of the surrounding shoulder musculature. Williams et al.[288] found that lifters report greater rate of perceived exertion (RPE) values when using unstable loads compared to stable pressing instruments. This could have major clinical implications if the goal is to reach a hypertrophy training zone of 70–80% of one repetition maximum without adding any additional weight. When using an unstable load (e.g. kettlebells attached to a straight bar by bands in order to create an oscillating effect) compared to a stable straight bar during an overhead press, there was greater muscle activation in the erector spinae and latissimus dorsi.[288] The most significant differences in almost all muscles (pectoralis major, latissimus dorsi, biceps, serratus anterior, rhomboids, erector spinae, and rectus abdominis) were observed when using an "earthquake bar" specifically designed to enhance oscillating kinetic energy.[288] These exercises were performed using a straight bar and double-arm overhead press variation, not a kettlebell chest press, so the research can't be directly applied, but is certainly relevant, as the bottoms-up position of the kettlebell does create an oscillating motion.

The first two phases of the Turkish get-up (see page 429) consist of a chest press and overhead press using a kettlebell, though not in a bottoms-up position. These two positions activate the pectoralis major, shoulder girdle musculature, and stabilizers. Position one (chest press) produces MVIC values of greater than 30% for pectoralis major, anterior deltoid, and triceps, and greater than 20% for infraspinatus. Position two (overhead press in conjunction with a partial sit up) produces less pectoralis major and anterior deltoid activation compared to position one, but increased activation throughout the rest of the arm shoulder girdle to greater than 40% MVIC for triceps and infraspinatus and greater than 30% MVIC for posterior deltoid and upper trapezius.[289] There is a lack of scientific evidence to support or deny that the kettlebell chest press will activate shoulder stabilizers to a greater extent, but the current body of research points to use of unstable loads during a chest press as a tool to shift the load away from the prime mover, potentially requiring other supporting muscles to participate. Research for the overhead press appears more concrete and will be detailed further later in this chapter.

- Start flat on the floor (easier) or bench (harder) with the knees bent
- Hold the kettlebell inverted with a neutral wrist
- Press the weight up
- Maintain a 45–60° angle of the shoulder (from neutral, arm at the side) during the lowering phase to avoid excessive external rotation torque
- Control the oscillation of the kettlebell during the both press and lowering phase

Figure 9-42 *Kettlebell bottoms-up press start position. Note the position of the wrist in neutral and stacked over the elbow*

Figure 9-43 *Kettlebell bottoms-up press end position*

BENCH PRESS

The bench press is often the exercise of choice to measure upper body strength. It is used recreationally, by amateur and professional sports teams, and in competitive weightlifting sports like powerlifting. Muscle activation is highest in the pectoral group and triceps during the bench press.[290] The grip width used during the bench press – wide, normal, or narrow – does not significantly influence muscle activation or training volume, except for enhanced lower biceps activation during the close grip bench.[283,291] The grip width for a normal bench is between 100–150% bi-acromial distance, so with both hands in line with or half the distance lateral the acromion process of each shoulder.[285,286,291] The bench press can be performed on varied degrees of incline as detailed earlier in this chapter, which will alter the muscle activation of the pectorals, deltoids, and triceps. There is a specific range within the bench press where most lifts fail, known as the "sticking region." In this region, the velocity of the bar transitions from its first peak to its first minimum (i.e., initial fastest point to the first corresponding slowest point) during the upward trajectory. If this point is overcome by the lifter, the bar will continue upward and reach a second peak velocity. Failure happens in this region when the vertical force generated by the lifter cannot overcome the weight of the barbell.[286] Higher one repetition maxima are observed when using partial repetitions that occur before the sticking region.[292]

A slow tempo used during the bench press can influence training volume due to increased time under tension. A slow eccentric phase of six seconds (compared to 2 seconds) required increased time spent exercising, but less total repetitions performed to reach muscle failure at 70% of 1RM.[291] Similar findings were observed when a slow eccentric phase of five and six seconds was combined with a slow concentric phase of three and four seconds, respectively, compared to a faster, two-second tempo.[293] A longer eccentric phase is also correlated to a lower 1RM weight that can be lifted due to time under tension – greater effort required over a longer period of time,[294,295] so it is important to consider tempo when determining repetition maximum or if the goal is to lift as much weight as possible.

- Position the eyes directly under the bar
- Adopt a grip between or beyond shoulder width that feels comfortable
- Keep the wrists erect and lift the bar off the support
- Bend the elbows and retract the shoulder blades as the bar is lowered to the chest (mid-sternum)
- Push the bar upward, away from the chest until the elbows are extended

Figure 9-44 *Bench press start position*

Figure 9-45 *Bench press end position*

CLOSE GRIP BENCH PRESS

The grip is considered narrow at 95–100% bi-acromial distance.[285,286,291] The narrow grip produces greater elbow flexion, and less shoulder extension and abduction. Force during the narrow version is directed more medially compared to normal and wide grip bench press.[286] Research suggests that a narrow grip results in increased peak power and velocity compared to a normal grip and therefore, may be used to develop power for activities where the arms remain close to the body (pushing, blocking, chest pass, etc.).[296,297]

- Position the hands on the bar in line with or slightly inward of the acromion process
- Bend the elbows and retract the shoulder blades as the bar is lowered to the chest (mid-sternum)
- Due to the grip, the elbows should remain close to the body
- Push the bar upward, away from the chest until the elbows are extended

Figure 9-46 *Close grip bench press start position. Note the grip distance compared to a regular bench press*

Figure 9-47 *Close grip bench press end position*

BENCH REDUCED RANGE OF MOTION

The theory of specificity states that in order to improve a specific skill, you must practice that skill. With that being said, if the aim is to improve range of motion within the bench press, it would be hypothesized that training in that troublesome range of motion would improve it and then potentially the overall bench press as a result. Unfortunately, this theory does not hold true when applied to the bench press. Training in a full range of motion not only produced greater neuromuscular improvements (1RM, mean propulsive velocity) in a full range of motion, but also produced greater gains when re-tested in partial ranges (two thirds and one third) when compared to the partial range of motion only groups.[298] If full range of motion training is better for strength development than reduced range of motion training, why use it? In a rehabilitation setting, an individual may not be able to perform a full range of motion bench press for a variety of reasons: pain at a specific point through the full range, restricted range of motion due to injury (e.g. shoulder dislocations with capsular repair, anterior instability, pectoralis major repair, etc.) or post-surgical protocol. A partial range can still produce strength gains within that specific range of motion, so it may be beneficial for someone who is physically not able to train within the full range, but must be progressed to full range training when able in order to maximize adaptations.

- Perform a bench press to a block placed on the chest or to crash bars set-up in a rack

Figure 9-48 *Reduced range of motion bench press start position*

Figure 9-49 *Reduced range of motion bench press end position*

PUSH-UPS

The push-up is a staple exercise in both basic and advanced strength training programs, exercise warm-ups, and high-intensity interval training. It is a bodyweight exercise that requires no equipment and has many modifications that can be used to increase or decrease difficulty. A traditional push-up requires an individual to support 69.16% of their body weight while ascending and 75.04% while descending.[299] The push-up test (repetitions to failure) is used as a measure of local muscular endurance and has been a recommended test by both the American College of Sports Medicine and National Strength and Conditioning Association for decades. Normative values based on age exist for push-up repetitions until failure for both men (standard push-up) and women (modified push-up performed on knees). The United States Army uses a two-minute push-up test as a measure of physical fitness. There is also evidence to support an inverse relationship of push-up capacity and cardiovascular related events. In the same study, firefighters able to complete more than 40 push-ups demonstrated a 96% reduction in cardiovascular related events compared with the group able to perform less than ten push-ups when measured over the course of ten years.[300]

A closed-chain exercise, the push-up often draws comparisons to the bench press, an open-chain exercise. The push-up and bench press consistently demonstrate comparable muscle activation of the pectoralis major and tricep brachii.[301–304] As load increases, increased muscle activation is required by pectoralis major, triceps, and anterior deltoid during the upward phase of the push-up and the biceps during the downward phase.[301–303] In comparison to the bench press, hand position during the push-up does significantly influence muscle activation. Narrow hand width push-ups produce greater muscle activation in the pectoralis major and triceps compared to standard (shoulder width) and wide hand grips (beyond shoulder width).[305–307] The narrow hand width is also preferred for activating the lower trapezius muscle.[308] A standard or wide hand width is preferred if the goal is to activate the serratus anterior.[305]

When using similar loads via band resistance, the push-up can produce similar increases in muscle strength compared to the bench press.[304] If an individual is unable to support their body weight to perform a regular push-up, the bench press, modified push-up on knees, or alternative push-up variations detailed below can be a substitute for building strength. The modified push-up only requires an individual to support 53.56% of their body weight while ascending and 61.80% while descending.[299] The research supports using the bench press and push-up interchangeably to build upper body strength.

- Position the hands at the desired width
  - Narrow (less than shoulder width) (see triceps, page 375)
  - Standard (shoulder width)
  - Wide (beyond shoulder width)
- Assume a high plank position with the body in a straight line
- Bend the elbows and lower the body to the floor
- Allow the shoulder blades to come together during the downward phase
- Avoid excessive extension in the lumbar spine or hips elevating up during the descent (Figure 9–52)
- Consider engaging the glutes and abdominals to maintain a rigid torso if needed
- Push through the upper body (as if pushing the floor away) during the upward phase
- The position of the arms will vary based on the hand width
  - For standard and wide grip push-ups, maintain a 45–60° angle of the shoulder (from neutral, arm at the side) during the lowering phase to avoid excessive external rotation torque (Figure 9–51)
  - For narrow grip push-ups, the arms will remain close to the side with the elbows tracking posteriorly

Figure 9-50 *Standard width grip start position*

Figure 9-51 *Standard width grip end position*

Figure 9-52 *Push-up fault – letting the hips sag*

Figure 9-53 *Push-up fault – excessively flaring the elbows*

WRIST PAIN DURING PUSH-UPS?

Wrist pain on the dorsal side of the wrist may occur if there is a limitation in wrist extension mobility, which may limit the performance of weight-bearing exercises like push-ups. There are a few simple methods that may alleviate pain and allow an individual with wrist pain to perform push-ups without issue. Place a folded towel just distal to the wrist and under the proximal portion of the hand to position the hand on a decline and thus reduce the amount of wrist extension that is required to perform the exercise from the floor. Use an elevated surface, like placing the hands on a box or exercise bench may also allow decreased range of motion, especially if the hands are positioned slightly anterior to the shoulder joint. Combining the elevated surface with the towel roll may also be appropriate. There is also the option to keep the wrist in neutral with no wrist extension. To do this, make a fist and weight bear on the knuckles instead of the palms while performing the push-up.

Figure 9-54 *Towel support to help decrease wrist extension range of motion*

Figure 9-55 *Knuckle push-ups with wrists in neutral*

BENCH PUSH-UP

The bench push-up increases the angle from the horizontal and therefore requires less body weight to be lifted during the movement. It is an alternative to the modified push-up on the knees for individuals that are unable to kneel or prefer to emulate regular push-up positioning.

- Assume a high plank position with the arms supported on a bench or elevated surface (mat, plyometric box, etc.)
- Bend the elbows and lower the chest to the bench
- Push through the upper body and extend the elbows as if pushing the bench away during the upward phase

Figure 9-56 *Bench push-up start position. Note the trunk angle*

Figure 9-57 *Bench push-up end position*

BAND RESISTED PUSH-UP

- Place a light to medium level resistance band around the upper back and secure the end under each hand
- Bend the elbows, lower the body to the floor, and allow the shoulder blades to come together
- Do not let the force of the band overpower the eccentric contraction during the lowering phase
- Push the floor away against the resistance of the band to return to the start point

Figure 9-58 *Band resisted push-up start position*

Figure 9-59 *Band resisted push-up end position*

SUSPENSION STRAP PUSH-UP

Suspension strap push-ups are a form of unstable surface training that increases muscle activation of the pectoralis major,[309,310] middle trapezius, rhomboids,[309] abdominals (rectus abdominis, obliques) and lower back muscles compared to regular floor push-ups.[309,310] Percentage of body weight and difficulty increases as the angle of the torso increases from vertical toward horizontal (180°).[311,312]

- Grasp the suspension straps and adopt a high plank position
- The straps should be taut
- Contract the abdominals and glutes
- Bend the elbows and lower the body down slowly to maintain stability
- Allow the shoulder blades to come together during the downward phase
- Push down through the straps evenly to return to the start position

Figure 9-60 *Suspension strap push-up start position*

Figure 9-61 *Suspension strap push-up end position*

ADDITIONAL CHEST EXERCISES

DUMBBELL ECCENTRIC CHEST FLY

The dumbbell fly produces similar muscle activation in the pectoralis major during the concentric phase and greater bicep activation during both the concentric and eccentric phases when compared to the bench press. During the lowering phase, the bench press elicits greater muscle activity in both the pectoralis major and triceps. The absolute load used during the dumbbell fly is significantly less than the bench press due to the longer moment arm and potentially from the increased stability requirement at the elbow joint from using dumbbells.[313] The dumbbell fly is therefore best used as an accessory exercise for pectoral and bicep muscle development.

- Use a flat bench with feet supported by the floor
- Press two dumbbells up to eye level
- Slowly lower the weights out to each side while maintaining a slight bend in the elbows
- Allow the shoulder blades to retract during the lowering phase
- Contract the pectorals and attempt to bring the biceps together (versus the hands) to return the weights to upright

Figure 9-62 *Dumbbell chest fly start position*

Figure 9-63 *Dumbbell chest fly end position*

CABLE OR RESISTANCE BAND CHEST FLY

If considering the anatomy of the chest, the low to high cable fly with the handles positioned low may bias the upper portion of the pectoralis (clavicular head). The muscle fibers of the upper pectoralis have a more vertical, superior-medial orientation and are more active in flexion based movements, like moving the cables from a lower to higher position. The muscle fiber orientation of the middle and lower portions of the pectoralis (sternal head) are horizontal and inferior-medial, so positioning the handles high and performing a high to low cable fly may activate these portions best.

- Set-up the cables to target the desired portion of the pectorals
- Stand in a split stance and tighten the abdominals for stability

- Keep a slight bend in the elbows with the palms facing forward
- Contract the pectorals to drive the biceps and hands toward each other in an arc type motion
- The wrists should face each other (regular chest fly), rotate upward (low to high) or downward (high to low) at end-range
- Keep the arms from extending beyond the shoulders during the eccentric phase

Figure 9-64 *Band chest fly start position*

Figure 9-65 *Band chest fly end position*

Figure 9-66 *Band chest fly low to high start position*

Figure 9-67 *Band chest fly low to high end position*

Figure 9-68 *Band chest fly high to low start position*

Figure 9-69 *Band chest fly high to low end position*

SINGLE-ARM HORIZONTAL ADDUCTION

- Position a cable column or resistance band at shoulder height with the palm facing midline
- There should be some tension in the cable or band
- Bring the arm across the body while maintaining a slight, but constant bend in the elbow
- Keep the arm from horizontally abducting 45° beyond neutral

Figure 9-70 *Single-arm horizontal adduction start position*

Figure 9-71 *Single-arm horizontal adduction end position*

LATISSIMUS DORSI

The latissimus dorsi is a very large muscle that spans the majority of the posterior trunk with attachment points to the spine, rib cage, shoulder, and pelvis via tendinous insertions and thoracolumbar fascia. It attaches to the intertubercular groove of the humerus between the pectoralis and teres major. The latissimus dorsi primarily functions to adduct, extend, and internally rotate the shoulder and it can also help depress the shoulder, rotate or laterally flex the trunk to the same side due to its attachment points. It appears to have the greatest moment arms for shoulder adduction and extension.[314]

PULL DOWNS AND PULL OVERS

Pull over and straight-arm pulldown exercises may be used to strengthen the latissimus dorsi and to provide a loaded stretch to improve overhead mobility. The eccentric portion of the contraction requires controlled lengthening under load followed by an end-range stretch, which the muscle must then overcome in order to complete the concentric portion of the contraction.

DUMBBELL PULL OVER

- Start in the supine position on a flat bench
- The feet can be in contact with the floor or supported on the bench with the knees bent
- Contract the abdominals and pull the rib cage down to ensure overhead range of motion is coming from the shoulder, not spinal extension and rib cage elevation
- Hold a dumbbell or kettlebell at chest to chin level
- If using a one dumbbell, the hands are placed in a diamond grip with the palms flat against the end of the weight
- If using two dumbbells, hold one in each hand using the hand grip
- If using a kettlebell, the bell is held parallel to the torso and either palming the sides of the bell or gripping each handle
- Maintain a soft elbow position without allowing the elbows to turn out
- Extended elbows may be uncomfortable and generate unnecessary stress on the elbow
- Excessive elbow flexion may shift some of the demand to the triceps
- Slowly lower the weight overhead, until a stretch is felt in the axilla or the back feels as if it is about to lift off the support surface
- Use the latissimus dorsi to pull the weight back up to the start position by leading with the elbows, not the hands

Figure 9-72 *Dumbbell pull over start position with single weight*

Figure 9-73 *Dumbbell pull over end position with single weight*

Figure 9-74 *Dumbbell pull over start position with weight in both hands*

Figure 9-75 *Dumbbell pull over end position with weight in both hands*

HOOK-LYING BAND PULL DOWN

The hook-lying band pull down is similar to the initial set-up of cable pull over, but in this exercise, the overhead stretch of the latissimus dorsi has been eliminated. This could serve as a substitute for a pullover in the event that overhead mobility is not tolerated or if the goal is to work on concentric activation of the latissimus dorsi and/or abdominals.

- Start in the supine position with the knees bent and feet in contact with the floor
- Position the shoulders in 90° flexion and choke up on or move away from the band until there is mild-moderate tension
- Grip the band with forearms pronated or neutral – use the hand position that produces the best "feel" with respect to muscle activation
- Contract the abdominals and pull the rib cage down
- Pull the band apart slightly and down toward the hips
- Return the arms to shoulder height in a controlled manner
- Maintain abdominal contraction throughout the pull and return

Figure 9-76 *Hook-lying band pull down start position*

Figure 9-77 *Hook-lying band pull down end position*

STRAIGHT-ARM PULL DOWN

The straight-arm pull down is performed with a set-up similar to the hinge pull down detailed in Chapter 6 (see page 76), but is executed with a more upright posture. Standing shoulder extension generates high levels of muscle activation for the latissimus dorsi at 64% MVIC.[55] In a small sample study, standing with the feet in a split stance versus a shoulder width or wider than shoulder width stance increased activation of the latissimus dorsi, potentially via contraction of the glute and tightening of the thoracolumbar fascia.[315]

- Grasp the band, cable, or bar with both hands at shoulder height
- Tighten the abdominals to limit accessory spinal motion
- Keep the arms straight and pull down toward the lateral hips (cable, band) or to the front of the torso (bar)
- Release and allow the arms to return to shoulder height

Figure 9-78 *Straight-arm pull down with band start position*

Figure 9-79 *Straight-arm pull down with band end position*

Figure 9-80 *Straight-arm pull down with rope start position*

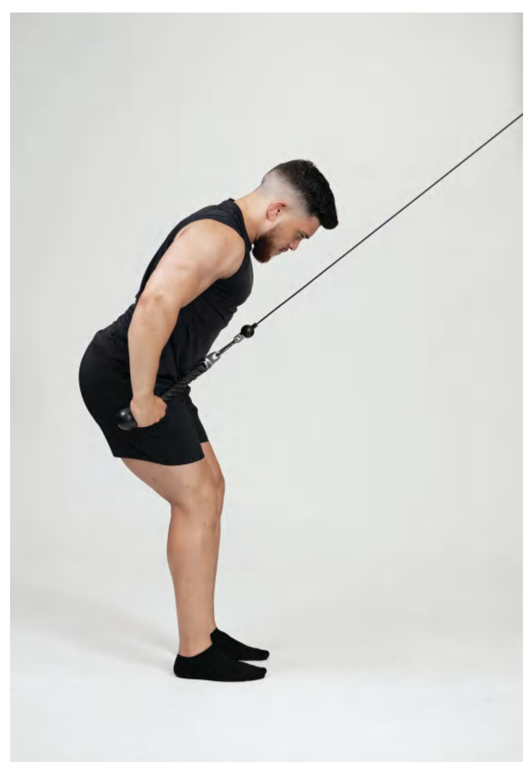

Figure 9-81 *Straight-arm pull down with rope end position*

PRONE SHOULDER EXTENSION

Prone extensions and chest-supported extensions on an incline bench require work from the latissimus dorsi, infraspinatus, teres minor and major muscles to lift the arm against gravity. Prone extension generates over 80% MVIC for the latissimus dorsi.[316,317] It also produces greater middle[55,318,319] and lower trapezius compared to upper trapezius activation.[318,319]

- Start on the stomach with the arm hanging over the mat, table, or bench
- Position the forehead on a towel roll or on top of the opposite hand for support
- Keep the elbow straight and lift the arm up and back until it is parallel with the torso
- Do not excessively retract the shoulder blade, but allow the shoulder blade to tilt backward with the arm
- Do not lift the arm far past the torso during the lift, as this may produce excessive scapula anterior tilt, and increase stress on the anterior shoulder

Figure 9-82 *Prone shoulder extension start position*

Figure 9-83 *Prone shoulder extension end position*

Figure 9-84 *Prone shoulder extension fault – excessive extension and anterior shoulder translation*

LAT PULL DOWN

The lat pull down can be executed using a pulldown bar, a machine, handles and other attachments, with a variety of different hand positions and grips: pronated (overhand), pronated wide grip, supinated (underhand), and narrow grip. The pull is performed from the overhead position to the chest. It is not uncommon to hear the narrative that the type of pull down variation used will dictate muscle activation. For example, the wide overhand grip pull down activates the latissimus dorsi to a greater extent, while the underhand pull down will increase activation of the biceps. This is not an absurd statement if you consider the biomechanics of each movement pattern and muscle actions, but the research available does not support it. Despite the assortment of pull downs to choose from, they all appear to activate the latissimus dorsi and biceps similarly.[320–322] There is only low-quality evidence that supports an overhand versus underhand grip to maximize latissimus dorsi activation when comparing both wide and narrow grip widths.[323] Therefore, the variation selected can depend on available equipment, skill level, form maintenance, and an individual's ability to feel the target muscle activate maximally.

- Grasp the bar or handles as pictured with respect to the desired variation
- Pull the bar to the sternum

During the overhand variations:

- The palms should face directly forward or angle upward slightly
- Do not allow the palms to rotate down to the floor – this will cause the shoulders internally rotate, which may reduce latissimus dorsi engagement and impinge on the superior shoulder (Figure 9–87)

During the underhand and neutral grip variations:

- Attempt to keep the elbows close to the sides of the torso during the pull
- Do not let the elbows extend beyond the torso significantly
- Control the upward momentum of the bar off the chest
- Do not hold the shoulders down and back – allow the shoulder blades to rotate upward, let the weight provide slight traction on the shoulders and a stretch to the latissimus dorsi (to be felt under the axilla) at end-range

Figure 9-85 *Overhand wide grip lat pull down start position*

Figure 9-86 *Overhand wide grip lat pull down end position*

Figure 9-87 *Lat pull down fault – palms rotate toward floor*

Figure 9-88 *Overhand grip lat pull down start position*

Figure 9-89 *Overhand grip lat pull down end position*

Figure 9-90 *Underhand grip lat pull down start position*

Figure 9-91 *Underhand grip lat pull down end position*

Figure 9-92 *Neutral grip lat pull down start position*

Figure 9-93 *Neutral grip lat pull down end position*

SINGLE-ARM CABLE LAT PULL DOWN

If the goal is to avoid unilateral compensation during a bilateral exercise or to mimic the demands of unilateral pulling movements, train specifically with a unilateral pull down. This can also be performed with a neutral, supinated (underhand), or pronated (overhand) grip.

- Set the cable high and position the body in line with or slightly in front of the handle
- A seated, kneeling, or half kneeling position can be used

Neutral grip:

- Grasp the handle with the palm facing midline
- Pull the elbow down to the side until the upper arm is parallel with the torso

Underhand grip:

- Grasp the handle with the palm facing the body
- Pull the elbow down to the side until the upper arm is parallel with the torso

Overhand grip:

- Grasp the handle with the palm facing away from the body
- Pull the elbow down to the side without letting the elbow or forearm travel inward
- Control the upward momentum of the cable
- Do not hold the shoulders down and back – allow the shoulder blades to rotate upward, let the weight provide slight traction on the shoulder and a stretch to the latissimus dorsi (to be felt under the axilla) at end-range

Figure 9-94 *Neutral grip single-arm lat pull down start position*

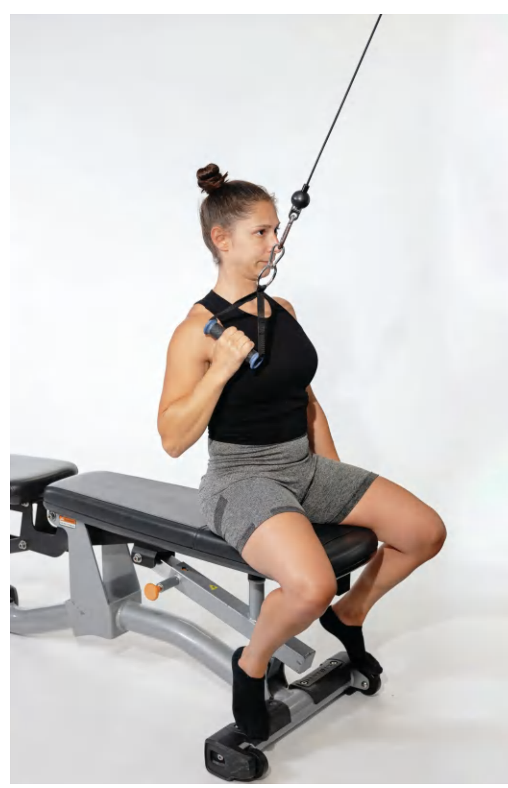

Figure 9-95 *Neutral grip single-arm lat pull down end position*

Figure 9-96 *Underhand grip single-arm lat pull down start position*

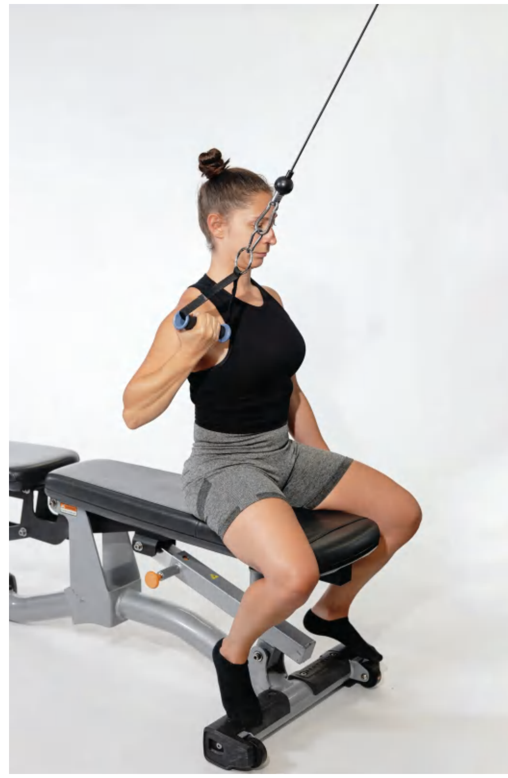

Figure 9-97 *Underhand grip single-arm lat pull down end position*

Figure 9-98 *Overhand grip single-arm lat pull down start position*

Figure 9-99 *Overhand grip single-arm lat pull down end position*

PULL-UP

Similar to the push-up, the pull-up is a bodyweight exercise that is used as a measure of muscular endurance and physical fitness. The ability to perform a greater number of pull-ups is correlated with better performance on tactical assessments of police officers and those in the armed forces.[324–326] Individuals that use a self-paced cadence[327] and those that have lower body mass[328,329] perform a greater number of maximal pull-ups than their counterparts do. Pull-up velocity (speed) and power (force × velocity) have been correlated to a higher level of swimming performance. Interestingly, unlike tactical performance, swimming performance is not correlated to the total amount of pull-ups performed.[330] Although a link between number of pull-ups was not found to have a significant effect on swimming performance, there is a strong linear relationship between velocity of one pull-up and amount of maximal repetitions completed in a set to failure using a regression analysis. This means that the faster an individual can perform one single repetition, the better they will likely perform on a maximal pull-up test.[331] Compared to the chin-up, the pull-up activates the lower trapezius to a greater extent and also produces large EMG values for the latissimus dorsi (greater than 100% MVIC), infraspinatus (greater than 70% MVIC), and lower trapezius (greater than 50% MVIC).[332] In order, from the start to end of the pull phase, the muscles activated are the lower trapezius, pectoralis major, erector spinae, infraspinatus, biceps, external oblique, and latissimus dorsi.[332]

HOLLOW BODY HANG

The hollow body position during a pull-up promotes abdominal muscle engagement, positions the rib cage over the pelvis, and will discourage excessive lumbar spine extension. It can be used as both a shoulder stability and core exercise.

- Grasp the bar with a pronated grip in a dead hang position
- Pull the shoulder blades down to activate the latissimus dorsi and "pack" the shoulders
- Contract the abdominals, pull the rib cage down, and angle the legs so the feet are positioned in front of the torso in order to create a slight "C" shape from the head to the feet
- Maintain this position for a timed hold

Figure 9-100 *Hollow body position*

REGULAR PULL-UP

- Grasp the bar with a pronated grip in a dead hang position
- Pack the shoulders by pulling up on the bar and depressing the scapulae (see scapular pull-ups, page 297)
- Use the hollow body position (Figure 9–100) to engage the abdominals or simply flex the knees to position the lower legs behind if a more extended back position is desired (Figure 9–103)
- Pull the elbows down toward the sides
- Pull the chest to the bar
- Lower down under control

Figure 9-101 *Pull-up start position*

Figure 9-102 *Pull-up end position*

Figure 9-103 *Pull-up with knees flexed*

KNEELING REDUCED RANGE OF MOTION PULL-UP

The kneeling pull-up is performed from the knees with a bar set to a lower height (e.g. smith machine, squat rack) to limit the amount of available range of motion, stretch on the latissimus dorsi, traction on the shoulder joint, and to reduce the overall body weight that must be lifted and lowered. This could be a lead-up exercise to a pull-up for an individual who is unable to perform a full bodyweight pull-up or a modification for an individual that has pain during the eccentric portion or with tractioning of the shoulder.

- Set the bar at a height that will allow the elbows to be fully extended with the hands gripping the bar
- Set-up under the bar in a tall kneeling position
- Pull the chest to the bar
- Slowly lower until knees are on the floor (dead stop)

Figure 9-104 *Kneeling pull-up start position*

Figure 9-105 *Kneeling pull-up end position*

STRAIGHT-LEG REDUCED RANGE OF MOTION PULL-UP

Similar to the kneeling pull-up, this assisted pull-up variation decreases the amount of body weight that must be lifted and allows the lower extremities to provide some assistance to complete the movement. If the legs are positioned on the floor, it will be less difficult than if the feet are positioned up on a bench, as the latter will allow an increased range of motion compared to the former.

- Set the bar at a height that will allow the elbows to be extended fully with the hands gripping the bar
- Set-up under the bar with the legs straight and heels rested on the floor (easier) or up on a bench (more difficult)
- Pull the chest to the bar
- Slowly lower until the elbows are fully extended

Figure 9-106 *Straight-leg pull-up start position*

Figure 9-107 *Straight-leg pull-up end position*

SCAPULAR-ONLY PULL-UPS

The goal of this exercise is to teach how to pack the shoulders prior to the pull and to encourage elevation and upward rotation of the scapulae during the lowering phase. It can be used as a lead-up exercise to pull-ups by building shoulder strength and stability in the bottom position when the concentric portion of the pull is still too challenging. It can also be used as an accessory movement for controlled mobility of the scapulae or for mobility due to the lengthening of the latissimus dorsi that occurs during the dead hang. The lower trapezius activates first during the pull-up,[332] so it is the first, and likely one of the primary, muscle activated during the concentric portion of the scapular pull-up.

- Grasp the bar in a dead hang position
- Activate the lower trapezius (and likely latissimus dorsi) by pulling up on the bar and depressing the scapulae
- The elbows remain straight, but the head will rise slightly when the shoulder blades are packed
- Slowly release and allow the shoulder blades to elevate and upwardly rotate

Figure 9-108 *Scapular-only pull-up start position*

Figure 9-109 *Scapular-only pull-up end position (scapular depression)*

PULL-UP ECCENTRICS

The concentric portion of the pull-up requires the full weight of the body to be lifted against gravity while also overcoming a full stretch on the latissimus dorsi. Therefore, it is often difficult for a novice to complete a regular pull-up, especially if they lack upper body strength. The eccentric pull-up helps build strength and control throughout a full range of motion using time under tension.

- Stand on a chair, plyometric box, bench, or a surface high enough to bring the body up as close as possible to the bar
- Grasp the bar and start with the elbows bent and chest to the bar
- Hold the top position for about two to three seconds
- Slowly lower down for at least three seconds until reaching a dead hang
- Step back onto the chair, plyometric box, bench, etc. and repeat

BAND ASSISTED PULL-UP

The band assisted pull-up provides support in the bottom position where tension on the band is the greatest to assist the first phase of the pull. This assistance decreases the amount of body weight that must be lifted and allows greater focus on the middle and end phase of the pull. The band can be secured under both feet or under one foot as pictured. The sequence is the same as the regular pull-up.

Figure 9-110 *Band assisted pull-up start position*

Figure 9-111 *Band assisted pull-up end position*

CHIN-UP

The chin-up is performed with a supinated grip and requires a greater amount of elbow joint range of motion compared to the pull-up. The chin-up activates the latissimus dorsi to the same extent as the pull-up, but produces greater pectoralis major and biceps activity[332] and potentially increased loading of the deltoid and rotator cuff muscles.[333] This variation can also be used as a substitute for a regular pull-up if an individual lacks shoulder abduction and external rotation range of motion.

- Grasp the bar with a supinated grip
- Pull up as the elbows drive down toward the sides
- Avoid driving the elbows backward and far beyond the torso during the pull
- Pull the chest to the bar
- Lower down under control

Figure 9-112 *Chin-up start position*

Figure 9-113 *Chin-up end position*

NEUTRAL GRIP PULL-UP

Similar to the chin-up, the neutral grip pull-up can be used to limit shoulder external rotation and abduction range of motion because the arms remain tight to the sides of the torso during the pull. Unlike the chin-up, it does not require full elbow supination. Many pull-up bars have a neutral grip attachment or specialized grips can be used.

- Grasp the bar with the palms facing each other
- Pack the shoulders by pulling up on the bar and depressing the scapulae
- Pull up as the elbows drive down toward the sides
- Avoid driving the elbows backward and far beyond the torso during the pull
- Pull the chest to the bar
- Slowly lower down to a dead hang

Figure 9-114 *Neutral grip pull-up start position. Use a neutral grip pull-up bar or handle attachments*

Figure 9-115 *Neutral grip pull-up end position*

ROWS

Rowing exercises target many muscles in the posterior trunk, including the latissimus dorsi, erector spinae, infraspinatus, teres major and minor, trapezius (upper, middle, lower), rhomboids, middle and posterior deltoids. Recruitment patterns indicate the latissimus dorsi is active to a greater extent than the rest of the supporting muscles at 50–80% MVIC during row variations.[334,335] In addition to strengthening the latissimus dorsi, free weight or barbell rowing exercises can be used to effectively train the lower back. Bent over rows, for example, generate greater muscle EMG activation of the erector spinae and multifidus compared to rows performed on a seated row machine, likely due to a smaller base of support, increased lumbar spine torque and muscle activity required to maintain a standing posture.[336] Bent over rows generate higher compressive forces on the spine and spinal flexion (3,576 N) compared to cable (2,457 N) and inverted rows (2,339 N).[335] Therefore, free weight and barbell rows may be utilized if the goal is to increase activation and concurrently train the lumbar erectors, but can also be substituted for an inverted row, machine, or chest-supported variation if training around a lower back injury or if the goal is to reduce lumbar spine load. In general, bilateral bent over rows will generate greater muscle EMG activation compared to unilateral rows due to the ability to lift heavier loads.[336] However, unilateral rows generate increased external oblique activation to control for trunk rotation[336] and may be beneficial if the goal is to train rotatory core stability.

A few common faults during the row are pinning the shoulder down and back throughout the movement and pulling the elbow too far past the torso. It is normal for the scapula to retract during the pull (concentric phase), but scapular protraction and upward rotation are essential to promote normal glenohumeral biomechanics during forward reaching (eccentric phase). The row should be performed to a range of slight shoulder extension, but extending the elbow well beyond the torso can result in excessive anterior shoulder displacement and scapula anterior tilt, which may create increased stress on the shoulder and/or recruit different muscles. If the olecranon is pointed toward the ceiling instead of posteriorly, the range of motion is too great. The row is a common exercise used for upper back muscle development, but there are minimal high-quality research studies evaluating their effectiveness, specifically those comparing the many variations and grips used.

Figure 9-116 *Row fault – Excessive shoulder extension and anterior shoulder translation*

Figure 9-117 *Bent over row fault – Excessive shoulder extension and anterior shoulder translation*

SEATED CABLE ROW

Seated cable rows can be performed with multiple grips (neutral, overhand, underhand) and attachments. As previously mentioned, there is no research that supports the type of grip, width, or attachment as superior, so the variation used can be based on clinician and patient preference and/or which enhances an individual's ability to feel the target muscle activate maximally.

- Utilize a seated row machine with footplates or secure the feet to the floor while sitting on a stable bench or chair
- Grasp the desired hand grip attachments (handles, straight bar, V-bar, etc.)
- Pull backward until the upper arms and elbows are in line with the side of the torso
- Release the pull and allow the shoulder blades to protract
- At end-range, allow the weight or resistance to traction the arm(s) to provide a stretch on the latissimus dorsi
- In the event of a rotator cuff strain, tractioning of the arms should be performed carefully and should not exacerbate pain

Figure 9-118 *Seated row neutral grip start position*

Figure 9-119 *Seated row neutral grip end position*

Figure 9-120 *Seated row overhand grip start position*

Figure 9-121 *Seated row overhand grip end position*

Figure 9-122 *Seated row underhand grip start position*

Figure 9-123 *Seated row underhand grip end position*

BENCH SUPPORTED DUMBBELL ROW

- Set the incline bench to about 30°
- Rest the chest on the bench
- The knees can be either straight or bent with the balls of the feet on the floor
- Pull back and up until the elbows are in line with the side of the torso without lifting the chest from the bench

Figure 9-124 *Bench supported row start position*

Figure 9-125 *Bench supported row end position*

STANDING SINGLE-ARM ROW WITH BAND OR CABLE

Unilateral rows in standing require increased stability. They can be performed with a band or cable column. Bands come in many levels of resistance, are easy to set-up, and are less expensive than a cable column. A cable column, on the other hand, will provide a tractioning force and stretch on the latissimus dorsi and posterior shoulder muscles at end-range during the lengthening phase. The resistance on the band is lessened during the eccentric phase, so it can't provide this effect.

- Stand in a split stance
- Position the leg on the opposite side of the target arm in front
- Grasp the handle and pull the arm back and toward the side of the body
- Let the elbow extend and allow the shoulder blade to protract

Figure 9-126 *Standing single-arm row start position*

Figure 9-127 *Standing single-arm row end position*

SINGLE-ARM DUMBBELL ROW

- Support the opposite arm and leg on a bench with the arm outstretched and knee bent
- An alternative start position is in standing, knees bent with the opposite arm outstretched and supported on a bench or dumbbell rack
- Pull the elbow up and back toward the back pants pocket
- Release the pull and allow the shoulder blade to protract as the weight is lowered
- The weight can traction the arm to provide a stretch on the latissimus dorsi at end-range
- Attach a band to the dumbbell (Figure 9–130) to train the rowing motion, encourage shoulder extension, and enhance the "feel" of latissimus dorsi muscle activation

Figure 9-128 *Single-arm dumbbell row start position*

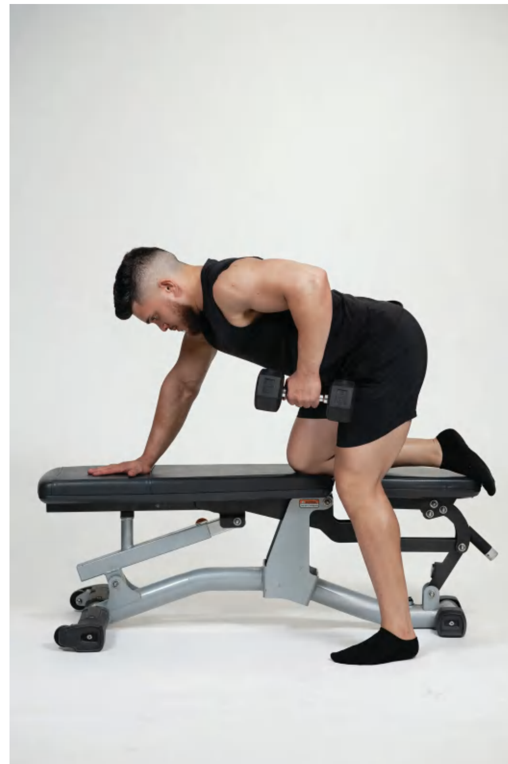

Figure 9-129 *Single-arm dumbbell row end position*

Figure 9-130 *Band attachment*

BARBELL BENT OVER ROW

The barbell row is performed using either a supinated (underhand) or pronated (overhand) grip. A simple web search returns an overwhelming amount of support for the use of the underhand row to target the lower portion of the latissimus dorsi and overhand row to target the muscles of the upper back. A likely explanation for this is that maintaining the arms closer to the body during the underhand row requires a greater amount of shoulder adduction, one of the primary actions of the latissimus dorsi. The overhand row requires a greater amount of shoulder abduction during the pull, as the elbows are further from the torso, which may activate the lower portion of the latissimus dorsi, rhomboids, middle trapezius, and posterior deltoids to a greater extent. There is no scientific evidence to support these claims and therefore, the grip used should be based on which is most comfortable and enhances an individual's ability to feel the target muscle activate maximally. The bent over row produces increased lumbar spine loads[335] and increased EMG activation of the erector spinae compared to other row variations[336,337] and therefore may not be appropriate in the earlier phases of lower back rehabilitation.

- Lift the barbell from a rack or floor using the desired grip
- Hinge at the hips and slide the barbell down the front of the thighs until at or just above knee level
  - If using an overhand grip, the torso should be more parallel to the floor (Figure 9–131) than when using the underhand grip (Figure 9–134)
- The knees should remain soft
- Contract the abdominals to maintain neutral spine or slight lumbar extension
- Retract the shoulder blades during the pull
- If using a pronated grip, pull the bar up to the upper abdomen and flare the elbows slightly
- If using a supinated grip, pull the bar up to the lower abdomen and keep the elbows tighter to the torso
- Release the pull and allow the shoulder blades to protract as the weight is lowered

Figure 9-131 *Barbell row overhand grip start position*

Figure 9-132 *Barbell row overhand grip end position*

Figure 9-133 *Barbell row underhand grip start position*

Figure 9-134 *Barbell row underhand grip end position*

DUMBBELL BENT OVER ROW

- Perform with the same technique as the barbell bent over row

BARBELL PENDLAY ROW

The Pendlay row combines an overhand barbell row with the conventional deadlift set-up (see page 97). The pull occurs from the floor, which eliminates use of momentum, the stretch-shortening cycle, and focuses more on the concentric portion of the contraction when compared to the barbell row. The plates can be placed on risers, similar to the rack pull (see page 94), in order to reduce range of motion if an individual has difficulty getting into the start position due to decreased hip mobility, hamstring flexibility, increased thoracic kyphosis, taller height, etc.

- Stand with the bar touching the shins
- Perform a hip hinge with a slight knee bend
- Grasp the bar outside of the knees using an overhand grip
- Pull up on the bar and raise the hips slightly to take the slack out of the bar
- The torso should remain almost parallel with the floor
- The buttocks should remain even with or below the level of the chest
- Pull the bar from the floor toward the lower portion of the chest and sternum while maintaining the position of the torso

Figure 9-135 *Barbell Pendlay row start position*

Figure 9-136 *Barbell Pendlay row end position*

MODIFIED PENDLAY ROW WITH KETTLEBELLS

Figure 9-137 *Kettlebell Pendlay row start position*

Figure 9-138 *Kettlebell Pendlay row end position*

SUSPENSION STRAP ROW

The suspension strap row uses a percentage of body weight for resistance. The amount of resistance increases when the torso is positioned parallel to the ground and decreases when positioned more upright. If we consider the vertical upright position, an individual will be required to lift about 37% of their body mass at 30°, 53% at 45°, 68% at 60 degrees, and 79% at 75°.[338] A systematic review determined that muscle activation of the latissimus dorsi, middle trapezius, posterior deltoid, and biceps brachii are very high at greater than 60% MVIC for all muscle groups during the suspension strap row.[310] Muscle activation also appears to be higher in the middle deltoid, obliques, and rectus abdominis when using the suspension strap row compared to the inverted row.[309] Increased abdominal muscle activation may be due to the instability created by the suspension straps.

The exercise can be performed as a "low" row with the shoulders at 0° (arms at sides), at 45° of abduction, or as a "high" row with the shoulders at 90° of abduction at the end of the concentric phase. A lower quality research study found that the high row variation appears to generate very high levels (greater than 60% MVIC) of muscle EMG activity in the upper, middle, and lower trapezius and posterior deltoid as well as high (40–60% MVIC) muscle EMG activity of the upper erector spinae. The low row, on the other hand, generated higher levels of latissimus dorsi activation.[339] Based on this research, low rows may be better to target the latissimus dorsi while high rows will engage other muscles of the upper back to a greater extent. Low rows also have lower upper to middle trapezius and upper to lower trapezius recruitment ratios compared to high rows[339] and therefore may be a better option for individuals with subacromial impingement, impaired glenohumeral or scapulothoracic mechanics, or those seeking to develop strength and greater balance of the scapula stabilizers prior to progressing to more advanced exercises.

- Position the body at the desired angle with the slack taken out of the straps
- Maintain weight on the heels
- The body should be in a straight line from the head to the feet

SUSPENSION STRAP LOW ROW

- Pull the arms toward the sides of the body
- The arms should remain close to the sides (neutral) or at a 45° angle of shoulder abduction
- The palms face each other upon completion of the pull
- Let the shoulder blades protract, arms straighten out, and lower the body back to the start point

Figure 9-139 *Suspension strap low row start position*

Figure 9-140 *Suspension strap low row end position*

SUSPENSION STRAP HIGH ROW

- Retract the shoulders, pull the straps apart and arms back
- The shoulders should be at 90° abduction and neutral rotation
- Keep the elbows level with the wrists throughout the pull
- The palms face down upon completion of the pull
- Let the shoulder blades protract, arms straighten out, and lower the body back to the start point

Figure 9-141 *Suspension strap high row start position*

Figure 9-142 *Suspension strap high row end position*

SUSPENSION STRAP UNDERHAND ROW

- Pull the arms toward the sides of the body
- The arms should remain close to the sides (neutral) or at a 45° angle of shoulder abduction
- The palms face up upon completion of the pull
- Let the shoulder blades protract, arms straighten out, and lower the body back to the start point

Figure 9-143 *Suspension strap underhand row start position*

Figure 9-144 *Suspension strap underhand row end position*

INVERTED ROW

The inverted row is performed using a fixed surface (barbell or smith machine). This exercise appears to activate the upper back to a greater extent than horizontal rows.[340] It generates very high (greater than 60% MVIC) muscle EMG activity for the posterior deltoid, latissimus dorsi, biceps, upper and middle trapezius and high (40–60%) muscle EMG activity for the lower trapezius, serratus anterior, lumbar multifidus, lumbar, and thoracic paraspinals.[341] An overhand or underhand grip position can be used. In general, the overhand grip mimics the position of a high row, while the underhand position resembles the low row due to the arms remaining closer to the sides at the end-range concentric phase; both variations were detailed previously. The underhand grip generates increased latissimus dorsi muscle activation, which was statistically significant when compared to the overhand grip[342] and is similar to the patterns observed during suspension strap rows. The inverted row may also have good utility to improve and maintain strength of back muscles when other exercises like deadlifts, bent over row, squats, back extensions, etc. are not tolerated. It can also serve as an accessory exercise in a back rehabilitation program due to its ability to target the involved musculature with less compressive and shear forces than other exercises like pull-ups, chin-ups,[343] or bent over rows.[335]

- Set a barbell or smith machine at the desired height, grasp the bar and walk the feet forward until at the desired angle

  - The difficulty increases with the bar set at a lower height and the torso more parallel to the floor
  - The difficulty decreases with the bar at a higher height and torso more vertical (e.g. use of a 45° angle)
- Maintain body weight on the heels and let the elbows extend straight
- Achieve a rigid torso that is in a straight line from the head to the feet

Figure 9-145 *Inverted row overhand grip start position*

Figure 9-146 *Inverted row overhand grip end position*

Figure 9-147 *Inverted row underhand grip start position*

Figure 9-148 *Inverted row underhand grip end position*

DELTOIDS

The deltoid group is made up of three separate muscles: anterior, middle, and posterior deltoid. All deltoid muscles act to elevate the humerus[314] and are very active in overhead pressing.[56] The anterior deltoid is the prime mover of shoulder flexion, while the middle deltoid performs shoulder abduction with the assistance of the rotator cuff (supraspinatus). The posterior deltoid has multiple functions and acts to horizontally abduct, extend, and externally rotate the shoulder. The deltoids, with the help of the shoulder ligaments and rotator cuff muscles, participate in providing stability about the glenohumeral joint complex. It is important to develop a balance between the deltoids, humeral depressors and rotators for optimal shoulder function.

SHOULDER FLEXION

DELTOID "HOVERS"

In the presence of a rotator cuff tear or shoulder joint impingement, lifting the arm overhead can be painful or accompanied by aberrant shoulder movement. Hovers use a small total range of motion to build strength and stability within a specific range. They also are likely to require less demand on the supraspinatus, which is more active during the earlier phase of abduction compared to the anterior and middle deltoids who peak later during the abduction movement.[314] This may be beneficial to help increase or maintain anterior and middle deltoid strength in the presence of a supraspinatus injury.

- Rest the arm on a stable surface at the desired height
- Keep the elbow straight and lift the arm up and over a small object
- This can be performed in a flexion or abduction pattern

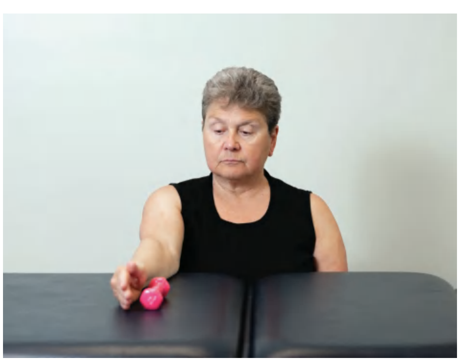

Figure 9-149 *Deltoid hover start position*

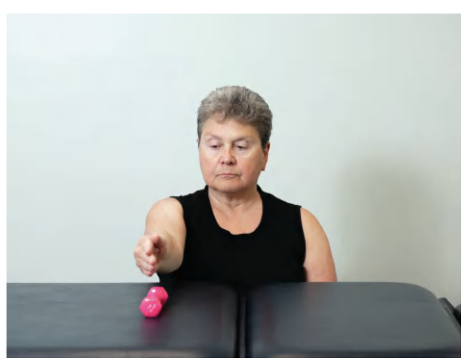

Figure 9-150 *Hover*

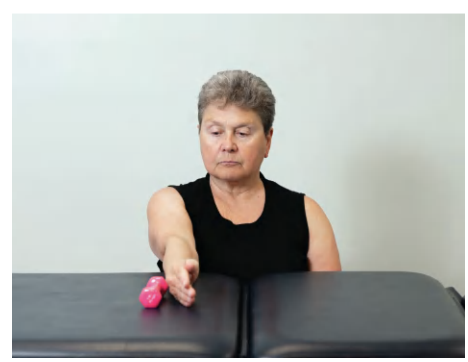

Figure 9-151 *Deltoid hover end position*

Supine flexion patterns are gravity minimized movements, which may be easier to perform than seated or standing variations in the setting of muscle weakness and atrophy and can serve as an entry point for strengthening through the full range of motion and overhead.

SUPINE BAND FLEXION

- Secure a band to the hip/pelvis area using the opposite arm
- Keep the elbow straight and lift the arm overhead while maintaining the arm in close proximity to the ear
- The hand position can be adjusted based on comfort to either palm down (not thumb down) or thumb up (neutral)

Figure 9-152 *Band secured to opposite hip*

Figure 9-153 *Band flexion end position*

SUPINE CABLE FLEXION

- Bend the knees with the feet secured flat on the floor for stability
- Use a rope attachment and grasp it between the legs
- Keep the elbows straight or soft and lift the arms up overhead
- Do not bend the elbows at the top of the motion, as this will engage the bicep
- Lower down to a minimum of 45° of shoulder flexion after each repetition in order to maintain time under tension

Figure 9-154 *Supine cable flexion start position*

Figure 9-155 *Supine cable flexion end position*

SUPINE OVERHEAD PRESS WITH BAND

- Loop a circular resistance band around the feet
- Hold the band with the elbows bent and palms facing forward (thumbs in) or palms facing each other (thumbs up)
- Press the band up overhead until the elbows are extended
- Maintain the arms in close proximity to the ears during the press

Figure 9-156 *Band overhead press start position*

Figure 9-157 *Band overhead press end position*

SEATED MINI BAND FLEXION

Use of a mini band may encourage increased activation of external rotators during a flexion movement. The external rotators are important to provide an inferior glide on the humeral head during overhead mobility and activation of these muscles during flexion may help to reduce or eliminate pinching that may be experienced at the middle- or end-range of motion.

- Place a mini band around the wrists with the thumbs facing up
- Pull the arms apart to create tension on the band until the wrists are in line with the shoulder joint
- Lift the arms up overhead and lower down while maintaining the same tension on the band throughout
- Hold dumbbells in each hand to increase difficulty

Figure 9-158 *Mini band flexion start position*

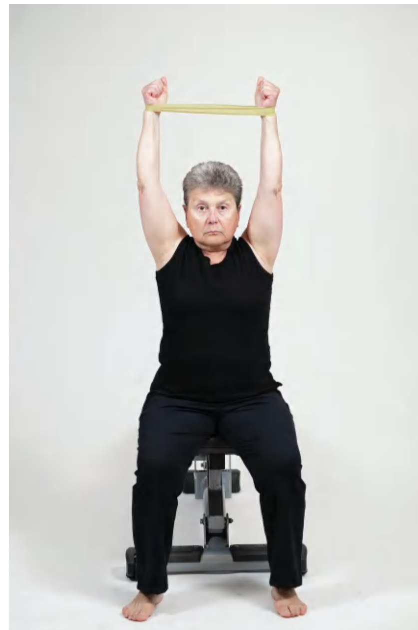

Figure 9-159 *Mini band flexion end position*

BENCH SUPPORTED FLEXION

A standing front raise will target the beginning to mid-range of the flexion movement. The bench offers an alternative angle at which to perform the front raise and focuses primarily on the mid- to end-range of motion. The bench allows the torso to remain supported throughout the movement.

- Set the bench at a 45° incline with the chest and stomach supported and feet in contact with floor
- Contract the abdominals for stability to reduce compensatory spine movement
- Keep the elbows straight and lift the arms up

Figure 9-160 *Bench supported flexion start position*

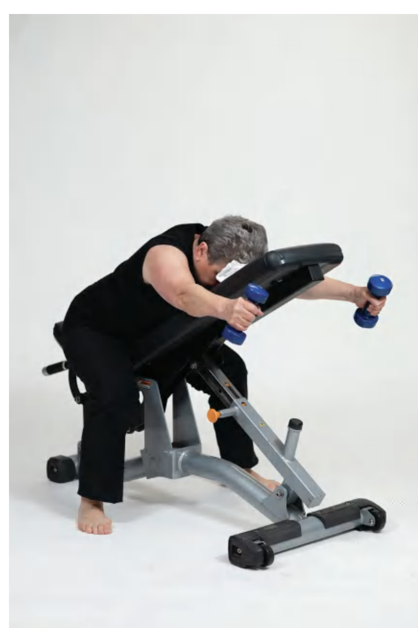

Figure 9-161 *Bench supported flexion end position*

INCLINE BENCH FLEXION

In the seated position, use of the incline bench can change the effect that gravity has on the arm during the elevation phase. It may provide a reduced challenge against gravity during the beginning to mid-range of motion (when compared to shoulder elevation with the torso positioned upright) and assistance from gravity past the middle until the end-range of motion.

- Set the bench at a 45–60° incline
- Keep the elbows straight and lift the arms up overhead
- Allow the arms to stretch overhead at the end-range
- Lower back to the starting point

Figure 9-162 *Incline bench flexion start position*

Figure 9-163 *Incline bench flexion end position*

KETTLEBELL BOTTOM-UP CARRY

The bottom-up kettlebell carry is an isometric exercise that primarily targets the deltoids and serratus anterior,[344] but has the potential to generate co-contraction of the rotator cuff due to the unstable nature of the load. The exercise can be performed in multiple positions: overhead, 90° of shoulder and elbow flexion, 90° of shoulder flexion and 45° of external rotation (scaption), 90° of shoulder flexion and external rotation.

- Position the kettlebell upside down
- Grasp the handle with a straight wrist
- Perform a static isometric hold or walk forward while maintaining the position

KETTLEBELL BOTTOM-UP CARRY IN NEUTRAL (90° OF SHOULDER FLEXION)

- Position the shoulder in 90° of flexion and no rotation
- Keep the elbow bent with the wrist stacked over the elbow joint
- Do not let the shoulder rotate internally or externally while holding the weight
- Do not let the elbow fall below the level of the shoulder joint

KETTLEBELL BOTTOM-UP CARRY IN SCAPULAR PLANE

- Position the shoulder in 90° of flexion with 0° rotation, then move the upper arm laterally until it is at a 45° angle from neutral
- Keep the elbow bent with the wrist stacked over the elbow joint
- Do not let the shoulder rotate internally or externally while holding the weight
- Do not let the elbow fall below the level of the shoulder joint

KETTLEBELL BOTTOM-UP CARRY IN 90° ABDUCTION AND EXTERNAL ROTATION

- Position the shoulder in 90° of flexion with no rotation, then move the upper arm laterally until it is at a 90° angle from neutral
- Use the muscles surrounding the shoulder to "center" the humeral head within the glenoid socket to maintain stability
- Keep the elbow bent with the wrist stacked over the elbow joint
- Do not let the shoulder rotate internally or externally while holding the weight
- Do not let the elbow fall below the level of the shoulder joint

Figure 9-164 *90° shoulder flexion bottom-up carry*

Figure 9-165 *Scapular plane bottom-up carry*

Figure 9-166 *90° shoulder abduction and external rotation bottom-up carry*

OVERHEAD KETTLEBELL BOTTOM-UP CARRY

- Press the kettlebell up overhead as if pushing the ceiling away
- Keep the elbow straight
- The weight of the kettlebell and wrist should be stacked over the shoulder at all times

Figure 9-167 *Overhead bottom-up carry*

OVERHEAD PRESSING

LANDMINE PRESS

The anterior deltoid muscle is very active during shoulder flexion above 120° and overhead pressing exercises, like the military press.[55] However, it may be difficult to perform overhead lifts in the presence of shoulder impingement, instability, tendinopathy, and/or rotator cuff pathology. The landmine press is performed in a modified range of motion to build strength and/or to prevent strength loss while training through an injury that may limit lifting weight directly overhead. The upward pressing motion may also encourage scapular upward rotation and protraction, one of the functions of the serratus anterior.

- Use a landmine attachment or position the end of the barbell in the corner of a wall
- Grasp the end of the barbell with the elbow bent
- Press the barbell forward and up into a modified overhead position
- Keep the elbow close to the body during the lowering phase
- Do not let the elbow pass the torso at the end of the lowering phase
- Perform a forward punch at end-range to activate the serratus anterior (optional, see page 361)
- This exercise can be performed in tall kneeling (Figures 9–168 and 9–169), half kneeling, or standing

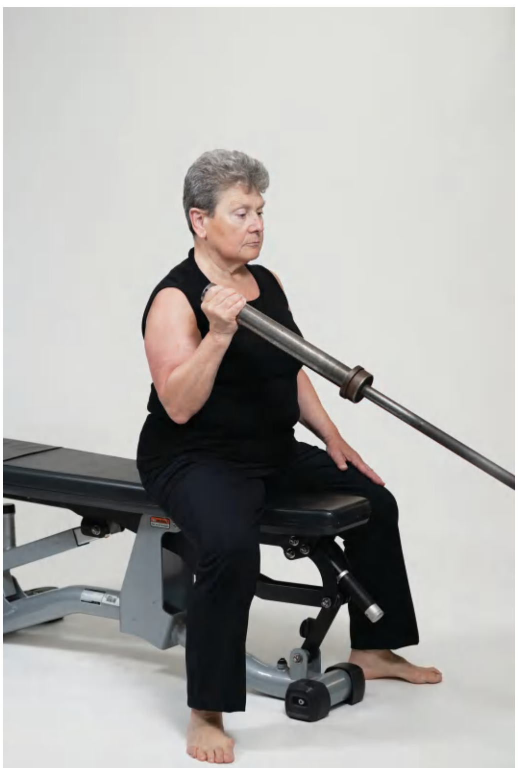

Figure 9-168 *Landmine press start position*

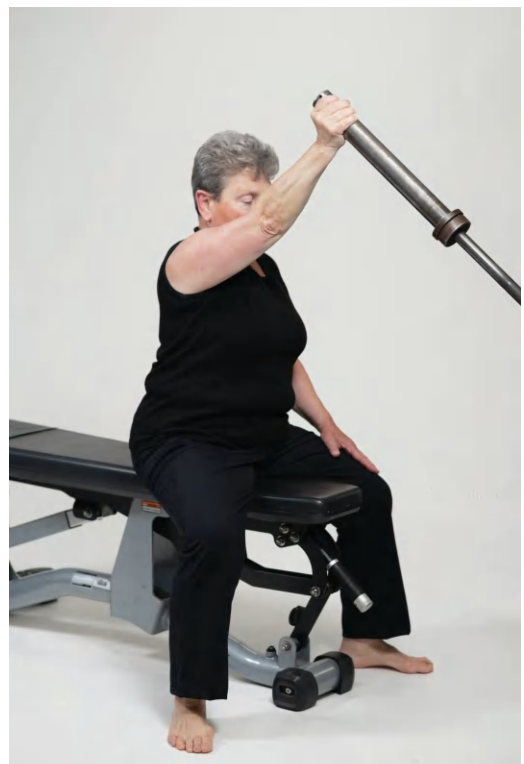

Figure 9-169 *Landmine press end position*

SCRAPE THE RACK PRESS

The scrape the rack press is similar to the landmine press because it modifies the angle of the press from directly overhead to at a slight angle. As a result, it may also be a good substitution for overhead pressing in the presence of pain or injury. The isometric press into the wall may result in lower activation of the upper trapezius and greater activation of the serratus anterior to promote scapular protraction and upward rotation, similar to the towel wall slide[345,346] or push-up plus,[347,348] but there is no current research on the scrape the rack press as a stand-alone exercise.

- Hold the barbell against a rack and stand at a slight distance away
- A PVC pipe, PVC pipe with weights attached, or weighted bar against a door frame can also be used
- Press the barbell or PVC pipe into the rack or door frame, then press up and overhead
- Maintain the palms facing forward and do not let the bar drop below the level of the chest on the descent

Figure 9-170 *Scrape the rack start position*

Figure 9-171 *Scrape the rack end position*

OVERHEAD PRESS

The overhead shoulder press or "military press" produces moderate to high levels of muscle activation for the anterior (33–62% MVIC) and middle deltoid (27–72% MVIC)[55,56] and high levels for the supraspinatus (80% MVIC).[55] It can be performed bilaterally or unilaterally in multiple positions including seated, tall kneeling, and half kneeling, depending on stability desired. A greater amount of stability will likely allow more weight to be lifted, but muscular activity tends to be greater as the base of support is reduced.[349]

The seated position is the most stable, while a tall or half kneeling position reduces the base of support and may provide greater engagement of abdominals and stabilizing muscles to maintain upright posture.

- Start with the weights in a neutral position, rested on each shoulder and palms facing each other
- Press the weights overhead and externally rotate the shoulders by turning the palms forward and angling the elbows out
- Turn the palms to face each other and angle the elbows inward during the lowering phase
- If an individual lacks the requisite shoulder external rotation range of motion to perform this exercise, an alternative method would be to press the weight up overhead and maintain the neutral position with palms facing each other during both the press and lowering phase (Figures 9-174 and 9–175)

Figure 9-172 *Overhead press start position*

Figure 9-173 *Overhead press end position*

Figure 9-174 *Overhead press neutral grip start position*

Figure 9-175 *Overhead press neutral grip end position*

SINGLE-ARM OVERHEAD PRESS

The single-arm press allows increased focus on the pressing movement through one arm, while requiring the rest of the body to stabilize against an uneven distribution of load. In pressing a weight overhead on one side, there must be muscle co-activation on the opposite side to prevent the body from tipping or leaning toward the side with the load. It is performed using the same technique as the bilateral overhead press as detailed above and can also be performed in multiple positions (seated, standing, half kneeling, tall kneeling, etc.) based on stability and the desired training effect.

PUSH-PRESS

The push-press is a multi-joint, "ballistic strength" exercise that incorporates use of the legs (via a triple extension of the hips, knees, and ankles) and upper body to powerfully propel a barbell or dumbbells overhead.[57,58] It can produce mechanical demand and power output similar to jump squats.[57,58,350,351] If an individual has decreased ability to perform jump squats and/or sprints because of lower body injury, the push-press may be an alternative exercise to maintain physical fitness, strength, and conditioning in lieu of plyometrics. The three steps to perform the push-press consist of: (1.) The dip, where the knees bend slightly and the hips shift back and down; (2.) The drive, where the hips, knees and angles extend and the weight starts to propel upward; and (3.) elbow lockout, where the elbows are fully extended with the weight overhead. An individual must have full shoulder mobility to perform this exercise correctly, to limit compensatory strategies like lumbar hyperextension and excessive stress on the shoulder joints or spine.

- Rest the barbell across the upper chest and grip the bar at shoulder width
- Perform the dip motion by bending the knees and shifting the hips back and down
- Begin the drive by pushing through the feet, contracting the glutes to drive the hips forward, and pressing the barbell up
- During the drive, triple extension should occur at the hips, knees, and ankles
- The neck and upper back will extend back slightly in order for the bar to clear the face
- Extend the elbows fully at the top with the weight overhead

Figure 9-176 *Barbell push-press start position*

Figure 9-177 *Barbell push-press end position*

The use of dumbbells instead of a barbell may be more appropriate for those with full shoulder flexion, but impaired external rotation or wrist range of motion.

- Hold two dumbbells in a neutral position, rested on the shoulder with the palms facing each other
- Perform the same dip, drive, and elbow extension phases as detailed above
- The weights remain in neutral during both the drive and elbow extension phases

Figure 9-178 Dumbbell push-press start position

Figure 9-179 Dumbbell push-press end position

FRONT AND LATERAL RAISES

ECCENTRIC FRONT RAISES WITH DUMBBELL

Eccentric front raises aim to target and train the ability of the anterior deltoid and potentially long head of the biceps tendon (if performed with forearm supinated) to lower the arm in a controlled manner. Eccentric flexion exercises also favor middle trapezius over upper trapezius activation, especially flexion between 180° and 60°[352] and may be helpful to incorporate if the goal is to reduce upper trapezius or increase middle trapezius activation.

- Use the opposite arm to lift the target arm to 90° (shoulder height)
- Keep the elbow straight and slowly lower the target arm without assistance from the opposite arm

Figure 9-180 Assist the weight to the start position

Figure 9-181 Controlled lowering phase

ECCENTRIC FRONT RAISES WITH PLATE

- Grasp the outside edges of the plate with both hands and press it up overhead
- Keep the elbows straight and slowly lower the plate until it is level with the chest, at or just below shoulder height
- Bend the elbows and pull the weight back in toward the chest, then repeat the movement

Figure 9-182 *Eccentric front raise with plate start position*

Figure 9-183 *Eccentric front raise with plate end position*

FRONT RAISE TO 90° OF FLEXION

The front raise is a popular exercise used for deltoid development likely because the anterior and middle deltoid have large flexor moment arms[314] and the load is held far from the body during the front raise. The muscle activation of the middle deltoid is high at greater than 50% MVIC. Similar levels of muscle activity were also observed in the upper trapezius (55% MVIC), lower trapezius (52% MVIC), serratus anterior (42% MVIC) and a very high level of muscle activation was achieved by the infraspinatus (71% MVIC).[353] Overall, there is limited research on muscle EMG activity during the exercise and when compared to other exercise variations.

- Grasp the weight with the arm at the side, elbow extended, and knuckles facing down
- Maintain the elbow straight and lift the arm to shoulder height (90°)
- Lower the arm under control

Figure 9-184 *Front raise to 90° start position*

Figure 9-185 *Front raise to 90° end position*

FRONT RAISE TO 120° OF FLEXION

If the front raise is performed to 120° of flexion with the shoulder in neutral (thumb up), greater muscle activation is achieved in the anterior deltoid (61% MVIC) and serratus anterior (67% MVIC) compared to the middle deltoid (32% MVIC) and infraspinatus (47% MVIC). Compared to the 90° front raise, there is similar muscle activation of the lower trapezius (49% MVIC). This variation also produces high levels of muscle activation in the teres minor and subscapularis.[55] Since these muscle groups were not tested during the front raise to 90° with neutral shoulder rotation, it is unclear if a similar level of muscle activation can be achieved with this exercise.

- Grasp the weight with the elbow extended and thumb facing up (shoulder external rotation)
- Maintain the elbow straight and lift the arm above shoulder height to 120°

Figure 9-186 *Front raise to 120° start position*

Figure 9-187 *Front raise to 120° end position*

LATERAL RAISE

The lateral raise is a shoulder abduction exercise and the anterior and middle deltoids, supraspinatus and infraspinatus are the muscles with the largest abductor moment arms.[314] In a study by Jakobsen et al.,[353] the lateral raise exercise generated high levels of muscle activation in the middle deltoid (69% MVIC), trapezius muscle group (54–63% MVIC), infraspinatus (56% MVIC), and serratus anterior (41% MVIC). In a more recent study by Campos et al.,[56] the lateral raise generated moderate levels of muscle activation in the anterior deltoid (21% MVIC), middle deltoid (30% MVIC), and posterior deltoid (24% MVIC). Activation of the middle deltoid and trapezius muscles were significantly greater during the lateral raise compared to the front raise. The lateral raise also generated significantly greater middle deltoid activation compared to the reverse fly exercise.[353] Therefore, the lateral raise may be superior to front raises and reverse flies to activate the middle deltoid.

Performing lateral deltoid raises above 90° may cause pain in those with impingement syndrome or rotator cuff pathology[354] because of the tendon of the supraspinatus getting pinched in the subacromial space. When the shoulder is in neutral (palm down) or internal rotation (thumb down) the greater tuberosity may not clear under the acromion process as the shoulder elevates overhead. Two solutions to this issue would be to perform lateral raises with the shoulder in neutral to 90° or perform to/above 90° with thumbs pointing up (shoulder external rotation). However, the muscle activation data above is based on the exercise when performed with the shoulder neutral to 90° elevation.

- Start with the arms at the sides
- With the elbows extended and palms down, lift the arm to shoulder height
- If any pain or pinching occurs, use the thumbs up (shoulder external rotation) position (Figure 9–190) and determine if any improvement in symptoms occurs

Figure 9-188 *Lateral raise start position*

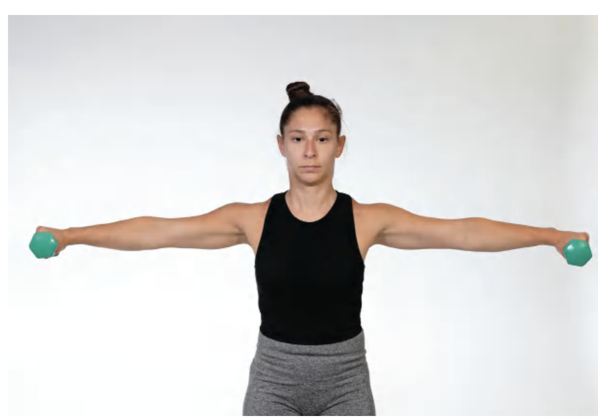

Figure 9-189 *Lateral raise end position*

Figure 9-190 *Shoulder external rotation with thumbs up*

HORIZONTAL ABDUCTION AND POSTERIOR DELTOID ACTIVATION

PRONE HORIZONTAL ABDUCTION WITH EXTERNAL ROTATION

Prone horizontal abduction produces moderate to high levels of muscle activation in the middle trapezius (38–87% MVIC),[55,318,355,356] lower trapezius (35–74% MVIC),[55,318,355,356] high levels in the infraspinatus (52–94% MVIC),[355, 357] posterior deltoid (51–63% MVIC),[355,357] and rhomboids (42% MVIC),[318] and moderate level in the teres minor (40% MVIC).[355] Upper trapezius activation ranged from low (15% MVIC)[318,356] in two studies to high (45–66% MVIC) in two alternative studies.[355] Prone horizontal abduction with external rotation has been reported as having a good ratio of middle and lower trapezius activation compared to the upper trapezius [318,319] meaning that it may be a good exercise to target the two former muscles while minimizing activation of the upper trapezius, but the research does not appear to be consistent. There also appears to be increased upper trapezius compared to serratus anterior activation, and should not be used if the goal is to target the serratus anterior over the upper trapezius.[352] A study by Sciascia et al.[358] also supported moderate to high levels of muscle activation in the supraspinatus, infraspinatus, and middle deltoid muscles (38–74% MVIC). Muscle activation appears to be higher in all target muscles with the shoulder in a greater degree of external rotation (thumb up) compared to the palm down and internal rotation (thumb down).[355,356]

- Start on the stomach with the forehead supported on a towel roll or rested on the opposite arm
- Position the body close to the edge of a raised surface (table, mat, bench, etc.) with the target arm hanging
- Rotate the thumb up to the ceiling (shoulder external rotation), maintain a straight elbow, and lift the arm up to shoulder height
- Retract the shoulder blade during the lift and avoid shrugging up toward the ear
- Muscle activation should be felt in the posterior shoulder muscles more than in the neck and upper trapezius
- Maintain a straight elbow and let the shoulder blade protract during the lowering phase

Figure 9-191 *Prone shoulder abduction start position*

Figure 9-192 *Prone shoulder abduction end position*

MACHINE POSTERIOR DELTOID FLY

The posterior fly produces high levels of muscle activation in the infraspinatus (60–70% MVIC),[359] middle (45–75% MVIC) and posterior (85–90% MVIC) deltoids.[359,360] Anterior deltoid activation is low at less than 20% MVIC.[360] Middle deltoid activation is greater during this exercise compared to lat pull downs and posterior deltoid activation is greater compared to both lat pull downs and seated rows.[360] Hand position during the exercise can significantly influence muscle activation. A neutral hand position (palms facing each other and thumbs up) produces significantly greater muscle activation of the infraspinatus and posterior deltoid compared to a pronated hand position (palms down).[359]

- Sit with the feet planted and grasp the handles with the desired grip
- Keep a soft elbow and pull the arms apart and back
- Do not allow the hands to translate too far beyond the torso

HORIZONTAL ABDUCTION BAND PULL-APART

The horizontal abduction pull-apart is similar to the reverse fly exercise using a machine, but requires only a resistance band instead of a large piece of exercise equipment.

- Grasp the band with the thumbs up (neutral rotation)
- Keep a soft elbow and pull the band apart
- Retract the shoulder blades during the pull and avoid shrugging the shoulders up
- Let the shoulder blades protract during the eccentric phase

Figure 9-193 *Band pull-apart start position*

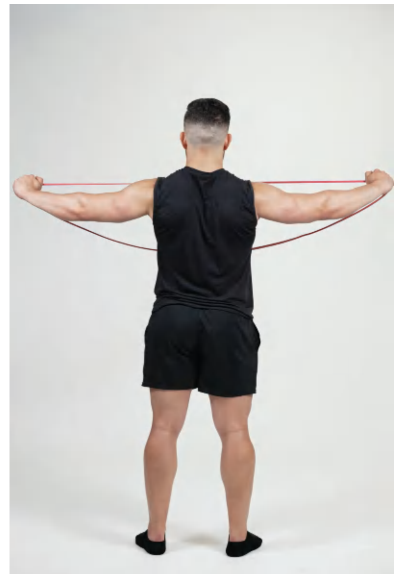

Figure 9-194 *Band pull-apart end position*

SIDE-LYING HORIZONTAL ABDUCTION

- Start in side-lying on the side opposite of the target arm
- Position the shoulder in 90° of flexion with the elbow straight
- The palm can be turned down or thumb up (shoulder external rotation)
- Horizontally abduct the arm until it is perpendicular to the trunk
- Maintain the elbow straight and slowly lower the arm
- Allow the shoulder blade to protract during the descent
- Let the arm horizontally adduct pass midline during the lowering phase to take advantage of the eccentric contraction and lengthening of the rotator cuff and deltoids

Figure 9-195 *Side-lying horizontal abduction start position*

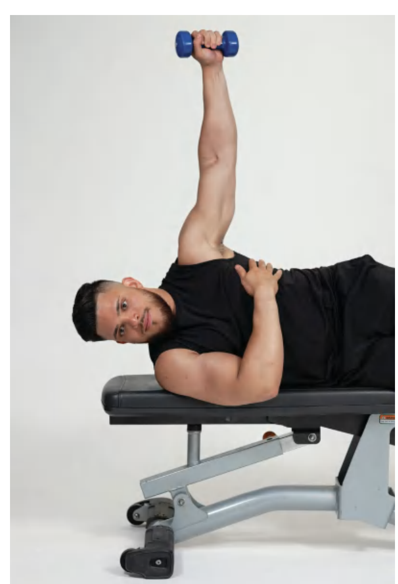

Figure 9-196 *Side-lying horizontal abduction end position*

HORIZONTAL ABDUCTION WITH OPPOSITE ARM PRESS

This exercise combines a horizontal abduction with a press in order to create a reactive neuromuscular training exercise for the stabilizing arm. As the moving arm performs a forward press, the stabilizing arm must maintain its position and resist horizontal adduction.

- Grasp a resistance band with one hand
- Keep a soft elbow and pull the band apart with what will be the stabilizing arm
- Perform a forward punch with the opposite (moving) arm against the band resistance
- Maintain the position of the stabilizing arm curing the punch

Figure 9-197 *Single-arm horizontal abduction*

Figure 9-198 *Forward press with opposite arm*

CHEST-SUPPORTED REAR DELTOID RAISE

The chest-supported rear deltoid raise aims to target similar muscles as the pectoral fly and horizontal abduction, but there are a few key differences regarding the set-up. An incline bench may decrease demand on the paraspinals and abdominals to maintain stability and may require less hamstring flexibility compared to a standing bent over raise. The incline bench variation may also reduce the amount of lumbar flexion range of motion that would be required to perform the seated bent over fly. The bench also decreases stability demands of the exercise and may allow a greater amount of weight to be lifted.[349] Decreased mobility requirements compared to the bent over raise may allow the exercise to be performed by a larger variety of patients.

- Set the incline bench to about 45°
- Start with the torso supported on the bench and feet in contact with the floor
- The knees can be bent or straight depending on comfort, length of the bench, leg length, etc.

- Grasp dumbbells in each hand with the palms facing each other
- Keep a soft elbow and lift the arms up to the side until at shoulder height
- The elbows should be slightly higher than the hands at the end-range
- Palms can either face the floor or each other by rotating the thumbs up at the end-range
- Control the lowering phase to increase time under tension
- Do not focus excessively on retracting the shoulder blades, but use the lift of the arm and horizontal abduction to contract the posterior deltoid

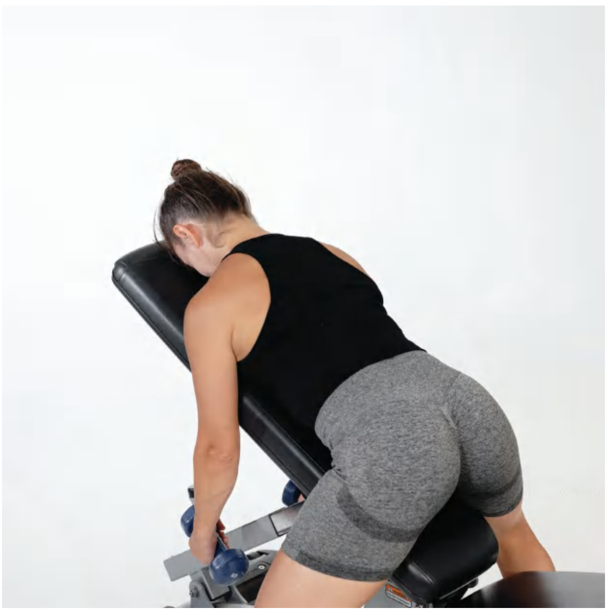

Figure 9-199 *Chest-supported rear deltoid raise start position*

Figure 9-200 *Chest-supported rear deltoid raise end position*

CHEST-SUPPORTED REAR DELTOID RAISE IN STANDING

This variation is appropriate for an individual who has the requisite mobility to achieve a hinge pattern. Similar to the hinge straight-arm pull down (see page 76), it may be used as an accessory exercise to develop upper back strength and trunk stability in a hinge position.

- Set the incline bench to a degree that is comfortable for the individual and keeps the torso above the horizontal (will vary due to height, leg length, torso length, etc.)
- Keep the knees soft and shift the hips back
- Rest the sternum on the edge of the incline bench
- Perform the remainder of the exercise with the same sequence as detailed above

Figure 9-201 *Standing chest-supported rear deltoid raise start position*

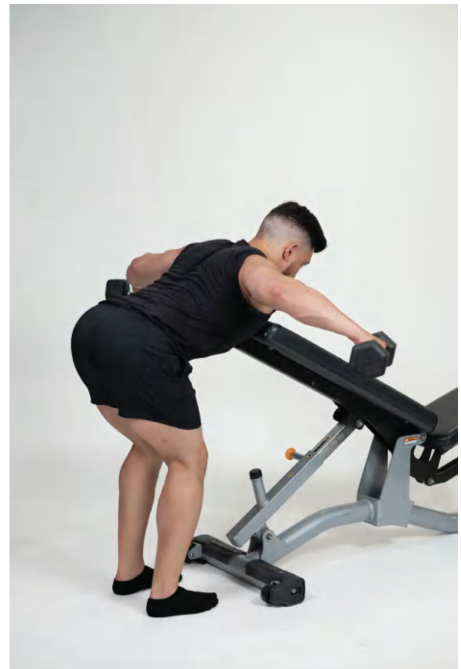

Figure 9-202 *Standing chest-supported rear deltoid raise end position*

FACE PULL WITH BAND

The face pull combines many movements, including shoulder horizontal abduction, external rotation, thoracic extension, scapula retraction, depression, protraction, upward rotation, and posterior tilt. It differs from the rowing motion because of the increased amount of shoulder external rotation and elevation. There is no scientific research on the face pull specifically, so its utility is inferred based on anatomy, biomechanics, and anecdotal accounts.

- Secure a super band loop to a stable support
- Grasp the loop with and overhand grip and light tension between each hand
- Step backward to take slack out of the band
- Pull the band apart and toward the face, anywhere between the eyes and mouth
- Pull the elbows back, rotate the forearms and hands up, so that they are facing forward toward the band at the end of the movement
- During the eccentric phase, let the resistance of the band pull the arms forward and the upper back round slightly
- This exercise can be performed in a seated or standing position
- The feet can be staggered if necessary in standing to maintain balance

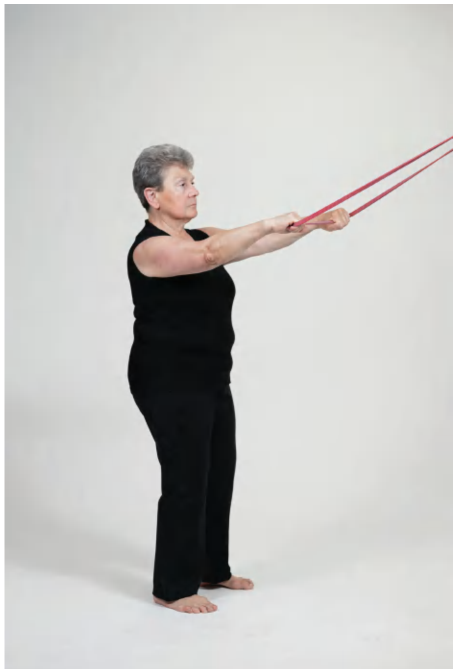

Figure 9-203 *Face pull with band start position*

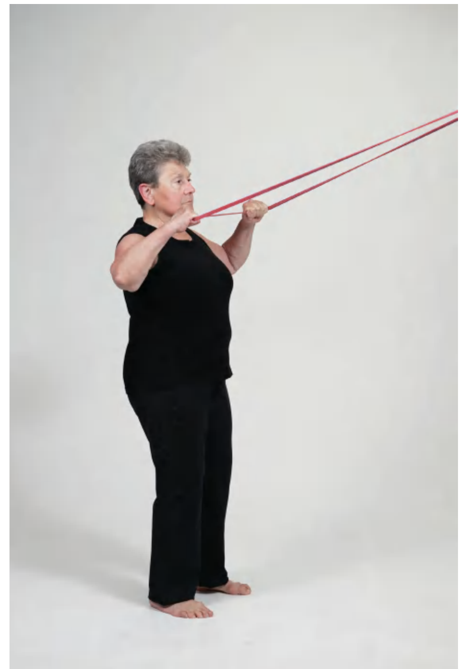

Figure 9-204 *Face pull with band end position*

FACE PULL WITH CABLE ROPE

- Use a rope attachment on the cable column
- Grasp the rope with an overhand grip
- Step backward until there is enough tension that you are being pulled forward slightly by the weight
- Lean back in order to use the body weight to maintain balance with use of body weight
- Pull the rope apart and toward the face
- The remainder of the exercise is performed with the same technique as the face pull using a band as described above

Figure 9-205 *Face pull with rope attachment start position*

Figure 9-206 *Face pull with rope attachment end position*

ROTATOR CUFF

The rotator cuff is made up of four muscles: the supraspinatus, infraspinatus, teres minor and subscapularis. These muscles are considered dynamic stabilizers of the shoulder joint and, apart from the shoulder capsule and small ligaments, they are the only other structures that provide stability and protection against dislocation.[361] The supraspinatus is active in early phase frontal plane abduction and throughout scapular plane elevation (lifting the arm at a 45° angle from neutral).[314] The infraspinatus and teres minor perform shoulder external rotation and extension. The subscapularis acts to depress and adduct the shoulder in the frontal plane and internally rotate the shoulder in the transverse plane. It also acts to assist shoulder abduction when the arm is in the scapular plane.[314] There are many "force couples" or simultaneous muscle actions that work together to promote optimal movement patterns and scapulohumeral rhythm. For example, the simultaneous actions of the subscapularis (internal rotator), infraspinatus and teres minor (external rotators) help create compressive force to stabilize the humeral head in the glenoid fossa of the scapula.[314] This mechanism helps counterbalance the humeral elevation force of the deltoid to prevent excessive upward translation of the humeral head, which may create less opportunity for impingement of the supraspinatus tendon in the subacromial space.

SHOULDER ISOMETRICS

Traditional shoulder isometrics using a door frame are often aimed at decreasing inflammation and initiating active muscle contractions without having the muscle change length, which can respect tissue healing timelines and may be more appropriate in the earlier phases of rehabilitation. The isometric exercises presented below can serve as alternative exercises or progressions from the door frame variation.

ISOMETRIC EXTERNAL ROTATION WITH TOWEL

- Bend the elbows to 90° and keep the upper arms in contact with the torso
- Pull the towel apart until taut and maintain the contraction for at least ten seconds

ISOMETRIC INTERNAL ROTATION WITH BALL

- Bend the elbows to 90° and keep the upper arms in contact with the torso
- Press a ball, weighted medicine or slam ball between the hands
- The ball can also be rested on a table top if the individual should not be holding weight

Figure 9-207 *Isometric external rotation*

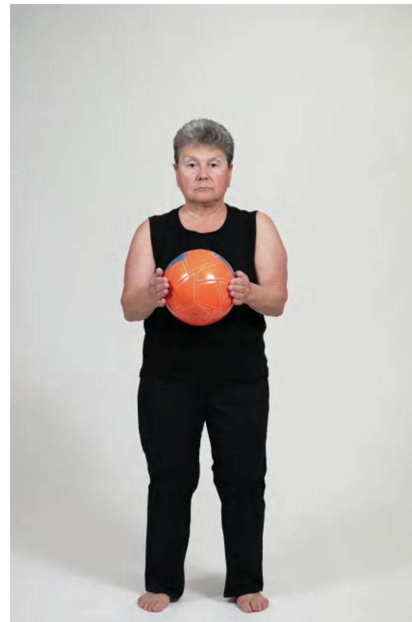

Figure 9-208 *Isometric internal rotation*

BOTTOMS-UP KETTLEBELL EXTERNAL ROTATION ISOMETRIC

- Bend the elbow to 90° and raise the shoulder
- The arm can be positioned at:
  - 90° flexion and 45° abduction (scapular plane) (Figure 9–209)
  - 90° flexion and abduction (full external rotation) (Figure 9–210)
- For an additional challenge, perform a concentric motion by slowly moving the arm between 90–45° abduction

Figure 9-209 *Scapular plane external rotation isometric*

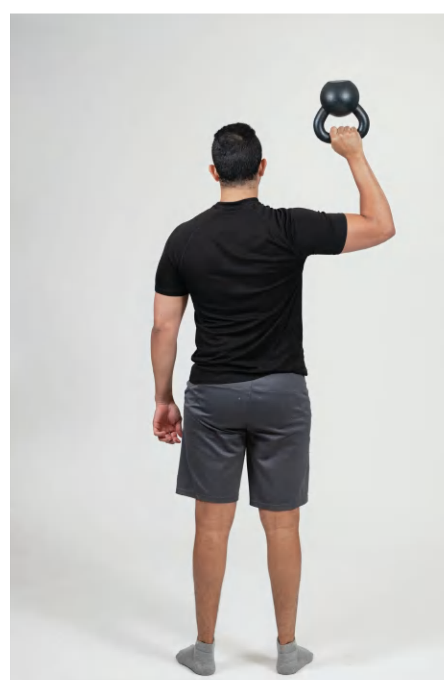

Figure 9-210 *90° abduction and external rotation isometric*

SHOULDER EXTENSION

Shoulder extension activates the latissimus dorsi (see page 284), but is also an effective exercise for the rotator cuff muscles, as the subscapularis, teres minor, and infraspinatus also function to perform shoulder extension. As previously explained, upper trapezius activation is also minimized during shoulder extension,[55,318,319] which can be beneficial if the goal is to decrease upper trapezius involvement in favor of other shoulder girdle and upper back muscles.

PRONE SHOULDER EXTENSION

See page 288.

STANDING SHOULDER EXTENSION

Standing shoulder extension generates high levels of muscle activation for the latissimus dorsi (64% MVIC), subscapularis (96% MVIC), teres minor (96% MVIC), and infraspinatus (50% MVIC).[55]

- Hold a band or cable column with either grip: palm down (pronated) or thumb up (neutral)
- Use the posterior shoulder muscles and the latissimus dorsi to pull the arm down to the side of the body
- Keep the elbow straight to avoid compensation by use of the triceps

Figure 9-211 *Standing shoulder extension with pronated grip start position*

Figure 9-212 *Standing shoulder extension with pronated grip end position*

SHOULDER EXTENSION 45° HOLDS

This shoulder extension variation is performed with a supinated grip, which increases shoulder external rotation. There is no research to support that shoulder extension with a supinated grip is superior for rotator cuff activation. However, if anatomy and muscle actions are considered, a greater degree of shoulder external rotation may increase activation of the infraspinatus, teres minor, and potentially the upper back through the actions of scapular retraction and depression. This exercise can be performed in tall kneeling to reduce degrees of freedom, allow greater focus on abdominal muscle activation and spinal position (as detailed below), or standing.

- Grasp the handles of a resistance band with a supinated grip (palm up or facing forward)
- Contract the abdominals to prevent the lower back from extending during the pull
- Keep the elbows straight and pull the arms back at a 45° angle
- Retract the shoulder blades as needed

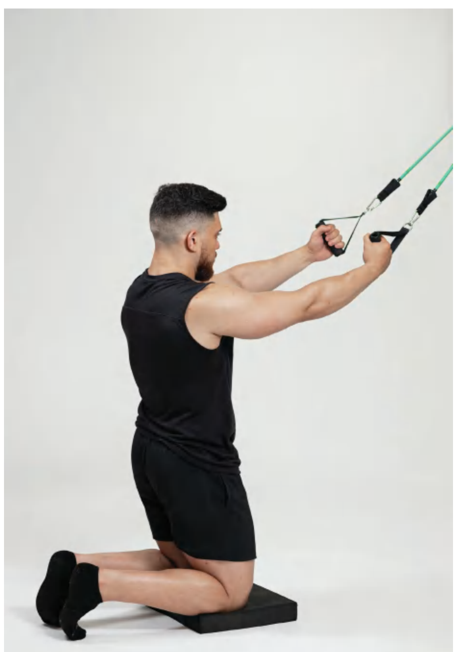

Figure 9-213 *45° hold start position*

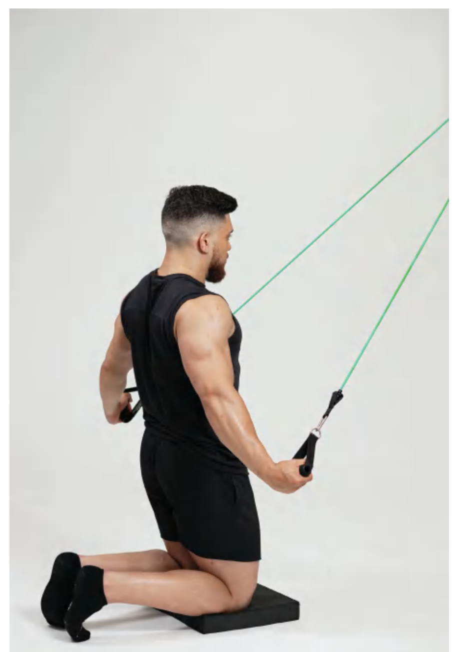

Figure 9-214 *45° hold end position*

SHOULDER SCAPTION

Elevation in the scapular plane (shoulder scaption) is performed at about 45° from frontal plane shoulder abduction and sagittal plane flexion. The supraspinatus has a constant abductor moment arm through the full range of shoulder scaption and is assisted by the deltoids. Other rotator cuff muscles, like the subscapularis and teres minor also help perform abduction in the scapular plane, which differs from their function as adductors during frontal plane abduction.[314] Scaption can be performed to 90° (shoulder height) or above shoulder height. This movement produces high levels of muscle activation for the supraspinatus (greater than 60% MVIC), middle, and posterior deltoid.[55,362] Scaption with thumbs facing up (full can) will decrease activity of the deltoids to activate the supraspinatus to a greater extent.[362] It also produces increased muscle activation of the upper trapezius[346] and serratus anterior,[55,363] likely due to the degree of scapular upward rotation, especially if performing above shoulder height.

- Start with the arms at the sides
- Lift the arms at a 45° angle with the thumbs up
- Let the shoulder blades upwardly rotate if performing above shoulder height

Figure 9-215 *Shoulder scaption start position*

Figure 9-216 *Shoulder scaption end position*

SCAPTION WITH RESISTANCE BAND

The addition of a band with light resistance is meant to help drive shoulder external rotation during elevation. As mentioned, the external rotators perform an important function of maintaining the humeral head in the shoulder socket and preventing excessive superior migration. This may be an appropriate variation to attempt if scaption performed without the band causes any pain or discomfort in the superior shoulder. Dumbbells can be used to increase difficulty.

- Place a band around the wrists and pull the arms apart to create tension
- Lift the arms up at a 45° angle to desired height
- Maintain the tension on the band throughout the lift and lowering phase

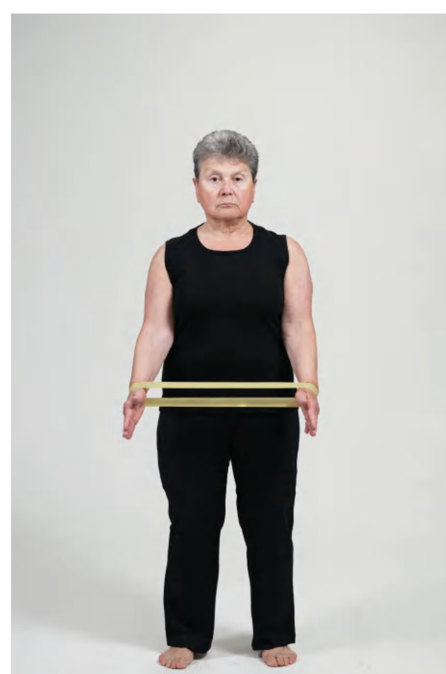

Figure 9-217 *Mini band scaption start position*

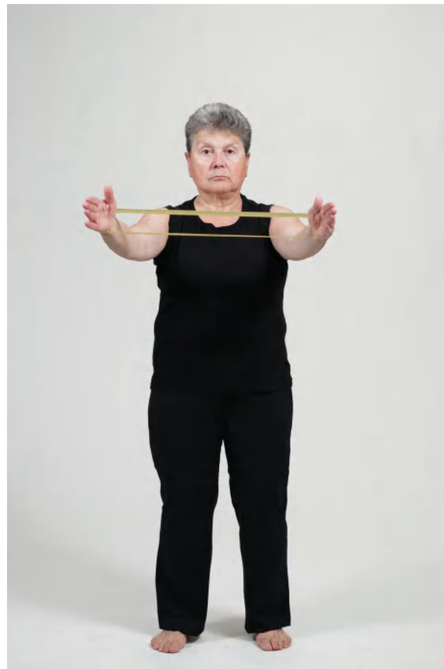

Figure 9-218 *Mini band scaption end position*

SCAPTION WITH BAND RESISTANCE INTO EXTERNAL ROTATION

- Pull the band across the body until there is light tension at about a 45° angle from neutral
- Raise the arm up to the desired height and lower back down to the side without losing tension on the band

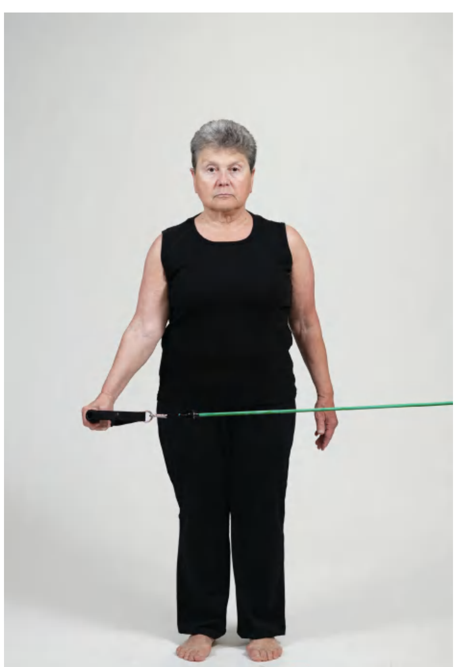

Figure 9-219 *Light tension on the band with the arm at the hip*

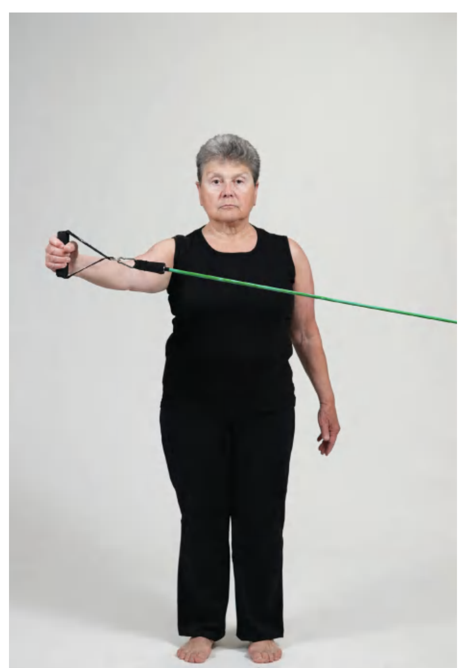

Figure 9-220 *Maintain tension with scaption raise*

DUMBBELL INCLINE BENCH SCAPTION RAISE

Performing scaption on an incline bench reduces the angle against gravity, which allows gravity to provide some assistance during the second half of the lift.

- Set an incline bench to the desired height (a higher incline provides less assistance against gravity and vice versa)
- Lift the arms at a 45° angle with the thumbs facing up

Figure 9-221 *Incline bench scaption raise start position*

Figure 9-222 *Incline bench scaption raise end position*

SHOULDER ROTATION

SUPINE EXTERNAL ROTATION

Supine external rotation is a gravity assisted movement that can be used to stretch the internal rotators and develop control into end-range positions with a small amount of resistance.

- Start on the back with the elbow at 90° flexion and shoulder at 90° abduction
- A small towel roll can be placed under the upper arm to keep the arm in line with the shoulder joint as needed (and may be required for an individual with a kyphotic thoracic spine)
- Slowly lower the arm backward into external rotation
- Use the internal rotators to lift the arm back up to neutral

Figure 9-223 Supine external rotation start position

Figure 9-224 Controlled lowering phase

SIDE-LYING EXTERNAL ROTATION

Side-lying external rotation produces moderate to high levels of muscle activation for the infraspinatus at about 40–60% MVIC[55,355,364,365] and teres minor at 50% to greater than 60% MVIC.[55,364,365]

- Start in side-lying on the side opposite the target arm
- Position the arm with the elbow bent to 90°
- Rotate at the shoulder joint to lift the forearm
- Maintain the upper arm in contact with the torso throughout the movement
- Lower the forearm under control
- A small towel roll can be used between the upper arm and torso for comfort, but is not required

Figure 9-225 Side-lying external rotation start position

Figure 9-226 Side-lying external rotation end position

SIDE-LYING EXTERNAL ROTATION HOLDS

If concentric and eccentric side-lying rotation through the full range is too difficult, performing a hold at a specific point in the range may help build strength and allow the muscle to contract in one specific portion of the range of motion.

- Have another individual support and position the arm at the desired range of motion
- Keep the upper arm against the torso and maintain this position as the support is removed
- Have another individual assist with lowering the arm

SIDE-LYING EXTERNAL ROTATION ECCENTRICS

Eccentrics can be used to build strength when the concentric portion of the motion is too difficult to perform with the desired weight (or weight of the arm). The eccentric only phase still generates high levels of muscle activation of the infraspinatus at greater than 60% MVIC while potentially contributing to muscle hypertrophy, tissue remodeling, tendon health, and pain reduction.[366]

- Have another individual support and position the arm at the desired range of motion
- Keep the upper arm against the torso and maintain this position as the support is removed
- Slowly lower the arm under control

Figure 9-227 *Assist to end-range of external rotation*

Figure 9-228 *Controlled lowering phase with support removed*

Figure 9-229 *Side-lying external rotation eccentric end position*

EXTERNAL ROTATION WITH ELBOW ON KNEE

- Sit with the knee bent and elbow resting on the top of the knee
- Maintain elbow contact with the knee to use it as a fulcrum
- Lift the forearm up and backward by externally rotating at the shoulder joint
- Lower the arm until parallel with the ground

Figure 9-230 *External rotation with knee support start position*

Figure 9-231 *External rotation with knee support end position*

EXTERNAL ROTATION LIFT-OFF

The lift-off focuses on improving stability, motor control, and thus the ability of the external rotators to effectively contract at their end-range. This may be used as a follow-up exercise to passive range of motion or stretching exercise to actively contract the muscles in a new range of motion. In order to modify the range of motion, this exercise can also be performed in prone, with support added as needed for the elbow and hand.

- Position the elbow against a door frame at 90° flexion and abduction
- Attempt to lift the hand and forearm off the door frame by externally rotating the shoulder

Figure 9-232 External rotation lift-off start position

Figure 9-233 External rotation lift-off end position

EXTERNAL/INTERNAL ROTATION WITH BAND OR CABLE

A systematic review by Edwards et al.[365] gathered data from EMG studies to determine levels of muscle activation during a wide range of rotator cuff exercises in order to guide post-operative care. External rotation performed in standing at 0° (39–50% MVIC), 45° (39% MVIC), and 90° of abduction (50% MVIC) all produce moderate to high levels of infraspinatus muscle activation regardless of the degree of arm elevation used. Teres minor muscle activation appears greatest at 90° abduction (69% MVIC), but external rotation performed at 0° (29–46% MVIC) and 45° of abduction (39% MVIC), still produce moderate to high levels. Surprisingly, external rotation at 0–90° of shoulder abduction even produce high levels of muscle activation in the subscapularis (57% MVIC), which is primarily an internal rotator.[365] External rotation performed with less shoulder abduction (e.g. at 0° versus 90°) also appears to activate the middle and posterior deltoids to a lesser degree.[55]

The same systematic review examined internal rotation exercises. Internal rotation produces high to very high levels of muscle activation in the subscapularis at 0° (40% MVIC), 45° (53% MVIC), and 90° (65% MVIC).[365] These are similar to the findings of Escamilla et al.,[55] who measured 50%, 53%, and 58% MVIC for the upper portion of the subscapularis for each exercise, respectively. The subscapularis as a whole, meaning when the upper and lower portions were not tested independently, produced very high levels of muscle activation at 0° (74% MVIC) and 90° (71% MVIC) shoulder abduction.[55] Internal rotation also produces very high levels of muscle activation in the teres minor at 0° (63% MVIC) and 90° abduction (93% MVIC), but only lower levels of muscle activation (less than 25% MVIC) in the infraspinatus.[55,365]

- Select the desired range of arm elevation:
  - 0° elevation (arm at side)
  - 45° (scapular plane) elevation
  - 90° abduction
- The direction of pull on the band or cable should be in line with the palm to train external rotation and dorsum of hand for internal rotation
- To train external rotation, the arm should be positioned in neutral rotation
- To train internal rotation, the arm should be positioned in 60° to 90° of external rotation

- If performing with no elevation, position the upper arm and elbow against the body or place a small towel roll under the elbow to help maintain contact with the torso
- If performing in any degree of elevation, maintain the height of the elbow throughout the entire movement by supporting it with the opposite arm or resting it on a raised surface (e.g. incline bench)

Figure 9-234 *0° elevation (arm at side) external rotation start position*

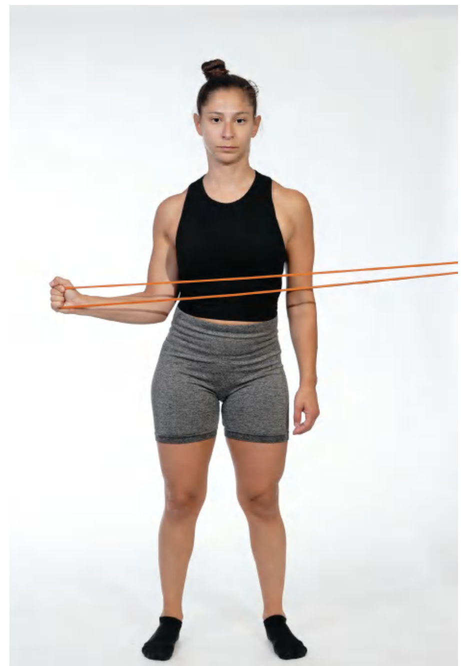

Figure 9-235 *0° elevation (arm at side) external rotation end position*

Figure 9-236 *Scapular plane external rotation start position*

Figure 9-237 *Scapular plane external rotation end position*

Figure 9-238 *90° abduction and external rotation start position*

Figure 9-239 *90° abduction and external rotation start position*

Figure 9-240 *0° elevation (arm at side) internal rotation start position*

Figure 9-241 *0° elevation (arm at side) internal rotation end position*

Figure 9-242 *Scapular plane internal rotation start position*

Figure 9-243 *Scapular plane internal rotation end position*

Figure 9-244 *90° abduction and internal rotation start position*

Figure 9-245 *90° abduction and internal rotation start position*

EXTERNAL/INTERNAL ROTATION WALK-OUT

The walk-out is an isometric exercise that can help build both reactive control and muscle endurance using reactive neuromuscular stabilization. The dynamic stepping component will require the muscle(s) to maintain the same position of the arm with each repetition against variable resistance and work in one specific range of motion throughout the entire exercise. This is best performed with a resistance band, so the resistance will increase while stepping away and decrease while stepping back to the start point. It can train either the external or internal rotators based on the direction of pull from the band.

- Select the desired range of internal or external rotation and elevation:
  - 0° elevation (arm at side) (Figures 9-234, 9–240)
  - 45° (scapular plane) elevation (Figures 9-236, 9–242)
  - 90° abduction and external rotation (Figures 9-238, 9–244)
- If performing with no elevation, position the upper arm and elbow against the body or place a small towel roll under the elbow to help maintain contact
- Position the arm accordingly if performing with elevation in the scapular plane or 90° abduction and external rotation
- Start with little to no resistance on the band
- Take small, slow side steps and maintain the arm in the same position
- Do not allow the shoulder to rotate in or out while stepping away from or returning to the start point
- The direction of pull on the band should be in line with the palm to train external rotation and dorsum of hand for internal rotation

ROW TO EXTERNAL ROTATION

- Position the band or cable between floor to knee high
- Start with an overhand grip
- Perform a rowing motion: pull the elbow back until 90° of elbow flexion and shoulder abduction
- Maintain the height of the elbow and externally rotate the shoulder to 90° until the palm is facing forward and knuckles are toward the ceiling

Figure 9-246 *Row to external rotation start position*

Figure 9-247 *Row*

Figure 9-248 *Row to external rotation end position*

Figure 9-249 *Resistance band placed around shoulder to increase external rotator activation and centration of humeral head in the glenoid socket*

PRONE EXTERNAL ROTATION

Prone external rotation requires the muscles involved to contract against the resistance of gravity, in addition to any weight used. This exercise produces high levels of rotator cuff muscle activation in the infraspinatus (50–54% MVIC), teres minor (45–48% MVIC), and supraspinatus (68–74% MVIC).[55,365] It also promotes a favorable activation ratio of the middle and lower trapezius to the upper trapezius[352] and high levels of muscle activation in the middle and posterior deltoids.[55] Prone external rotation may be a substitution for prone horizontal abduction if the goal is to minimize upper trapezius activation.[55,352]

- Start with the elbows bent to 90° and knuckles facing the floor
- Externally rotate the shoulder until the forearms are parallel with the floor

Figure 9-250 *Prone external rotation start position*

Figure 9-251 *Prone external rotation end position*

PRONE EXTERNAL ROTATION TO OVERHEAD PRESS

- Perform on a flat bench, physioball or incline bench
- Start with the elbows bent to 90° and knuckles facing the floor (Figure 9–250)
- Externally rotate the shoulder until the forearms are parallel with the floor or bench (Figure 9–252)
- Press the arms overhead without allowing the palms to fall below the elbows (Figure 9–253)

Figure 9-252 *Prone 90° abduction and external rotation*

Figure 9-253 *Overhead press*

Exercises performed in the side-lying position place less demand on the shoulder elevators, as these muscles, in theory, do not have to work as hard to overcome the resistance of gravity. The posterior shoulder girdle and external rotator muscles, on the other hand, must remain engaged throughout the movement in order to resist the arm traveling toward the midline of the body (horizontal adduction) throughout the movement.

SIDE-LYING SHOULDER FLEXION

- Position on one side with the target arm on top
- Position the arm at 90° of shoulder flexion
- Keep the elbow straight and lift the arm up overhead
- Lower back down to the hip
- Allow the scapula to rotate upward during the ascent and rotate downward during the descent

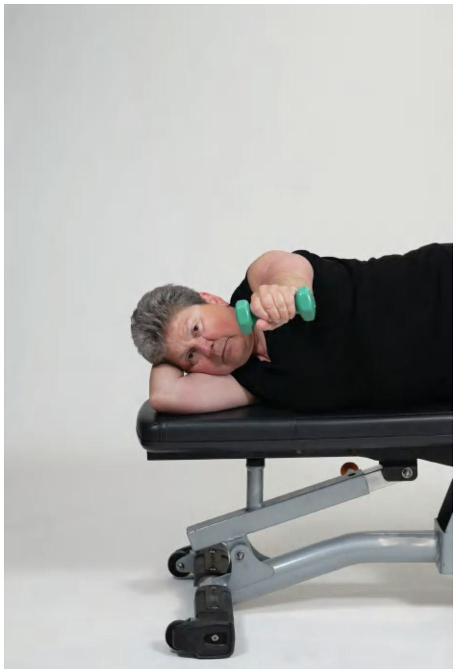

Figure 9-254 *Side-lying flexion to 90°*

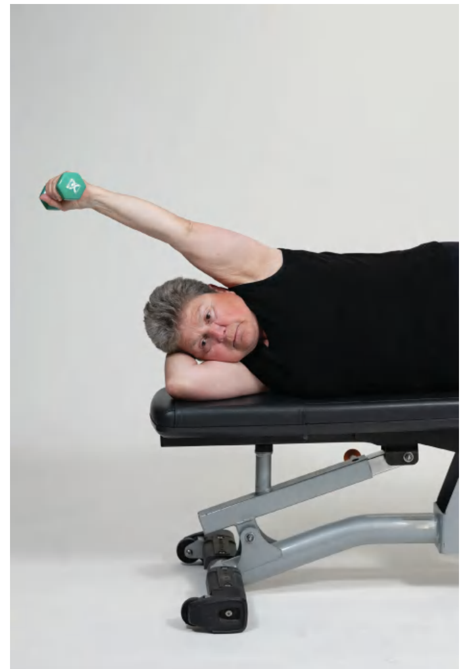

Figure 9-255 *Side-lying overhead flexion*

SIDE-LYING FORWARD PRESS

- Position on one side with the target arm on top
- Start with the elbow flexed to 90° and upper arm in contact with the torso
- Perform a forward pressing motion until the elbow is straight and shoulder is at 90° of flexion
- Bend the elbow and pull back until the upper arm is in contact with the torso

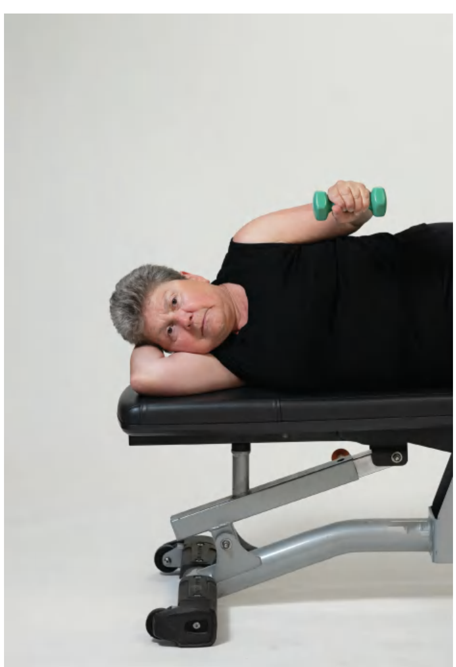

Figure 9-256 *Side-lying press start position, upper arm in contact with torso*

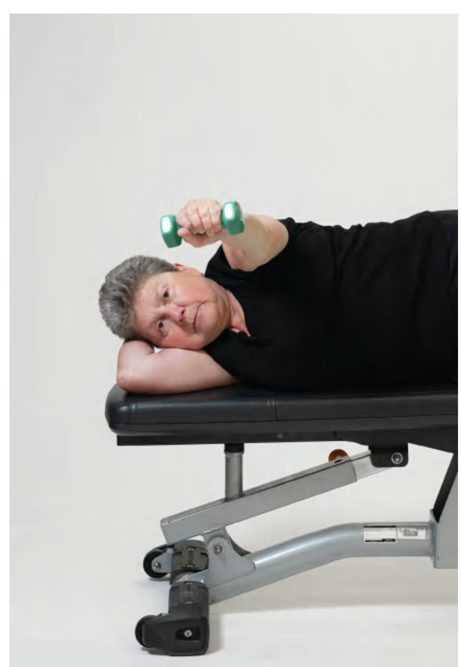

Figure 9-257 *Forward press*

SIDE-LYING HORIZONTAL ABDUCTION

See page 332.

STABILITY AND REACTIVE CONTROL

There is limited research available on the utility and benefits of reactive stability exercises for the rotator cuff, but the methodology behind these exercises is based on proprioceptive neuromuscular facilitation techniques (PNF), particularly rhythmic stabilization. Rhythmic stabilization requires force to be applied in alternate directions and, therefore, muscle contractions must occur on both sides of the joint to maintain a static position. Force is often applied quickly and in an unpredictable fashion which further challenges a muscle's ability to react in order to stabilize. These exercises can be performed with manual resistance from the provider's hands or can be implemented in a modified fashion with exercise equipment, the latter of which are the methods that are detailed below.

REACTIVE SIDE-LYING EXTERNAL ROTATION

- Start in side-lying on the side opposite of the target arm
- Hold a small weighted ball in the hand of the target arm
- Position the arm with the elbow bent to 90°
- Rotate at the shoulder joint to lift the forearm
- Maintain the position of the shoulder as best as possible and open the hand to release, then quickly catch the weighted ball before it drops
- This causes a contraction of the internal rotators to retrieve the ball, followed by a contraction of the external rotators to lift the arm and maintain arm height
- Perform for the prescribed number of repetitions, at pace and until fatigue, or until the ball drops
- Maintain the upper arm in contact with the torso throughout

Figure 9-258 *Side-lying shoulder external rotation*

Figure 9-259 *Reactive catch*

REACTIVE PRONE EXTERNAL ROTATION

- Hold a small weighted ball in the hand of the target arm
- Start with the elbows bent to 90° and knuckles facing the floor
- Externally rotate the shoulder until the forearms are parallel with the floor
- Maintain the position of the shoulder as best as possible and open the hand to release, then quickly catch the weighted ball before it drops

Figure 9-260 *Prone shoulder external rotation*

Figure 9-261 *Reactive catch*

REACTIVE SIDE-LYING HORIZONTAL ABDUCTION

- Start with the elbow straight and shoulder in 90° of flexion
- Maintain the humeral head centered in the glenoid socket by avoiding excessive scapular protraction and retraction
- Maintain the position of the shoulder as best as possible and open the hand to release, then quickly catch the weighted ball before it drops
- This causes a contraction of the horizontal adductors and internal rotators to retrieve the ball, followed by a contraction of the posterior shoulder girdle muscles to lift the arm and maintain arm height

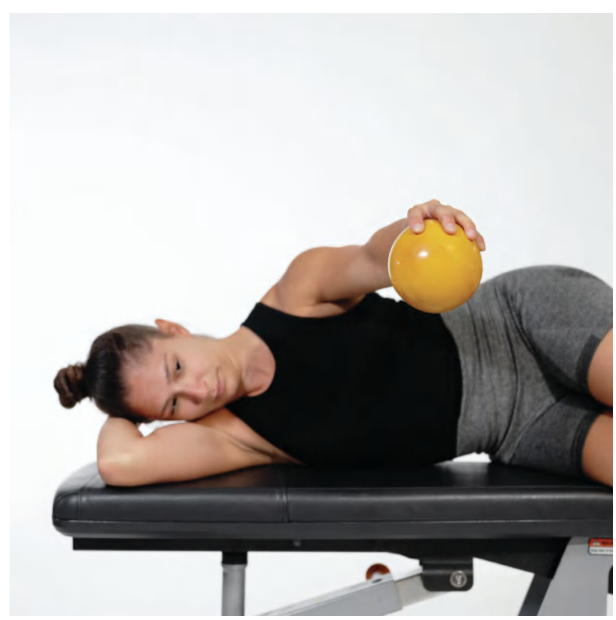

Figure 9-262 *Side-lying shoulder horizontal abduction*

Figure 9-263 *Reactive catch*

REACTIVE PRONE HORIZONTAL ABDUCTION

- Lift the arm up to shoulder height with the palm facing down
- Retract the shoulder blade during the lift and avoid shrugging up toward the ear
- Maintain the position of the shoulder as best as possible and open the hand to release, then quickly catch the weighted ball before it drops

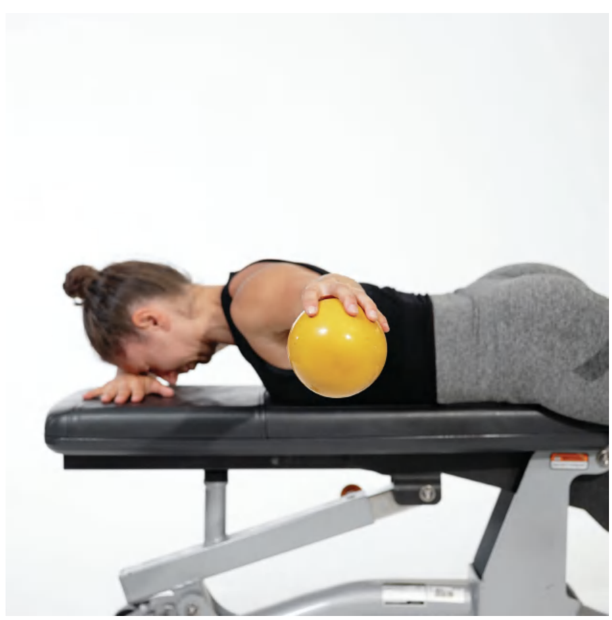

Figure 9-264 *Reactive prone shoulder horizontal abduction set-up*

REACTIVE STANDING HORIZONTAL ABDUCTION WITH BAND

- Grasp the ends of a band in each hand with the palms facing each other
- Pull the arms apart using the posterior shoulder muscles until there is significant tension in the band
- Let the arms come forward in a small range of horizontal adduction motion (2–4 inches), then overcome the pull of the band by immediately pulling the arms back
- When performed repetitively, this will create an oscillating motion and a co-contraction about the shoulder
- This can also be performed with the arms overhead in a "Y" position or in shoulder external rotation to target a different muscle group

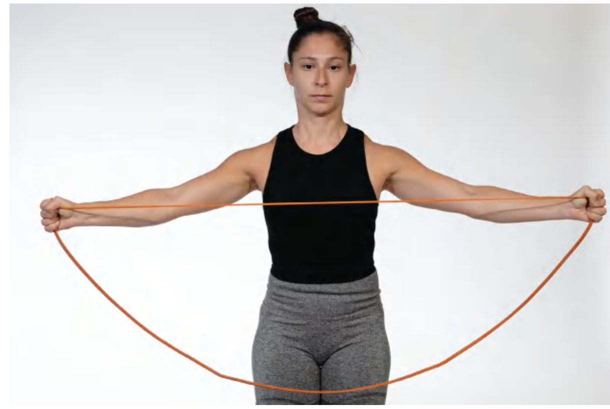

Figure 9-265 *Reactive shoulder horizontal abduction with band start position*

REACTIVE WALL BALL EXTERNAL ROTATION

- Stand facing a wall with the arm at 90° abduction and external rotation
- Use a small weight ball to perform repetitive small range tosses into the wall
- Maintain the height of the arm throughout
- This can also be performed with the arm in flexion, scaption, or abduction (not pictured)

Figure 9-266 *Reactive wall ball external rotation start position*

BOTTOMS-UP KETTLEBELL EXTERNAL AND INTERNAL ROTATION

- Hold the kettlebell by the handle with a neutral wrist and press up to 90° flexion
- Rotate the shoulder out to 90° abduction and external rotation, then rotate back to neutral
- Keep the kettlebell steady and maintain the height of the elbow throughout
- See bottoms-up kettlebell isometrics (page 338) or bottoms-up kettlebell carry (page 318) for positioning

SERRATUS ANTERIOR

The serratus anterior attaches to the medial border of the scapula and the upper rib cage. It is often called the "boxer's muscle" due to its primary function – scapula protraction or horizontal abduction, which is required for striking. In addition to scapula protraction, the serratus muscle also functions with the upper and lower trapezius muscle to rotate the scapula upward and to help keep good contact with the rib cage in order to prevent scapula winging.[367] Upward rotation of the scapula is important for maximizing subacromial space and to maintain the appropriate lines of force from the rotator cuff and deltoid muscles.[368] For example, if the scapula has difficulty with protraction and upward rotation from the serratus anterior, there may be greater demand on other muscles to overcome a retracted and downwardly rotated scapula during upper extremity movements.

SERRATUS PUNCHES AND LIFTS (OPEN-CHAIN)

SUPINE SERRATUS PUNCH

The supine punch allows an individual to focus on scapular protraction without the force of gravity, which may place greater demand on other muscles to maintain the height of the arm, particularly the rotator cuff and upper trapezius.[55,352] The exercise induces moderate to high serratus anterior activation with significantly lower activation of surrounding muscles,[55,369] which is a consideration during the early phases of rehabilitation. This can be performed at 90° to 120° of shoulder flexion depending on the desired degree of shoulder elevation.

- Start on the back with the elbow straight and shoulder flexed to 90°
- Perform a punching motion toward the ceiling and allow the scapula to protract
- During the descent, allow the scapula to retract and sink back down into the table/floor
- Do not bend the elbow during the lowering phase

Figure 9-267 *Supine serratus punch start position*

Figure 9-268 *Supine serratus punch end position in scapular protraction*

SUPINE ELBOW LIFT WITH BAND

Serratus exercises that are performed with a flexed elbow reduce degrees of freedom. This may improve motor control and overall understanding of the movement pattern if an individual has difficulty with scapula protraction and attempts to compensate by bending the elbow.

- Wrap a resistance band behind the back and assume a supine position
- Secure the band by bringing it over the tip of the elbow, along the forearm and up to the hand with enough tension to keep it in place

- Protract the scapula by reaching the elbow up toward the ceiling
- Emphasize upward rotation (if desired) by slightly angling the tip of the elbow up toward the shoulder in an arc type motion
- Retract the scapula by bringing it back toward the floor

Figure 9-269 *Supine elbow lift start position*

Figure 9-270 *Supine elbow lift end position in scapular protraction and upward rotation*

STANDING SERRATUS PUNCH (PUNCH "PLUS")

A standing forward punch performed with a resistance band or cable machine mimics pressing movements that may be required for striking, other sport specific movements or job tasks. This can be performed as a full range press from elbow flexion to full extension (forward punch) or from a completely extended arm position (punch plus). This variation produces a high level of muscle activation in the serratus anterior (42–67% MVIC)[55,363] and a significantly greater degree of serratus anterior compared to pec minor activation.[363]

- Set the cable or band at shoulder height
- Stand in a split stance – the leg on the same side of the pressing arm should be the rear leg
- Start with the elbow in 90° flexion and upper arm in line with the torso
- Press the arm forward until the elbow is fully extended
- At end-range, aim to fully protract the shoulder blade ("plus" component)
- Allowing a small amount of contralateral upper back rotation is appropriate after the shoulder blade is fully protracted
- Keep the elbow extended and allow the shoulder blade to retract
- Bend the elbow and allow the upper arm to return to the side of the torso
- Alternatively, the elbow can remain in full extension while performing scapula protraction and retraction for repetitions

Figure 9-271 *Standing serratus punch start position*

Figure 9-272 *Forward punch*

Figure 9-273 *Punch "plus" with additional scapula protraction*

LANDMINE PUNCH

The landmine punch is similar to the landmine press (see page 320), but the emphasis is now on isolated protraction and retraction of the scapula while the arm remains elevated for the purpose of biasing the serratus anterior.

- Use a landmine attachment or position the end of the barbell in the corner of a wall
- Grasp the end of the barbell with the elbow bent
- Press the barbell forward into a modified overhead position
- Perform a forward punch (scapular protraction) and then allow the scapula to sink back into retraction
- Do not lower the arm between each repetition
- This exercise can be performed in half kneeling (pictured) or standing

Figure 9-274 *Landmine punch start position*

Figure 9-275 *Punch "plus" with additional scapula protraction and upward rotation*

STANDING ELBOW LIFT WITH DUMBBELL

- Hold a dumbbell in the hand of the target arm and rest one end on the shoulder
- Position the shoulder in the scapular plane, at about 45° of abduction
- Focus on protracting the scapula and lifting the elbow up toward the ceiling in an arc type motion to assist with upward rotation

Figure 9-276 *Standing elbow lift start position*

Figure 9-277 *Scapula protraction and upward rotation*

DYNAMIC HUG

The dynamic hug exercise uses a resistance band or crossed cable pulley system to perform shoulder adduction combined with scapular abduction and protraction. This exercise generates significant muscle activation for the subscapularis (58–62% MVIC), supraspinatus (46–62% MVIC), pectoralis major (46% MVIC), anterior deltoid (45% MVIC), teres minor (69% MVIC) and serratus anterior (67% MVIC).[55] There is a greater activation of both middle and lower serratus anterior with the addition of a "plus" component (a dedicated scapular protraction movement at end-range) compared to the traditional dynamic hug and push-up plus exercises.[317]

- Set a resistance band or cable column at shoulder height
- Face away from the resistance and grasp both handles with the palms facing down, elbows and shoulders at 90° of flexion and neutral rotation
- Press the arms forward, protract the shoulders as if attempting to bring the palms together
- Let the elbows bend and travel backward to return to the start position

Figure 9-278 *Dynamic hug start position*

Figure 9-279 *Dynamic hug end position with scapula protraction*

D1 SHOULDER FLEXION (UPPERCUT)

The uppercut is a diagonal pattern of shoulder flexion that combines flexion, horizontal adduction and internal rotation of the shoulder, as well as scapular protraction. It primarily targets the serratus anterior and generates 100% MVIC.[55] If the middle and lower serratus anterior fibers are tested in isolation, this exercise generates greater than 60% MVIC for both portions, which are similar to values observed during the push-up plus.[317]

- Set a resistance band or cable column at the lowest height setting
- Grasp the handle with the palm facing up
- Keep a soft elbow, lift the arm up and across midline toward the opposite shoulder
- The palm should be facing the body, knuckles facing up, and elbow bent upon completion of the lift
- Focus on protracting the shoulder blade toward the end-range

Figure 9-280 *D1 shoulder flexion start position*

Figure 9-281 *D1 shoulder flexion end position*

WALL SLIDES

The wall slide is an active assisted exercise; it uses assistance from the wall to help overcome the weight of the arm and the force of gravity in order to elevate the limb. The wall also provides a surface to push into, which may assist with scapular protraction and upward rotation. The wall slide generates a moderate level of muscle activation in the serratus anterior[346,370] and low to moderate levels of muscle activation in the majority of muscles surrounding the shoulder.[365,371] Therefore, it may be used during the early phases of the rehabilitation process and/or if the goal is to focus on scapular protraction and upward rotation while potentially decreasing compensatory movement patterns.

- Place the palms down or ulnar side of the hands against a wall with the thumbs up (to increase shoulder external rotation)
- Press into the wall to promote scapular protraction
- Slide the hands up the wall until the elbows are extended and the arms resemble a "Y" shape
- Focus on scapular upward rotation during elevation
- This exercise can also be performed unilaterally

WALL SLIDE WITH BAND RESISTANCE

The addition of a resistance band around the wrists increases recruitment of the surrounding rotator cuff and scapulothoracic muscles, including the serratus anterior.[370]

Figure 9-282 *Wall slide start position*

Figure 9-283 *Wall slide end position*

- Place a resistance band around the wrists or between each hand
- Perform the wall slide exercise as detailed above
- Maintain tension on the band throughout the movement
- Keep the wrists in line with the elbows and do not allow the band to pull the wrists inward

Figure 9-284 *Wall slide with band resistance start position*

Figure 9-285 *Wall slide with band resistance end position. Tension on the band is maintained at end-range*

SERRATUS PUSH-UPS

As detailed earlier in this chapter, the push-up is a bodyweight exercise that activates the muscles of the chest and upper extremities. Serratus push-ups, also known as push-up "plus," require a similar initial set-up, but instead of bending the elbows and dropping the chest toward the floor, the elbows remain extended throughout the exercise. The concentric and eccentric movements are now strictly scapular protraction and retraction, which will target the serratus anterior. There are many variations of this exercise, which can be beneficial for different individuals considering their training experience, pain, or phase of the rehabilitation process. For example, if a serratus push-up performed from the high plank position is too difficult or painful, the exercise can be changed to being prone on the elbows or quadruped position, which will require less weight-bearing and therefore scapular protraction against a decreased percentage of bodyweight. Resistance can also be added to increase difficulty using a band wrapped around the shoulder blades and upper back, as detailed below.

HIGH PLANK SERRATUS PUSH-UPS (PUSH-UP "PLUS")

Serratus push-ups from the high plank position on the floor produce high levels of muscle activation in the serratus anterior from 60%[372] to greater than 80% MVIC[345,373] and relatively low upper trapezius activation,[345,372,373] which creates a favorable upper trapezius to serratus anterior activation ratio.[345,347,373,374] This exercise can be performed on both stable and unstable surfaces (e.g. BOSU ball, physioball, suspension straps, etc.), but unstable surfaces have been shown to increase upper trapezius activation.[345,347,348] The hands should be positioned at about shoulder width apart and at about 110° of shoulder flexion to maximize serratus anterior muscle activation,[348] but if shoulder range of motion is impaired or if this degree of shoulder elevation causes discomfort it may be best to position the hands directly under the shoulders at 90°. These factors may be important to consider and may be beneficial if the primary goal is serratus anterior strengthening. This exercise can be performed from the floor or various inclines. However, it appears that increasing the incline will in turn decrease global muscle activation.[372]

- Start in high plank position with the hands stacked directly under or just anterior to the shoulder or humeral head

- Push the ground away to protract the shoulder blades
- Allow the shoulder blades to sink backward into retraction, but maintain the elbows in extension
- The primary movement is scapula protraction and retraction on a fixed rib cage

Figure 9-286 *High plank serratus push-up start position*

Figure 9-287 *High plank serratus push-up end position in scapula protraction*

PRONE ON ELBOWS SERRATUS PUSH-UP

The prone on elbows position is appropriate for anyone who has impaired shoulder girdle stability, pain or difficulty weight-bearing on outstretched arms, bends the elbows during the retraction phase, or if the goal is to limit the amount of body weight supported by the upper extremities.

- Start with the elbows bent, forearms and hips in contact with the floor
- The elbows should be stacked directly under or just anterior to the humeral head
- Drive through the forearms as if pushing the ground away to protract the shoulder blades and round the upper back
- Let the shoulder blades retract and upper back sink down into some extension
- Maintain the hips in contact with the floor and a neutral to slightly extended neck throughout

Figure 9-288 *Prone on elbows serratus push-up start position*

Figure 9-289 *Prone on elbows serratus push-up end position in scapula protraction*

QUADRUPED SERRATUS PUSH-UP

Similar to the prone on elbows push-up, the quadruped position will decrease the amount of body weight that must be supported, but will increase difficulty through weight-bearing on outstretched arms.

- Start in the quadruped position with the elbows extended and hands stacked directly under or just anterior to the shoulder or humeral head
- Push the ground away to protract the shoulder blades
- Allow the shoulder blades to sink backward into retraction, but maintain the elbows in extension
- *Image of band resistance around back*

Figure 9-290 *Quadruped serratus push-up start position*

Figure 9-291 *Quadruped serratus push-up end position in scapula protraction*

Figure 9-292 *Band resistance*

BEAR PLANK SERRATUS PUSH-UP

- Start in the quadruped position, bearing weight on both hands and balls of feet
- Push through the hands and feet to slightly lift the knees from the floor
- Maintain this position and perform scapula protraction and retraction without any compensatory movement from the lumbar spine or elbows
- Allow the shoulder blades to sink backward into retraction, but maintain the elbows in extension

Figure 9-293 *Bear plank serratus push-up start position*

Figure 9-294 *Bear plank serratus push-up end position in scapula protraction*

FOREARM PLANK SERRATUS PUSH-UP

- Start in the forearm plank position, bearing weight through the elbows and both feet
- Maintain a neutral lumbar spine throughout while performing scapula protraction and retraction as detailed above

Figure 9-295 *Forearm plank serratus push-up start position*

Figure 9-296 *Forearm plank serratus push-up start position in scapula protraction*

HIGH PLANK SINGLE-ARM PROTRACTION/RETRACTION DIPS

- Position one hand on an elevated surface (small step, yoga block, weight plates, etc.) about 3–5 inches from the floor
- Assume a high plank position with the opposite hand in contact with the floor
- Drive through the elevated hand to protract the shoulder blade
- At the same time, lift the opposite hand from the floor by retracting the opposite scapula until the shoulders are level with each other
- Reach the opposite arm down to the floor and retract the scapula of the elevated arm to reverse the movement
- Maintain abdominal tension and pelvis stable throughout
- This exercise can be performed from the floor or on an elevated surface, like a bench

Figure 9-297 *Scapula retraction*

Figure 9-298 *Scapula protraction*

STEP WALK-OVER

- Start in high plank position next to an exercise step
- Contract the abdominals to enhance lumbo-pelvic stability and to resist trunk rotation as the support from one hand is removed
- Lift the hand closest to the step and place it on the far end of the step
- Drive through the hand on the step to unload the opposite arm and lift that hand from the floor onto the step
- Lift the hand off the far edge of the step and place it onto the floor at a slight distance to leave enough space that will soon be occupied by the opposite arm
- Lift the opposite arm up and place onto the floor next to the step
- Repeat in the opposite direction

Figure 9-299 *Step walk-over start position*

Figure 9-300 *Step up*

Figure 9-301 *Both hands on step*

Figure 9-302 *Step down*

Figure 9-303 *Step walk-over end position*

HIGH PLANK TO PIKE SCAPULAR PUSH-UP

Prerequisites for performing this exercise include good hamstring and calf flexibility. Also, this may not be the most appropriate exercise variation for anyone with flexion sensitive lower back pain and/or neural tension.

- Start in a high plank position and drive the hips up toward the ceiling
- Maintain the elbows straight, but keep a soft bend in the knees
- Push through the hands to drive the floor away – this will cause the shoulder blades to rotate upward
- Release the press and allow the shoulder blades to sink back and down

Figure 9-304 *High plank start position*

Figure 9-305 *Pike*

Figure 9-306 *Scapular push-up with protraction and upward rotation*

SERRATUS PUSH-UP WITH SUSPENSION STRAPS

The suspension straps provide an unstable surface that may further challenge shoulder and scapular stability. Unstable surface training usually increases muscle activity in the target and supporting muscles, most notably the upper trapezius.[347,372] The suspension serratus push-up, however, is performed at an incline, so the same effect is not observed and upper trapezius activation remains low (less than 20% MVIC).[372]

- Start in high plank position on the suspension straps
- Stack the hands directly under or just anterior to the shoulder or humeral head
- Contract the abdominals for stability
- Push the ground away to protract the shoulder blades
- Allow the shoulder blades to sink backward into retraction, but maintain the elbows in extension

Figure 9-307 *Suspension strap high plank*

Figure 9-308 *Scapula protraction*

SERRATUS SLIDES AND BEAR CRAWLS

Serratus slides and crawls encourage scapula protraction and upward rotation through weight-bearing and shoulder elevation. The exercise may also serve as a means to address overhead shoulder mobility and pressing movements if they are painful against gravity. Performing the exercise on an elevated surface, like a mat or table, or using the quadruped position during slides will decrease the difficulty. Upper body strength and the ability to support the body's weight may be a limiting factor for some individuals.

QUADRUPED SERRATUS SLIDES

- Start in the quadruped position and contract the abdominals to provide lumbo-pelvic stability
- Use a sliding disk (on a turf or carpet) or towel (on a smooth surface) under one hand
- Keep the elbow straight, press into the floor and maintain this press while sliding the arm forward
- Pull the arm back to the start position
- Press down through the stance arm and maintain the elbow straight to maximize stability

Figure 9-309 *Quadruped slide start position*

Figure 9-310 *Quadruped slide end position with scapula upward rotation*

QUADRUPED SLIDES WITH FOAM ROLLER

A foam roller will decrease weight-bearing through the moving arm and increase weight-bearing through the stance arm. Perform the exercise as detailed above, but instead of using a Valslide or towel, position the ulnar side of the wrist or forearm on a foam roller with the thumb facing up. Press into the foam roller as you slide the foam roller forward and back.

Figure 9-311 *Quadruped slide with a foam roller start position*

Figure 9-312 *Use of a foam roller to assist upward rotation*

HIGH PLANK SERRATUS SLIDE

- Start in the high plank position and contract the abdominals to provide lumbo-pelvic stability
- Use a sliding disk (on a turf or carpet) or towel (on a smooth surface) under one hand
- Keep the elbow straight, press into the floor and maintain this press while sliding the arm forward
- Pull the arm back to the start position
- Press down through the stance arm and maintain the elbow straight to maximize stability
- Do not let the hips rise, drop down, or rotate side to side throughout

Figure 9-313 *High plank slide start position*

Figure 9-314 *High plank slide end position with scapula upward rotation*

MODIFIED HIGH PLANK SERRATUS SLIDE

Figure 9-315 *Modified high plank slide start position*

Figure 9-316 *Modified high plank slide end position with scapula upward rotation*

BACKWARD BEAR CRAWL

Backward bear crawls require both protraction and upward rotation of the shoulder blade. As the moving arm transitions backward, upright posture is maintained by the push-off and closed-chain elevation of the weight-bearing arm.

- Start in the quadruped position, bearing weight on the balls of the feet and both hands
- Push through the hands and feet to slightly lift the knees from the floor
- Contract the abdominals to provide lumbo-pelvic stability
- Push down through the weight-bearing arm for support as the moving arm and opposite leg move backward
- Repeat this on the opposite side so that each arm and opposite leg moves reciprocally

Figure 9-317 *Start position in bear plank*

Figure 9-318 *Backward crawl*

TRICEPS

The tricep brachii muscle group is made up of the medial, lateral, and long “heads,” which are just three separate muscle bellies. The primary function of the tricep group is elbow extension, but each portion of the tricep contributes differently depending on the degree of shoulder elevation.[375] The long head activates similarly independent of shoulder elevation and will be the greatest contributor to elbow extension at low shoulder elevation angles (e.g. in 0° of shoulder elevation with the upper arm at the side). This may be due to increased muscle length during shoulder elevation, as the long head attaches at a higher point (on the glenoid fossa) than its counterparts.[375] The lateral and medial heads, however, demonstrate increased muscle activation at greater degrees of shoulder flexion compared to the long head. The medial head appears superior to the lateral head with respect to muscle activity and force generation.[375] There is no research to support that forearm position (pronated, supinated, neutral) contributes to tricep muscle activation or isolating a particular portion of the tricep, so use the grip that feels most comfortable for each individual.

When performing tricep extensions using the push down exercises below, the degree of elbow flexion that is allowed on the eccentric phase is important to consider based on the desired goal. If the goal is to lift the heaviest amount of weight, it may be best to return to 90° elbow flexion between repetitions, as the muscles will need to contract from mid-range, instead of end-range after each repetition, which provides a greater mechanical advantage for the triceps. Also, there will be less time under tension, which will likely allow a greater number of repetitions at the desired weight to be performed. If the goal is to focus on increased muscle stretch and time under tension via eccentric lengthening, it may be best to let the elbow flex beyond 90° after each repetition.

DOUBLE-ARM TRICEP PUSH DOWN PRONATED GRIP

- Use an overhand grip on a cable column (straight bar attachment) or resistance band
- Position the upper arm in contact with the torso and the elbow flexed to 90°
- Press down and extend the elbows
- Do not let the humeral head travel forward and/or the upper arm travel backward into shoulder extension

Figure 9-319 *Double-arm push down pronated start position*

Figure 9-320 *Double-arm push down pronated end position*

DOUBLE-ARM TRICEP PUSH DOWN SUPINATED GRIP

- Perform the exercise as detailed above, but use an underhand grip on a cable column (straight or EZ-bar attachment) or resistance band

Figure 9-321 *Double-arm push down supinated start position*

Figure 9-322 *Double-arm push down supinated end position*

SINGLE-ARM TRICEP PUSH DOWN PRONATED GRIP

- Perform the exercise as detailed above, but use an overhand grip on a cable column (handle attachment) or resistance band

Figure 9-323 *Single-arm-arm push down pronated grip start position*

Figure 9-324 *Single-arm-arm push down pronated grip end position*

SINGLE-ARM TRICEP PUSH DOWN SUPINATED GRIP

- Perform the exercise as detailed above, but use an underhand grip on a cable column (handle attachment) or resistance band

Figure 9-325 *Single-arm push down supinated grip start position*

Figure 9-326 *Single-arm push down supinated grip end position*

STANDING ROPE PUSH DOWN

- Position the upper arm in contact with the torso and the elbow flexed to 90°
- Pull the rope down and apart to extend the elbows
- Do not let the humeral head travel forward and/or the upper arm travel backward into shoulder extension

Figure 9-327 *Rope attachment push down start position*

Figure 9-328 *Rope attachment push down end position*

SKULL CRUSHER NEUTRAL GRIP

- Hold a dumbbell in each hand with a neutral grip (palms face each other)
- Start with the shoulders flexed to 90° and elbows extended
- Allow the elbows to bend until the weights are in line with the temples
- Do not let the upper arm and elbows travel forward (shoulder extension) or out to the side (shoulder horizontal abduction) as the elbows bend
- Drive the weights toward the ceiling to extend the elbows
- Perform this exercise on the floor instead of a bench to reduce the available range of motion

Figure 9-329 *Skull crusher neutral grip start position*

Figure 9-330 *Skull crusher neutral grip end position. The upper arms remain stationary while the elbows flex*

SKULL CRUSHER SUPINATED GRIP

- Hold a weighted bar with a pronated grip (palms facing the feet)
- Start with the shoulders flexed to 90° and elbows extended
- Allow the elbows to bend until the hands pass beyond the forehead
- Do not let the upper arm and elbows travel forward (shoulder extension) as the elbows bend
- Drive the bar toward the ceiling to extend the elbows
- Perform this exercise on the floor instead of a bench to reduce the available range of motion

Figure 9-331 *Skull crusher supinated grip start position*

Figure 9-332 *Skull crusher supinated grip end position. The upper arms flex as the elbows flex for additional range of motion*

ROLLING TRICEP EXTENSIONS WITH KETTLEBELLS

- Hold a kettlebell in each hand with a pronated grip (palms facing the feet)
- Start with the shoulders flexed to 90° and elbows extended
- Allow the elbows to bend until the kettlebells are in line with the temples
- Do not let the upper arm and elbows travel forward (shoulder extension) or out to the side (shoulder horizontal abduction) as the elbows bend
- Instead of extending the elbows from this position, lower the elbows toward the sides of the torso by allowing both the wrists and shoulders to extend
- From this position, press the weights straight up to end in the start position
- Perform this exercise on the floor instead of a bench to reduce the available range of motion

Figure 9-333 *Rolling tricep start position*

Figure 9-334 *Tricep skull crusher*

Figure 9-335 *The shoulders lower and extend to drop the elbows toward the sides of the torso*

DOUBLE-ARM OVERHEAD TRICEP EXTENSION

- Start in a split stance
- Grasp a resistance band or cable column using the desired attachment based on which grip is preferred (handle for pronated grip or tricep rope for neutral grip)
- Start with the arm elevated above shoulder height and elbow flexed to 90°
- Extend the elbows by pulling the resistance band or rope forward and apart
- Do not lower the upper arm (shoulder extension) during elbow extension

Figure 9-336 *Overhead tricep extension start position*

Figure 9-337 *Overhead tricep extension end position*

45° HOLD TRICEP EXTENSIONS

This exercise utilizes the same set-up position as the shoulder extension 45° holds (see page 340), but instead of allowing the shoulders to flex in between each repetition, the shoulders remain extended and the primary concentric to eccentric contraction is elbow extension

This exercise can be performed in tall kneeling to reduce degrees of freedom, allow greater focus on abdominal muscle activation and spinal position (as detailed below), or standing.

- Grasp the handles of a resistance band with the palms facing forward
- Contract the abdominals to prevent the lower back from extending during the pull
- Keep the elbows straight and pull the arms back at a 45° angle
- Retract the shoulder blades as needed
- Maintain this position and allow the elbows, but not the shoulder to flex
- Extend the elbows by driving the hands backward, but do not let the hands extend too far beyond the shoulders

Figure 9-338 *45° tricep extension start position*

Figure 9-339 *45° tricep extension end position*

TRICEP KICKBACK

- Grasp a resistance band or cable
- If using a cable, grasp either just above the clip without using an attachment, a tricep rope, or other attachment that can be held with a neutral grip (palm facing inward)
- Stand a slight distance from the resistance and hinge forward
- The opposite arm can rest on the hip, knee, or a bench (if available)
- Start with the upper arm in line with the torso and the elbow flexed to 90°
- Drive the hand backward to extend the elbow
- Do not allow excessive humeral head forward translation and/or upper arm shoulder extension in order to maintain emphasis on the triceps
- Flex the elbow to return to the start point

Figure 9-340 *Tricep kickback start position*

Figure 9-341 *Tricep kickback end position*

CLOSE GRIP PUSH-UP

Push-ups were covered extensively earlier in this chapter (page 276), but if we consider the tricep muscle group exclusively, hand position appears to matter with respect to muscle activation. The narrow hand position push-up produces significantly greater EMG muscle activation of the triceps when compared to a wide hand position.[303,307]

- Position the hands directly below the shoulders and inside shoulder width
- It is also appropriate to use a "diamond grip" where the thumb and pointer fingers contact each other and are positioned below the level of the sternum, but this may be more difficult for those with wrist issues
- Assume a high plank position with the body in a straight line from the torso to the feet
- Bend the elbows and lower down to the floor while keeping the elbows tight to the body, ideally pointing them directly backward toward the feet
- Allow the shoulder blades to come together during the downward phase
- Avoid excessive extension in the lumbar spine or hips elevating up during the descent
- Consider tightening the glutes and abdominals to maintain a rigid torso if needed
- Push through the upper body (as if pushing the floor away) during the upward phase

Figure 9-342 *Close grip push-up start position*

Figure 9-343 *Close grip push-up end position*

BODYWEIGHT SKULL CRUSHER

- Start in a high plank position with the hands in contact with the floor or an elevated surface (bench, smith machine, racked barbell, suspension straps, etc.)
- Position the hands above shoulder height
- Bend the elbows and shift the weight of the body backward and down
- Press through the hands and use the triceps to extend the elbow to propel back to upright

Figure 9-344 *Bodyweight skull crusher start position in high plank*

Figure 9-345 *Bodyweight skull crusher end position*

BICEPS AND BRACHIALIS

The bicep brachii muscle group is made up of the short and long heads. The long head tendon travels between the greater and lesser tuberosities of the humerus and attaches to the superior glenoid fossa of the scapula while the short head attaches to the coracoid process on the anterior portion of the scapula. The bicep group performs elbow extension, forearm supination, and assists shoulder elevation. The brachialis is also an elbow flexor, but due to its attachment point on the ulna it is an active elbow flexor independent of forearm position.

Figure 9-346 *Isometric elbow flexion*

ISOMETRIC ELBOW FLEXION

- Start with the elbow in flexion at 90° (or desired range)
- Position the anterior wrist under a surface that will not move and push up into that surface

FARMER'S CARRY IN 90° OF ELBOW FLEXION

- Hold dumbbells in each hand with the elbows flexed to 90°, palms facing up, and upper arm in contact with the sides of the torso
- Contract the abdominals to help maintain a rigid torso
- Walk a straight path distance while maintaining the weights in position

Figure 9-347 *Isometric elbow flexion carry*

ECCENTRIC SHOULDER FLEXION WITH SUPINATED GRIP

This exercise is not meant to maximize bicep hypertrophy and strength, but may prove helpful in the setting of bicep long head tendon irritation. Forearm supination will help to target the long head of the bicep during the eccentric portion.

- Start with the elbow extended and arm at the side with the palm facing forward
- Use the opposite arm to lift the target arm up to shoulder height
- Maintain the height of the arm once the assistance of the opposite arm is removed and lower slowly, under control

Figure 9-348 *Assisted shoulder flexion with supinated grip*

Figure 9-349 *Controlled lowering phase*

DUMBBELL BICEP CURL

- Hold a dumbbell in each hand with the arms at the sides and palms facing the thighs
- Curl the dumbbell up by flexing the elbow and supinating the forearm so that the palm is facing up
- Lift the elbow up and forward as if bringing the dumbbell to the sternum or chin
- Allow the forearm to pronate, extend the elbow and lower the weight under control until the arm is at the side
- Alternate sides after each repetition

Figure 9-350 *Alternating bicep curl start position*

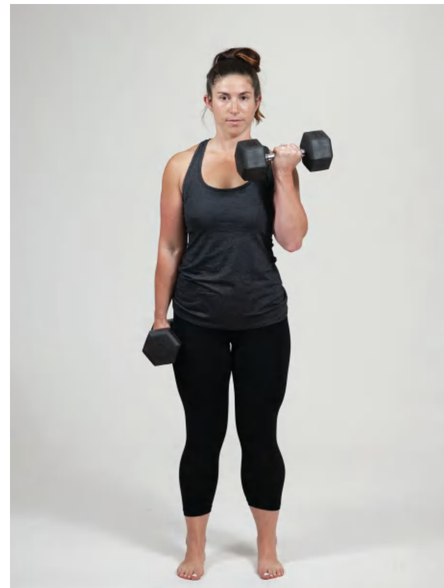

Figure 9-351 *Alternating bicep curl end position*

BARBELL BICEP CURL

- Hold a barbell with the palms facing up
- Curl the weight up by lifting the elbows up and forward as if bringing the barbell to the sternum or chin
- Do not let the elbows travel backward and allow the shoulder to extend during the curl, as this will stretch the bicep and place additional stress on its long head
- Lower the weight under control as the elbows extend

Figure 9-352 *Barbell bicep curl start position*

Figure 9-353 *Barbell bicep curl end position*

HAMMER CURL

- Hold a dumbbell in each hand with the arms at the sides and palms facing the thighs
- Curl the dumbbell up by flexing the elbow up and forward as if bringing the dumbbell to the sternum or chin

- Do not let the elbows travel behind the shoulder joint during the curl, as this will put the bicep on stretch during the concentric portion
- Extend the elbow and lower the weight under control until the arm is at the side
- Keep the palm facing midline of the body (neutral grip) throughout the movement
- Alternate sides after each repetition

Figure 9-354 *Hammer curl start position*

Figure 9-355 *Hammer curl end position*

HOOK-LYING HAMMER CURL

- Start on the back with the knees bent and feet facing the cable column
- Hold a rope attachment between the knees with a neutral grip
- Maintain the back flat to the floor and flex the elbows as if bringing the rope toward the shoulders or ears
- The floor will automatically prevent any excessive shoulder extension

Figure 9-356 *Hook-lying hammer curl start position*

Figure 9-357 *Hook-lying hammer curl end position*

PRONATED CURL

The bicep brachii is more active with a supinated compared to a pronated grip.[376] So, if the goal is to decrease bicep brachii activation to better bias the brachialis, the pronated curl may be a good option. An individual must have full, or nearly full, forearm pronation range of motion to perform this exercise correctly.

- Use a barbell or EZ-curl bar
- Position the arm against the side
- Lift the elbow up past 90° with the palm facing down
- Keep the elbows in contact with the torso and avoid shoulder extension throughout

Figure 9-358 *Pronated curl start position*

Figure 9-359 *Pronated curl end position*

PREACHER CURL

The preacher curl puts more emphasis on training the bicep at a longer muscle length, as a greater amount of torque is applied when the biceps is in an elongated position.[377,378] Training at longer muscle lengths has also been shown to increase muscle hypertrophy of the biceps[378,379] and other muscles in the lower extremities.[380,381]

- The degree of incline of the bench will depend on an individual's height, arm length, and comfort
- Position the entire upper arm on the bench

Figure 9-360 *Preacher curl start position*

- Hold a dumbbell with the palm facing up and elbow flexed
- Slowly extend the elbow until just prior to end-range extension or a range of motion that the individual can control
- Curl the weight back up to the start point
- Initially, start with a lighter weight that can be easily controlled, as the short head of the biceps may be vulnerable to rupture if using heavier loads that the tissue is not prepared for

Figure 9-361 *Preacher curl end position*

CONCENTRATED CURL

The concentrated curl is similar to the preacher curl, but uses support of the elbow on the knee instead of a bench. If an incline bench is not available, this exercise is an appropriate substitute.

- Start seated with the elbow of the target arm rested on the lower portion of the thigh and arm angled toward the midline of the body
- Hold a dumbbell with the palm facing up
- Let the elbow extend between the legs
- Curl the weight back up to the start point

Figure 9-362 *Concentrated curl start position*

Figure 9-363 *Concentrated curl end position*

EXTRA RANGE SEATED CURL

- Set an incline bench between 45–60° and hold dumbbells in each hand
- Lower the weights under control until the elbows are extended
- Allow the shoulders to extend to put the biceps on increased stretch
- Flex the elbows and lift the arm up into slight shoulder flexion
- This exercise can be performed bilaterally (Figure 9–365) or unilaterally while holding the non-working arm in elbow flexion (isometric contraction) during the working set (Figure 9–366)

Figure 9-364 *Extra range seated curl start position*

Figure 9-365 *Extra range seated curl end position*

Figure 9-366 *Isometric hold with unilateral curl. Entire working set performed with one arm prior to switching to opposite arm*

BICEP CABLE OR RESISTANCE BAND CURL

- Set the cable column on the lowest height setting with a straight bar, EZ-curl bar, or handle attachment
- Curl the weight up by lifting the elbows up and forward as if bringing the bar to the sternum or chin
- Maintain the elbows close to the sides of the torso
- Do not let the elbows travel backward and allow the shoulder to extend during the curl, as this will put the biceps on stretch
- Lower the weight under control as the elbows extend, but stop just prior to full extension to maintain constant tension on the biceps
- This can be performed bilaterally (Figures 9–367 and 9–368) or unilaterally with a handle attachment

Figure 9-367 *Bicep curl with resistance band start position*

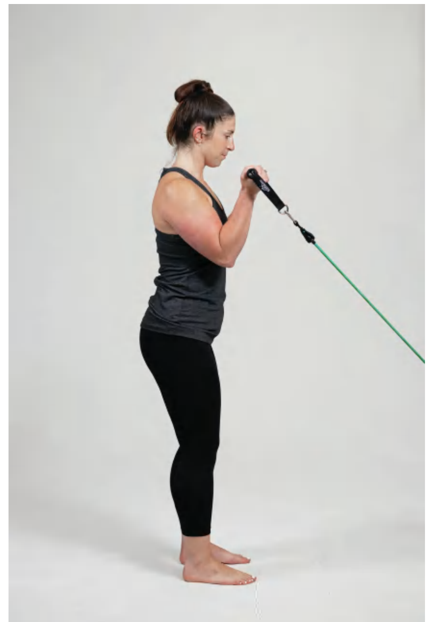

Figure 9-368 *Bicep curl with resistance band end position*

CABLE BICEP CURL AT 90° SHOULDER FLEXION AND ABDUCTION

- Use a handle attachment and set the cable column at least a few inches below shoulder height
- Start with the elbow extended and shoulder joint at 90° flexion and abduction
- Perform a bicep curl as if bringing the hand toward the side of the head, but maintain the position of the shoulder throughout
- Let the elbow extend under control
- Lighter weights are used during this exercise as the traction from the cable creates increased stretch on the biceps

Figure 9-369 *Bicep curl at 90° shoulder flexion and abduction start position*

Figure 9-370 *Bicep curl at 90° shoulder flexion and abduction end position*

FOREARM AND GRIP TRAINING

The muscles of the forearm are responsible for movements at the elbow, many gross and fine motor tasks of the arm, including maintaining a grip. The wrist flexors and forearm pronators are located on the anterior (palmar) side of the forearm and include the pronator teres, flexor carpi radialis and ulnaris, palmaris longus, flexor digitorum superficialis, and pronator quadratus. The extensors and supinators are located on the posterior (dorsal) side and include, but are not limited to, the extensor carpi radialis longus and brevis, extensor digitorum, and extensor carpi ulnaris.

Grip strength has important implications for an individual's health and wellness. Evidence supports it is a predictor of mortality and disease,[382,383] overall strength,[382,384] bone mineral density, hospital admissions, and function.[382] Individuals with type 2 diabetes who have both low bone mineral density and decreased grip strength, have higher prevalence of cardiovascular disease, heart disease, and peripheral artery disease.[385] Grip strength is predictive of cardiovascular disease and associated mortality[386] and has been found to be even more predictive than blood pressure.[387]

WRIST FLEXION

- Hold a dumbbell with the palm facing up
- Provide support for the forearm with the opposite arm or by resting it on the knee, bench or table
- Curl the wrist up using the forearm flexors
- Lower down under control

Figure 9-371 *Wrist flexion start position*

Figure 9-372 *Wrist flexion end position*

WRIST EXTENSION

- Hold a dumbbell with the palm facing down
- Provide support for the forearm with the opposite arm or by resting it on the knee, bench, or table
- Lift the wrist up using the forearm extensors
- Lower down under control

Figure 9-373 *Wrist extension start position*

Figure 9-374 *Wrist extension end position*

ECCENTRIC ONLY WRIST FLEXION OR EXTENSION

- Eccentric wrist flexion or extension focuses exclusively on the lowering phase
- Perform the exercise as detailed above, but the concentric portion must be assisted by the opposite hand
- Remove the support of the opposite hand, maintain end-range for one to two seconds, then slowly lower down without assistance

Figure 9-375 *Assist into wrist extension*

Figure 9-376 *Wrist extension eccentric*

Figure 9-377 *Assist into wrist flexion*

Figure 9-378 *Wrist flexion eccentric*

PRONATION TO SUPINATION WITH HAMMER

- Hold a hammer vertically with a neutral grip (thumb up)
- Provide support for the forearm with the opposite arm or by resting it on the knee, bench, or table
- Slowly lower the hammer toward midline and allow the forearm to pronate
- Turn the thumb up and turn the hammer away from midline until the forearm is fully supinated

Figure 9-379 *Neutral start position*

Figure 9-380 *Controlled lowering phase into pronation*

Figure 9-381 *Supination from fully pronated position*

PRONATION OR SUPINATION WITH RESISTANCE BAND

- Attach a thin resistance band across a squat rack or another stable structure
- Support the target forearm with the opposite arm
- To perform pronation, grasp the band with the palm up, and rotate the forearm while turning the thumb toward midline
- To perform supination, grasp the band with the palm down, and rotate the forearm while turning the thumb away from midline

Figure 9-382 *Underhand grip for forearm pronation start position*

Figure 9-383 *Forearm pronation*

Figure 9-384 *Overhand grip for forearm supination start position*

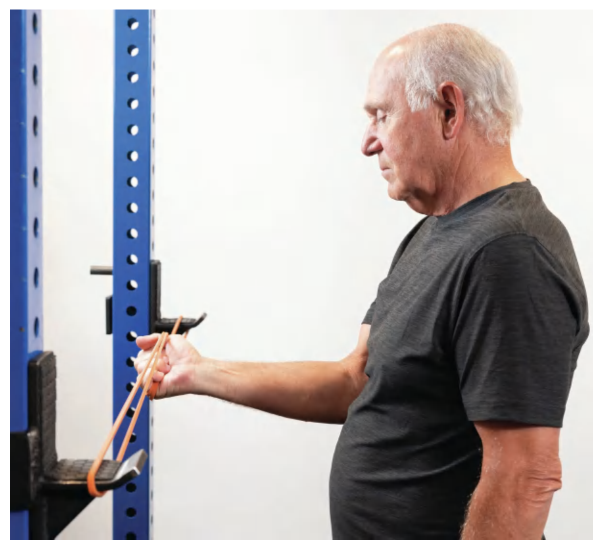

Figure 9-385 *Forearm supination*

TOWEL HANG

Towel hangs can be performed vertically by using thin towels and a pull-up bar or horizontally by attaching towels to a barbell or smith machine. This exercise requires an individual to maintain a grip on the towel while supporting their body weight.

- Start with a firm grasp on the towels using a neutral grip (thumb up)

Figure 9-386 *Towel hang from inverted row*

- Extend the elbows and allow the arms to support the body's full weight
- Contract the abdominals and latissimus dorsi (by depressing the shoulder blades down) to enhance stability as needed

Figure 9-387 *Towel hang from pull-up bar*

PLATE PINCH

- Place a small plate between the thumb, index, and middle finger and pinch the fingers together to hold it in place
- Extend the elbow and maintain the arm at the side
- Contract the abdominals to enhance stability as needed and perform a hold for time

Figure 9-388 *Plate pinch*

WIDE GRIP

- Grasp the wide end of a dumbbell or kettlebell from the bottom
- Extend the elbow and maintain the arm at the side
- Contract the abdominals and posterior shoulder muscles to enhance stability as needed and perform a hold for time

Figure 9-389 *Wide grip kettlebell*

Figure 9-390 *Wide grip dumbbell*

MONKEY GRIP

- Grasp the handle of a dumbbell or kettlebell with only the fingers, not the thumb
- Extend the elbow and maintain the arm at the side
- Contract the abdominals and posterior shoulder muscles to enhance stability as needed and perform a hold for time

Figure 9-391 *Monkey grip*

FARMER'S CARRY

See page 428.

THORACIC SPINE

The thoracic spine is responsible for a small amount of motion into flexion and extension, but a greater degree of rotation, due to the anatomy of the vertebrae. The thoracic spine sits between the neck, shoulder girdle, and lumbar spine. There is a large body of research on regional interdependence and the thoracic spine, meaning that improving mobility at the thoracic spine can have an impact on issues that arise both above and below the upper back.[388,389] Reduced shoulder range of motion,[390] decreased scapula posterior tilt,[391] and increased stress on the anterior shoulder[388,391] are observed with increased thoracic kyphosis. Mobilization and manipulation of the thoracic spine have also been shown to improve neck pain[392–395] and cervical range of motion,[395–397] though the quality of the available evidence is not overly compelling. The exercises detailed below are not all necessarily meant to improve thoracic mobility, but rather to load the thoracic spine, develop stability and strength in the surrounding muscles as a means to help maintain any improvements made during both passive manual therapy and active mobility exercises.

THORACIC EXTENSION

PRONE ON ELBOWS THORACIC EXTENSION

- Start with the elbows bent, forearms and hips in contact with the floor or table
- The elbows should be stacked directly under the shoulders
- Maintain the arms in contact with the floor or table and extend the upper back by lifting the chest
- Drive the hips into the floor and perform a posterior pelvic tilt to limit lumbar spine extension

Figure 9-392 *Prone on elbows thoracic extension start position*

Figure 9-393 *Prone on elbows thoracic extension end position*

PRONE THORACIC EXTENSION

- Start on the stomach with the chest in contact with the floor or table
- Retract the shoulder blades and extend the upper back by lifting the chest
- Drive the hips into the floor and perform a posterior pelvic tilt to limit lumbar spine extension
- Place a pillow under the chest to increase difficulty, as the concentric contraction will occur closer to end-range

Figure 9-394 *Prone thoracic extension start position*

Figure 9-395 *Prone thoracic extension end position*

PHYSIOBALL THORACIC EXTENSION

- Position the physioball under the abdomen and lower rib cage
- Bend the knees and secure the front of the thighs against the ball
- Let the upper back flex over the ball
- Contract the abdominals and glutes to stabilize the lower back
- Lift the chest and upper back up into extension
- Drive the hips into the ball and perform a posterior pelvic tilt to limit lumbar spine extension

Figure 9-396 *Physioball thoracic extension start position*

Figure 9-397 *Physioball thoracic extension end position*

THORACIC ROTATION

LUMBAR LOCKED THORACIC ROTATION WITH BAND

- Start in the quadruped position and rock back onto the heels to limit motion from the lumbar spine
- Loop a resistance band around the shoulder of the target arm
- Position the hand on the back of the head or neck
- Open the chest and rotate through the upper back against the resistance of the band as if trying to turn the tip of the elbow toward the ceiling
- Rotate in the opposite direction, round the upper back, and turn the elbow inward toward midline with assistance from the band

Figure 9-398 *Thoracic rotation with band start position*

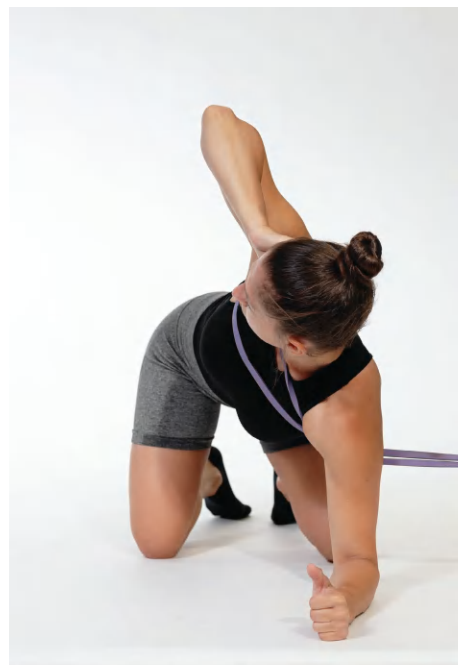

Figure 9-399 *Thoracic rotation with band end position*

SINGLE-ARM ROW TO THORACIC ROTATION

- Perform a single-arm row as detailed on page (xx)
- At the end of the pull phase, maintain the upper arm at the side and rotate at the upper back as if trying to look over the shoulder on that side
- Do not continue to pull the elbow back during the rotation phase, as this may result in excessive shoulder extension, increased stress on the anterior shoulder, and likely less rotation from the thoracic spine

Figure 9-400 *Single-arm row start position*

Figure 9-401 *Row*

Figure 9-402 *Thoracic rotation*

HIGH PLANK THORACIC ROTATION

- Start in the high plank position with the feet greater than hip-width apart
- Contract the abdominals and glutes to stabilize the lumbar spine and lower body
- Bear weight on both feet and one arm

- Lift the opposite arm, open the chest, and rotate through the upper back as if trying to turn the elbow or fingertips (if performing with a straight elbow) toward the ceiling
- The hips rotate slightly, but the majority of the motion occurs at the upper back
- Return to the start point with both hands on the floor to maximize stability before the next repetition

Figure 9-403 *High plank start position*

Figure 9-404 *Thoracic rotation*

ARM BAR ROTATION (REGULAR AND FULL ROTATION)

The arm bar rotation is a shoulder stability and loaded mobility exercise for the thoracic spine, pectorals, and latissimus dorsi.[344]

- Start on the back with the elbow straight, neutral wrist, and firm grip on the kettlebell handle
- Flex the knee on the same side with the foot in contact with the floor
- The opposite arm can be overhead or straight out to the side if an individual has limited overhead mobility
- Press the kettlebell up toward the ceiling (Figure 9–405) and protract the shoulder (Figure 9–406)
- Lift the hip on the same side into flexion (Figure 9–407)
- Let the hip fall across the midline toward the floor (Figure 9–408)
- Keep the arm stacked over the shoulder as the trunk follows the leg to rotate
- Turn the neck and always keep the eyes on the kettlebell
- Turn the thumb up to externally rotate the shoulder to provide additional stability
- Once the inside of the knee is in contact with the floor, rotate back to the start position
- To increase difficulty, straighten the moving leg and continue to rotate until the front of the pelvis and chest are facing the floor (Figure 9–409)
- To complete this variation, the stationary arm must be overhead at the start of the exercise
- The moving arm should remain stacked over the shoulder joint
- Flex the knee of the moving leg and rotate back to the start position

Figure 9-405 *Start position*

Figure 9-406 *Shoulder protraction*

Figure 9-407 *Lift moving leg into flexion*

Figure 9-408 *Moving leg crosses midline*

Figure 9-409 *Pelvis rotates to floor*

LUNGE KB ROTATION

- Hold a kettlebell at chest height
- Perform a reverse lunge (page 198)
- Maintain the position of the lower body and turn the upper back to each side
- Take a breath out at end-range, which may allow further rotation
- Do not rotate at the hips or let the knees turn in or out


Figure 9-410 *Lunge*


Figure 9-411 *Thoracic rotation*

MEDICINE BALL ROTATIONAL TOSS

- Stand away from a solid wall with the feet apart in a comfortable, wide stance with the feet facing forward and knees soft
- Grasp a medicine ball with both hands
- Rotate the trunk backward and pivot on the front foot to allow the front knee to turn slightly inward and back knee slightly outward
- Use power and pivot on the back foot to rotate the trunk in the opposite direction and release the ball toward the wall
- Contract the abdominals throughout and be sure to rotate through the legs and hips as described in order to decrease rotational stress on the lower back

Figure 9-412 *Medicine ball at midline*

Figure 9-413 *Rotate and pivot*

Figure 9-414 *Follow through to toss ball against a solid wall*

STANDING KETTLEBELL WINDMILL

The kettlebell windmill is an advanced mobility and loaded mobility drill for the thoracic spine, hip rotators, adductors, hamstrings, and shoulders. It can be performed standing if an individual has good hamstring and hip mobility. Otherwise, it is best performed in half kneeling to limit degrees of freedom and prevent compensation from inadequate hamstring flexibility.

- Stand with feet wider than hip-width apart
- Place the opposite hand on the side of the thigh (Figure 9–415)
- Keep the knees soft and shift the hip on the same side as the weight backward into a hinge (Figure 9–416)
- Slide the oppose hand down the thigh toward the inside of the foot (Figure 9–417)
- Keep the elbow straight and arm stacked directly over the shoulder joint
- Push the hips forward and lift the torso back to upright

Figure 9-415 *Kettlebell windmill start position*

Figure 9-416 *Hinge hips to slide hand down thigh*

Figure 9-417 *Kettlebell windmill end position*

HALF KNEELING KETTLEBELL WINDMILL

- Start in the half kneeling position (Figure 9–418)
- On the same side as the forward leg, grasp the handle of the kettlebell with a neutral wrist and press it overhead
- Shift the hip on the same side as the weight backward into a hinge (Figure 9–419)

- Reach the opposite arm toward the floor and place the palm on the floor in front of the knee (Figure 9–419)
- To increase difficulty, place the forearm on the floor (Figure 9–420)
- Keep the elbow straight and arm stacked directly over the shoulder joint
- Push the hips forward and lift the torso back to upright

Figure 9-418 *Half kneeling kettlebell windmill start position*

Figure 9-419 *Hinge hip and reach opposite arm to floor*

Figure 9-420 *Place elbow on floor (optional)*

CHAPTER 10

ABDOMINALS

DOI: 10.4324/9781003526599-10

The abdominal muscle group is made up of three layers: superficial, intermediate, and deep. The superficial layer is made up of the rectus abdominis, which are commonly referred to as the "six-pack" muscles. The rectus abdominis extends from the sternum and ribs to the pubic bone and primarily performs abdominal and lumbar flexion (e.g. abdominal crunch type motions). The intermediate layer is made up of the internal and external oblique muscles, which perform flexion, side bending, and rotation of the trunk. The internal oblique performs trunk rotation toward the same side of the body to which the muscle is attached, while the external oblique performs contralateral rotation. The deep layer is the transverse abdominis, which extends from the sternum and lower ribs to the pelvis. It is also connected to fascia and ligaments about the pelvis and lower back. It acts to compress the rib cage, all the organs deep to it, and helps create tension and stability around the abdominal region, pelvis, and spine. Chapter 3 highlighted the basic methods to appropriately activate and feel the abdominal muscles contract, all of which can be applied to many of the exercise progressions in this chapter. Abdominal muscle strengthening may be beneficial for many different conditions. It has been studied to improve diastasis recti (separation of the rectus abdominis and widening of the linea alba that occurs during pregnancy),[398–400] pelvic floor muscle dysfunction,[401,402] hip dysfunction,[403–405] lower back pain,[406,407] and stroke recovery,[408,409] just to name a few.

DEAD BUG PROGRESSION

The dead bug hold is an anterior core exercise that builds on the basic stabilization techniques learned in Chapter 3. It teaches an individual to maintain lumbar neutral (anti-movement stability) while breathing and bracing. It requires an isometric contraction of the rectus and transversus abdominis to depress the rib cage and maintain the contraction. Dynamic movement of the extremities (dead bug with alternating arms, legs, or both) can be added to challenge the abdominals in a lengthened range and teaches an individual to resist movement of the spine when the limbs are in motion (dynamic stability). It is important that there is no space between the lower back and the floor throughout the movement, as space implies that the lumbar spine is in fact extending. If the exercise is too difficult with the feet elevated, the feet can be positioned on the floor, which will reduce stability demands,

DEAD BUG HOLD

- Start on the back with top of head up against a wall
- Position the arms overhead with elbows bent and palms of hands on the wall
- The legs can be positioned in 90° of hip and knee flexion (more difficult) or knees flexed with the feet on the floor (less difficult)
- Take a deep breath in through the nose, filling the stomach with air
- Forcefully breathe out, depress the rib cage down, activate the anterior core muscles and brace to maintain this position
- Lightly press the hands into the wall as if pressing the wall away to enhance the contraction of the abdominal muscles
- Take small breaths while breathing in order to maintain the abdominal contraction
- Alternatively, a resistance band and an isometric hold while pulling in the direction of shoulder extension can be used instead of pushing into a wall

Figure 10-1 *Dead bug hold using wall*

Figure 10-2 *Dead bug hold using band for latissimus dorsi activation and to enhance abdominal contraction*

DEAD BUG ALTERNATING ARMS

When performed with alternating shoulder flexion, the dead bug will lengthen the latissimus dorsi and thoracolumbar fascia, which will promote lumbar extension and, in turn, will challenge the abdominals to remain engaged to maintain lumbar neutral. This exercise can be performed unilaterally with alternating arms or bilaterally holding a kettlebell or dumbbell for weight.

- Start on the back with the legs positioned in 90° of hip and knee flexion (more difficult) or knees flexed with the feet on the floor (less difficult)
- Position each arm in 90° of shoulder flexion
- Contract the abdominals and depress the rib cage
- Lift one arm overhead and maintain the opposite arm stationary
- Alternate arms once the moving arm returns to the start point

DEAD BUG ALTERNATING LEGS

- Start on the back with the legs positioned in 90° of hip and knee flexion (more difficult) or knees flexed with the feet on the floor (less difficult)
- Contract the abdominals and depress the rib cage
- Use the wall press or band resistance as detailed above to further engage the abdominals
- Extend the hip and knee of one leg until it is hovering above the ground while the opposite leg remains stationary
- Alternate legs once the moving leg returns to the start point

Figure 10-3 *Dead bug 90° hip and knee flexion start position*

Figure 10-4 *Alternating legs only*

Figure 10-5 *Dead bug with feet on floor start position*

Figure 10-6 *Alternating legs only*

DEAD BUG ALTERNATING ARM AND LEG

- Start on the back with the legs positioned in 90° of hip and knee flexion (more difficult) or knees flexed with the feet on the floor (less difficult)
- Position each arm in 90° of shoulder flexion
- Contract the abdominals and depress the rib cage
- Reach the moving arm overhead and extend the opposite leg
- Alternate sides once the moving arm and leg return to the start point

Figure 10-7 *Dead bug 90° hip and knee flexion start position*

Figure 10-8 *Alternating arms and legs*

Figure 10-9 *Dead bug with feet on floor start position*

Figure 10-10 *Alternating arms and legs*

ANTI-MOVEMENT STABILITY

Anti-movement stability exercises, as described in Chapter 2 (Table 2–1), require maintenance of one position while the limbs are not moving. The goal is to remain stationary, while outside forces (e.g. gravity, resistance, etc.) act on the body.

SOLDIER PLANK

The soldier plank increases the base of support compared to a regular forearm plank and therefore decreases stability demands, as the weight-bearing surface is located at the knees, not on the balls of the feet.

- Start on the stomach with the forearms and knees in contact with floor
- The arms are positioned wider than shoulder-width and knees are wider than hip-width
- Contract the abdominals and push through the knees and forearms to lift the torso and thighs off the floor

Figure 10-11 *Soldier plank start position*

Figure 10-12 *Soldier plank*

FOREARM PLANK

See page 182.

BEAR PLANK

- Start in the quadruped position bearing weight on the balls of the feet and both hands
- Push through the hands and feet to slightly lift the knees from the floor (Figure 10–13)
- Contract the abdominals to provide lumbo-pelvic stability and maintain this position
- The back should be flat, like a table top

Figure 10-13 *Bear plank*

HIGH PLANK

- Start in high plank position with the elbows straight, hands stacked under the shoulders, knees straight with weight through the balls of the feet
- Contract the abdominals and glutes
- Maintain the spine in a neutral position, avoid excessive arching (stomach sinking toward floor) or hips rising

Figure 10-14 *High plank*

SIDE PLANK

See page 144.

FLEXION-BASED ABDOMINAL EXERCISES

MODIFIED ABDOMINAL CRUNCH

- Start on the back with one leg bent up
- Place the palms on the floor underneath the lower back
- Contract the abdominals and pull the rib cage down
- Lift the head first, followed by the upper torso, driving the lower back down into the hands
- Breathe out during the lift to enhance the abdominal contraction
- The forearms can be used for support on the floor
- Avoid compensatory action (e.g. lifting up or driving into the floor) of the outstretched leg

Figure 10-15 *Abdominal crunch start position*

Figure 10-16 *Abdominal crunch end position*

OBLIQUE CRUNCH

- Start on the back with one leg bent up and the opposite shoulder flexed to 90°
- Contract the abdominals and pull the rib cage down to flatten the lower back to the floor
- Lift the head
- Contract the obliques by attempting to bringing the chest on the side of the flexed shoulder toward the hip on the side of the flexed leg
- The flexed arm should move across the body with contraction of the abdominals and should not drive the movement

Figure 10-17 *Oblique crunch start position*

Figure 10-18 *Oblique crunch end position*

Figure 10-19 *Oblique crunch alternate arm orientation start position*

Figure 10-20 *Oblique crunch alternate arm orientation end position*

HOLLOW BODY HOLD

- Start on the back with the legs straight and arms overhead
- Contract the abdominals, lift the legs, head, arms, and shoulder blades from the floor
- The lower back should remain flat to the floor throughout

The hollow body hold is an advanced, flexion-based core stability exercise. It requires a significant amount of strength to keep both the upper trunk and legs elevated, while also maintaining the lower back flat to the floor. The regressions are aimed to activate the same muscles, but with decreased demand, as the arms or legs remain closer to the midline of the body; this decreases the lever arm on the abdominal muscles.

Figure 10-21 *Hollow body hold start position*

Figure 10-22 *Hollow body hold end position*

MODIFIED HOLLOW BODY HOLD WITH KNEES BENT

- Start on the back with the hips and knees flexed (Figure 10–23)
- Contract the abdominals, lift the head and shoulder blades from the floor (Figure 10–24)
- Reach the arms forward until the hands pass the thighs (Figure 10–25)
- The lower back should remain flat to the floor throughout

Figure 10-23 *Modified hollow hold knees bent start position*

Figure 10-24 *Head lift*

Figure 10-25 *Arm reach*

DYNAMIC STABILITY

Movement of the extremities will require the trunk to resist excessive movement to remain balanced. Exercises may challenge flexion and extension of the spine (e.g. dead bug variations, forearm plank pot stirs, body saw, etc.) or may dynamically challenge rotational stability of the rectus, obliques, and even smaller muscles in the lower back, like the multifidus (e.g. bird dog variations, high plank shoulder taps, chops, lifts, etc.). Multi-planar exercises like the Turkish get-up and those that require reciprocal limb movement similar to locomotion, like bear crawls, and loaded carries also require the body to remain stable against internal and external forces while in motion.

TURTLE ROLL

The turtle roll is an anti-segmentation exercise, meaning that the goal is to resist any movement of the trunk, particularly the separation and independent movement of the trunk from the pelvis, while the body is in motion. This exercise is an appropriate progression from a dead bug variation and a regression from those that require weight-bearing through the arms and legs in a bear plank or high plank position.

- Start on the back with the shoulders, hips, and knees in 90° of flexion
- Place a physioball on the stomach between the arms and thighs
- Contract the abdominals and press into the ball to create a co-contraction with the arms (shoulder extension) and thighs (hip flexion) (Figure 10–26)
- Maintain this contraction and start to slowly rock to one side, allowing the torso and extremities to move as one (Figure 10–27)
- Rock back and forth to each side for as many repetitions as possible (Figure 10–28)
- As the abdominals fatigue, momentum may take over and flip the body to one side or the trunk and limbs will attempt to segment

Figure 10-26 *Turtle roll start position*

Figure 10-27 *Rock to one side (no spinal segmentation)*

Figure 10-28 *Rock to opposite side (no spinal segmentation)*

FOREARM PLANK POT STIR ON PHYSIOBALL

- Start in a forearm plank position with forearms rested on physioball
- The shoulders should be stacked over the elbows
- Contract the abdominals and perform a clockwise circle with the forearms
- Repeat in a counterclockwise direction

Figure 10-29 *Forearm plank on physioball*

Figure 10-30 *Shift arms forward to the 12 o'clock position*

Figure 10-31 *Start of clockwise motion toward the 6 o'clock position*

FOREARM PLANK BODY SAW

- Start in a forearm plank position
- Push through the balls of the feet down into plantarflexion and pull the elbows back as if driving the elbows toward the side of the torso
- Rock back onto the heels into dorsiflexion and drive the elbows away from the torso as if trying to slide the elbows forward across the floor
- Avoid the pelvis from rising toward the ceiling or sinking toward the floor throughout
- Alternatively, place the feet or forearms on slider disks or a slide board to allow increase range of motion

Figure 10-32 *Forearm plank*

Figure 10-33 *Rock back*

Figure 10-34 *Rock forward*

FOREARM PLANK HIP EXTENSIONS

See legs, Chapter xx.

PRESS OUT

- Grasp a resistance band or cable column with a hand over hand grip at chest height
- Keep the knees soft and use a base of support width of the feet that feels comfortable, but secure
- Contract the abdominals
- Press the resistance away from the chest, then pull it back in
- Avoid changing the position of the spine or torso during the movement
- To increase difficulty, press up, then overhead, as the abdominals will need to work against dynamic arm movement and a longer lever arm

Figure 10-35 *Press out start position*

Figure 10-36 *Press out*

Figure 10-37 *Lift overhead (optional)*

FOREARM PLANK BIRD DOG

- Start in a forearm plank position
- Contract the abdominals and keep the hips level
- Reach one arm forward while lifting the opposite leg from the ground
- Use the stationary arm, leg, and abdominals for stability to keep the trunk from excessively flexing, extending, or rotating to one side
- To decrease difficulty, this can be performed with the feet stationary and alternating arm reaches only

Figure 10-38 *Forearm plank*

Figure 10-39 *Opposite arm and leg reach*

HIGH PLANK SHOULDER TAPS

- Start in a high plank position
- Contract the abdominals and glutes
- Lift one hand from the floor, tap the opposite shoulder, then repeat on the opposite side
- Avoid excessive lateral rocking and be sure to stabilize for trunk rotation when one support arm is removed
- If reaching to the shoulder is too difficult, tap the elbow or wrist, as either will require decreased stance time through the weight-bearing upper extremity

Figure 10-40 *High plank*

Figure 10-41 *Alternating shoulder tap*

BEAR PLANK SHOULDER TAPS

- Start in the quadruped position bearing weight on the balls of the feet and both hands
- Push through the hands and feet to lift the knees from the floor slightly
- Contract the abdominals to provide lumbo-pelvic stability and maintain this position
- Lift one hand from the floor, tap the opposite shoulder, then repeat on the opposite side
- Avoid excessive lateral rocking and be sure to stabilize for trunk rotation when one support arm is removed
- If reaching to the shoulder is too difficult, tap the elbow or wrist

Figure 10-42 *Bear plank*

Figure 10-43 *Alternating shoulder tap*

HIGH PLANK BIRD DOG

- Start in high plank position
- Contract the abdominals and glutes
- Reach one arm up and forward while kicking the opposite leg back
- Maintain the spine in a neutral position to avoid excessive lumbar extension or trunk rotation

Figure 10-44 *High plank*

Figure 10-45 *Alternating arm and leg reach*

HIGH PLANK KETTLEBELL PULL THROUGH

- Start in high plank position with a kettlebell positioned on the outside of one hand (Figure 10–46)
- Contract the abdominals and glutes
- Lift the hand opposite the weight from the floor, reach past midline and grasp the weight (Figure 10–47)
- Drag the weight across the body until positioned on the outside of the moving hand (Figure 10–48)
- Repeat on the opposite side
- Avoid excessive lateral rocking and be sure to stabilize for trunk rotation when one support arm is removed and during the pull

Figure 10-46 *High plank*

Figure 10-47 *Grasp kettlebell with opposite arm*

Figure 10-48 *Pull through*

BIRD DOG PULL DOWN

- Start in the quadruped position and contract the abdominals
- Grasp a resistance band in one hand with the arm straight
- Contract the abdominals to provide lumbo-pelvic stability and maintain this position
- Extend the leg opposite of the moving arm (Figure 10–49)
- Perform shoulder extension with the moving arm until the arm is parallel with the torso (Figure 10–50)
- Contract the opposite glute for added stability

Figure 10-49 *Leg extended and opposite shoulder flexed*

Figure 10-50 *Leg extended and opposite shoulder extended*

SPLIT STANCE PULLDOWN

- Start in a split stance
- Grasp a resistance band in the hand opposite of the back leg with the arm straight
- Contract the abdominals to provide lumbo-pelvic stability and maintain this position
- Perform shoulder extension with the moving arm until the arm is parallel with the torso
- Contract the opposite glute for added stability

Figure 10-51 *Split stance*

Figure 10-52 *Extend arm opposite of forward leg*

SIDE PLANK ROWS

- Position the elbow directly under the shoulder
- Bend the knees and position the legs so that the knees line up with the middle of the forearm (about 30° of hip flexion)
- Contract the abdominals and drive the outside of the lower leg into the floor to lift the hips up and forward
- Grasp a resistance band or cable column with the non-weight-bearing arm
- Pull the elbow to the side of the torso
- Allow the shoulder blade protract as the arm straightens out
- Do not allow compensatory rotation or movement of the trunk during the row

Figure 10-53 *Side plank*

Figure 10-54 *Side plank with single-arm row*

CHOP (TALL KNEELING)

- Start in tall kneeling with a resistance band or cable column set from above
- Grasp a rope attachment or resistance band with the palm of the hand closest facing up and the far hand facing down
- Contract the abdominals and pull the rib cage down
- Keep the elbows relatively straight and pull the resistance toward the opposite hip
- Flex the torso, as if trying to bring the upper rib cage and abdominals toward the opposite hip, which will activate the obliques
- Place a medicine ball between the knees and perform an adductor squeeze if desired to increase neuromuscular drive and to provide additional stability

LIFT (TALL KNEELING)

- Start in tall kneeling with a resistance band or cable column set from above
- Grasp a rope attachment or resistance band with the palm of the hand closest facing down and the far hand facing up
- Contract the abdominals and pull the rib cage down
- Keep the elbows relatively straight and lift the arms across the body and up, pulling the resistance toward the opposite shoulder

- Upon returning to the start point, the torso may flex slightly toward the hip on the same side of the resistance
- Place a ball between the knees and perform an adductor squeeze to increase neuromuscular drive and to provide additional stability

Figure 10-55 *Tall kneeling chop start position*

Figure 10-56 *Tall kneeling chop end position*

Figure 10-57 *Tall kneeling lift start position*

Figure 10-58 *Tall kneeling lift end position*

CHOP (STANDING)

- Start in a split stance with the outside leg (furthest from the resistance) in front
- Perform the exercise with the same technique as detailed above

Figure 10-59 *Standing chop start position*

Figure 10-60 *Standing chop end position*

LIFT (STANDING)

- Start in a split stance with the outside leg (farthest from the resistance) in front
- Perform the exercise with the same technique as detailed above

Figure 10-61 *Standing lift start position*

Figure 10-62 *Standing lift end position*

BEAR CRAWL (FORWARD)

- Start in the bear plank position (see page 413)
- Push down through the weight-bearing arm for support as the moving arm and opposite leg move forward
- Take only a small step with the foot
- Repeat this on the opposite side so that each arm and opposite leg moves reciprocally
- Contract the abdominals throughout to provide lumbo-pelvic stability and to avoid side-to-side rocking of the pelvis

Figure 10-63 *Bear plank*

Figure 10-64 *Reciprocal crawl*

BEAR CRAWL LATERAL

- Start in the bear plank position (as detailed above)
- Push down through the weight-bearing arm for support as the moving arm and opposite leg move laterally to one side
- Repeat this on the opposite side so that each arm and opposite leg moves reciprocally
- Do not perform a cross-over step with the hands or feet

Figure 10-65 *Bear plank*

Figure 10-66 *Lateral crawl with reciprocal arm and leg movement*

Figure 10-67 *Lateral crawl*

Figure 10-68 *Lateral crawl, continued*

LOADED CARRY

Load carriage exercises, similar to squats, are practical exercises to train because they mimic a foundational daily activity. Loaded carries aim to increase grip, upper body and core strength that may be required for a wide range of tasks, from manual labor to carrying multiple grocery bags in one trip. They may also be used as an exercise to improve physical conditioning and power, as the body will work to propel a greater total load with maximal velocity.

The farmer's carry exercise produces greater stride rate, reduced stride length and ground contact time compared with regular, unloaded walking.[410,411] The lower ground contact time may demand a higher degree of stability and unilateral strength. A bilateral farmer's carry produces greater activation of erector spinae, latissimus dorsi, glutes, and obliques, as well as a greater degree of spinal compression compared to a unilateral (suitcase) carry.[410] Those that perform well on the farmer's carry may have greater range of motion in the ankles, thighs, and demonstrate both increased stride length and stride rate compared to their lower performing counterparts. They also tend to reach a maximum velocity toward the end of the walk compared to lower performers who usually reach maximal velocity at the middle of the walk distance.[410] Those with less fat mass and better balance scored on objective testing usually perform better in the unilateral carry.[412]

FARMER'S (LOADED) CARRY

- Grasp a weight in each hand
- Shrug, then retract and depress the scapulae to stabilize the shoulders and prevent the weights from providing excessive traction to the arms
- Contract the abdominals
- Start to walk forward at a pace that will allow stability to be maintained through the trunk and that limits lateral trunk lean

Figure 10-69 Hold weights in each hand

Figure 10-70 Walk forward while holding weights

SUITCASE CARRY

- Grasp a weight in one hand
- Irradiate tension in the opposite arm by clenching the fist, activating the shoulder muscles, and keeping the arm pulled down close to the side of the torso
- Perform with the same technique as the farmer's carry
- Due to the unilateral load, limiting lateral trunk lean may be more difficult

TURKISH GET-UP (TGU)

The Turkish get-up is an advanced exercise that requires movement in every plane and targets the strength and stability of the shoulder, abdominals, lower body, and core. Similar to the windmill (page 406) and arm bar rotation (page 402), the TGU is also a loaded mobility exercise for the shoulder, hips, and upper back, which may make it a good accessory exercise to perform after unloaded mobility exercises. During the first few phases of the TGU from supine to the extended elbow position, the TGU produces high levels of muscle activation in the upper trapezius, tricep, posterior deltoid and latissimus dorsi of the supporting (weight-bearing) arm, as well as moderate to high levels of muscle activation of the anterior deltoid, upper trapezius, infraspinatus, tricep, and posterior deltoid of the overhead arm. Moderate to high levels of muscle activation of the anterior deltoid, bicep, tricep, infraspinatus, and posterior deltoid continue until the weight-bearing arm is no longer in contact with the floor. The highest degree of muscle activation in the later phases are in the anterior deltoid and upper trapezius of the overhead arm.[289]

- Start on the back with one knee bent (Figure 10–71)
- Perform a chest press with the arm on the same side straight up into 90° of shoulder flexion
- Either hold a shoe or yoga block on a flat palm (beginner) or a kettlebell with a neutral wrist (advanced) as pictured
- Press the arm toward the ceiling and contract the abdominals to lift the trunk and prop onto the opposite elbow (Figure 10–72)
- Press the floor away to extend the elbow (Figure 10–72)
- Drive the foot of the bent knee into the floor to perform a bridge (Figure 10–73)
- The three points of contact with the floor are the opposite hand, the foot of the bent knee, and the heel of the outstretched leg
- Bend the knee of the outstretched leg and pull it backward until it is resting on the floor underneath the hip (Figure 10–74)
- Push through the ball of the foot and press the weight up until the torso is erect in a half kneeling position (Figure 10–75)
- Externally rotate the hip of the back legs needed by bringing the lower leg and foot inward toward midline
- Stand up (Figure 10–76)
- The goal is to keep the eyes on the weight (or shoe/yoga block) and maintain shoulder stability throughout
- To return to the start position, perform the entire sequence in reverse or put the weight down and start from the floor again

Figure 10-71 *TGU start position*

Figure 10-72 *Press up to prop up on opposite elbow, then outstretched arm*

Figure 10-73 *Bridge up*

Figure 10-74 *Bend knee to sweep leg behind and externally rotate rear hip*

Figure 10-75 *Push-up to half kneel*

Figure 10-76 *TGU end position*

CHAPTER 11

REHABILITATION AND PROGRAMMING CONSIDERATIONS FOR SPECIFIC CONDITIONS

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ANTERIOR CRUCIATE LIGAMENT (ACL) RECONSTRUCTION

The ACL prevents forward translation of the tibia on the femur. This ligament is essential to maintain knee stability during changes of direction, especially pivoting and cutting, as required during many activities and sports. Unfortunately, when injured, it can take from eight months to over a year of rehabilitation to fully return to sport or unrestricted activity after surgical repair. ACL tears can occur from traumatic contact (e.g. direct force to the knee) or non-contact (e.g. plant and twist or jump landing) injuries. Non-contact injuries are the most common mechanism of injury.[413–415] Females are more likely to sustain an initial ACL injury compared to their male counterparts,[413–418] but both groups have an increased risk (around 20%) to suffer a second ACL injury after their first.[419] A rupture of the graft on the surgical limb as well as an ACL tear to the non-surgical limb has both been shown to occur.[419,420]

ACL risk factors are considered either non-modifiable or modifiable. Non-modifiable risk factors, like sex and bone anatomy are things that we cannot change.[413] For example, females have a greater Q-angle, the angle from the hip to the knee joint, than males.[413,415,418] A greater Q-angle may result in increased resting knee valgus. ACL rehabilitation and injury prevention should focus on modifiable factors including, but not limited to, range of motion, strength, balance, neuromuscular control, power, and return to sport or activity specific movements.[413] For example, females demonstrate increased knee abduction angles (knee valgus) and a more upright posture with less knee flexion during jump landing tasks.[418] Greater quadricep compared to hamstring strength has also been shown to increase anterior tibial translation, dynamic knee valgus, and decrease neuromuscular control, which may place greater stress on the ACL.[413,415] Hamstring to quadricep strength ratios in healthy athletes have been reported as about 60–80% in a scoping review[421] and a ratio of 0.6 or greater, indicating that the hamstrings and quadriceps better co-activate, may decrease the risk of ACL and hamstring injuries.[194] The closer this ratio is to 1 or 100% may indicate a more effective co-contraction and stabilizing effect.

Return to sport and unrestricted activity after ACL reconstruction does not come without risk, but it appears that the risk of re-injury decreases by 51% each month that said return is delayed and return should not occur until at least nine months post-operatively.[165] In addition, it is also important to consider objective testing, as decreased risk of re-injury is observed in those who meet certain return to sport criteria.[165] Limb symmetry index (LSI) is a measure of how the injured limb compares to the non-injured side and is calculated using simple division: injured limb score / non-injured limb score. A systematic review of level two evidence by Ashigbi et al.[422] finds decreased risk of re-injury and significant predictive when LSI greater than 90% is achieved on hop tests and strength testing. A study by Grindem et al.[165] found that only 5.6% of patients who passed their return to sport testing suffered reinjuries compared to 38.2% of patients who did not pass. Also, specifically with respect to quadricep strength, 33.3% of patients who returned to sport with quadriceps LSI less than 90% suffered reinjuries compared to 12.5% with quadriceps LSI greater than 90%.[165] Similarly, Kyritsis et al.[423] observed a four times greater risk of graft re-rupture in an average of 105 days following return to sport if six return to sport tests were not met. The specific return to sport tests used in each study are detailed in Table 11–1.

Individuals who undergo ACL reconstruction have significantly worse psychological barriers compared to healthy controls.[424] Therefore, it is important to consider psychological readiness during the decision-making process to return to full activity and sport participation. Factors of psychological readiness include, but are not limited to, fear, motivation, confidence, and overall self-efficacy.[425–427] Psychological readiness may or may not correlate with actual physical function and objective testing.[428] Subjective

Table 11-1 *Two similar protocols for return to sport testing after ACL reconstruction. The left column (A) is a protocol adapted from the research of Grindem et al.*[165] *and the right column (B) is adapted from the research of Kyritsis et al.*[423]

Return to sport testing (RTS) after ACL reconstruction	
ACL RTS protocol #1	ACL RTS protocol #2
Quadricep isokinetic strength testing • LSI >/=90%	Quadricep and hamstring isokinetic strength testing • Quad LSI >90%
Single-leg hop for distance • LSI >/=90%	Single-leg hop for distance • LSI >90%
Crossover hop for distance • LSI >/=90%	Crossover hop for distance • LSI >90%
Triple hop for distance • LSI >/=90%	Triple hop for distance • LSI >90%
6m timed hop • LSI >/=90%	T-test (average of 3 trials) • <11 sec
Knee Outcome Survey Activities of Daily Living Scale (KOS-ADLS) • Completed	Sport-specific on field rehabilitation • Completed
Global rating scale (GRS) of perceived function • Completed	

assessments like the ACL Return to Sport after Injury scale (ACL-RSI), Knee Self-Efficacy scale, and the International Knee Documentation Committee (IKDC) subjective knee evaluation form (Table 11–2) are often used to identify deficits in psychological readiness.[425–427,429]

There are many protocols that exist to guide ACL rehabilitation and although there are some guidelines that remain in place to protect graft integrity based on the phase of healing, it is important to remember that recovery is not always linear. Progression from one phase to the next may vary based on the presentation and needs of each specific client. For example, return to jogging is often "allowed" at week 12 post-operatively, but if adequate quadricep strength, single-leg balance in stance, and the ability to perform

Table 11-2 *Three different subjective scales used to determine psychological readiness to return to sport following ACL reconstruction. The left column (A) details the ACL-RSI which was validated by studies conducted by Dingenen and Gokeler*[426]*, Ardern et al.*[429]*, Webster and Feller*[430]*; the middle column (B) details the K-SES which was validated by studies conducted by Biescher et al.*[431] *and Thomee et al.*[432]*; the right column (C) details the IKDC which was validated by studies conducted by Zhou et al.*[433]*, Muller et al.*[434]*, and Irrgang et al.*[435]

ACL Return to Sport after Injury scale (ACL-RSI)	***Knee Self-Efficacy scale (K-SES)***	***International Knee Documentation Committee (IKDC) subjective evaluation***
A cut-off score of 56 points at four months postoperatively predicted return to sport at one year follow-up • Sensitivity: 58% • Specificity: 83% The full and short versions of ACL-RSI both demonstrate fair-good predictive value for returning to pre-injury sport participation with scores of 62 and 60 points, respectively, at six months post-operatively. Similar levels of sensitivity and specificity as detailed above were also reported.	A score >/= 7 indicates acceptable self-efficacy Those with higher levels of muscle function reported greater self-efficacy on K-SES	A score of 84.5 at six months was predictive of return to sport at one year follow-up • Sensitivity: 87% • Specificity: 73% A score of 75.9 was considered a passing score for patient reported satisfaction with knee function between 1–5 years post-operatively • Sensitivity: 83% • Specificity: 96% Minimal detectable change (MDC): 9 points

light plyometrics (e.g. pogo hops, skipping) are not achieved, then it is unlikely to be appropriate to progress to running.

Although each individual can present differently at the start and/or during the recovery process, it is important to prioritize exercise, specifically muscle hypertrophy training. The goal of hypertrophy training is to grow the size of the muscle, which has the tendency to atrophy post-operatively. Other considerations to enhance muscle activation and growth are neuromuscular electrical stimulation (NMES) in conjunction with exercise[436–441] or use of blood flow restriction training to stimulate muscle hypertrophy at lower loads (30% of 1RM).[439,442–446] Describing both of these active modalities in detail is beyond the scope of this book, but both appear promising as methods to improve muscle growth, especially when high intensity resistance training is contraindicated. These methods can be researched in textbooks and studied through continuing education courses.

The following phases of rehabilitation are based on clinical practice guidelines and current evidence,[420,440,447–451] exercise physiology and biomechanics. There are many common exercises that emphasize extension (e.g. heel props, assisted knee extension using a strap, knee extension overpressure, etc.) and knee flexion (e.g. heel slides, seated knee flexion, etc.). However, range of motion, swelling reduction, and manual therapy, though important, are not the focus of this textbook. The primary focus here is hypertrophy and strength-based exercises that should follow the principles of periodization and progressive overload, as well as neuromuscular training, like single-leg stability and jumping mechanics.

Surgical protocols distributed by each surgeon should have guidelines for appropriate weight-bearing restrictions, range of motion, swelling, etc. that should help determine readiness to progress to the next phase. In general, it is important to understand that weight-bearing exercises generate less ACL strain than non-weight-bearing exercises.[452] In addition, some exercises may need to be avoided or prioritized based on graft type and phase of healing. For example, hamstring curls are often avoided in the early post-operative phase after a hamstring graft[440] as are exercises that excessively load the anterior knee, like knee over the toe lunges after a patella tendon graft in the early phase. Similarly, open-chain knee extension from 90° to 0° is often avoided in the first four weeks post-operatively in order to reduce the amount of torque and stress on the graft.[440] This is an ongoing and highly debatable topic, as it has been studied that simply walking on normal ground can generate similar tensile forces on the ACL as open-chain knee extension,[452] which will be discussed later in this chapter.

BEGINNING OR EARLY PHASE (WEEKS 0–4)

RESTORE FULL KNEE EXTENSION AND MAXIMIZE QUADRICEP MUSCLE ACTIVATION

A knee extension deficit pre-operatively is a risk factor for a knee extension deficit post-operatively.[440] An extension deficit post-operatively could predispose an individual to a cyclops lesion, scar tissue that forms within the intercondylar notch.[453,454] Loss of knee extension, even as little as three to five degrees, is also associated with worse outcomes.[162,166] This is unsurprising, as an extension deficit may simply limit the ability of the quadricep to contract maximally and, in turn, may affect the ability to regain muscle size and strength. Quadricep strength symmetry is part of the decision-making process to return to running, jumping, and sports. A strength deficit of greater than 20% is associated with worse self-reported outcome at two years post-operatively.[440]

- Straight leg raise (see page 181)
- Supine quad sets (see page 181)
- Prone TKE (see page 181)
- Standing TKE (see page 183)
- Plank variations (see page 182)
- Knee extension isometrics from 90° to 60° (see page 183)
- P-ball "leg press" (see page 184)
- Backward walking (toe to heel transition)

MAXIMIZE KNEE FLEXION RANGE OF MOTION AND PROMOTE SYMMETRY DURING BILATERAL EXERCISES

Knee flexion angle is often less on the surgical side compared to the non-surgical limb during bilateral exercises, like squats. This can result in less ground reaction force,[455] less knee extensor moment,[455,456] and can be observed as the individual shifts away from the surgical side during the descent and/or at maximal depth. This asymmetry is associated with quadricep strength deficits that persist at greater than one year post-operatively.[456] Assisted variations and box squats may be helpful to combat this compensatory strategy, as they provide some level of tactile feedback with respect to depth. Corrective strategies, like placing a band around the waist or placing a small riser under the surgical extremity during the squat, like a weight plate or book, may also be appropriate. Force plates that give direct feedback on the percentage of weight and ground reaction force produced by each limb may be helpful, but are also costly to purchase.

- Assisted squatting (see page 42)
- Box squats (see page 50)
- Bridge variations (if non-hamstring graft) (see page 106)
- Correcting a lateral shift (see page 62)

RESTORE NORMAL GAIT MECHANICS

- Gait training, with or without crutch, focusing on heel to toe transition during initial contact, single-leg stability and terminal knee extension during stance phase, and knee flexion during swing phase
- Step overs of varied heights
    - Place a hurdle or small object in front of the target leg
    - Lift the foot, hip and flex the knee to fully clear the object without circumduction at the hip
    - Place the heel on the floor in front of the object, then bring the foot back over the object and repeat
    - This is helpful to perform on both sides, as the stance leg will also need to participate to maintain stability during the opposite leg's swing phase

EARLY NEUROMUSCULAR CONTROL

There is consensus among clinical practice guidelines that indicates neuromuscular training should be a component of both ACL rehabilitation[448,451] and ACL prevention programs.[457–460] Neuromuscular training improves the ability of the central nervous system to conduct and send the appropriate signals to the muscles that will produce the desired movement pattern. It incorporates balance and stability of the trunk and extremities, plyometrics, speed, agility, reaction time, and coordination. Ideally, at least some of these exercises should be specific enough to mimic the demands of a particular activity or sport.[461] Neuromuscular training interventions vary significantly between research studies, so an optimal prescription is unclear. In this phase, the interventions will be very basic and aimed at improving double and single-leg stability, which can often be combined with gait training and mechanics during both bodyweight and resistance exercise. For example:

1. Ability to shift weight back and forth between each leg in double-leg stance
2. Use of visual and tactile feedback to improve awareness of knee position to prevent valgus collapse during the squat
3. Maintain single-limb stability during the stance phase of gait or with dynamic movements of the non-involved extremities
4. Maintain a "soft" knee during balance exercises and adjusting both the leg and trunk position versus defaulting to hyperextension to maintain balance

IMPROVE OR MAINTAIN HIP, ABDOMINAL MUSCLE, AND CALF STRENGTH

- Exercises that focus on the glutes, abductors, and adductors, abdominals and gastroc-soleus complex may help combat muscle atrophy, as well as build strength and stability above and below the knee joint
  - See Chapters 5, 6, 7, 8, and 10
- Exercises that may torque the knee, like open-chain hip external or internal rotation, should be avoided until the next phase and should always be performed in a pain-free range with lower weight to start

INTERMEDIATE OR MIDDLE PHASE (WEEKS 4–16) WEEKS 4–10

MAINTAIN KNEE EXTENSION AND RESTORE FULL FLEXION RANGE OF MOTION

- Continue knee extension exercises from beginning/early phase as needed
- Emphasize terminal knee extension during gait and the concentric contraction of knee extension exercises
- Continue assisted flexion and corrective strategies as needed
- Utilize maximal pain-free range of motion during flexion exercises

INITIATE OPEN-CHAIN KNEE EXTENSION

- Start in a reduced range of motion (e.g. 90° to 45°)
- Progress to full range (90° to 0°) between weeks 8–12 as appropriate

Open-chain knee extension after ACL reconstruction has been a controversial topic for some time and it is often avoided because of fear of increasing the risk of graft laxity or failure. Open-chain knee extension may be superior to closed-chain exercise at increasing quadricep strength.[462,463] This could be because of the higher levels of muscle activation achieved during some open versus closed-chain exercises,[168] greater specificity of the leg extension exercise with respect to knee extensor strength testing protocols[169] or simply the increased quadricep forces required for knee extension.[464] Though there is some promising research available, the majority of the research does not definitively confirm a true difference between open- and closed-chain exercises for increasing muscle strength.[465] Therefore, a combination of both methods should be used throughout the rehabilitation process.

A randomized controlled trial by Fuduka et al.[466] observed a faster recovery in quadricep strength at 19 and 25 weeks, as well as 17 months post-operatively when knee extension was initiated four weeks post-operatively in a reduced range of motion (90–45°) compared to full range of motion (90–0°) extension initiated at 12 weeks post-operatively. A consistent theme amid the available evidence is that initiation of open-chain knee extension at four weeks post-operatively in a reduced range of motion does not increase graft laxity.[462,465,466] This is not surprising, as knee extension from 90–45° produces a minimal strain on the ACL.[465,467] However, it is important to note that initiation of open-chain exercises should be performed slowly with lower loads in a reduced range of motion, then progressed accordingly. Use of high loads, especially when performed between 40° and 0° of knee extension, will produce higher strain on the graft.[464,467] Full range of motion produced no detrimental effects on graft laxity when initiated at 12 weeks post-operatively using low loads.[466] Still, if the surgeon or rehabilitation professional prefers a conservative approach, ACL strain is minimal with knee extension performed from 90–60°.[465,467] So, at the very least, this can be initiated at four weeks without negative side effects.

MAXIMIZE STRENGTH AND SYMMETRY DURING BILATERAL EXERCISES

- Assisted squatting (see page 42)
- Bodyweight and/or loaded squats (see page 46)
- Bridge variations (see page 106)
- Deadlift variations (see page 73)
- Leg press (see page 194)
- Hamstring curl variations (see page 208)

PRIORITIZE SINGLE-LEG OR MODIFIED SINGLE-LEG LOADING

- Assisted squats (see page 44-45)
- Stagger stance, single-leg box, or wall squats (see page 54)

- Lunge variations (see page 195)
- Step-up/down variations (see page 204)
- Staggered stance or single-leg deadlift variations (see page 87)
- Leg press (see page 194)
- Leg extensions (see page 188)
- Hamstring curl variations (see page 208)

PROGRESS NEUROMUSCULAR CONTROL

- Primarily knee joint position sense with strength training exercises
- Double- and single-leg dynamic balance

The volume and difficulty of neuromuscular training should increase in this phase. When implemented as part of an ACL injury prevention program, higher frequency (sessions per week) and duration (length of session) are more likely to reduce the risk of ACL injury.[468] Neuromuscular training may be best utilized if performed for greater than 20 minutes per session, multiple times per week, with a total training volume of greater than 30 minutes per week.[457,468] Many exercises can easily be integrated into the initial exercise demonstration and subsequent practice repetitions with feedback provided.

CONTINUE HIP, ABDOMINAL MUSCLE, AND CALF STRENGTHENING

- Progress to more difficult variations compared the beginning/early phase as appropriate

WEEKS 10–16

TEST QUADRICEP AND HAMSTRING STRENGTH RATIOS

- Perform isometrically (e.g. dynamometer, force gauge, or crane scale) or isokinetically with a specialized machine
- Achieve greater than 80% quadricep LSI to return to running

A quadricep LSI of less than 80% may present as altered knee joint biomechanics, particularly decreased knee flexion moment,[469,470] which may be why it is used as a milestone prior to return to running. Knee extension ROM should be at least 0°, flexion ROM should be at least 95% of the opposite side, and the knee should be without swelling to return to running.[471] Kline et al.[472] also recommends a lateral step-down endurance test of as many repetitions as possible in 30 seconds. This test was studied as predictive of knee flexion and extension moment during running.[471,472] Return to running usually occurs no sooner than week 12 post-operatively.[448,473] A slow progression and a pain monitoring model, as mentioned in Chapter 2, may be when determining the appropriate running volume or progressing it.

CONTINUE TO PRIORITIZE BILATERAL AND UNILATERAL LOWER BODY STRENGTHENING

- Quadriceps, hamstrings, hips, and calf muscles

START LIGHT PLYOMETRIC TRAINING (IN ORDER TO PROGRESS TO JOGGING AT WEEK 12–14)

- Medicine ball slams (for deceleration and force absorption)
- Modified jump squats

PROGRESS NEUROMUSCULAR CONTROL

- Double and single-leg dynamic balance (see page 250)
- Line drills
    - Stand in front of a line (tape, crease in floor, etc.) on the balls of the feet
    - Quickly transition one foot forward over the line, followed by the other foot, then backward with each foot and repeat
    - The goal is to remain close to the line, but to clear it with each repetition
- Multi-directional lunges
- Running-specific exercises that enhance single-leg dynamic stability
    - Forward to reverse lunges (see page 200)
    - Runner step-up (see page 205)
    - Running man SLDL (see page 93)

RETURN TO RUNNING PROGRESSION

- Pogo hops
    - Place the feet close together and rise onto the balls of the feet
    - Perform double-leg jumps in place with a consistent, soft knee bend, equal push-off, and soft landing
    - This exercise is similar to the movement pattern of jumping on a pogo-stick, hence the name
- Skipping
- High knees

ADVANCED OR LATE PHASE (WEEKS 16–24)

TEST QUADRICEP AND HAMSTRING STRENGTH RATIOS

- Achieve greater than 85% quadricep and hamstring LSI

CONTINUE BILATERAL AND UNILATERAL LOWER BODY STRENGTHENING

- Quadriceps, hamstrings, hips, and calf muscles (either in clinic or via gym program)
- Ensure ability to load the anterior knee without pain (e.g. knee over toe lateral and forward step downs, step ups, lunges, squats, etc.)

PRIORITIZE NEUROMUSCULAR CONTROL DURING ALL EXERCISES

- Challenge and integrate multiple systems (visual, sensory, vestibular) using a variety of different conditions (e.g. eyes open vs. eyes closed, compliant surfaces, expected and unexpected perturbations, multi-tasking, etc.)

PROGRESS PLYOMETRIC TRAINING AS APPROPRIATE

- Jump squats
- Box jumps
- Depth jumps
- Skater hops
- Diagonal bounding
- Double and single-leg forward hopping
- Hurdle hops forward and lateral

INITIATE AGILITY EXERCISES AS APPROPRIATE

- Modified t-test exercises (side shuffling, backpedal, forward, and backward jogging)
- Crossover steps and/or carioca
- Cone drills and weaving
- Jogging with slow change of direction
- Reactive cutting at reduced speed
- Resisted running and shuffling

RETURN TO SPORT PHASE (WEEKS 24+)

CONTINUE STRENGTHENING VIA GYM PROGRAM

- Achieve greater than 90% quadricep and hamstring LSI

PRIORITIZE NEUROMUSCULAR CONTROL

- Sprinting
- Sport or activity specific drills focused on acceleration, deceleration, change of direction, and coordination
- Reactive cutting at high speed
- Integration of sport-specific stick work, dribbling, catching, etc.

ACHILLES TENDINOPATHY

Achilles tendinopathy is an overuse injury of the Achilles tendon that occurs when repetitive mechanical stress exceeds the capacity of the tissue[474] and it does not have adequate time to recover after loading.[475]

Healthy tendons are made up of type I collagen, an extracellular matrix to hydrate the tendon, and other cells like collagen producing fibroblasts. Tendons that suffer from chronic tendinopathy demonstrate significant differences in their structure, function, and cellular make-up. These tendons appear thicker, but contain more type III collagen, which is disorganized and more loosely packed, has a greater water content, and contains many cells indicative of cell death and inflammation. As a result, the tendons lack elasticity and load-bearing capacity.[474]

Mid-portion Achilles tendinopathy accounts for over 60% of cases while insertional Achilles tendinopathy has a much lower incidence rate under 25%.[475–477] Palpation is one of the most accurate and reliable methods of diagnosing a mid-portion versus insertional issue with 78% and 77% sensitivity and specificity, respectively.[478] Mid-portion and insertional tendinopathies must be treated differently from a rehabilitation standpoint, as explained below.

RISK FACTORS

There are a variety of risk factors that could lead to the development of Achilles tendinopathy including impaired plantarflexion and hip muscle strength, impaired dorsiflexion and subtalar range of motion, pes cavus (high arch), increased pronation, older age, obesity, diabetes, medication use (fluoroquinolones and corticosteroids), training errors, poor load management, footwear and hard, uneven, or inclined training surfaces.[475,476,478–480] A detailed subjective assessment should help uncover training or load management issues. Between 60 and 80% of individuals admit to increasing intensity and duration of training load too rapidly leading to an overuse injury;[476] these factors can be easily modified and monitored. The tendon may initially become painful and inflamed at or just above its insertion on the calcaneus (insertional tendinopathy) or at the middle of the tendon bulk, two to six centimeters above the insertion (mid-portion tendinopathy).[474,478] Repetitive overload to the tendon may occur from both tensile (stretch-shortening) and compressive loads caused by footwear, bony prominences, or excessive closed-chain ankle dorsiflexion.[475,481]

CONSERVATIVE MANAGEMENT

Achilles tendinopathy is usually managed conservatively, but the recovery process can be lengthy and can take over six months.[482] The intervention that is most supported by high-quality scientific evidence is, you guessed it: exercise. The 2018 revised APTA clinical practice guidelines (CPGs) highlight the importance of including mechanical loading and activity modification into an Achilles tendinopathy rehabilitation program. Mechanical loading appears most successful when using either a heavy load, slow-speed (both concentric and eccentric) exercise or eccentric exercises.[478] Activity modification can allow an individual to continue to perform their usual activities like running, sports, or other exercises while recovering from Achilles tendinopathy. When combined with a progressive loading program, keeping pain below five out of ten while performing impact activities (running and jumping) promoted the same level of healing as replacing these activities with low impact exercises (swimming, running in water, biking, and walking).[39] Complete rest is actually contraindicated because symptoms are likely to recur once activity resumes and the tendon is over-stressed.[482]

Table 11-3 *Functional test battery for Achilles tendinopathy. Normal performance is considered 90% limb symmetry. Adapted from Silbernagel et al.*[483]

Functional test battery for Achilles tendinopathy
Single-leg vertical jump for height
Single-leg hopping in place (frequency, height, flight, and contact time)
Single-leg drop to vertical jump for height
Weighted concentric single-leg heel raise (measured in power)
Weighted eccentric to concentric single-leg heel raise (power)
Single-leg heel raise for endurance with 10% of body weight added (at 30 raises/min frequency)

In a prospective trial, only 25% of asymptomatic individuals who completed a rehabilitation protocol demonstrated full lower extremity function.[482] Full function was considered 90% limb symmetry during a battery of plyometric, muscle strength, and endurance tests, (Table 11–3). Individually, the tests were proven to have excellent test-retest reliability and 88% sensitivity when performed together,[483] meaning that the battery is very good at detecting those with lower extremity deficits. These studies suggest that rehabilitation should focus on both symptom reduction and restoring full function prior to full, unrestricted return to activity.

MID-PORTION TENDINOPATHY MANAGEMENT

Implementing a loading program for mid-portion Achilles tendinopathy can produce results within two weeks, likely due to neural mechanisms and pain modulation, while minimal clinically important difference in pain and function (as measured by the VISA-A) can be achieved within four weeks.[484] Full recovery may take up to a year,[475] but gains generally plateau within the first 12 weeks of initiating the exercise program.[484] Evidence supports two primary loading programs: eccentric exercise and heavy, slow resistance training that combines eccentric and concentric contractions.

ECCENTRIC STRENGTHENING

A 12 week eccentric strengthening regimen known as the "Alfredson protocol" (Table 11–4) has been proven successful in significantly reducing pain, restoring eccentric and concentric plantarflexion strength, and aiding return to pre-injury level of running within 12 weeks.[485] This protocol has been proven superior to concentric training in a randomized prospective trial with 82% participants reporting satisfaction and returning to pre-injury level of function compared to just 36% in the concentric group.[486] An eccentric loading protocol by Yu et al.[487] based on the Alfredson protocol also yielded greater results than concentric training with respect to pain and performance measures (ankle dorsiflexion endurance, balance, and agility). In addition, randomized controlled trials using the Alfredson protocol produced 63% to 82% patient satisfaction after 12 weeks[486,488] and there is consensus among follow-up studies that changes in pain and function are maintained or will continue to improve over a period of four to five years.[489–491] The Alfredson protocol calls for 180 repetitions per day, which may be difficult for some patients because of pain, time constraints, baseline physical activity level, and/or self-discipline. A small, randomized trial compared

***Table 11-4** Alfredson eccentric training protocol for mid-portion Achilles tendinopathy adapted from Alfredson et al.*[485]

Alfredson protocol			
	Sets	Repetitions	Frequency
Weeks 1–12			
Single-leg eccentric heel rise from step with knee straight	3	15	2×/day
Single-leg eccentric heel rise from step with knee bent	3	15	2×/day
Weight is added via backpack or weighted calf raise machine when there is no discomfort remaining during bodyweight raises			

***Table 11-5** Reduced volume "do as tolerated" eccentric training protocol for mid-portion Achilles tendinopathy adapted from Stevens et al.*[492]

Reduced volume, "do as tolerated" protocol			
	Sets	Repetitions	Frequency
Weeks 1–6			
Single-leg eccentric heel rise from step with knee straight	3	15 repetitions recommended, but instructed to complete a "tolerable" amount	2×/day
Single-leg eccentric heel rise from step with knee bent	3	15 repetitions recommended, but instructed to complete a "tolerable" amount	2×/day
Weight is added via backpack or weighted calf raise machine when there is no discomfort remaining during bodyweight raises			

the Alfredson protocol to a similar program with a reduced volume (mean of 112 repetitions per day) and shortened the time frame to six weeks (Table 11–5). The trial found no difference between the Alfredson and reduced volume protocol with respect to pain, function, and treatment satisfaction, which supports using fewer total repetitions over a shorter period to produce similar results. It is important to note that this study also shortened the duration of the Alfredson protocol from 12 to 6 weeks for comparison, so potential differences between groups at 12 weeks are unknown.[492]

HEAVY, SLOW RESISTANCE TRAINING (HSR)

HSR is resistance training with emphasis on key factors: percentage of 1RM (ideally at least 70%), rate of loading (slower lifting tempo controls force over time), volume-load (load, sets, and repetitions).[493] HSR has gained popularity in patellar tendon rehabilitation due to its proven efficacy regarding pain reduction and return to function, potential to induce greater tendon adaptations, and long-term benefits when compared to other treatment methods.[494–496] When used to treat Achilles tendinopathy, a comparison of HSR and eccentric training (Table 11–6) revealed that both methods produced clinically meaningful improvements in pain and function, but there were no statistically significant distances between groups. Patient satisfaction was 80% for the eccentric training group and 100% for the HSR training group at 12 weeks. At one year follow-up, patient satisfaction was 76% and 96% for each group, respectively, again with no statistically significant difference measured between groups.[497] Results of both treatment programs were still positive, which supports the use of heavy-slow resistance training for similar outcomes even though it is performed at a lesser frequency with fewer total repetitions per week. The lower frequency may increase adherence to the training program and allow for adequate recovery time between sessions.

Silbernagel et al.[475] developed a comprehensive treatment model that consists of both eccentric and concentric training, which combines the eccentric and HSR protocols (Table 11–7). This model is based

Table 11-6 Heavy, slow resistance protocol for mid-portion Achilles tendinopathy adapted from Beyer et al.[497]

Heavy, slow resistance protocol					
	Sets	Repetitions	Frequency	Rest	Tempo
Seated heel raise with knee flexed (seated calf raise machine)	Week 1: 3 Weeks 2–12: 4	Week 1: 15 Weeks 2–3: 12 Weeks 4–5: 10 Weeks 6–8: 8 Weeks 9–12: 6	3×/week	2–3 minutes between sets 5 minutes after all 3 exercises	3 second eccentric 3 second concentric
Heel raise with knee straight (leg press machine)					
Standing heel raise with knee straight standing on plate (barbell or smith machine)					

on current evidence and their prior research that observed less pain, stiffness, swelling, and greater patient satisfaction using combined concentric-eccentric training when compared to a control group performing only stretching, double-leg, and single-leg heel raise.[491] Silbernagel et al.[39] also reinforced the importance of the pain monitoring model, which was discussed in Chapter 1. This model is meant to allow an individual to exercise or continue their sport and leisure activities while recovering from Achilles tendinopathy without impeding their recovery. To reiterate, pain during activity should not exceed five out of ten on the pain scale, should subside within 12–24 hours, and there should not be a baseline increase in pain or tendon stiffness after each week.[39]

Table 11-7 Comprehensive treatment protocol for mid-portion Achilles tendinopathy (combined eccentric and concentric exercise) adapted from Silbernagel et al.[475]

Comprehensive treatment protocol (combined eccentric and concentric exercise)			
	Sets	Repetitions	Frequency
Weeks 1–2			
Double-leg heel rise from floor	3	10–15	1×/day
Single-leg heel rise from floor	3	10	
Eccentric heel rise from floor	3	10	
Seated heel rise	3	10	
Weeks 2–5			
Double-leg heel rise from step	3	15	1×/day
Single-leg heel rise from step	3	15	
Eccentric heel rise from step	3	15	
Seated heel rise	3	15	
Quick rebounding heel rise	3	20	

Table 11-7 *(Continued)*

Weeks 3–12			
Single-leg heel rise from step with weight	3	15	1×/day or 2–3×/week if using heavy loads
Eccentric heel rise from step with weight	3	15	
Seated heel rise	3	15	
Quick rebounding heel rise	3	20	
Plyometric training			
3–6 months			
Single-leg heel rise from step with weight	3	15	2–3×/week
Eccentric heel rise from step with weight	3	15	
Quick rebounding heel rise	3	20	

INSERTIONAL TENDINOPATHY MANAGEMENT

Exercise is still the primary treatment method for insertional tendinopathy, but this condition may benefit from limiting heel drop past neutral during eccentric exercise.[498] Twelve weeks of traditional eccentric exercise (heel drop past neutral) was considered satisfactory in 89% of participants with mid-portion tendinopathy, but only 32% satisfactory for insertional.[499] In comparison, eccentric calf raise training performed from the floor (no heel drop) yielded satisfactory results in 67% of participants with insertional tendinopathy and significantly reduced pain levels in both groups of satisfied and not satisfied participants.[500] This may have to do with decreasing compression of the calcaneus on the deep portion of the tendon and retrocalcaneal bursa that can occur during closed-chain dorsiflexion.[251,501,502] HSR has not yet been studied in this population, but may be beneficial if the range of motion into closed-chain ankle dorsiflexion is controlled for.

The protocols listed serve as a guide to exercise prescription based on the best available evidence. In order to incrementally load the Achilles from the acute to chronic phases of rehabilitation, it may also be useful to learn how loading to the Achilles tendon differs between specific exercises. Baxter et al.[250] established a "loading index" for the Achilles tendon based on peak loading, impulse, and rate via a study using motion capture and force plates. Exercises were separated into four tiers based on intensity; intensity increases as the loading index reaches one (Table 11–9). Exercises in tier one may be more appropriate during the early phases of rehabilitation than exercises in tier four.

Table 11-8 *Eccentric only exercise protocol for insertional Achilles tendinopathy adapted from Jonsson et al.[500]*

Eccentric-only exercise protocol					
Sets	Repetitions	Frequency	Duration	Contraction type	Weight
3	15	2×/day	12 weeks	Eccentric only	Added gradually via a weighted backpack

Table 11-9 *Achilles tendon loading index adapted from Baxter et al.*[250] *Values closer to 1 indicate a higher intensity exercise and therefore increased loading to the Achilles.*

Achilles tendon loading index	
Exercise	Loading index
Tier 1 (low intensity)	
Double-leg seated heel raise Single-leg seated heel raise Squat Low step-up (lead leg) High step-up (lead leg) Double-leg heel rise	0.1–0.25
Tier 2	
Double-leg rebounding heel rise Lunge (lead leg) Low step down (lead leg) Low step-up (trail leg) High step down (trail leg) Walking (stance leg) Low step-down (trail leg) Forward jump (double leg) High step-down (leading leg) High step-up (trailing leg) Lunge (trailing leg) Double-leg countermovement jump Single-leg rebounding heel rise Single-leg heel rise	0.28–0.49
Tier 3	
Double-leg drop jump Double-leg hop Running (stance leg) Double-leg forward hop Single-leg countermovement jump Single-leg forward jump	0.5–0.75
Tier 4 (high intensity)	
Single-leg hop Single-leg drop jump Single-leg lateral hop Single-leg forward hop	0.76–0.92

PATELLA TENDINITIS AND TENDINOPATHY

Patella tendinitis is an acute reactive or inflammatory process of the tendon, while tendinopathy is its sub-acute or chronic counterpart that usually involves some degree of tendon degeneration.[503,504] Pain is usually located below the lower pole of the patella, but not beyond the tibial tuberosity where the tendon inserts. Pain is worse under load, during quadricep dominant movements, especially those that require jumping, so much so that patella tendon issues are often referred to as "jumper's knee," as they are very prevalent in sports that require repetitive impact like volleyball, basketball, and running.[505–507] Individuals may also complain of pain during exercises that excessively load the anterior knee, like stairs and lunges. There are no definitive risk factors for patella tendinopathy, as the available evidence is either conflicting or of lower quality. However, the research leans toward increased activity volume, greater hamstring flexibility,[505,506] decreased ankle dorsiflexion,[505,508] increased forefoot varus, decreased hip internal rotation range of motion and less hip external rotator strength[509] as factors to consider.

Patella tendon issues, like the Achilles, are often treated with load management strategies and activity modification, not complete rest.[39,507,510] Reducing activity volume and removing painful triggers may be helpful in the short-term to decrease tendon irritation,[504,507] especially if the tendon pain is of acute onset, potentially from a sudden increase in activity. For example, if regular loaded squats are painful, Spanish squats may be a good substitute as there is less anterior knee translation. Similarly, if forward lunges are not tolerated, reverse lunges may be an appropriate alternative. Other strategies include decreasing the total volume (e.g. sessions per week), load or range of motion during an exercise.

CONSERVATIVE MANAGEMENT

Exercise therapy is one of the most studied interventions used to treat patella tendinopathy, but an optimal protocol has yet to be determined. Several reviews suggest a multi-phase approach for progressive tendon loading with a combination of isometric, isotonic, energy storage exercises (plyometrics, acceleration, and deceleration) and sport-specific movements.[503,507,510] Isometric exercises are used for short-term, immediate pain relief after intervention,[74,507,511–516] while eccentric exercise and heavy, slow resistance exercise have been studied to improve pain and function in the long-term.[503,510,511,517] Ultimately, the optimal management strategy must be decided on a case-by-case basis and may differ depending on degree of tendon irritation, chronicity, whether the individual is in-season or off-season for their sport or activity, and response to the prescribed treatment.

ISOMETRIC EXERCISE

Isometric leg extensions can be performed with a leg extension machine or simply by kicking into a wall (see page 183) or stable object. They can provide immediate pain relief[514,518] that may last up to 45 minutes.[514] Isometric quadricep exercises also have the ability to reduce pain in-season, when an athlete is still actively participating in their sport in addition to completing rehabilitation exercises.[74,513,516] A reduction in pain in most studies is determined by the numerical rating scale and performing a single-leg decline squat (SLDS) (see page 59) prior to and following the intervention.[74,507,514–516,518] The SLDS is performed on a board set at a 25° angle and is terminated at 50° of knee flexion. It was determined to be a simple and effective test for eliciting patella tendon pain in symptomatic individuals.[519] The fact that isometric exercises appear to provide immediate pain relief may support their use as a primary treatment strategy, as part of a home or in-season exercise program, and/or at the beginning or end of the session prior to or after performing isotonic or other exercises. A review of the current evidence on isometric exercise is detailed below (Tables 11–10 to 15).

Table 11-10 *Isometric exercise protocol as detailed by Rio et al.*[514]

Study Design	**Intervention**	**Results**
Single-blinded randomized cross-over study	Isometric knee extension at 60-degrees of knee flexion at 70% MVC 5 × 45 seconds with two-minute rest between sets 2–3 times per day	Immediate pain relief and sustained at 45 minutes post-intervention

Table 11-11 *Isometric exercise protocol as detailed by Pearson et al.*[518]

Study Design	**Intervention**	**Results**
Randomized clinical trial	*Short-duration group:* Isometric knee extension at 30-degrees of knee flexion at 85% MVC 24 × 10 seconds with 20-second rest break between repetitions *Long-duration group:* Isometric knee extension at 30-degrees of knee flexion at 85% MVC 6 × 40 seconds with 80-second rest break between repetitions 5 days/week for 4 weeks	Significant reduction in pain for both groups immediately and at four-week follow-up without any significant difference between groups

Table 11-12 *Isometric exercise protocol as detailed by Rio et al.*[74]

Study Design	**Intervention**	**Results**
Pragmatic case series	Double-leg Spanish squat 5 × 30 second isometric hold Performed weekly for four weeks	Significant linear reduction in pain (average of 49%) throughout the four-week intervention

Table 11-13 *Isometric exercise protocol as detailed by Rio et al.*[515]

Study Design	**Intervention**	**Results**
Randomized clinical trial	Isometric knee extension at 60-degrees of knee flexion at 80% MVC 5 × 45 seconds Four days/week for four weeks	Significantly greater pain reduction immediately post-intervention when compared to an isotonic exercise group

Table 11-14 *Isometric exercise protocol as detailed by Van Ark et al.*[516]

Study Design	*Intervention*	*Results*
Randomized clinical trial	Isometric knee extension at 60-degrees of knee flexion at 80% MVC 5 × 45 seconds with two-minute rest between sets Four days/week for four weeks	Significant decrease in pain at four-week follow-up

Table 11-15 *Isometric exercise protocol as detailed by Holden et al.*[512]

Study Design	*Intervention*	*Results*
Randomized crossover trial	Isometric knee extension at 60-degrees of knee flexion at 70% MVC 5 × 45 seconds with two-minute rest between sets	Immediate pain relief that was not sustained at 45-minutes post-intervention

ECCENTRIC EXERCISE

There is a significant body of research that supports the use of eccentric exercise as an effective treatment strategy for long-term management and has long since been considered the gold standard for patellar tendinopathy. However, upon further review, it appears just as effective or potentially less effective than other treatment strategies, especially when considering patient satisfaction.[494,496,507,520] This may be because eccentric exercise protocols are often performed with greater frequency (e.g. daily)[494,496,510,520] and encourage a significant level of pain provocation and may not be well tolerated if the tendon is highly sensitized.[503,507,520] The single-leg decline squat (Table 11–16) is used often in eccentric loading protocols where the lowering phase is performed with the symptomatic leg only and the concentric phase is either performed with both legs or the uninvolved side.[494,507,511,521]

HEAVY, SLOW RESISTANCE EXERCISE (HSR)

HSR exercise includes both the concentric and eccentric portions of a contraction that are progressively overloaded accordingly. Ideally, it is performed at greater percentages of 1RM than eccentric exercise will allow. The research that supports that this type of exercise appears to be of higher quality than eccentric exercise,[496,507] may produce either the same or more favorable results for patient satisfaction,[494,496,507,520] pain,[520] and tendon structure.[494,496] HSR appears to be just as effective at isometrics for improving pain and function.[516] If the loads are well tolerated, it makes sense to continue progressive resistance exercise in conjunction with or as a progression from isometric exercises. Also, despite the term "heavy," it has been studied that both heavy (90% of 1RM) and moderate (55% 1RM) loads will both produce similar positive changes in pain, strength, and patient satisfaction when the total exercise volume is equated.[522] A review of the current evidence on HSR exercise for patella tendinopathy is detailed in Tables 11–17 to 19.

Table 11-16 *Eccentric and progressive loading exercise protocol as detailed by Breida et al.*[520]

Study Design	*Intervention*	*Results*
Single-blinded randomized control trial	*Eccentric exercise group:* Stage 1: Single-leg decline squat 3 × 15 to 60-degrees of knee flexion 2 × daily for 12 weeks Pain >5/10 allowed Add additional load via a backpack if minimal or no pain Stage 2: sport-specific and continue stage 1 exercises 2×/week	No difference between return to sport rate between groups Significant difference in pain score favoring the progressive resistance exercise group
	Progressive loading group: Stage 1: Isometric exercises Single-leg press or knee extension at 70% MVC 5 × 45 seconds at 60-degrees of knee flexion Performed daily Stage 2: Isotonics Isometric exercises from stage 1 Isotonic single-leg press or knee extension 4 × 15 between 10- and 60-degrees of knee flexion Progress to 4 × 6 and increase ROM 0–90 degrees Performed on alternating days Stage 3: Energy storage Isometrics from stage 1 Isotonics from stage 2 Jump squats, box jumps and cutting maneuvers 3 × 10 double leg initially Progress to 6 × 10 single leg All performed on alternating days Stage 4: sport specific Sport specific exercises performed every 2–3 days to allow for recovery Isometrics from stage 1 performed on days sport specific exercises were not completed Return to sport: When all exercises in stage 4 are performed with pain </=3/10 Continue to perform stage 1 and 2 maintenance exercises 2×/week	Significantly greater amount of patients reporting excellent satisfaction in the progressive resistance group No statistically significant difference in patient satisfaction when data was dichotomized

Table 11-17 *Concentric and eccentric loading exercise protocol as detailed by Van Ark et al.*[516]

Study Design	*Intervention*	*Results*
Randomized clinical trial	Single-leg knee extensions at 80% 1RM 4 × 8, perform one leg, then the opposite, rest 15 seconds Three-second concentric and Four-second eccentric phase Ideally, increase weight by 2.5% each week Four days/week for four weeks	Significant decrease in pain at four-week follow-up No difference between concentric-eccentric and isometric groups

Table 11-18 *Heavy, slow resistance exercise protocol as detailed by Agergaard et al.*[522]

Study Design	*Intervention*	*Results*
Randomized clinical trial	Double-leg press Single-leg knee extension 100 to 40-degrees with three seconds concentric and three second eccentric phase Two to three-minute rest between sets 3×/week for 12 weeks Load adjustment performed every other week based on repetition maximum testing *Heavy load group:* Starts at 55% and progressed to 90% 1RM Week 1: 15 Week 2: 12 Week 3: 10 Week 4: 8 Week 5: 6 Week 6: 5 Weeks 7–12: 4	No difference between groups in pain, strength, and patient satisfaction at 12- and 52-week follow-up with significant improvement in these outcome measures
	Moderate load group: 55% 1RM maintained throughout Week 1: 15 Week 2: 14 Week 3: 13 Week 4: 11 Week 5: 9 Week 6: 8 Weeks 7–12: 7	

Table 11-19 *Heavy, slow resistance exercise protocol as detailed by Kongsgaard et al.*[494]

Study Design	*Intervention*	*Results*
Single-blinded randomized control trial	*Eccentric training group:* Single-leg decline squats with three-second eccentric phase Add additional load via a backpack 3 × 15 repetitions with two-minute rest between sets 2 × daily for 12 weeks *Heavy, slow resistance group:* Squat, leg press and hack squat: 4 sets Week 1: 15 Weeks 2–3: 12 Weeks 4–5: 10 Weeks 6–8: 8 Weeks 9–12: 6 Three-second concentric and three-second eccentric phase Two-minute rest between sets 3×/week for 12 weeks	Significantly greater patient satisfaction in heavy, slow resistance group at 12 weeks and 6-month follow-up Significant decrease in patella tendon thickness and cross-sectional area at 12 weeks in heavy, slow resistance group Significant increase in peak knee extension moment, peak tendon force, quadricep and patella tendon cross sectional area in both groups Significant increase in markers of collagen cross links, which may indicate tissue repair and remodeling, in heavy, slow resistance group

ROTATOR CUFF DISORDERS AND SHOULDER IMPINGEMENT SYNDROME

A rotator cuff disorder is diagnosed through an MRI scan, diagnostic ultrasound, and/or a thorough assessment by a trained professional that reveals an issue with one or multiple muscles that make up the rotator cuff: the supraspinatus, infraspinatus, teres minor and subscapularis. A rotator cuff tear has the potential to affect 30–40% of adults older than 60.[523,524] Surprisingly, asymptomatic rotator cuff tears are twice as common compared to symptomatic rotator cuff tears, the former of which has a prevalence rate of over 40% and this rate appears to increase with age.[524,525] Asymptomatic rotator cuff tears may turn symptomatic within the first one and a half to three years in 23% to 51% of individuals, potentially due to tear enlargement and may result in impaired shoulder function.[524] These facts somewhat support the “you are not your imaging” mentality in the rehabilitation profession and the idea that structural integrity is not a clear indicator of pain and function. Although there have been meta-analyses that have found statistically significant differences in these factors between intact rotator cuff repairs and those that have re-torn, many of these measures do not meet the minimal clinically important difference or do not have a direct comparison of clinical significance.[526–528]

The optimal management strategy for rotator cuff tears, like many conditions, has yet to be determined. There is a significant body of research that reveals similar outcomes of surgical and conservative management (physical therapy) at one- to two-year follow-up for small- and medium-sized tears.[523,529–534] Those who do not initially opt for surgery have also been shown to have positive outcomes when pursuing surgical intervention after 12 weeks of exercise therapy, so an initial trial of conservative management did not adversely affect the surgical outcome.[535] Recent research by Moosemayer et al.[536] advocates for primary rotator cuff repair over conservative management after completion of a ten-year follow-up study. In 2010, a one year follow-up study revealed greater benefit of primary surgical repair on patient outcomes when compared to conservative management.[537] Differences between the groups were maintained at both five- and ten-year follow-up and there continued to be more positive outcomes in the surgery group.[536,538] If tears that are treated conservatively have the potential to progress over time, further studies should include a longer follow-up period to determine if results remain consistent.

Large tears can also benefit from conservative management but have the potential to progress to a point operative repair may no longer be an option due to increased fatty tissue infiltration and muscle atrophy.[529,535,539] However, some individuals may not be good candidates for surgical repair after full-thickness tears, as those over 60 years with chronic, degenerative tears often have less favorable outcomes[532,535,539] and as a result, exercise therapy may be the treatment of choice to improve pain and function.

Rotator cuff repairs will usually be presented with a strict surgical protocol that will not allow active range of motion or strengthening exercises for the first six to eight weeks, though this is dependent on each individual surgeon. The first six weeks will likely consist of passive and active assisted range of motion for the shoulder, passive and active range of motion of the scapula, manual therapy, active range of motion of the bicep and tricep as able, and resistive exercise for the wrist and forearm as appropriate. The exercises in this chapter will be most useful for the middle to end stages of rotator cuff repair or non-surgical management of a rotator cuff injury when active range of motion, bodyweight and use of resistance are allowed. After a rotator cuff tear or repair, especially those that require a long period of immobilization and/or restricted range of motion, it is important to first restore muscular endurance through a full range of motion prior to progressing to heavier weight or strength-based exercises.

Shoulder impingement is a broad term used to describe pinching of the rotator cuff or bicep tendons either inside the shoulder joint (internal impingement) or outside of the joint (external impingement), usually in the subacromial space. Internal impingement is common in overhead athletes, particularly throwers, and involves the supraspinatus or infraspinatus tendon, superior to anterior glenoid labrum, the long head of the biceps tendon, and the posterior capsule. During maximal abduction and external rotation of the shoulder, the supraspinatus and/or infraspinatus tendons become impinged between the greater tuberosity as it rotates posteriorly and the glenoid cavity or labrum. This presents as posterior shoulder pain during throwing (maximal abduction and external rotation), posterior capsule stiffness, loss of internal rotation and will potentially occur in the presence of other conditions, like partial rotator cuff tears, shoulder instability, or superior to anterior labral (SLAP) lesions.[540–542] External impingement occurs in the subacromial space when the supraspinatus tendon and/or long head of the biceps tendon becomes entrapped between the acromion process and humeral head. Narrowing within the subacromial space can be caused by inflammation from repetitive movements, trauma, bony anatomy, or impaired scapulohumeral rhythm (see page 337). Those with external shoulder impingement often experience a painful arc of motion between 70° and 120° of shoulder elevation,[542,543] among other special test findings. This, however, may make it difficult to perform overhead or rotatory movements with the painful upper extremity.

Conservative treatment, which includes exercise therapy, is the preferred management strategy for shoulder impingement, especially if there is no rotator cuff tear. Similar to the outcomes observed between surgical repair and exercise therapy alone to treat rotator cuff tears, shoulder impingement surgery in the form of acromial decompression is similar to exercise therapy at long-term follow-up.[544–546] Exercise should focus on strengthening the rotator cuff and shoulder stabilizers.[542,543,547] Significant strength deficits in shoulder abduction (29%), external rotation (33%), horizontal abduction (18%) and protraction (8%) have been observed in individuals with shoulder impingement and this, along with a thorough exam, should help to guide exercise selection.[548] Also, for internal impingement in particular, deficits in internal rotation range of motion should be addressed[541] through both stretching and follow-up strengthening exercises. A randomized controlled trial by Sharma et al.[549] found that progressive resistance exercise improves isometric shoulder muscle strength greater than motor control exercises alone, which is not surprising due to the progressive resistance and greater variety of muscles targeted. An older randomized controlled trial by Holmgren et al.[550] also highlights the importance of resistance based exercise, as the intervention group that completed a 12-week evidence-based progressive resistance exercise program experienced significantly greater improvements in shoulder function, pain, disability, quality of life, and a greater amount (69%) reported a successful outcome compared to the control group (24%). The control group completed an exercise program that was not periodized, did not include any external load or progression of exercises. Also, fewer individuals in the intervention group (20%) ultimately decided to proceed with surgery compared to the control group (63%).[550] A randomized control trial by Clausen et al.[551] found that only 51% of a large sample participating in exercise therapy achieved an acceptable outcome after four months without any significant difference between a higher dosage and regular dosage exercise groups. So, although it appears that conservative management can make a significant impact and produce positive outcomes for individuals suffering from shoulder impingement, there is a subgroup of individuals who may fail the first line treatment strategy and opt for surgical intervention after three to four months.

SCAPULAR STABILIZATION AND SERRATUS ANTERIOR EXERCISES

- Serratus punch (see page 359)
- Prone on elbows thoracic extension (see page 398)
- Prone on elbows serratus push-up (see page 336)
- Serratus wall slides (see page 364)
- Side-lying flexion (see page 353)
- Side-lying horizontal abduction (see page 332)
- Side-lying forward press (see page 354)
- Side-lying external rotation (see page 344)
- Supine external rotation (for range of motion and eccentric control) (see page 343)
    - Be cautious in the setting of subscapularis repair

DELTOID AND ROTATOR CUFF STRENGTHENING EXERCISES:

- Supine flexion (see page 315)
- Deltoid hovers (see page 314)
- Supine OH press (see page 316)
- Prone external rotation (see page 352)
- Prone horizontal abduction thumb-up (see page 330)
- Prone shoulder extension (see page 288)
- Chest supported rear deltoid raise (see page 333)
- Band pull-apart (see page 331)
- Front raise (see page 326)
- Lateral raise (see page 329)

- Scaption variations (see page 340)
- Standing external rotation (see page 347)
- Standing internal rotation (see page 347)
- Standing shoulder extension (see page 339)
- Face pull (see page 335)

PRESSING EXERCISES:

- Floor press (see page 268)
- Modified/regular push-up (see page 276)
- Chest press incline or regular (see page 268-272)
- Bench press (see page 274)
- Landmine press (see page 320)
- Overhead press (see page 322)
- Serratus push-ups (see page 365)
- Triceps (see page 375)

PULLING AND BICEP EXERCISES:

- Row variations (see page 301)
- Lat pulldown (see page 289)
- Scapular pull-up (see page 297)
- Modified/regular pull-up (see page 294)
- Biceps (see page 384)

ADVANCED SHOULDER STABILITY:

- Reactive catch (see page 355)
- Reactive wall-ball (see page 358)
- Turkish get-up (TGU) (see page 429)
- Overhead shrug (see page 266)
- Kettlebell bottoms up press (see page 272)
- High plank tap (see page 420)
- Thoracic rotation plank (see page 401)
- High plank pull throughs (see page 422)
- Step walk over (see page 369)
- Bear crawl forward/backward (see page 374)
- High plank single-arm protraction/retraction dips (see page 368)

LOWER BACK PAIN

Lower back pain is prevalent in about 9.4% of individuals globally. It is the leading cause of global disability, measured in years lived with the disability, and has the sixth highest disease burden.[552] Exercise is a recommended treatment for both acute and chronic lower back pain. This includes, but is not limited to, strengthening, endurance, motor control, and other general exercise. According to clinical practice guidelines, the only other recommended stand-alone treatment to address back pain is thrust or non-thrust joint mobilization and it is recommended to combine other treatments like dry needling, soft tissue and nerve mobilization with other interventions.[553] The research is consistent in recommending exercise, but does not necessarily stand behind one specific mode of exercise or consider a particular type of exercise as more beneficial than another. As explained in Chapter 5, exercise that uses high loads, like deadlifts, may be just as effective as low-load motor control exercises for lower back pain, muscle strength, and endurance.[105–107] In addition, each individual may respond to a particular mode of exercise differently, so it is important to be well versed in a variety of management strategies. Exercise selection is best determined after completing a thorough exam that may reveal a directional preference of flexion or extension – the movement or posture that the body prefers, provide insight into the acuity or mechanism of injury (e.g. acute pain caused by bending and lifting or chronic, non-specific pain), different pathoanatomical causes (e.g. disk herniation, spinal stenosis, degenerative changes, etc.), strength, range of motion, quality of movement, and activity limitations. A review of the current evidence for acute lower back pain management (Tables 11–20 to 11–24) and chronic lower back pain management (Tables 11-25 to 11–29) is detailed below.

ACUTE LOWER BACK PAIN

Table 11-20 *Core stability training and its effect on acute lower back pain as detailed by Aluko et al.*[554]

Study Design	*Intervention*	*Results*
Randomized control trial	*Control group:* Core stability class with specific and general exercises Pelvic tilts Heel slides Prone scapula retraction Prone scapula W Prone hip extension Thoracic rotations Clamshells Bridges Cat camel Single knee to chest Lower trunk rotation Child pose 5–10 repetitions of each *Exercise group:* Core stability exercises from control group plus 8 additional stabilization exercises for the transversus abdominis and lumbar multifidus Prone and seated abdominal hollowing Supine alternating leg lifts with abdominal activation Four-point pelvic shifts in quadruped Alternating heel slide Trunk curl Seated pelvic tilts Seated alternating march Ten repetitions of each Three-week, six-week, and three-month follow-up for both groups	Improved, but no statistically significant differences between groups in mean trunk sagittal acceleration, pain, and disability Increased cross-sectional area of transverse abdominis and lumbar multifidus in both groups is not statistically significant, but is clinically significant at six weeks

Table 11-21 *Core stability training and its effect on acute lower back pain as detailed by Ye, et al.*[555]

Study Design	Intervention	Results
Randomized control trial	*Control group:* General exercise Individualized program of stretching exercises for legs, spine, strengthening of the abdominal flexor muscles and lumbar extensor muscles *Exercise group:* Lumbar spine stabilization exercise Static stability exercises with deep transverse abdominis and lumbar multifidus contractions (curl-up, pelvic bridge, side bridge, bird dog, plank) Progression to dynamic stabilization on a ball or foam roll Integration into functional activities, daily living, and work tasks if applicable 45-minute sessions, 3×/week for 12 weeks	No difference in pain or disability between groups at three-months post-intervention Both groups significantly reduced pain and disability

Table 11-22 *Exercise compared to reduce physical activity as detailed by Huber et al.*[556]

Study Design	Intervention	Results
Randomized single-blinded study	*Control group:* Instructed to reduce physical activity and spinal loading *Exercise group:* Isometric contractions of trunk extensors, rectus abdominis in hook lying with pillow support under lumbar area. Isometric contractions of gluteus maximus, quadriceps femoris, ankle and lower leg extensors in hook-lying 20 repetitions, 10 second hold 3×/day for 20 days	Significant improvement in muscle strength, spine range of motion, pain level, and reduced number of positive SLR tests No improvement in control group

Table 11-23 *Systematic review of effective interventions for acute and sub-acute lower back pain as detailed by Gianola et al.*[557]

Study Design	Intervention	Results
Systematic review and meta-analysis	N/A: systematic review, see results	Acute (<6 weeks) and subacute (<3 months) of non-specific low back pain Non-pharmacological treatments, including exercise and manual therapy, were most effective for reducing pain and disability in the first week after onset. Manual therapy was most effective in the short-term (1 month)

***Table 11-24** Systematic review of effective interventions for acute and sub-acute lower back pain as detailed by Pocovi et al.*[558]

Study Design	Intervention	Results
Systematic review	Walking, running, cycling, or swimming groups No intervention Alternate interventions (e.g. usual physical therapy or other exercise)	Low certainty evidence determines that walking and running are less effective than alternative interventions for reducing pain in the short and medium-term Low certainty evidence determines that cycling is less effective than alternative interventions for reducing pain in the short term Low certainty evidence determines that swimming is no different than alternative interventions for reducing pain in the short term High certainty evidence determines that walking and running are less effective than alternative interventions for reducing disability in the short and medium-term Moderate certainty evidence determines that cycling is less effective than alternative interventions for reducing disability in the short- and medium-term High certainty evidence determines that walking and running are more effective than no intervention for reducing pain in the short and medium-term and disability in the short-term Low certainty evidence determines that swimming is more effective than no intervention for reducing pain in the short and medium-term Walking and running was less effective than alternative interventions for improving quality of life in the short and medium term and fear avoidance in the short-term

CHRONIC LOWER BACK PAIN

***Table 11-25** Systematic review of exercise compared to no treatment, usual care, or placebo for chronic lower back pain as detailed by Hayden et al.*[559]

Study Design	Intervention	Results
Systematic review	N/A: systematic review, see results	Moderate certainty evidence that exercise is more effective for treating lower back pain and functional limitations than no treatment, usual care or placebo, but only met the minimal clinical important difference for pain

***Table 11-26** Exercise therapy compared to self-care and no treatment for chronic lower back pain as detailed by Rantonen et al.*[560]

Study Design	Intervention	Results
Randomized control trial	*Intensive outpatient rehabilitation group:* 1 hour exercise sessions 2–3×/week for 3 weeks Intensive 3-week course of muscle strengthening and endurance exercise and multidisciplinary education; 5 days/week for 6.5 hours/day for 3 weeks (111 hours total over 6 weeks) *Outpatient physical therapy group:* 1-hour exercise session of muscle strengthening and endurance exercise 2–3×/week for 12 weeks (24–36 hours total) *Self-care group:* Received back pain education *Control group:* Received no treatment or education	Active interventions reduced physical impairment and improved quality of life compared to self-care or no treatment control at two-year follow-up Medium effect sizes observed for physical impairment, pain intensity, and pain related fear in both the intensive outpatient rehabilitation and outpatient physical therapy groups compared to control at two-year follow-up. Medium effect size observed for improved quality of life in the outpatient physical therapy group compared to control at two-year follow-up. Large effect size observed for improved disability in the intensive outpatient rehabilitation group compared to control at two-year follow-up. No difference between self-care and control group for all outcomes.

Table 11-27 *Motor control exercise compared to graded activity for chronic lower back pain as detailed by Macedo et al.*[561]

Study Design	*Intervention*	*Results*
Randomized control trial	*Trunk muscle motor control exercise group:* Ten repetitions for ten second holds for each targeted muscle group with progression to functional static and dynamic activities *Graded activity group:* Individualized, submaximal exercises based on movements that were deemed “problematic” and combined with cognitive-behavioral techniques 1 hour exercise session for 8 weeks total 2×/week for 4 weeks 1×/week for 4 weeks	No significant difference between groups for pain, function, disability, or quality of life

Table 11-28 *Core stabilization and PNF exercise compared to a general exercise control group for chronic lower back pain as detailed by Areeudomwong et al.*[562]

Study Design	*Intervention*	*Results*
Randomized control trial	*Core stabilization exercise (CSE) group:* Isolated and co-contractions of deep trunk muscles, diaphragm and pelvic floor in “minimal loading” positions prone or seated positions Difficulty is progressed by adding co-contractions during bridging, bird dog, and single knee to chest 10 repetitions for 10 second holds *Proprioceptive neuromuscular facilitation (PNF) exercise group:* Rhythmic stabilization of trunk flexors and extensors, alternating concentric, eccentric and isometric contractions of the trunk muscles in a sitting position, chop and lift patterns	CSE and PNF groups demonstrated significant improvements in pain, disability, patient satisfaction compared to control group after 4 weeks and at 3 month follow-up. CSE and PNF groups demonstrated significant improvements in deep trunk muscle activity compared to control group after 4 weeks.
	3 sets for 15 repetitions 30 minute exercise sessions 3x/week for 4 weeks for both CSE and PNF groups *Control group:* 5–10 minutes of ultrasound General trunk strengthening exercise program (trunk curl-up, diagonal curl, and single-leg extension) 3 sets of 10 repetitions 20 minute exercise sessions 3x/week for 4 weeks	

Table 11-29 *Systematic review of most effective exercise type for management of chronic lower back pain as detailed by Grooten et al.*[563]

Study Design	*Intervention*	*Results*
Systematic review	N/A: systematic review, see results	No exercise type is proven more effective than another Low to moderate quality evidence that exercise, regardless of the type is more effective than no or minimal intervention for reducing pain and disability Moderate quality evidence that aerobic exercise is just as effective as resistance exercise for the reduction of pain and disability Moderate quality evidence that motor control exercise for the reduction of pain compared to minimal intervention

DISC HERNIATIONS AND DEGENERATIVE JOINT DISEASE (DJD)

An intervertebral disc is made up of a hydrated, gelatinous inner layer called the nucleus pulposus that is surrounded by the annulus fibrosus, an outer layer of collagen connective tissue.[564] The disc sits between each vertebra as a support structure and shock absorber for the variable movements and forces that the spine endures[564,565] during normal activity, exercise, and sport. Acute herniations caused by trauma (e.g. stress that exceeds the capacity of spine to withstand load) or degenerative herniations from the disc flattening as a result of dehydration, aging, or repetitive loading[565] are very common and present in both symptomatic and asymptomatic individuals.[566] Though disc issues are more common in symptomatic individuals, there is a high prevalence in the asymptomatic population.[566] Disc degeneration, disc height loss, and osteophyte formation,[564] was found in 37% of 20-year-old and 96% of 80-year-old asymptomatic individuals. Disc bulges, which occur when the nucleus pulposus pushes outward into the annulus, are found in 30% of 20 and 84% of asymptomatic 80-year-olds and it appears that incidence increases with age. Also, surprisingly, greater than 50% of asymptomatic 30–39 years of age have findings of disk degeneration, height loss, or bulging on imaging.[566] These findings do not discredit those with discogenic back pain, but imaging that does not correlate with an individual's reported pain pattern may be incidental and a normal process of aging. Fortunately, 85% of acute disc herniations demonstrate symptom resolution in about 8–12 weeks without undergoing any specific intervention and disc herniations can be treated with conservative management with a 60–90% success rate.[565] Improvements in imaging are also quite common to see and more severe disc herniations actually tend to demonstrate the most improvement or regression back into the normal disc space. Extrusions, which occur when the disc material expands beyond the border of the annulus but not into the spinal canal, have a 70% rate of regression. Sequestrations, which occur when the disc material migrates into the spinal canal, have a 96% rate of regression. Bulges and protrusions, which are just larger bulges, regress at a rate of 13% and 41%, respectively.[567] Disc material that expands outward into the central spinal canal or lateral foraminal space can cause inflammation and irritation of the longitudinal ligament and nerve roots, producing localized or radicular pain, symptoms that expand distally and away from the source of injury.[564]

Surgery versus conservative management to treat disc issues is a widely debated topic, but in absence of significant neurological symptoms (e.g. cord compression on imaging, myotomal weakness, abnormal reflexes) that may warrant emergent surgery, non-surgical treatment is obviously the least invasive option. There is limited concrete evidence that supports either as a superior treatment and the most appropriate path may depend on an individual's response to conservative care or other factors. For example, those with symptoms for less than six months tend to respond better to both surgery and conservative care. Surgical outcomes for individuals with comorbidities, like diabetes and obesity, tend to be less favorable.[568] A review of the Spine Patient Outcomes Research Trial (SPORT) by Carlson et al.[568] highlighted that significant improvements were demonstrated in both the surgical and non-surgical patients at two-year follow-up, but small differences favored the surgery group. Improvements were maintained in both groups at four- and eight-year follow-up. A systematic review by Chen et al.[569] found that surgery was more effective than non-surgical treatment in the short and medium-term, but the quality of evidence was considered to be very low. Other studies, however, found no significant long-term benefit of surgery compared to conservative management. A systematic review and meta-analysis by Dan-Azumi et al.[570] found that although early surgical intervention for those suffering from lumbar disc herniation with radiculopathy was more beneficial than conservative management in the short-term, there were no significant differences with respect to outcomes between both treatments in the long-term. Similarly, a prospective cohort study by Gugliotta et al.[571] found a faster and more significant reduction in pain level over the first six weeks, neurological symptoms over the first six to twelve weeks, and greater functional improvement at one year in the surgery group. However, there were no significant differences between the surgery and conservative care groups at two-year follow-up for all outcome domains.[571]

A controlled clinical trial by Ye et al.[555] found that although there was no difference between the general exercise and lumbar stabilization exercise groups at three months, both groups significantly reduced pain and disability scores at three and twelve months compared with pre-intervention. The lumbar stabilization exercise proved to have greater long-term effects, as this group demonstrated significantly improved lower back pain and disability compared to the general exercise control group after one year. Lumbar stabilization and motor control exercises in this study consisted of progressive activation of deep core muscles, including the transverse abdominis and lumbar multifidus in a stable neutral spine position. Activation of these muscles continued with transition to the curl up, bridge, side plank, and exercises performed in quadruped. There was an eventual progression to dynamic stabilization and functional activities.[555] Motor control training was found in multiple studies to be more beneficial than other passive treatment modalities, like transcutaneous electrical stimulation (TENS), for reducing disk related pain, function, and disability.[572,573] A systematic review by Pourahmadi, et al.[572] found that motor control exercises provided greater long-term improvements in function compared to traditional, general exercises, though many of the studies that were included had a high risk of bias. Besides stabilization and motor control training, other types of exercise like yoga and Pilates have also found to be appropriate interventions for disc related pain. A randomized control trial by Taspinar et al.[574] found that six weeks of tri-weekly clinical Pilates produced significant improvements in pain, disability, quality of life, flexibility, static and dynamic endurance compared to a control group that was instructed to continue their usual daily activities. A randomized control trial by Yildirim and Gultekin[575] found that 12 weeks of bi-weekly yoga resulted in significant improvements in pain, disability, and function compared to a control group with differences maintained at six-month follow-up.

LUMBAR SPINAL STENOSIS

Lumbar spinal stenosis refers to narrowing within the central spinal canal and/or facet joints to the point where the spinal cord, nerves, and vasculature become compromised due to lack of space. The condition is most often a result of progressive degeneration and is most common in individuals over 65 years old. People with spinal stenosis usually have a combination of lower back pain, bilateral lower extremity weakness, pain, aching, and burning that is worse in standing, walking, and other extended postures that close down the intervertebral or foraminal space. If these symptoms relieve with seated rest, forward flexion, or an alternative method of cardiovascular activity, like biking instead of walking, it usually indicates some degree of neurogenic claudication due to impingement on spinal vasculature and nerve roots.[576–578]

A randomized clinical trial by Schneider et al.[579] compared non-surgical management strategies of medical care (medications or injections), group exercise, and manual therapy combined with exercise (stabilization, strengthening, and stretching) groups. The manual therapy with exercise group demonstrated significant improvements in self-reported function and objective walking capacity compared to the other groups at two months. At six months, there were no statistically significant differences between groups, though all maintained any gains made in their walking distance.[579] A systematic review by Ammendolia et al.[580] found moderate quality evidence that manual therapy and exercise provide short-term, clinically significant improvements compared to other treatments, including medical care, which is in support of the findings by Schneider et al. Exercise for spinal stenosis that is supervised (e.g. by a rehabilitation professional) resulted in both short and long-term improvements in pain, quality of life, physical function[581,582] and decreased the rate of surgical intervention at 1 year follow-up compared to unsupervised exercise.[582]

LUMBAR INSTABILITY AND SPONDYLOLISTHESIS

Lumbar instability occurs when the spine is unable to maintain its stable position, move normally under load, and/or when the vertebrae lose their normal segmental mobility, the ability to move one at a time independent of each other.[583] This can occur due to spinal degeneration, fractures, or impaired muscle recruitment and progression of instability can cause more serious conditions like spondylolisthesis, cauda equina, or cord compression.[385,583] Spondylolisthesis is the anterior translation of one vertebra on the segment above or below due to a pars interarticularis fracture, the area on the posterior side of the vertebra between the superior and inferior articular pillar. The stress fracture itself is termed spondylolysis and usually results from repeated extension and repetitive loads.[584] On imaging, lumbar instability may present as a pars interarticularis fracture on X-ray or facet joint degeneration or fluid on CT/MRI.[585] Physical assessments, including the prone lumbar instability test, passive lumbar extension test,[585,586] lumbar extension load test, hypermobility as determined by passive mobilization,[585] and lumbar catch sign,[587] among others. Most of the research on exercise as a treatment for lumbar instability focuses on stabilization exercise. A randomized controlled study by Areeudomwong et al.[587] compared core stabilization exercise to a control group using only heat packs and stretching exercises. After ten weeks, the core stabilization exercises provided a significant reduction in pain, functional disability, and increased deep abdominal muscle activation when compared to the control group.[587] A randomized controlled trial by Puntumetakul et al.[583] compared core stabilization exercise and general strengthening. The core stabilization group had significantly less pain and increased deep abdominal muscle activation after ten weeks. In addition, both groups demonstrated significant improvements in the degree of segmental translation. Unfortunately, all results were not maintained at the 12-month follow-up.[583]

MOTOR CONTROL AND STABILITY EXERCISES

- Dead bug variations (see page 410)
- Plank (see page 182, 413)
- High plank shoulder taps (see page 420)
- Plank rotations (see page 401)
- Thoracic rotation lunge (see page 404)
- Turtle roll (see page 417)

- Split stance pull down (see page 423)
- Bear crawls (see page 427)
- Dowel hinge (see page 75)
- Assisted squats (see page 42)
- Box squats (see page 50)
- Chop and lift (see page 424)
- Side plank (see page 144, 424)
- Oblique crunch (see page 415)
- Press out (see page 419)

EXTENSOR MUSCLE STRENGTHENING

- Prone on elbows (see page 398)
- Superman (see page 114)
- Hyperextension hold/lower back plank (see page 115)
- Hyperextension (see page 117)
- 45° hyperextension (see page 121)
- Reverse hyperextension (see page 126)
- Modified plantigrade hip extension (see page 170)

FLEXOR MUSCLE STRENGTHENING

- Modified crunch (see page 414)
- Hollow body hold (see page 416)
- Hanging knee raises (see page 178)

FUNCTIONAL AND GENERAL EXERCISE

- Deadlifts (see page 73)
- Squats (see page 37)
- Push-ups (see page 276)
- Bridges (see page 105)
- Rows (see page 301)
- Farmer's walk (see page 428)

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