

CrossFit: An Overview and Considerations for Physical Therapists

Holli M. McClendon, SPT
University of North Carolina at Chapel Hill
Division of Physical Therapy

Introduction

CrossFit, a fitness regimen founded by Greg Glassman in 2000, is now considered one of the most popular and rapidly growing sports in the United States.^{2,10,19,32,36} It started with a single gym, or “box” as it is called by the CrossFit community, and has grown into an empire of over 13,000 worldwide affiliates with up to 4 million people using the free “workout of the day” (WOD) for their physical training.⁴¹ Public acknowledgement as a legitimate sport is generally considered to have been achieved in 2011 after a significant Reebok sponsorship and ESPN coverage of the CrossFit Games.² While CrossFit long has been popular with servicemen and women including military personnel and firefighters, participation by recreationally active adults and adults looking to improve their fitness is rising.¹⁷

Along with the popularity, injury rates due to CrossFit have also risen. It isn't uncommon for CrossFit boxes to have an employed in-house physical therapist, or at least one that they contract with or frequently communicate with. Studies of injuries related to CrossFit currently estimate that the rate is similar to that of gymnastics, Olympic weightlifting and power weightlifting.^{22,49} Because typically the goal of the rehabilitation process for patients injury from CrossFit is to return to the CrossFit environment, it is important for healthcare providers to understand the business and training principles of CrossFit as well as injury prevention and screening methods that are relevant to the type of training encouraged in CrossFit workouts. Physical therapists are in a unique position to become a bridge between healthcare recommendations and specific communities where individuals spend time, work and play – such as CrossFit boxes. In addition to direct interventions, a major role of physical therapists in the prevention of injury and disability and the promotion of wellness and fitness, according to the APTA, is to provide education and collaborative consultation to individuals and communities that are at-risk.³⁷

What Is CrossFit?

The physiological goal of CrossFit, according to Glassman, is to improve performance in ten specific fitness domains - accuracy, agility, balance, cardiovascular and respiratory endurance, coordination, flexibility, power, speed, stamina, and strength – through maximizing the body's neuroendocrine response and by using programming that consists of “constantly varied, high-intensity, functional movements.”¹⁴ These training methods are typically derived from gymnastics, powerlifting (the bench press, squat and deadlift) and Olympic Weightlifting (the clean and jerk and the snatch).^{19,36} There are nine specific fundamental movements of CrossFit: the air squat, front squat, overhead squat, shoulder press, push press, push jerk, deadlift, sumo deadlift high pull, and medicine ball clean.^{14,17} These movements are typically performed at high intensity and in short periods of time, with most WODs lasting less than 20 minutes.^{22,50} Rowing, running, plyometric activities, kettlebells, and jumping rope are frequently incorporated into the WODs along with the power movements.²²

Figure 1. The 9 Fundamental Movements of CrossFit. *From The CrossFit Training Guide.*¹⁴

Air Squat

Maintain a neutral spine with chest up, gaze forward, weight bearing through heels, and core tight. Feet are slightly wider than shoulder width and very slightly toed out. The squat should break parallel.



Front Squat

The bar rests across the upper chest and shoulders, with elbows high and fingers wrapped underneath the bar. The descent should be controlled with the same form as the Air Squat.



Overhead Squat

Be sure to begin this technique with a dowel (i.e. little to no weight). Begin with the bar overhead, wide grip. Slowly descend with the same form as the Air Squat, pulling back on the bar to keep it in the frontal plane.



Shoulder Press

The bar rests across the shoulders with a grip slightly wider than the shoulders, elbows under and in front of the bar. Feet are shoulder width apart. Press bar overhead in the frontal plane, tilt head slightly back to allow the bar to pass.



Push Press

Set up like the Shoulder Press. Bend the knees and hips while keeping the torso upright – approximately 20-25% of the depth of a squat (dip). Without pausing, forcefully extend the knees and hips (drive). As the knees and hips complete extension, the shoulders and arms press the bar overhead in the frontal plane (press).



Push Jerk

Set up like the Shoulder Press. Dip and drive like the Push Press. Press the bar overhead while simultaneously dipping a second time to catch the bar in a partial squat, then stand fully erect.



Deadlift

Begin with feet under the hips, grip spaced wide enough that the hands won't touch the legs throughout the lift, bar positioned over the toes, shoulders slightly forward of the bar, chest and gaze up, shoulder blades pulled back and down, and core tightened. Weight should be through the heels. As the knees extend, the shoulders and hips rise at the same rate (torso angle remains the same). Once the knees extended, the hips extend forcefully with the spine neutral, keeping the bar close to the body throughout the pull.



Sumo Deadlift Highpull

Stance is wide (“sumo” style) and grip is narrow, gaze is forward. Pull begins with knee and hip extension. Nearing the peak of hip extension, extend the hips and shrug forcefully, keeping the elbows above the bar and bringing the bar to just below the chin. The bar should be lowered to a hang position first, then to the ground.



Medicine Ball Clean

Begin at the bottom of a squat (heels down, head up, normal lordosis of the spine). Arms are extended around the sides of the medicine ball. Arms remain locked as the knees and hips forcefully extend while the shoulders shrug, so that the ball ascends close to the body in a straight line. Rapidly drop into a low squat again so that the ball can be caught with the elbows high (not beside the ribs). Maintain the ball in the caught position and ascend until fully upright.



CrossFit is considered to be a culture, a lifestyle and a community by those who are involved in it and those who understand it.⁵⁰ Participants of this fitness program, often called “CrossFitters,” will typically use terminology that has been developed by CrossFit to categorize types of WODs, such as AMRAP (as many reps as possible in set time), a Sprint or Chipper (set number of reps done as quickly as possible), and METCON (metabolic condition, which avoids the heavy lifting).^{40,51}

Considerations for Physical Therapists*How do CrossFit injury rates compare to other sports?*

Little research has been done to examine injury rates and prevalence of injury within CrossFit despite increasing numbers of reported injuries.^{22,49} Weisenthal et al (2014) performed a descriptive epidemiology study using a survey of 386 respondents who had been participating in CrossFit for less than 6 months and who participated at least 4 days per week for 30-60 minutes at a time. The overall injury rate for this sample was 19.4%. There was no significant difference of age, length of participation duration, or number of days of participation per week. Males had a significantly higher injury rate than females, though they also found that females were more likely to seek help from a coach or training and hypothesized that this might be related to the difference between sexes.⁴⁹ A study by Smith et al (2013) regarding the changes in aerobic fitness and body composition due to CrossFit reported a 16% drop out rate of their subjects due to injury.⁴⁶

Compared to gymnastics, powerlifting and Olympic Weightlifting, injury rates were similar. Compared to contact sports such as rugby, injury rates were lower.²² Interestingly, injury rates were similar to and often less than common adult fitness activities such as long-distance running and group fitness classes.^{22,49}

Weisenthal et al found that acute but mild injuries were the majority of those reported among 396 CrossFit participants, with the majority of injuries categorized as general inflammation and pain (30.8%), followed by sprains/strains (17.2%). Ruptures (3.7%) and dislocations (2.5%) were the most uncommon injuries.⁴⁹ Overall, the shoulder is the most commonly reported injured location, followed by the spine, then the knee.^{22,49} These are also the

three most commonly injured areas for competitive Olympic weightlifting and powerlifting sports.^{6,28,45} Gymnastics movements are most commonly associated with shoulder injury, while power lifting movements are most commonly associated with lower back and knee injury.⁴⁹ Repetitive performance of movements performed in a biomechanically incorrect way over time can place abnormal stress on musculoskeletal tissues resulting in chronic injury.²⁸ For these reasons, it is important for physical therapists to recognize proper weightlifting technique and be able to make corrections in the patient's movement if the coach has not done so before injury occurs.²⁶

Discretion is needed for choosing a safe box.

CrossFit is unlike other popular fitness programs in that local boxes aren't franchises; they are independently owned affiliates that pay an annual \$3000 fee for rights to use the brand name. All it takes for an individual to open their own box is for them to take a \$1000, 2-day long certification course that teaches them the CrossFit philosophy and the fundamental movements.¹⁷ Although the CrossFit Headquarters provides a daily WOD for all affiliates to use freely, individual boxes are able to create their own programming regardless of their certification level.^{7,17} The CrossFit headquarters does not regulate who can and cannot open a box, because they believe that their business model combined with the market will naturally allow exceptional boxes to succeed and poorly run boxes to fail.¹⁷ Because of this, a common critique of CrossFit programming is the lack of coach experience and subsequent lack of individualization for more inexperienced CrossFitters.²² The US Department of Defense and the American College of Sports Medicine have raised concerns about insufficient coaching, the need for training progression and scaling for less competent individuals, and the importance of supervision to prevent injury.²⁵ Programs that require an introductory training session for beginners are associated with lower injury rates than those that do not.⁴⁹ Additionally, a higher level of CrossFit coach supervision during workouts has been associated with lower injury rates,⁴⁹ suggesting that smaller classes or increased number of coaching staff per class may allow for increased participant supervision and lower the risk of injury.

Injured CrossFitters typically have the goal of returning to CrossFit.

In order to provide patient-centered care, the rehabilitation goal will often revolve around them returning to their usual hobbies and sports. Dan Pope, a physical therapist who has been highly immersed in the world of weightlifting and CrossFit for years, recommends using CrossFit tools during the rehabilitation process. Because these athletes are typically using kettlebells, pull-up bars and barbells in their daily life, it may be beneficial to progress to using these tools before discharging them with clearance to return to CrossFit. It is also a physical therapist's responsibility to screen for future injury risk and to identify abnormalities in the biomechanics of CrossFit movements. Asking questions about the patient's home CrossFit box is important in order to gain insight into the typical programming. Therapists can provide exercise modifications that the CrossFit coach may be missing, and have conversations with the coach when necessary.⁴⁰ Therapists who are interested in treating CrossFit athletes or in employment through a CrossFit gym can increase their knowledge of the philosophy and movements of the sport by taking the CrossFit Level 1 Certificate Course.⁴⁰

There is empirical support for the foundational principles of CrossFit.

While studies examining the neuroendocrine response of CrossFit WODs specifically are limited, literature does show an association between this response and high-intensity training combined with high heart rates and short rest intervals, which are commonly referred to as high-intensity interval training (HIIT) or high-intensity functional training (HIFT).^{3,32,44} Shing et al (2013) investigated the physiological changes of a HIIT program for rowers compared to a traditional program, and found that the HIIT program was associated with higher concentrations of post-exercise adiponectin, increased VO_{2max} , and decreased body fat percentage after the 4-week program. Adipose tissue has an established role in the endocrine system through regulation of energy storage and metabolism. Adiponectin is a protein secreted by the adipose tissue that is associated with improved athlete performance, improved body composition and improved recovery.⁴⁴ Similar studies looking at more untrained subjects such as individuals with type 2 diabetes²⁹ and sedentary, obese individuals³⁰ found similar outcomes following HIIT/HIFT program interventions. Chronic adaptations to this type of programming include decreased resting heart rate, decreased body fat percentage, decreased fasting insulin and improved hyperglycemia, increased release of catecholamines and growth hormones, and skeletal muscle adaptations such as improved mitochondrial capacity.^{3,29,30,44} Because of generally short duration of the workouts, CrossFit provides an appealing and efficient conditioning option for individuals with busy lifestyles who need these outcomes but who have decreased time in their day available to dedicate to fitness.^{2,29}

CrossFit can be beneficial for patients.

CrossFit promotes functional fitness, which involves movements that emulate those used in everyday life.² CrossFit also utilizes motivational principles that contribute to the adherence of participants to the programming. Exercise adherence is typically influenced by enjoyment of exercise and intrinsic motivational factors, while extrinsic factors contribute more toward initiation of exercise.²⁵ Both intrapersonal- and interpersonal-based competition are emphasized at CrossFit boxes through the strict recording of times, scores and weights for each individual workout.²² Individuals typically evaluate their competence through either mastery (comparing their current performance to their past performance) or performance (comparing their performance to the performance of others). The times, scores and weights collected at each affiliate become public to all CrossFit members, which allows the more competitive athletes to see their rankings and the beginning participants looking to lose weight or gain strength to track their personal progress and be held accountable in a community atmosphere. Research shows that sex differences exist in evaluating competence, with more females using a mastery approach and more males using a performance approach. Additionally, differences exist for duration of sport participation, with individuals who have participated longer being associated with a performance approach and individuals who are newer being associated with a mastery approach.³⁶

Several studies have examined the influence of CrossFit-like high-intensity, low volume exercise interventions on behavioral and psychological variables in many populations such as middle-aged cancer survivors, overweight and obese individuals, and aging men.^{20,24,25,27} A 6-week low-volume, high-intensity interval training (HIIT) intervention for lifelong sedentary older men compared to the normal exercise routine of age-matched lifelong exercisers resulted in increased weight management motives in the sedentary group.²⁷ Heinrich et al (2015) used a 5-week high-intensity functional training (HIFT) intervention with three 60-minute session per week that was based on the CrossFit programming with non-smoking middle-aged cancer

survivors.²⁴ Over the 5 weeks, there was a 75% adherence rate, significant increases in body composition and functional movement outcome measures, and an improvement in the emotional functioning domain of a health-related quality of life outcome measure.²⁴ A study of 23 obese and overweight subjects compared an 8-week long CrossFit-based HIFT intervention to a moderate-intensity aerobic and resistance training intervention (ART).²⁵ The CrossFit HIFT intervention incorporated introductory training sessions into weeks 1-2, and each session included a warm-up and cool-down. The HIFT group reported significantly higher exercise enjoyment, and the 3 subjects who dropped out of the HIFT had lower baseline enjoyment scores. Additionally, all HIFT subjects reported an intent to continue HIFT post-intervention while only 56% of the ART subjects reported an intent to continue ART post-intervention. The injury rate among the HIFT subjects was 4.3%. The researchers cited the benefit of CrossFit due to the ease of access, time-efficient nature of the workouts, and the safety.²⁵ A larger, long-term study of 62 middle-aged and overweight/obese subjects examined the impact of HIIT plus lifestyle interventions over 9 months and found no adverse events, an adherence rate of 97%, and significant improvements in body mass index, waist circumference, maximal exercise capacity, and a significant overall reduction in the prevalence of metabolic syndrome by 32.5%.²⁰

Screening for Abnormal Movement

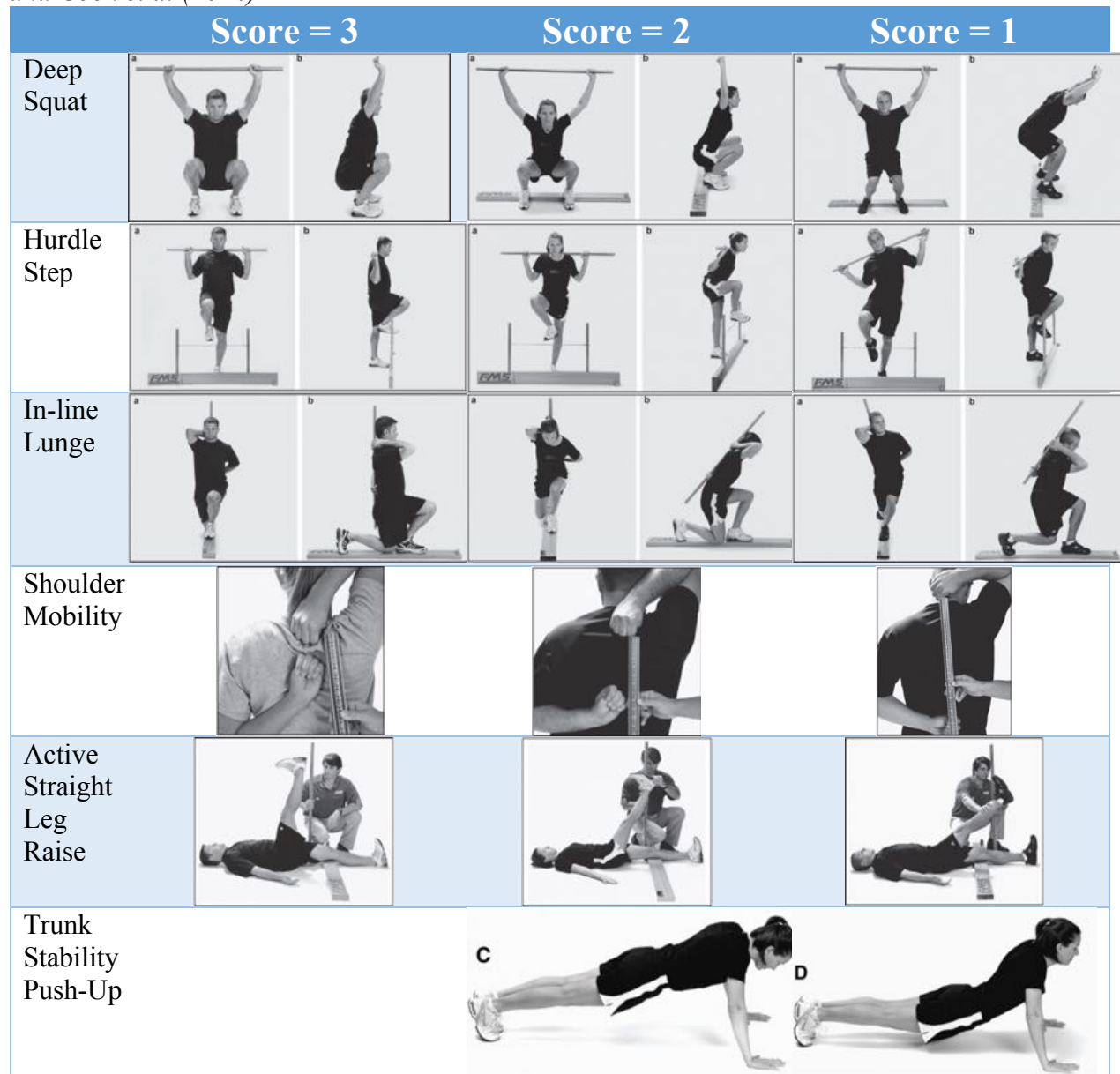
There are several factors including musculoskeletal movement abnormalities, balance deficits and decreased core stability that have been associated with increased injury risk.^{15,38,43,47} Specifically, resistance training programs performed at high intensity with short rest periods can cause fatigue and impaired short term performance, as well as altered movement biomechanics that can predispose the individual for injury.²⁶ The APTA position for physical therapists' role in prevention, wellness, fitness and health promotion is clear. Physical therapists are uniquely positioned as a bridge between the medical world and the communities where individuals spend time, and have the ability to adapt health recommendations to specific environments such as CrossFit boxes.³⁷ Screening tools can provide a guideline for evaluating movement to identify abnormalities, and to track program through use as outcome measures. For more active populations, Functional Movement Systems is a company that developed the Functional Movement Screen (FMS) and the Y Balance Test (YBT). These tools are often used in sports medicine settings and were designed to evaluate movement (FMS) and functional motor control and symmetry (YBT).^{15,40,48} In regards to CrossFit, physical therapist and FMS expert Gray Cook and physical therapist Dan Pope both advocate for the use of the FMS with CrossFit athletes to allow for improved coaching and technique correction. Cook refers to a "coaching bottleneck," which is when a coach detects a movement abnormality (such as dynamic knee valgus during a squat) but cannot correct the abnormality with verbal cueing due to a musculoskeletal imbalance (weak hip abductors). The purpose of the FMS is to detect the musculoskeletal issues that lead to poor technique in the first place, which supports the use of FMS in the CrossFit setting.^{9,40}

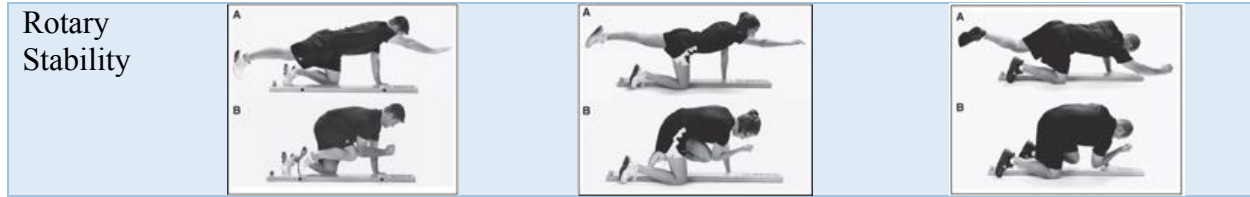
The Functional Movement Screen.

The FMS requires the individual to perform neurodevelopmentally-based 7 movements: the deep squat, hurdle step, in-line lunge, shoulder mobility, active straight leg raise, trunk stability push-up, and rotary stability.⁵ The theory behind FMS is that individuals with pain or compensation strategies during these movements will similarly exhibit poor movement patterns

during their sport, possibly placing them at intrinsic risk of injury.^{15,47} Each movement is graded on a scale of 0-3; a 0 indicates pain with the movement, 1 indicates the individual is unable to complete the movement, 2 indicates the individual is able to complete with movement with compensation, and 3 indicates the individual is able to complete the movement without compensation.¹⁵ *Figure 1* shows what an individual might look like during each movement depending on the score. Generally, there is an association of increased injury in individuals with composite scores at or below 14, however this does not mean that individuals with scores greater than 14 are ruled out from injury risk.^{5,15,47} The FMS has the benefit of being relatively quick and easy to administer for raters with experience.^{5,15,18}

Figure 1. Movement examples for the FMS for each score. *Images taken from Cook et al (2014) and Cook et al (2014)^{12,13}*





A systematic review and meta-analysis by Cuchna et al (2015) synthesized the literature relating to the reliability of the FMS. Among 7 studies that all used physically active participants and were of greater quality than case studies, the authors found moderate overall evidence of good interrater reliability that improved with level of rater experience, and moderate overall evidence of good intrarater reliability which also improved with rater experience. This increases the confidence level for FMS experienced clinicians who are using the FMS to track changes in movement patterns over time, as the changes are more likely due to patient improvements than to rater error.¹⁵

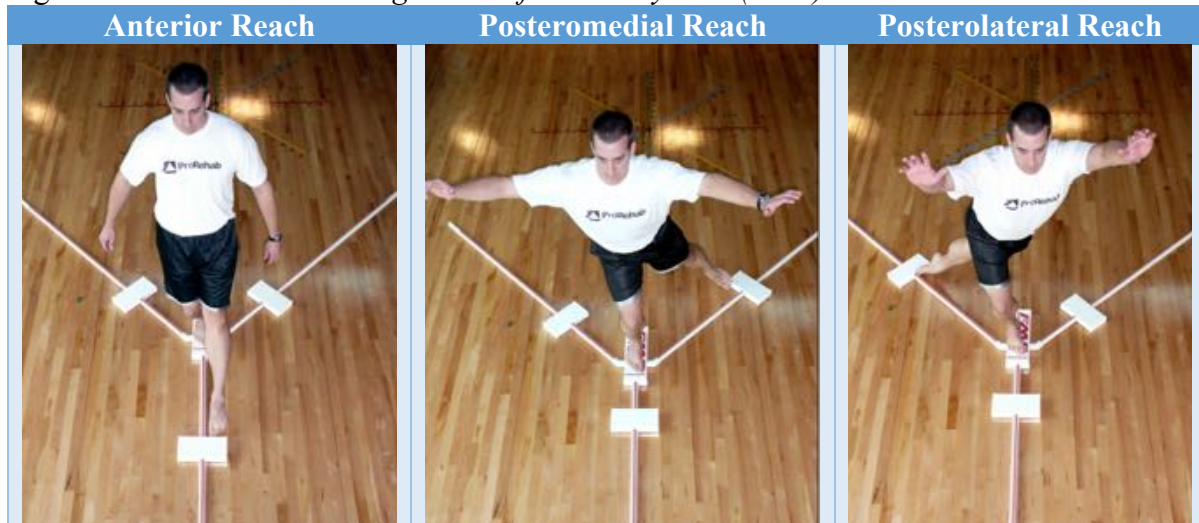
The value of the FMS as an injury prediction tool has also been widely studied. Butler et al (2013) examined the FMS as an injury predictor for firefighter trainees. Baseline fitness measures and a baseline FMS score was taken for 108 trainees prior to a 16-week physically intense training academy, and all musculoskeletal injuries were tracked throughout the training. The deep squat and trunk stability push-up were two FMS components that were significant for predicting injury, with a sensitivity of 80% and a specificity of 62%. The authors hypothesized that these two movements may have greater ability to predict injury risk due to the complexity and involvement of core and upper and lower extremity strength and mobility.⁵ In 160 healthy college-aged athletes, Garrison et al (2015) took FMS and tracked injuries incurred during a competitive season. Of the 52 athletes who sustained injury, the average FMS score was 13.6. The mean FMS score for athletes who remained uninjured was 15.5. The authors' sensitivity and specificity analysis supported existing evidence that a score of 14 provides the most desirable balance of specificity (73%) and sensitivity (67%). The odds ratio score of 5.61 for FMS scores of 14 or lower in this study suggests that athletes with this score have a 5 times greater risk of injury than athletes who score 15 or greater. History of past injury in the athletes of the Garrison et al study increased the risk to 15 times greater chance of injury.¹⁸

The Y Balance Test.

The Y Balance Test (YBT) is a quicker and more simplified version of the Star Excursion Balance Test that requires the subject to stand in single-limb stance while using the non-stance leg to reach in 3 separate directions (which create the shape of a "Y"): anterior, posterolateral, and posteromedial. *Figure 2* shows a demonstration of each reach direction. The sum of the distance reached for each direction relative to the length of the leg yields the composite score, and value for injury prediction in athletic populations has been associated with overall scores that do not reach a specific cut-off score or for asymmetries between distances reached.^{38,43} In a young, active population, Plisky et al (2006) found two YBT findings that may be risk factors for lower extremity injury: a 4 centimeter or greater difference between the right and left leg reach distances in the anterior direction and if the sum of the 3 reach scores were 94% or less of the leg length.³⁹ Several studies of active populations have demonstrated evidence of good reliability, whether examining intrarater scoring on the same day or interrater scoring over multiple days.^{34,38,43} Flexibility is a specific factor that may influence scores on the YBT.³⁴ In a study of healthy young adults performing both active range of motion (AROM) tests and the YBT,

Overmoyer et al (2015) found significant a correlation between ankle dorsiflexion AROM with the knee extended and scores for anterior and posterolateral directions. There was also a significant correlation between ankle dorsiflexion with the knee flexed to 90 degrees and scores for all 3 directions. Finally, there was a correlation between hip AROM and scores for posteromedial and posterolateral directions. Flexibility is required of the stance leg to reach each direction; simultaneous hip flexion, knee flexion and ankle dorsiflexion of the stance leg is required for lengthy reaching with the opposite leg.³⁴

Figure 2. Y Balance Test. Images taken from Plisky et al (2009).³⁸



Evaluation of a Movement: The Squat

The squat is a fundamental movement not only in CrossFit and other weightlifting sports, but in everyday function.^{11,31} Although it is important for physical therapists to be familiar with other lifts performed in CrossFit, such as the snatch or clean and jerk, the squat is the basis for proper technique in these and other advanced lifts that are typically encountered during CrossFit workouts¹⁴ and is the most advantageous lift for improving strength and power.²³ The CrossFit Training Guide further discusses the fundamental nature of squats and denounces chairs and stools as something invented by the western world that is slowly decreasing the average individual's hip extension strength and power.¹⁴ Due to the utmost importance of squatting for safe participation in CrossFit and other HIFT fitness regimens, and for the purposes of this paper, proper squat technique and injury prevention mechanisms will be reviewed.

In training regimens, the squat is effective for improving athletic performance because it is a complex movement that activates multiple muscle groups along the kinetic chain.³¹ When performed externally loaded with heavy weights or with intense repetition, the most frequent complaints elicited by squats are of low back pain⁴⁵ and knee pain.^{26,42} Serious cases of low back pain are often the result of spondylolysis or spondylolisthesis.⁶ The National Strength and Conditioning Association position statement on squat technique addresses the core principles of a squat.⁴² The descent should be controlled until the thighs are *at least parallel* to the floor, the lower legs should be close to vertical, the feet should be firmly in place and flat, and the trunk should maintain a normal lordotic curve and remain as close to vertical as possible.⁴² *Figure 3* demonstrates the sequence of a correct squat.

Figure 3. Correct squat sequence. *Image taken from The CrossFit Training Guide.*¹⁴

In the 1980's, squatting to a full depth (below parallel) was discouraged due to claims that full depth squats can cause knee ligament instability and excessive knee compression and shear forces.¹¹ Since then, this claim has been invalidated by numerous kinematic and epidemiology studies.^{4,8,11,23} Comparing the knee stability (as measured by a knee ligament arthrometer) of individuals after an 8-week half-squat program to an 8-week full depth squat program, Chandler et al (1989) found no difference in ligament stability. Additionally, performing the same arthrometry measurements on a group of elite, long-term power and Olympic weightlifters demonstrated that these athletes had significantly less ligament laxity as a whole than the less trained individuals who performed the study.¹¹ A review by Hartmann et al (2013) of 164 articles found little evidence that full depth squats are unsafe for the musculoskeletal system or that they increase the risk of passive tissue injury. The authors also concluded that with proper technique instruction and a progression of loading, full depth squats can be effective in injury prevention.²³ In choosing between machine-based squats and barbell squats, barbells squats may result in less shear forces at the knee. For individuals with pre-existing knee pathology, degenerative changes, or who are obese and need to be more mindful of forces within the knee joint, the barbell front squat specifically may reduce compression within the knee joint as opposed to the barbell back squat.²¹

Squat depth can also influence muscle activation. A study by Caterisano et al (2002) assessing the relationship between squat depth and muscle activation found that gluteus maximus activity varied across partial, parallel and full depth squats, while vastus medialis, vastus lateralis and biceps femoris activity remained fairly constant.⁸ A study by Bryanton et al (2012) further supported this with their findings that the relative muscular effort of the hip and knee extensors was limited by parallel squats and increased during full depth squats.⁴ Greater relative muscular effort of the hip extensors and ankle plantarflexors during full depth squatting occurred with

heavier barbell loads, while lighter loads with full depth squatting resulted in greater relative muscular effort from the knee extensors.⁴ Because strength of these groups of muscles is considered essential for normal functional movement and power, full depth squats may be ideal both for athletes and individuals in the rehabilitation process.^{4,8}

Minimizing unsafe shear forces within the lower back can be achieved by maintaining as close to a vertical position as possible for the spine and ensuring proper technique.^{26,31,42,45}

Figure 4 demonstrates several variations of an incorrect squat. During high-intensity short-rest workouts, decreased hip abduction due to fatigue of the glute muscles and hamstrings can lead to compensation for hip extension with the hip adductors and dynamic knee valgus due to excessive hip adduction. Quadriceps fatigue is also associated with increased anterior trunk lean, which can increase unwanted shear forces on the spine.^{26,31} Patients should be encouraged to utilize rest periods during their training programs, particularly for high-intensity, low-volume programming like CrossFit that typically offer decreased periods of rest. While the notion of remaining standing and upright for a more active recovery during rest periods is pervasive in many sports and fitness programs, supine or seated rest positions may allow for a much quicker recovery of work capacity and greater decreases in heart rate and VO_2 as compared to a standing or active recovery position.³³

Figure 4. Variations of an incorrect squat. *Image taken from The CrossFit Training Guide.*¹⁴

Common Faults or Anatomy of a Bad Squat



Not breaking the parallel plane

Rolling knees inside feet

Dropping head

Losing lumbar extension (rounding the back - this may be the worst)



Dropping the shoulders

Heels off the ground

Not finishing the squat - not completing hip extension

In addition to teaching participants of CrossFit and HIFT workouts as well as coaches how to identify abnormalities in their body position during workouts, there are several other techniques that may be helpful for improving squat biomechanics. A study by Adelsberger et al (2014) compared a 10-minute warm-up routine and a 10-minute stretching routine to a control group to examine the effect on subjects' center of pressure and stability during an air squat, an overhead squat, and a deadlift. The result was that the stretching routine had the greatest impact on stability and center of pressure was more directed toward the heels, which enhanced the subjects' ability to maintain an upright trunk. Improved range of motion of the kinematic chain of weightlifting movements may allow a more optimal posture for both performance and injury prevention.¹ *Figure 5* demonstrates how a squat in an individual with good range of motion might differ from the squat in an individual with poor range of motion. Visual cueing through use of video or a mirror and verbal cueing may also be useful feedback for individuals re-learning the squat correctly.^{14,31} *Figure 6* provides a list of suggested verbal cues that may help assist individuals in attaining proper squat technique.

Figure 5. A squat in an individual with poor range of motion (a) versus good range of motion (b). *Image taken from Adelsberger et al (2014).*¹

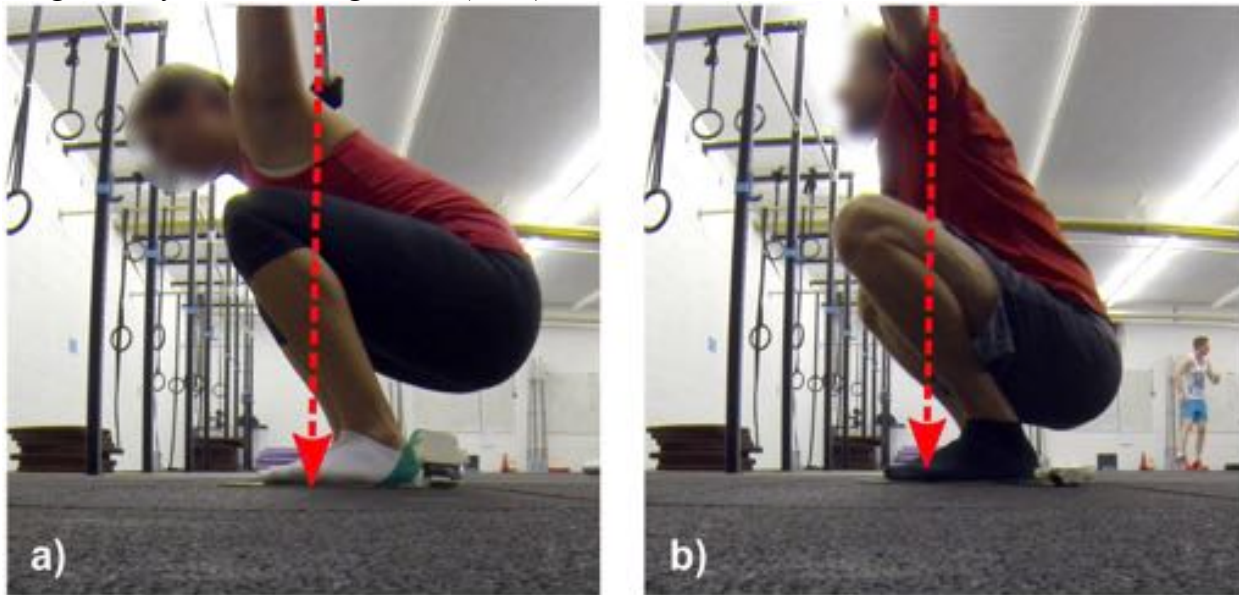


Figure 6. Suggestions of Verbal Cues for Squat Correction. *Taken from The CrossFit Training Guide.*¹⁴

| How to Squat | |
|--|--|
| Here are some valuable cues to a sound squat. Many encourage identical behaviors. | |
| <ol style="list-style-type: none"> 1. Start with the feet about shoulder width apart and slightly toed out. 2. Keep your head up looking slightly above parallel. 3. Don't look down at all; ground is in peripheral vision only. 4. Accentuate the normal arch of the lumbar curve and then pull the excess arch out with the abs. 5. Keep the midsection very tight. 6. Send your butt back and down. 7. Your knees track over the line of the foot. 8. Don't let the knees roll inside the foot. 9. Keep as much pressure on the heels as possible. 10. Stay off of the balls of the feet. 11. Delay the knees forward travel as much as possible. | <ol style="list-style-type: none"> 12. Lift your arms out and up as you descend. 13. Keep your torso elongated. 14. Send hands as far away from your butt as possible. 15. In profile, the ear does not move forward during the squat, it travels straight down. 16. Don't let the squat just sink, but pull yourself down with your hip flexors. 17. Don't let the lumbar curve surrender as you settle in to the bottom. 18. Stop when the fold of the hip is below the knee - break parallel with the thigh. 19. Squeeze glutes and hamstrings and rise without any leaning forward or shifting of balance. 20. Return on the exact same path as you descended. 21. Use every bit of musculature you can; there is no part of the body uninvolved. 22. On rising, without moving the feet, exert pressure to the outside of your feet as though you were trying to separate the ground beneath you. 23. At the top of the stroke stand as tall as you possibly can. |

Donnelly et al (2006) found that the direction of gaze during the squat can influence body position as well. The authors recommended discouraging a downward gaze during the squat, as this resulted in more excessive hip flexion and anterior trunk lean as compared to individuals with a more neutral or upward gaze.^{16,31} CrossFitters may also question the physical therapist about appropriate shoe wear, specifically whether they should wear weightlifting specific shoes. A study by Sato et al (2012) examined the kinematic differences in a barbell back squat while wearing weightlifting shoes versus wearing running shoes. They found that the knee extensor excitability was increased while wearing weightlifting shoes due to the slightly declined angle of the foot, and individuals wearing weightlifting shoes during their squat displayed less anterior trunk lean as measured by the anterior displacement of the barbell. The authors suggest the use of weightlifting shoes for beginners or lower-skilled weightlifters that lack good range of motion.⁴²

Conclusion

Physical therapists, especially those working in sports or outpatient settings, are more likely than ever to encounter patients who currently participate in CrossFit or who are considering it due to the rising popularity of the regimen for recreation, fitness and sport. Knowledge of the types of movements commonly encountered – such as the squat, the risks and benefits of participation, the training programming, and the business philosophy of CrossFit will allow physical therapists to rehabilitate injured patients in a way that will allow them to return to CrossFit or their HIFT regimen of choice. This information will also allow physical therapists to

educate interested patients, and those who could potentially benefit from participation, about CrossFit³⁶ in a way that empowers them to make discerning and informed choices about the box they choose to participate in.

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