A REHABILITATION MANUAL OF CORRECTIVE EXERCISES FOR THE

FUNCTIONAL MOVEMENT SCREEN™ BASED ON SCORE

A Project

by

Lindsay Nicole Mazur, ATC

Summer 2019

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A Project

Presented

to the Faculty of

California State University, Chico

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In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

in

Kinesiology

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DEDICATION

I would like to dedicate this project to all individuals that have encouraged me to pursue and that have contributed in some way to this project.

ACKNOWLEDGEMENTS

I would first like to thank my family, friends and fellow athletic trainers who have supported my idea for this project since the beginning and have continuously encouraged me throughout the process. I would like to thank former athlete and graphic design major, Jamie Ikeda for helping create a platform for this manual to be delivered. She used her educational background combined with my project goal to produce a manual both appealing to the eye and easy to use. I hope this project can help her in her career as much as it has helped me.

This project could not have happened without the assembly of my committee. I would like to thank Stephen Henderson for taking on this project with a graduate student he had never met or worked with before. We bonded over the FMS™ and how it may bring change to the field. I thank him for his expert advice on the FMS™ and the drop-in conversations about the potential for this manual.

Scott Barker's contribution to this project has truly made this manual stand out from the technological aspects it features, however this is only a small portion of what this committee member has helped me accomplish. As a graduate assistant athletic trainer under his supervision he has given me the opportunity to learn from him over the past few years. That knowledge and experience is priceless. I would like to thank Scott for that and for the continued support into my next step as a young athletic trainer.

Finally, I would like to thank my committee chair Dr. Melissa Mache. She has supported my academic endeavors since the start of my graduate career here at Chico.

From teaching me how to perform biomechanical research in her classroom to being co-authors on independent research. She has also pushed my academic work to being better than I thought it could be. With countless edits and review this project has become the best work, I can share through the entirety of my academics. I will take these values into the next steps of my career.

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## ABSTRACT

A REHABILITATION MANUAL OF CORRECTIVE EXERCISES FOR THE FUNCTIONAL MOVEMENT SCREEN™ BASED ON SCORE


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Master of Arts in Kinesiology

California State University, Chico

Summer 2019



The high occurrence of injuries in athletics has led to an increase in popularity of injury predictive tools. However, implementing these tools can create burdens for sports medicine practitioners, including, time, appropriateness, and trustworthiness. The Functional Movement Screen™ (FMS™) is an assessment tool that, in part, addresses these burdens. It contains seven movement patterns that provide a whole-body assessment of functional movement by assigning scores zero to three. By correcting identified dysfunctions, the goal is to reduce the number and severity of injuries in sport; however, developing an individualized corrective exercise program can be a timely task. Therefore, the result of this project is a manual of corrective exercises to improve scores on the FMS™.

An extensive literature review process was completed to compile an appropriate list of corrective exercises. To insure the highest quality evidence was used for each exercise, the manual incorporated the Strength of Recommendation Taxonomy (SORT). The manual is designed so that anyone with FMS™ results can be prescribed exercises to improve dysfunctions identified based on score. Locating FMS™ score for a given movement provides the user with corrective exercises including a thorough description, purpose, target tissue, prescription, video, and SORT reference.

Fifty-five exercises were included to correct the nine dysfunctions outlined by the FMS™. After a familiarization session with a supervising rehabilitation specialist, all exercises can be performed independently. Implementing this manual, will allow for efficient, individualized prescription of corrective exercises, while still providing quality care for all.

# CHAPTER I

# INTRODUCTION

The Functional Movement Screen™ (FMS™; Functional Movement Systems Inc., Chatham, VA) was originally created to clear healthy high school football players for participation in strength and conditioning programs. The tool was developed to specifically assess the dynamic and functional capacities of the athlete. After creator Gray Cook published the FMS$^{TM}$, professional teams, strength and conditioning coaches, and athletic trainers began adopting his approaches to functional testing well beyond the high school football population (Cook, Burton, Hoogenboom, & Voight, 2014a). Currently, the FMS$^{TM}$ is used during both pre-participation physicals and to determine an athlete's readiness to return to sport at the completion of an injury rehabilitation program.

The FMS™ consists of seven individual tests and three clearing tests. Prior to being tested for the shoulder mobility (SM), trunk stability push-up (TSPU), and rotary stability (RS) tests, a clearing test must be performed pain-free to ensure the test itself does not cause injury. Once the clearing tests have been successfully completed an athlete will then be asked to complete the seven individuals tests of the FMS$^{TM}$. The individual tests include the deep squat (DS), hurdle step (HS), in-line lunge (ILL), SM, active straight-leg raise (ASLR), TSPU, and RS tests. These movements are individually scored on a scale of three to zero based on the following general FMS™ scoring criteria:

> A score of 3 represented the ability to perform the functional movement without compensation. A score of 2 was assigned if the participant performed the movement

> with compensations. A score of 1 was assigned if the participant was unable to perform the movement according to published guidelines, and a score of 0 was reserved for participants who had pain with the movement or presented with pain while performing a clearing test (Chimera, Smith & Warren, 2015; Cook, Burton, Kiesel, Rose & Bryant, 2010).

Most often FMS™ scores are reported as composite scores ranging from zero to twenty-one. The composite score is the result of the sum of individual scores received on all seven movement patterns, using the lower of the two scores for unilateral tests (e.g., the HS is assessed for both the left and right limb in the moving position, however, only one score from these two tests is used in computing the composite score).

Though the composite score is commonly used to interpret the results of the FMS™, it is important to realize that it may mask important results of the individual tests (Mokha, Sprague, & Gatens, 2016). When a greater emphasis is placed on individual test scores the assessor can better understand existing movement dysfunctions. These movement dysfunctions are typically presented as mobility or stability issues at involved joints. The identified dysfunctions become the blueprint for rehabilitation specialists to develop program of corrective exercises to address the identified dysfunction. For example, during the DS, a score of a "two" indicates minor dysfunction exists with either closed kinetic chain ankle dorsiflexion or thoracic extension (Cook et al., 2014a). Therefore, if a therapeutic exercise has been shown to improve dorsiflexion and it is implemented into the training program for an individual who scored a “two” on the DS, with sufficient time their ankle dorsiflexion and DS score should improve. Although no investigation exists to justify exercises to improve DS score from “two” to “three”, we do know that slant board gastrocnemius stretching results in improved ankle dorsiflexion (Jeon, Kwon, Yi, Cynn, & Hwang, 2015). Given this evidence it seems reasonable to believe that implementing slant board gastrocnemius stretching in a training program would help an athlete improve their DS score. Using existing evidence and this logic, exercises can be identified for each dysfunction to build an evidence-based exercise program.

Existing exercise programs to improve FMS™ score have not documented the use of such an evidence-based approached to select exercises for inclusion in their programs. For example, some researchers have effectively implemented a generic "one-size-fits-all" exercise prescription approach to increase FMS™ composite scores (Bodden, Needham, & Cochalingam, 2015; Dinc, Kilinc, Bulat, Erten, & Bayraktar, 2017; Kiesel, Pliskey, & Butler, 2011; Song, Woo, So, Kim, Lee & Kim, 2014; Stanek, Dodd, Kelly, Wolfe, & Swenson, 2017). These programs are not designed individually based on FMS™ movement scores and associated dysfunctions (e.g. DS score "two" to improve ankle dorsiflexion) and often require supervision of the athlete during the completion of the program. The lack of specificity in these programs and the time demands of implementing and supervising the exercise programs are problematic. An intervention program that can be easily implemented with specificity, in a variety of settings, and would not require intense supervision on behalf of the practitioner would prove to be a useful tool. A manual of this nature may be one means of effectively delivering this type of exercise program.

Some manuals and guides for corrective exercise programs related to the FMS™ do currently exist; however, these manuals are not evidence-based in nature nor are they easily used. For example, the "FMS Exercise and Progression Manual" provides exercises based on FMS™ score along with prescription; however, information necessary for implementation is scattered throughout the manual and no rationale is given for exercise inclusion (Cook, Burton, & Fields, n.d.). The FMS™ website (Functionalmovement.com, 2018) also provides a library containing approximately ninety-five exercises. However, the organization of the website makes it difficult for the user to find the correct exercise and implement it without the help of a rehabilitation specialist (Functionalmovement.com, 2018). "Pursuit Fitness and Performance: Corrective Exercise List" includes multiple progression levels and demonstration video links for exercises intended to address movement dysfunctions identified by FMS™ scores. Though, the sources' credibility is not available for reference (Pursuitfitnessandperformance.com, 2018). Collectively, existing manuals and exercise lists can provide useful information (e.g. video, exercise purpose, and score-based exercises) to aid in the construction of the first evidence-based manual intended to address movement dysfunctions identified by FMS™ score. With the inclusion of sound evidence-based material in this manual, the use of the FMS™ and the developed manual might be more easily implemented and widely accepted by practicing medical providers.

The manual developed for the purpose of this project has been constructed using an evidence-based approach. During the development of the manual each article collected was assessed using a rating scale: The Strength of Recommendation Taxonomy (SORT) (Ebell et al., 2004). Citations with the strongest ratings were used in the manual; a feature non-existent in current manuals. Furthermore, exercises specific to each score (i.e., 1 or 2) for each movement pattern were included in the manual. Each exercise is also accompanied by the exercise purpose, target tissue, video instruction, and prescription.

## Purpose of Project

The purpose of the manual is to create an athletic trainer and strength and conditioning coach friendly guide of corrective exercises that can be implemented to improve scores on the FMS™. It is believed that improving FMS™ scores will ultimately reduce the risk of injuries associated with the movement dysfunctions identified by the FMS™. The focus of the manual is the corrective exercises themselves whereas background information regarding how to screen athletes is presumed to be understood prior to using the manual. The manual will serve as a tool to quickly use the FMS™ score to provide specific exercise prescription for each individual test and score for a given assessment.

## Scope of the Project

The manual will contain eight chapters; one introductory chapter followed by one chapter dedicated to each of the FMS™ individual movement patterns. For each movement pattern, a brief description is provided, implications for each scoring criteria is given, and this information is followed by corrective exercises designed to improve the identified dysfunction. Each exercise is accompanied by the citation(s) associated with the strongest available evidence supporting the exercise's use.

This manual is designed for practitioners who have experience implementing and interpreting the FMS™ and want to prescribe exercises to address the dysfunction(s) identified by the athlete's score on a given FMS™ movement. It is expected that the exercises provided in the manual will be prescribed to athletes or physically active individuals who are without a current injury. After the practitioner has introduced the prescribed exercises, the athlete should then be able to use the manual as a guide to continue the program independently.

## Significance of the Project

An evidence-based manual intended to address dysfunctions identified in FMS™ results does not yet exist. A manual of this nature that includes quality evidence may impact the current resistance, among rehabilitation and strength and conditioning professionals, to implement this functional movement assessment tool. A tool, like the completed manual, that is readily available to prescribe corrective exercises based on the FMS™ results would ease the time burden placed on rehabilitation and strength and conditioning specialists. A manual including exercises appropriate for addressing the identified dysfunctions would make the process easier for both the assessor and the athlete, and ultimately allow the provision of a higher standard of care for athletes.

## Limitations

This project cannot be completed without some limitations. The manual is based on creator Gray Cook's outline of dysfunctions associated with each movement pattern based on score (Cook et al., 2014a; Cook et al., 2014b). The exercises prescribed in the manual are based on Cook's assumptions, though at present, there is limited evidence to verify whether all dysfunctions identified in the FMS™ are in fact reflective of the score earned by an individual. In addition, the manual does not include evidence that the individualized programs created by the manual will improve FMS™ scores. Rather it is known that individual exercises address the suggested dysfunction. Further research will be necessary to understand the effectiveness of the programs suggested in the manual.

## Definition of Terms

Abduction

A movement of a limb or part of the body away from the midline.

Active straight leg raise (ASLR)

A maneuver performed supine while raising a leg as high as possible with hip flexion, knee extension, and ankle dorsiflexion as described in the FMS™.

Adduction

A movement of a limb or part of the body towards the midline.

Composite score

The sum of the seven individual FMS™ test scores. For the five tests that are completed bi-laterally, the lower of two scores is used to compute the composite score.

Deep squat (DS)

A squat performed as deeply as possible while holding a PVC pipe overhead as described in the FMS™.

Disease-oriented evidence

"These outcomes include intermediate, histopathologic, physiologic, or surrogate results (e.g., blood sugar, blood pressure, flow rate, coronary plaque thickness) that may or may not reflect improvement in patient outcomes." (Ebell et al., 2004).

Dorsiflexion (DF)

Motion at the ankle towards the dorsal aspect of the foot or upward.

Dysfunction

Impaired or abnormal function.

Evidence-based research

Information that is based on sound research, not opinion. Involves the process of collecting and analyzing data with the use of prior research to answer a new question.

Functional movement assessment

A catch-all term for non-standardized assessment tools used by rehabilitation specialists to determine the quality and efficiency of a physical movement.

Functional Movement Screen™ (FMS™)

A seven-step screening system designed by Gray Cook, with three clearing tests, designed to rank movement patterns of active people from basic to normal function (Cook et al., 2010, pp. 17).

Functional testing

The process of performing a functional movement assessment.

Hurdle step (HS)

A maneuver in which the participant steps over a hurdle adjusted to tibial tuberosity height while maintaining hip, knee and ankle alignment, taps the floor with the lead heel and returns to the starting position as described in the FMS™.

Injury predictive screening tool

Any tool used to predict and reduce the risk of injury. Umbrella term for fitness, cardiovascular, strength, or proprioceptive screening.

In-line lunge (ILL)

A lunge performed in the tandem position while holding a PVC pipe along the spine as described in the FMS™.

Level of evidence

"The validity of an individual study is based on an assessment of its study design. According to some methodologies, levels of evidence can refer not only to individual studies, but also to the quality of evidence from multiple studies about a specific question or the quality of evidence supporting a clinical intervention, for purposes of maintaining simplicity and consistency" (Ebell et al., 2004).

Mobility

Freedom of motion in terms of tissue extensibility and joint range of motion (Cook et al., 2010, pp. 263).

Patient-oriented outcomes

"These are outcomes that matter to patients and help them live longer or better lives, including reduced morbidity, reduced mortality, symptom improvement, improved quality of life or lower cost." (Ebell et al, 2004)

Plantarflexion (PF)

Motion at the ankle towards the plantar aspect of the foot or downwards.

Proprioception

The awareness of position or movement of a body part.

Range of motion (ROM)

The total motion of a joint within each plane of motion expressed as degrees.

Rotary stability (RS)

A maneuver performed in the quadruped position where the knee and elbow are flexed to touch as described in the FMS™.

<u>Self-mobilization</u>

A manual therapy intervention performed by oneself, in which a force is applied to stretch a joint capsule to improve range of motion.

<u>Sensitivity</u>

A measure of a tests' ability to correctly identify individuals with a disease or condition.

<u>Shoulder mobility (SM)</u>

A maneuver performed when one shoulder is maximally adducted, extended, and internally rotated and the other shoulder is maximally adducted, flexed and externally rotated as described in the FMS™.

<u>Specificity</u>

A measure of a tests' ability to correctly identify individuals without a disease or condition.

<u>Stability</u>

At the joint, resistance provided by motor control units involving musculoskeletal and neuromuscular tissues to maintain the position of the body in demanding situations.

<u>Strength of recommendation</u>

"The strength (or grade) of a recommendation for clinical practice is based on a body of evidence (typically more than one study). This approach considers the level of evidence of individual studies; the type of outcomes measured by these studies (patient-oriented or disease-oriented); the number, consistency, and coherence of the evidence as a whole; and the relationship between benefits, harms and cost." (Ebell et al., 2004)

Trunk stability push-up (TSPU)

A push-up performed with various hand positions and knee assistance as described in the FMS™.

Validity

The extent to which a test measures what it is intended to measure. Sensitivity and specificity are other interpretations of this measure defined previously.

# CHAPTER II

# LITERATURE REVIEW

## Introduction

The NCAA Injury Surveillance Program (NCAA-ISP) reported 3,825 collegiate soccer injuries between the years 2009 and 2015 (Roos et al., 2017). The same report showed 8.07 and 8.44 injuries per 1,000 athletic exposures (i.e., practice, competition, and strength and conditioning training) for men and women, respectively (Roos et al., 2017). Similarly, the NCAA-ISP reported 3,939 collegiate basketball injuries between the years 2009 and 2015 and rates of 7.97 and 6.54 per 1,000 exposures for men and women, respectively (Zuckerman et al., 2018). Though, the figures reported for total injuries and injuries per 1,000 exposures are staggering, these numbers are likely underestimates of the total number of injuries. The high amount of athletic injuries reported suggests the need for better strategies for potentially predicting and then working to prevent these injuries.

The need for injury prediction tools becomes even more apparent when the costs (e.g., time loss from participation and money) associated with these injuries are taken into consideration. For example, 52.5% of women's soccer injuries and 46.1-48.7% of women's basketball injuries reported in the NCAA-ISP resulted in time lost from participation, with durations of time loss ranging from a few days to an entire career (Roos et al., 2017; Zuckerman et al., 2018). In addition to the lost participation time, these sports injuries can also cost a significant amount of money and time, for injury rehabilitation, physician's appointments, surgeries, and tuition dollars. For example, an athletic department's annual contribution to medical expenses at the collegiate level ranges from $52,800 at a Division II college without football to $628,000 at a Division I college with football (Lipford & Slice, 2017). Given the variety of expenses associated with collegiate sports injuries, effective methods of injury prediction and injury rate reduction could help save enormous amounts of time and money.

The responsibility of implementing these practices to help reduce injury rates has recently shifted to rehabilitation specialists (Maiorana et al., 2018). Completing pre-participation physicals (PPE) is one commonly used practice intended to identify individuals who may be at a greater risk of injury. Most organizations require a PPE to compete in athletics and often athletic trainers are responsible for completing the orthopedic component of these examinations. In theory this is a good fit given the expertise of these professionals, however in practice several issues arise:

1. The amount of time required to administer such assessments to a large number of athletes can be overwhelming or potentially impractical.
2. Selecting an assessment that is appropriate for evaluating athletes who participate in a variety of sports.
3. Trusting the assessment will not only help to identify those individuals who may be at a greater risk of injury but will also provide information to assist the

> practitioner in addressing the identified dysfunctions and help athletes participate as safely as possible (Bird et al., 2016).

If rehabilitation specialists choose to implement a systematic means of reducing injury rates, then these potential barriers must be addressed.

One attempt at addressing the workload increase associated with administering PPEs was the National Athletic Training Association (NATA) recommendation for the 90-second examination (Conley et al., 2014). Though the examination is efficient and well recognized it is limited in that it only involves the assessment of isolated strength and flexibility. If we are truly interested in reducing injury rates, more robust assessments are likely needed. With this in mind some orthopedic assessments now include the evaluation of functional capacity and movement quality by means of a functional movement assessment (Bird et al., 2016). These tools are designed to provide information about injury risk based on how an athlete moves (e.g., identifying pre-existing dysfunctions or post-injury limitations). In addition to using these assessments prior to participation they are also useful in determining when an athlete can safely return to play after injury. These tools may take longer than 90 seconds to complete, however the information they provide can be the first step in attempting to reduce injury rates and likely save time in treating injuries that arise from dysfunctions that may have been missed using the 90 second screen.

After identifying dysfunction in a functional movement assessment, implementing a corrective plan is the next step prior to participation. If the assessment that is implemented does not include exercise prescriptions to “treat” the identified dysfunction(s) then this work falls to the rehabilitation specialist, again adding to the workload of these individuals. To address this potential barrier, it seems that any assessment tool should be supplemented by an exercise prescription program that can be used to address movement dysfunctions identified by the assessment.

In summary, a predictive plan to reduce injury rates in athletics is needed. It is recognized that such a plan likely places a higher demand on rehabilitation staff members initially, however, it is also possible that if such a program is effective it will save time in injury rehabilitation. Regardless, action must be taken to ease the burden for implementing a functional movement assessment and developing corrective exercise guidelines to supplement the results of these assessments. Therefore, the aim of this literature review is to discuss current evidence associated with various injury predictive screening tools, provide evidence for the effectiveness of the Functional Movement Screen$^{TM}$, and justify the construction of a score-based manual of corrective exercises to be used in conjunction with the FMS$^{TM}$.

## Injury Predictive Screening Tools

In athletics, functional movement assessments hold high value as one component of the umbrella of injury predictive screening tools. This form of assessment consists of body-weight dynamic movements that require the simultaneous use of multiple joints and muscles. Athletes typically perform functional and sports-related maneuvers to determine readiness to participate or return to play and minimize the chance of injury or re-injury. The more the functional movement assessment can replicate the demands of sport, the more confident the rehabilitation specialist can be in allowing the athlete to participate or return to play safely. In addition to considering how well an assessment most closely replicates a variety of sport and athletic maneuvers, an athletic trainer or rehabilitation specialist must consider the reliability, validity, cost, time, and space demands of the assessment (Prentice, 2008, pp.488). The variety of tools available is helpful as various settings (e.g., physician appointments, physical therapy clinics, athletic training rooms, and strength and conditioning settings) often require the use of different assessments based on the equipment and facilities available. An assessment that best meets all the requirements of the practitioner will ultimately prove to be the most beneficial.

Selecting the most appropriate assessment can be a difficult task as at present a variety of tools exist that may meet the needs of a various practitioners. For example, tools such as the Cleveland Clinic RPE score, star-excursion balance test (SEBT), Y-balance test (YBT), balance error scoring system (BESS), isokinetic muscle testing, questionnaires (e.g., pre-participation health questionnaire [Edouard et al., 2014]), hop and jump test, landing error screening system (LESS), tuck jump assessment, and the FMS™ have all been used to identify individuals with increased injury risk. Each of the assessments listed measure different components related to safe sport participation, such as cardiovascular fitness, proprioception, strength, and functional movement. Appropriateness of each assessment may be determined by the setting and clinical discipline (e.g., primary care, cardiology, and orthopedics) in which administration takes place. Often little to no advanced technology or equipment is available within an athletic rehabilitation setting, a consideration that must be made when selecting an injury predictive assessment.

One assessment that only requires the use of a foam pad and an assessor is the BESS. It is a standardized static balance test used within athletics. This test was initially designed as a diagnostic tool for concussions, it involves the evaluation of balance in three stances (i.e., double leg, singe leg, and tandem) on both a solid floor and a compliant foam pad. The test is scored by number of "errors", lending the test to subjective bias. As a result, low inter-rater (ICC=0.44-0.83) and intra-rater reliability (ICC=0.50-0.88) have been reported for each stance position (Finnoff, Peterson, Hollman, & Smith, 2009). Given current evidence, other tests that have better reliability and are specifically intended for musculoskeletal injury risk screening are likely more appropriate to accomplish the goal of identify individuals who may be at a greater risk of injury.

Like the BESS, the YBT was also designed to assess balance; however, it involves a more dynamic approach that relates more to the functional movements of sport. The YBT requires the user to stand on a single leg and reach with the other limb as far as they can in three directions (i.e., anterior, posteromedial, and posterolateral) while maintaining balance. The intended purpose of the YBT is to assess balance and asymmetries, and ultimately predict lower extremity injury. However, in a group of Division I athletes, performance on YBT was not a predictor for lower extremity injury even after accounting for other injury risk factors (e.g., sex, body mass index, prior lower extremity surgery, and sport) (Lai et al., 2017). Therefore, the value of the YBT for use as an injury risk screening tool seems to be minimal.

The LESS was developed to address some of the deficiencies in the previously described screens and create a cost and time effective drop-landing assessment. The drop-landing task requires dynamic, eccentric loading similar to the jumping and landing requirements of many sports. Two video cameras positioned perpendicular to frontal and sagittal planes are used to record the athlete performing the drop-landing task. A 17-point checklist is subsequently used to analyze the video and score the test (Padua et al., 2009). Despite the dynamic nature of the assessment and comprehensive scoring system, LESS performance has not been shown to be predictive of injury, nor was it useful in identifying those individuals who have previously suffered a lower extremity injury among Division I soccer players (James, Ambegaonkar, Caswell, Onate, & Cortes, 2016). Given that the LESS was developed primarily for the prediction of ACL injuries it may also be too specific in nature to provide a robust understanding of an athlete's risk for injury.

In contrast to the LESS, the FMS™ test incorporates a full-body approach to functional assessment by including seven different movement patterns. Given the robust nature of the test, the FMS™ may be the most popular and well-known functional movement assessment within the athletic community (Everard et al., 2017). Professional teams, collegiate teams, high schools, physical therapy clinics, and membership athletic gyms are just some of the settings adopting the FMS™ principles. The FMS™ contains seven individual tests scored on a scale of zero to three by an assessor. The seven tests include the deep squat (DS), hurdle step (HS), in-line lunge (ILL), rotary stability (RS), shoulder mobility (SM), active straight-leg raise (ASLR), and trunk stability push-up (TSPU). Composite scores (i.e., the sum of scores from the seven exercises), individual scores from each exercise, and movement asymmetries are potential options for interpreting the results of the FMS™. Importantly, given the robust nature of this assessment it likely addresses the second concern presented by Bird et al. (2016) in that it could be useful for athletes who participate in a wide variety of sports.

## The Functional Movement Screen™

The FMS™ addresses the second issue presented by Bird et al. (2016), by including a number of individual tests that require the use of the full-body to complete, which helps to better replicate a variety of sports-related maneuvers. Strict scoring criteria for individual tests, which other injury predictive assessments do no possess, also help the FMS™ address the third issue presented by Bird et al. (2016). That is, the scores that result from the FMS™ can be related to specific movement dysfunctions and can then been used to develop an appropriate corrective exercise plan (Cook et al., 2010). Due to the advantages of using the FMS™, there has been a recent spike in research related to the FMS™ including several comparisons with other well-known assessments (e.g., static balance, the YBT, injury history questionnaires, and the LESS) (Chimera et al., 2015; Clifton, Harrison, Hertel, & Hart, 2013; Engquist, Smith, Chimera, & Warren, 2015; Everard et al., 2017; Lisman, Nadelen, Hildebrand, Leppert, & Motte, 2018). These comparisons have repeatedly demonstrated the superior characteristics of the FMS™.

One way in which the FMS™ has been shown to be a better tool than others is the fact that it can be administered at any time in comparison to exercise activity, this allows for more flexibility in a large-scale screening process. For example, FMS™ results have shown to not be affected by administrative time when compared to a static balance test performed before and after a fatiguing exercise protocol. In recreationally active men and women, static balance decreased after the fatiguing exercise; however, the

FMS™ composite score and individuals scores were not affected by the fatiguing exercise (Clifton et al., 2013). Therefore, administration time in relation to physical activity does not play a role in the FMS™ assessments.

The FMS™ is also capable of distinguishing between athletes of elite capacities compared to the general population. For example, the FMS™ has been compared to the YBT to establish test differences in individuals of varying athletic capacities. The FMS™ individual scores were able to expose functional differences between NCAA Division I student-athletes and general college students, that the YBT otherwise could not (Engquist et al., 2015). Therefore, the FMS™ individual scores prove to be more sensitive than the YBT. The FMS™ and YBT were also compared between middle school, high school, and collegiate athletes. Between these populations, the FMS™ was also able to distinguish collegiate athletes, who scored higher on the DS, ILL, ASLR, and TSPU, from high school and middle school athletes while the YBT was not able to distinguish between populations (Lisman et al., 2018). As hypothesized the elite athletes performed better and the FMS™ individual tests were the only means of detecting these differences.

The FMS™ and YBT have also been evaluated to better understand what pre-existing conditions may lead to differences in performance on the respective assessments. Injury history and sex of the individual were highly predictive of performance on both the FMS™ and YBT (Chimera et al., 2015). However, the YBT was not able to distinguish between types of pre-existing injuries; whereas, individuals with a history of a specific injury could be identified by one of the various FMS™ individual tests. For example, when compared with participants without a history of injury, individuals with a history of hip injury scored lower on the DS and HS, and individuals with a history of hip surgeries had limitations with HS and ILL. Taken together this evidence suggests the YBT is not as sensitive as the individual FMS™ tests when it comes to identifying those individuals with a history of a specific lower extremity injury or surgery (Chimera et al., 2015).

In addition to being superior at identifying individuals with injury history, the FMS™ has also been determined to be better at predicting whether an individual is at a greater risk for any type of athletic injury. When compared to the LESS, a moderate negative correlation (-0.487) was found between the two assessments when using the composite scoring system, suggesting that these assessments are not interchangeable (Everard et al., 2017). Researchers were surprised by this finding as the LESS test was designed to assess eccentric strength and dynamic control, otherwise missed by the FMS™. However due to time constraints if one assessment must be chosen, the FMS™ provides a much broader approach by assessing the full-body through multiple tests. This investigation may support that an assessment consisting of various tasks and levels of difficulty, like the FMS™, may be superior to one drop-landing test alone to assess functional capacity.

Collectively, the current literature suggests the FMS™, especially individual maneuvers of the assessment, provide greater feedback about the quality of a person's functional movement capacity. These comparative studies have continuously provided evidence to support the use of the FMS™ as an assessment to clear athletes for participation prior to a competitive season and for assisting in the determination of readiness to return to play after an injury. Given the effectiveness and efficiency of the FMS™, its' injury prediction capabilities for athletes who participate in a variety of sports, and the fact that the results by score and associated dysfunction can be directly turned to exercise prescription it seems the FMS™ is well suited to address the three issues posed by Bird et al. (2016).

FMS™ Scoring and Interpretation

Each FMS™ movement pattern is scored using a scale of zero to three to establish the quality of movement, readiness to participate, and injury risk. The sum of individual test scores results in the composite score ranging from zero to twenty-one. Some controversy exists regarding how the scores should be interpreted. That is, should we attempt to interpret the composite score or should focus be given to the individual movement scores. Most research conducted has used the composite score to attempt to establish the injury prediction capabilities of the FMS™. A composite score lower than fourteen has been thought to be a predictor of injury (Bushman et al., 2016; Garrison et al., 2015; Knapik et al., 2015; Warren et al., 2015). However, among soldiers categorized as “high risk” based on this criterion (i.e., a composite score lower than fourteen) only 33% that incurred a subsequent injury were correctly categorized (Bushman et al., 2016). Therefore, 67% of injuries were missed by the FMS™ composite score threshold (i.e., individuals who scored greater than fourteen and still experienced injury). There was also a large number of false-positives, those that were identified as “high risk” that did not have an injury.  Thus, it appears the composite score is not sensitive enough to be used as an injury predictor if used in a clinical setting.

Another issue with the composite score is its’ inability to detect bilateral asymmetries. Eighty-four NCAA Division II student-athletes performed the FMS™ prior to sport participation and were subsequently tracked through a competitive season.  For data analysis, the participants were divided into groups based on composite score, individual test scores, and asymmetries. It was concluded that asymmetries and low individual test scores were better predictors of injury than the composite score (Mokha et al., 2016). For example, if an athlete were to score a three on all individual tests except to score a one on the SM test, the composite score would be interpreted as nineteen classifying them as "low risk". However, the individual may be at "high risk" for a shoulder injury given their poor performance on the SM test. This illustrates the need to pay close attention to individual FMS™ test scores to help identify dysfunction for the anatomical structures utilized in the completion of that specific maneuver. Given the current evidence the FMS™ composite score should be interpreted with caution and perhaps more attention should be given to scores on individual tests of the FMS™.

## Description of FMS™ Maneuvers

Given the importance of the individual movement scores a thorough description of each maneuver along with available descriptive research has been provided to assist in the understanding of the FMS™.

### Deep squat

During the DS, the participant is asked to squat as deeply as possible while holding a PVC pipe overhead, maintaining an upright posture, and moving downward until the femur reaches horizontal. The DS is intended to assess bilateral mobility of the hips, knees, and ankles. To perform the DS, closed kinetic chain dorsiflexion, knee flexion, hip flexion, thoracic extension, shoulder flexion, and shoulder abduction are required. Interpretations for each of the DS scores have been provided in Table 1. As is true for all

FMS$^{TM}$ movement scores a "three" indicates no dysfunction, "two" indicates minor limitations exist, a "one" indicates gross limitations, and a “zero” indicates the movement is painful and further evaluation is needed (Cook et al., 2014a).

A couple of attempts have been made to independently confirm the dysfunctions associated with the respective DS scores. For example, Bulter et al. (2010) used kinematic analysis and force plates to describe the biomechanics of the DS and attempted to distinguish between the different DS scores (i.e., 1, 2, and 3). No significant differences were found between groups (i.e., FMS$^{TM}$ DS scores) for peak dorsiflexion angles with angles of 24.5º ± 2.3º, 27.9º ± 2.6º, and 31.4º ± 1.8º for group scores 1, 2, and 3, respectively. However, at the knee, significant differences existed between all three groups with peak knee flexion values of 84.7º ± 4.3º, 111.0º ± 4.9º, and 130.7º ± 3.8º for groups 1, 2, and 3, respectively. Similarly, at the hip, there were significant differences between groups with 88.8º ± 5.1º, 117.5º ± 4.0º, and 121.1º ± 2.0º peak hip flexion for groups 1, 2, and 3, respectively (Butler et al., 2010). Though Jenkins et al. (2017) used a slightly different approach they also determined that active hip ROM was related to DS score (r=0.342). Based on present evidence it would seem that hip flexion range of motion is a predictor of DS score as suggested by Cook et al. (2014a). However, other dysfunctions believed to be associated with DS scores (i.e., insufficient closed kinetic chain dorsiflexion and limited thoracic extension) have not yet been explicitly confirmed with evidence-based research.

<u>Hurdle step</u>

During the HS, the participant is asked to step over the FMS™ test kit adjusted to the tibial tuberosity height while maintaining balance, ankle, knee, and hip alignment, and holding a PVC pipe across the shoulders. The individual completing the exercise must simply tap the front heel to the floor and then return to the starting position. The HS movement is performed and scored separately for each limb. The HS assesses bilateral functional hip, knee, and ankle mobility and stability. The stance limb requires hip, knee, and ankle stability and closed kinetic chain hip extension. The moving limb requires knee and hip flexion and open kinetic chain dorsiflexion. Therefore, poor performance may represent poor stance limb stability or moving limb mobility. Interpretations for each of the HS scores have been provided in Table 1 (Cook et al., 2014a).

Some investigators have attempted to relate HS scores to the claimed dysfunctions associated with each score. For example, the relationship between ankle dorsiflexion ROM, hip flexion ROM and FMS™ HS scores have been examined (Janicki, Switzler, Hayes & Hicks-Little, 2017; Jenkins et al., 2017). Investigators found no correlation between active ankle dorsiflexion and the HS score. When the participants were grouped by score dorsiflexion values of 16.42º and 14.67º for the right and 16.00º and 14.19º for the left were found for scores “three” and “two”, respectively. For active hip flexion, weak relationships were found between ROM and HS score for men ($r=0.451$) and women ($r=0.536$) (Janicki et al., 2017). Similarly, the Jenkins et al. (2017) found a significant correlation between hip flexion and the HS for the right limb ($r=.301$). When participants were grouped by scores 124.25 º and 116.93º hip flexion for the right extremity and 116.63º and 116.97º for the left were found for the score “three” and “two” groups, respectively (Janicki et al., 2017). A closer look may be needed for score “three” to determine why the average hip flexion value is not more similar bilaterally; however, the observed differences in values, though not statistically significant, support suggestions by Cook et al. (2014a). At present we do not have any descriptions of how knee flexion ROM and balance relate to HS scores. Kinematic investigations are still needed to create a thorough biomechanical profile for each of the FMS™ HS scores and support FMS™ dysfunction guidelines.

In-Line Lunge

During the ILL, the participant is asked to stand in tandem on the test kit with the rear toe (i.e., the testing limb) on the zero marker and front heel on the tibial measurement (i.e., height from ground to tibial tuberosity in standing). While holding a PVC pipe along the spine, maintaining an upright posture, and keeping balance, the rear knee is lowered to the test kit and returned to starting position. The ILL assesses hip, knee, and ankle closed kinetic chain mobility, hip abductor stability, and quadriceps flexibility. The ILL also utilizes rotational, deceleration, and lateral movements. Poor performance may indicate imbalance in hip adductor strength or mobility. Interpretations for each of the ILL scores have been provided in Table 1 (Cook et al., 2014a).

The only investigation conducted thus far to better understand the FMS™ ILL scores was performed to associate active hip ROM measures with ILL score. Significant correlations between the ILL and hip flexion for the right (r=0.422), and the left (r=0.351) limbs were found (Jenkins et al., 2017). This investigation provides confirmation that hip ROM plays a role bilaterally in ILL performance. No investigation, to date, has described the role of the hip abductors in maintaining stability during the ILL.

Shoulder Mobility

During the SM test, the participant is asked to perform maximal shoulder adduction, extension, and internal rotation on one arm and maximal abduction, flexion, and external rotation while maintaining a fist with both hands. The space in inches between hands is then compared to the length of the hand (i.e., distal crease of the wrist to tip of the third digit) to determine the SM score. If the distance is less than a single hand's length the participant receives a "three". If the distance is between one and one and a half hand lengths, the participant receives a "two". If the distance is greater than one and half hand lengths, the participant receives a "one". Contradicting the name, the SM test does not only screen for dysfunction related to glenohumeral joint ROM, but also requires proper scapular mobility and thoracic spine extension. The movement is performed and scored bilaterally with arms in opposite positions. The test arm is considered the upper arm. Interpretations for each of the SM scores have been provided in Table 1 (Cook et al., 2014b).

The SM proposed dysfunctions have been validated by an investigation in overhead athletes (Sprague, Mokha, Gatens, & Rodriquez, 2014). For example, Sprague et al. (2014) compared shoulder total rotational range of motion (TRROM), also referred to as the total arc or passive internal rotation to passive external rotation measures, to SM test results. A five-degree bilateral TRROM discrepancy is considered to be a predisposing condition for shoulder injury, however this investigation choose to use a ten-degree asymmetry to create a more inclusive group for analysis (Sprague et al., 2014). Asymmetries in TTROM greater than 10º were found in 40/114 overhead athletes screened. In the same 114 athletes, 45/114 presented with an asymmetry on the SM test. However, only 17/45 clinically tested had a ten-degree asymmetry based on TTROM, this seems to indicate that deficits other than TTROM must exist when SM test performance is low (Sprague et al., 2014). It is possible that these other deficits are related to pectoralis minor tightness, weak latissimus dorsi, or scapular dyskinesis as suggested by Cook et al. (2014b); however, these dysfunctions have not yet been investigated.

Active Straight Leg Raise

During the ASLR, while in the supine position the individual is asked to lift their leg as far as they can while holding ankle dorsiflexion, knee extension, and contralateral limb extension. The ASLR requires active hamstring and gastrocnemius flexibility, core stabilization, and contralateral limb activation. The test is performed and scored for each limb. The lateral malleolus position of the moving limb compared to contralateral limb landmarks determines score. If the lateral malleolus reaches above the anterior superior iliac crest (ASIS) a score "three" is received. If the lateral malleolus is between the patella and ASIS a score "two" is received. If the lateral malleolus is below the patella a score "one" is received. Interpretations for each of the ASLR scores have been provided in Table 1 (Cook et al., 2014b).

The ASLR can be used for a number of purposes. For example, in the clinical setting it can be used as a hamstring extensibility test, whereas others may use it as a quadricep strengthening exercise. In the rehabilitation setting it has also been used as a key stepping stone in the recovery process of many lower extremity surgeries (Houglum, 2005, pp.877). Simultaneous activation of the quadriceps and relaxation of the hamstrings is needed to reach maximal flexion in this test. To this author's knowledge no investigation exists that specifically describes ASLR test score in relation to kinematic and ROM measures; however, this may be due to the straight-forward nature of the test.

Trunk Stability Push-Up

During the TSPU, the participant is asked to assume the push-up position and perform one standard push-up with no lag in the lumbar spine. Score is determined by hand placement and varies between men and women. For men, hands are placed shoulder width apart and thumbs at the forehead level. If unable to complete, hands are moved to chin level to receive a score “two”. For women, hands are initially placed shoulder width apart at chin level. If unable to complete, hands are moved to shoulder level to receive a score “two”. If both genders are unable to perform with compensations, they receive a score “one”. Interpretations for each of the TSPU scores have been provided in Table 1 (Cook et al., 2014b).

The TSPU scoring criteria implements different hand placements during the push-up to change the level of difficulty of the test. Variations in hand placement during a standard push-up are known to affect muscular activation, with a backward hand placement (i.e., hands placed 20 cm below the acromion) being most beneficial for total upper body strengthening (Marcolin et al., 2015). While, both the forward (i.e., hands placed 20 cm above the acromion) and backward hand positions in neutral width show the greatest activation of the abdominal and back musculature (Marcolin et al., 2015). These findings directly support the FMS™ guidelines, as score is decreased as hands are moved backwards requiring more upper body strength and less core stability to perform the TSPU. This means the TSPU requires a component of stability and upper body strength to perform well. This concept has also been confirmed by measuring EMG activations during the TSPU concluding that core isokinetic and isometric strength are required to successfully perform the task (Johnson et al., 2018). Therefore, improvements in core stability and strength may be necessary to improve score on the FMS™ TSPU.

Rotary Stability

During the RS test, the participant, while in the quadruped position, is asked to perform an ipsilateral knee and elbow tuck, followed by extending the ipsilateral arm and leg without major weight shifts. The participant is evaluated and scored on each side of the body. If the maneuver cannot be performed to receive a "three" within three attempts, the compensation is to perform the same movement with the contralateral knee and elbow. If the movement can be performed a score "two" is received. Interpretations for each of the RS scores have been provided in Table 1 (Cook et al., 2014b).

The RS is the second maneuver categorized as a stability test (Cook et al., 2014b). The stability demands of the RS have been confirmed through an EMG analysis of the maneuver (Johnson et al., 2018). It was concluded that core stability, specifically isokinetic and isometric strength, is required to score higher on the RS test (Johnson et al., 2018). However, no evidence exists to determine if the dysfunctions believed to be associated with each score are accurate.  For example, if a score of "one" is received on the RS test dysfunctions are believed to exist with poor asymmetric trunk stability in the sagittal plane. Though, at present this purported dysfunction is only supported by anecdotal evidence based on clinical expertise.

## FMS™ Reliability and Validity

The reliability and validity of the FMS™ scoring criteria have been investigated repeatedly to develop a better understanding of the usefulness of the FMS™ as a screening tool (Bonazza et al., 2017; Burnet, Carpenter, & Pidcoe, 2003; Busch et al., 2017; Bushman et al., 2016; Dorrel et al., 2018; Garrison et al., 2015; Knapik et al., 2015; Minick et al., 2010; Leeder, Horsley, & Herrington, 2016; Shultz, Anderson, Matheson, Marcello, & Besier, 2013; Smith, Chimera, Wright, & Warren, 2013; Warren et al., 2015). Intra-rater reliability, inter-rater reliability, and validity have been assessed for the FMS™ composite score and in some cases for individual movement patterns. The following discussion provides an overview of the existing evidence regarding the reliability and trustworthiness of the FMS™.

### Intra-Rater Reliability

In terms of the FMS™, intra-rater reliability is defined as the ability of one rater to consistently rate the same performance over multiple viewings. A meta-analysis determined the FMS™ provides excellent intra-rater reliability (ICC=0.81) (Bonazza et al., 2017). Based on current evidence regardless of FMS™ experience, raters are able to consistently rate movers (Minick et al., 2010; Smith et al., 2013, Shultz et al., 2013). For example, excellent live-vs-video test-retest reliability (ICC=0.92) was established for the FMS™ composite score by five assessors with various backgrounds (i.e., one undergraduate student, one physical therapist, two athletic trainers, and two strength and conditioning coaches) (Shultz et al., 2013). It was also established by four raters (i.e., an entry level physical therapy student with FMS™ experience but not certified, a certified FMS™ tester, a faculty member in athletic training with a Ph.D. in biomechanics and movement scientist with no previous experience with FMS™) scoring nineteen subjects over two testing sessions, with ICC ranging from 0.81 to 0.91 (Smith et al., 2013). FMS™ raters have established excellent intra-rater reliability making it a satisfactory tool for use in a clinical setting.

Inter-Rater Reliability

The extent to which multiple raters score the same performance consistently is considered inter-rater reliability. In terms of the FMS™, if multiple raters view one participant performing the FMS™ maneuvers, all raters will give that participant similar scores if inter-rater reliability is good. When the composite score is used, a meta-analysis determined the FMS™ provides excellent inter-rater reliability (ICC=0.81) (Bonazza et al., 2017). When multiple raters score the same FMS™ test performance, it has been established that regardless of experience they also score similarly (Minick et al., 2010; Smith et al., 2013). For instance, inter-rater reliability (ICC=0.91) was established by comparing four raters (i.e., non-certified FMS™ athletic trainer, certified FMS™ athletic trainer, athletic trainer with biomechanics Ph.D., and an entry-level physical therapy student) with varying levels of experience who scored the same twenty athletes in a single testing session (Smith et al., 2013). Similarly, two experts and two novices independently rated forty college athletes who completed the FMS™. When scoring all FMS™ individual tests, seventeen scores were compared between the raters (i.e., DS, HS right, HS left, HS final, ILL right, ILL left, ILL final, SM right, SM left, SM final, ASLR right, ASLR left, ASLR final, TSPU, RS right, RS left, and RS final). Novice raters assigned the same score on 14 of the 17 assessments which was similar to the expert raters who agreed on 13 of the 17 tests (Minick et al., 2010). Additionally, twenty physiotherapists scored five athletes video recorded FMS™ performance with the assistance of an information pack with standardized instructions. It was found there was excellent inter-rater reliability (ICC=0.906) and FMS™ experience did not strengthen or weaken reliability (Leeder et al., 2016). Based on current evidence, FMS™ raters have established excellent reliability meaning raters with varying levels of experience can confidently perform the assessment.

Individualized Reliability

Often the composite score is used to determine the reliability of the FMS™, however it is likely important to examine the reliability of each individual FMS™ test. Smith et al. (2013) reported took this approach and examined inter-rater reliability for individual FMS™ maneuvers. Results showed that the inter-rater reliability for the HS was the least reliable (ICC=0.30 and 0.35 for testing sessions one and two, respectively) while SM was the most reliable (ICC=0.98 and 0.96 for testing sessions one and two, respectively). For the other five individual tests reliability ranged from ICC = 0.62 to ICC = 0.94 (Smith et al., 2013). The reliability results for the individual FMS™ tests may help novice raters focus on specific tests to ensure they are reliably scoring the FMS™. Overall, reliability values for the individual tests appear to be strong enough to be considered trustworthy.

Validity

Two distinct types of validity have been investigated related to the FMS™ that will be referred to as predictive validity and true validity. The majority of research has been related to the predictive validity of the FMS™. One prospective study reported that among 257 Division II athletes who completed the FMS™ prior to their sport season, a score of fifteen or below was a predictor of injury during their subsequent competitive season (Dorrel et al., 2018). However, the sensitivity (0.63) and specificity (0.48) associated with these findings were relatively low (Dorrel et al., 2018). Others have also attempted to establish the predictive validity of the FMS™ composite scores (Bushman et al., 2016; Garrison et al., 2015; Knapik et al., 2015; Warren et al., 2015). For instance, in 160 Division I athletes FMS™ composite scores were used to determine a cut-off composite score of fourteen or less as a predictor of injury based on injury data collected throughout the competitive season. Specifically, a score of fourteen or below was related to a 2.51 times greater risk of injury. The, sensitivity (0.67) and specificity (0.73) of the fourteen or below score were also reported as acceptable values for the FMS™ as an injury predictive tool (Garrison et al., 2015). However, the predictive validity of the composite score may be somewhat dependent on the population as coast guard cadets who were classified as "high risk" based on their FMS™ composite score, only exhibited a 1.1 times greater injury risk than "low risk" individuals. Additionally, relatively low sensitivity (0.55) and specificity (0.49) emphasizing the fact that using the composite score as a means of predicting injury may not be suitable for all populations (Knapik et al., 2015). Although many attempts at establishing acceptable predictive validity for a composite score cut-off exists, low sensitivity and specificity seem to limit the strength of this tools. Alternatively, individual test scores and asymmetries may be more useful as an injury predictor (Mokha et al., 2016).

It is likely that more attention should be given to individual test scores, however, less is known about the predictive validity of the individual components of the FMS™. One study has looked at the predictive validity of the SM test in baseball players

(Busch et al., 2017). Specifically, they used the FMS™ to create a group of "good" (i.e., FMS™ score 2 or 3) and "bad" movers (i.e., FMS™ score 1 or 2) and found that "poor" movers were more likely to experience one overuse injury in the preseason and competitive season than "good" movers (OR = 6.10 and OR = 17.07, respectively). Thus, establishing the predictive validity of the SM test. There is a wide range of information related to the use of the FMS™ as an injury predictive tool; however, more information regarding the predictive validity of each individual FMS™ maneuver is needed.

Collectively, these investigations demonstrate moderate predictive validity with a slightly better than 50/50 chance of the screen correctly identifying individuals that will sustain an injury. Even with these odds, it is likely that injury rates can be reduced. Furthermore, as the body of literature examining the utility of the FMS™ continues to grow and a better understanding of the predictive validity of the individual FMS™ scores is developed it is likely that the utility of the FMS™ will become even greater.

<u>"True" Validity</u>

Validity is the extent to which a test measures what it was intended to measure, "true" validity for the FMS™ has not been measured. Currently, practitioners use the FMS™ in hopes of identifying individuals with movement dysfunction that may place them at a greater risk of injury. However, if one examines the FMS™ guidelines (Cook et al., 2014a; Cook et al., 2014b), nowhere does it say that individual tests are diagnostic in nature or intended to predict injury. Rather, the guidelines list dysfunctions associated with each movement pattern based on assigned score. For example, hip mobility has been related to DS, HS, and ILL performance. As hip mobility deficits are a common dysfunction described by low score on these tests, the association between decreased hip mobility and FMS™ score indicates that these tests are in fact measuring what they were intended to measure (Jenkins et al., 2017). Further investigations such as this for all individual dysfunctions and tests will provide a stronger sense of the FMS™'s "true" validity. Unknown "true" validity is a concern when developing a manual of corrective exercises to accomplish the project goal to improve scores on the FMS™; however, the potential flaw must be accepted to further research in the FMS™ field and develop a better understating of the usefulness of FMS™.

## FMS™ and Corrective Exercise Programs

### Improvements in FMS™ Scores

Corrective exercises have been used to successfully improve FMS™ scores. A wide variety of holistic programs have been shown to result in changes in FMS™ composite scores when implemented (Basaer, 2017; Bodden et al., 2015; Dinc et al. 2017; Kiesel et al., 2011; Song et al., 2014; Stanek et al., 2017). However, these programs are not specific to FMS™ test results, rather they have been designed as catch-all approaches to improving FMS™ composite scores. A more thorough description of these programs can be found in following sections.

### Implemented Corrective Exercises

Corrective exercise programs have been investigated to determine their effects on the FMS™ composite score (Basaer, 2017; Bodden et al., 2015; Dinc, et al., 2017; Kiesel et al., 2011; Song et al., 2014). One of the first studies was designed to determine if an off-season intervention program increased professional football player's FMS™

scores. Completion of the seven-week program resulted in improved FMS$^{TM}$ scores for both non-lineman (13.3±1.9 vs. 16.3±2.4 pre to post) and lineman (11.8±1.8 vs. 14.8±2.4 pre to post) (Kiesel et al., 2011). On a smaller scale, twenty-four male soccer players enrolled in a twelve-week investigation consisting of three progressive four-week exercise programs focused on mobilization, stabilization, and integration. Significant increases in FMS$^{TM}$ composite scores were seen in both the intervention and control groups; however, greater improvements were observed in the intervention group (14.83±1.46 vs. 16.79±1.61) (Dinc et al., 2017). Implementing a balance training program for an eight-week period also improved FMS™ scores in male volleyball players (Linek, Saulicz, Mysliwiec, Wojtowicz, Wolney, 2016). Each of these programs, although different, showed not only that FMS$^{TM}$ scores are modifiable, but that improvements in FMS™ composite scores can be achieved through a variety of methods.

If FMS™ scores can be increased then, in theory, injury risk and injury rates should decrease, and current evidence seems to support this notion. For example, among the Dinc et al. (2017) participants improvements in FMS$^{TM}$ scores were accompanied by a decrease in injury severity (i.e., time loss from participation) for the intervention group compared to the controls. This study indicates corrective programs can be used to decrease the injury severity if implemented before participation.

Existing programs aimed at improving FMS$^{TM}$ scores have proven to be effective; however, logistically these programs present several limitations when considered in light of the three issues that arise when implementing an injury predictive tool (Bird et al., 2016). Perhaps the most important limitation is the need for staff to supervise individuals day-to-day can be a limiting factor. For instance, all sixty-two athletes received supervision for a minimum of four sessions tailored to individual needs in the investigation by Kiesel et al. (2011). In most athletic settings outside the professional sports world, this same approach is not possible due to time and financial constraints. If a program of corrective exercises is to be easily and effectively implemented the time demands of doing so must be one of several considerations.

Another consideration in the development of such a program is the specificity of the program. It is known that constructing a program tailored to the specific needs of an individual results in improved FMS™ scores (Dinc et al., 2016; Kiesel et al., 2011). However, in many settings the labor-intensive nature of such an approach is not feasible given the large number of athletes a practitioner may be working with. Some attempts to simplify this individualized approach, and minimize time demands, have been made. Stanek et al. (2017), based corrective plans on categories and poor performance on individualized tests: stability (i.e., TSPU and RS), mobility (i.e., ASLR and SM), and advanced movements (i.e., DS, HS, and ILL). With this structure fifty-six firefighters improved FMS™ scores from $12.09 \pm 2.75$ to $13.66 \pm 2.28$ over an eight-week period (Stanek et al., 2017). Given the observed improvements with this category-based approach to developing a specific corrective exercise program, it seems feasible that a similar algorithm approach may provide an effective and efficient way to individualize programs based on FMS™ score.

In addition to considering the specificity of the corrective exercise program, the duration of the program should also be considered. Improvements in FMS™ score have been observed at both twelve-weeks (Dinc et al., 2017) and seven-weeks (Kiesel et al., 2011). However, after just four-weeks of a corrective exercise program was completed a group of MMA fighters were able to demonstrate a significant increase in the FMS™ composite score (13.25 ± 0.87 vs. 15.17 ± 1.21) (Bodden et al., 2015). Interestingly, composite scores did not continue to improve between weeks four and eight of this intervention (15.33 ± 1.43 at eight weeks). Further suggesting that longer intervention periods may not be needed (Bodden et al., 2015). Therefore, intervention duration is one element of the corrective exercise program that must be closely monitored.

All programs presented in this discussion have shown improvements in the FMS™ composite score. Collectively, there have been positive results implementing corrective exercises to improve FMS™ score providing sufficient evidence that the FMS™ score is modifiable. However, many of these articles do not provide a comprehensive list of the corrective exercises used during the respective interventions. The lack of detail provided makes it difficult to replicate these findings in a clinical setting and further emphasizes the need for a manual that can be implemented without the need for supervision and can be easily made specific to the mover based on FMS™ score.

<u>Existing Manuals</u>

Some manuals and guides for corrective exercise programs related to the FMS™ do currently exist; however, these programs are not evidence-based in nature (Cook, Burton, & Fields, n.d.; Functionalmovement.com, 2018; Long & Woolever, n.d.; Pursuitfitnessandperformance.com, 2018). For example, the "FMS Exercise and Progression Manual" provides exercises based on FMS™ individual score along with prescription information such as sets and repetitions per exercise (e.g., DS score "one" is instructed to complete a prone quadricep stretch to be held for five to ten seconds and repeated three to five times). However, the organization of the manual may make it difficult or cumbersome for potential users of the manual as a large number of pages exist between the exercises listed for each FMS™ movement pattern and the full descriptions of the listed exercises. Furthermore, the rationale provided for selecting each exercise is minimal at best (Cook, Burton, & Fields, n.d.). This type of manual is not ideal for practitioners in a health-related field attempting to implement quality exercises in an efficient manner.

Similar issues can be found with the corrective exercises offered on the FMS™ website (Functionalmovement.com, 2018). The site provides a library of approximately ninety-five exercises intended to address the dysfunctions associated with the various FMS™ movements and scores. Online the user can click through specific exercises based on the exercise name and picture. After selecting an exercise, the exercise purpose and dysfunction correction is apparent (e.g., when you click on "Active Leg Lowering to Bolster" you learn that the exercise is intended to address dysfunctions in hip mobility and dynamic stability). However, the website does not include specific exercise prescriptions or movement pattern assignment or score-based progression for the exercises (Functionalmovement.com, 2018). Again, organization and specificity are lacking in this source of corrective exercises. Other more informal exercise manuals can also be found online. One such manual is the "Pursuit Fitness and Performance: Corrective Exercise List" which includes multiple progression levels and demonstration video links (Pursuitfitnessandperformance.com, 2018). However, in an online format the sources' credibility is not available for reference.

Potentially the most favorable manual that exists comes from SMARTGroup Training. Their layout includes exercise purpose, the target tissue, and specifies the FMS™ movement pattern (e.g., DS and TSPU) intended to be addressed by each exercise. This type of organization is more thoughtful than other sources discussed; however, exercises in this manual are not prescribed based on the score (i.e., 0, 1, or 2) achieved on the individual FMS™ test (Long & Woolever, n.d.). Collectively, existing manuals and exercise lists can provide a foundation to construct the first evidence-based manual to improve FMS™ scores that are specific to the dysfunction(s) identified by individual FMS™ scores. With the addition of sound evidence-based material in the proposed manual, the FMS™'s current quality of corrective exercise programs may be more confidently implemented by practicing medical providers to improve score. By trusting that the manual and the exercises provided within will improve the functional capacity of the user, the manual will ultimately aid in solving the third issue presented in Bird et al. (2016). Thus, a manual with strong evidence to back-up individual exercises is proposed.

Manual Development

The process of developing a manual based on scientific evidence that also ensures quality and applicability have been established by Donaldson et al. (2016). These researchers have laid out a series of steps that must be taken to ensure that an injury preventative program is reliable and safe. Donaldson et al. (2016) describe this process by example of the FootyFirst program, a lower limb injury preventative exercise training program implemented in the Australian football community. They describe a generalized process for creating corrective exercise programs that are based on both quality evidence-based research and expert opinion. Additionally, they acknowledge the value in assessing how users feel about the program created using the methods they have outlined. Donaldson et al. (2016) encourage the use of a check and balance system to developing a quality intervention program that consists of six steps:

1. Compiling research evidence, using clinical experience, and understanding the end-user audience.
2. Consulting with experts.
3. Engaging with the end-users.
4. Testing the intervention.
5. Evaluating against relevant theory.
6. Obtaining feedback from early implementers (Donaldson et al., 2016).

This process involves the development of many drafts of a corrective exercise program using the feedback received in each step to modify and improve the program. It is unclear whether existing FMS™ manuals were developed using this process (Cook, Burton, & Fields, n.d.; Functionalmovement.com, 2018; Long & Woolever, n.d.; Pursuitfitnessandperformance.com, 2018). Without proper reference it can only be assumed that only expert opinion and experience contributed to finalized manuals, otherwise skipping the most important step in the process: compiling research evidence, clinical experience, and knowledge of implemented context (Donaldson et al., 2016). For the purpose of this project, only steps one and two were completed. Further investigation of the implementation of the proposed manual is outside the scope of this project but should be pursued.

## Conclusion

Injury in athletics is a common and seemingly inevitable occurrence for most athletes at some point in their career. Considering the statistics related to the volume, rate, severity, and cost of injuries, injury reduction measures should be taken whenever possible. The PPE is one process that can be implemented to identify those who may be at a greater risk of injury. The use of a functional movement assessment during the PPE is growing in popularity. Given the time required for implementation, its' appropriateness for a wide variety of athletes and sports, and the trustworthiness of the tool, the FMS™ has become one of the most well-known, widely implemented, and researched functional movement assessments. The FMS™ movements target mobility, stability, and advanced movements involving the lower extremities, upper extremities, and trunk. When the results of the FMS™ point to specific dysfunctions, corrective exercises can be used to improve score and ultimately prevent injury volume and severity.

Currently no easy-to-use or well-organized manual exists to select and implement individualized corrective exercises based on FMS™ score. Creating this manual will ease the time burden of addressing dysfunctions identified in screening a large number of people, by being readily available to prescribe corrective exercises based on the FMS™ results. Although not every injury can be prevented, a large number can be if athletes are moving in a functional way with full ROM and adequate strength. Creating a manual of corrective exercises to improve mobility, stability, and score on the FMS™ with evidence-based research to support selected exercises is a key step in the process of reducing injury risk for athletes.

# CHAPTER III

# METHODOLOGY

## Introduction

The FMS™ is a structured approach to functional testing, meant to identify individuals with movement dysfunction who might be pre-disposed for a greater risk of injury (Cook et al., 2010). The assessment continues to gain popularity in the athletics setting, likely due in part to its' ease of administration. It also fits the criteria for a good functional movement assessment, by requiring minimal time, being suitable for most athletic populations, and being a trustworthy assessment (Bird et al., 2016). However, addressing dysfunctions identified by the screen have yet to become as structured as the screen itself. A number of strategies, ranging from individualized exercise plans implemented by a supervising practitioner to general exercise programs available online, have been used to improve scores on the FMS™; however, these programs lack justification for the prescribed corrective exercises (Bodden et al., 2015; Dinc et al., 2017; Kiesel et al., 2011; Song et al., 2014; Stanek et al., 2017). Therefore, the purpose of this project was to create an evidence-based manual of corrective exercises specific to improving scores on the FMS™.

The manual created is a tool that can be used immediately in the field of sports medicine and strength and conditioning. To meet the standards of a research project, this manual is the outcome of an extensive literature review of FMS™ published research articles and current best practices in rehabilitation strategies. An online portable document format (pdf) with printable take-home exercise prescriptions are available by request and can be distributed via email. In addition, this pdf can be printed for easy access in an athletic training room setting. Although at the completion of this project, the manual has not yet undergone investigation to the validate the effects of implementing these corrective exercises to improve FMS™ score; it can be used with confidence because the strongest level of evidence currently available is provided for each exercise included in the manual (see manuscript Appendix A; manual Appendix A and B). The next step, beyond the scope of this project, is to design and implement a study to determine the efficacy of the exercises prescribed in this manual.

## Population

This manual is designed to be used by sports medicine or strength and conditioning specialists with existing knowledge of the FMS™. Qualifications required to implement this manual include:

1. Experience screening athletes using FMS™ standardized instructions.
2. An understanding of the anatomical dysfunctions described.
3. Experience demonstrating and prescribing exercises.
4. Experience reading and interpreting scientific research.

Therefore, this manual is not intended to be used by a lay-person.

The exercises in the manual are designed to be prescribed to physically active individuals or athletes that do not have existing pain with exercise, or pre-existing musculoskeletal injuries. For the exercises in this manual to be successful the individual who completes the exercises should possess the following characteristics:

1. No current musculoskeletal injury.
2. No pain with the three FMS™ clearing tests.
3. The ability to complete basic movement patterns of the FMS™ without pain.

The corrective exercises provided in the manual are assumed to have the same level of difficulty and safety concerns as physical activity and training methods regularly performed by athletes. Therefore, the exercises prescribed in the manual do not place the user at a higher than normal risk for injury.

## Manual Development

The evidence-based manual developed through the completion of this project is the result of evidence gathered through an extensive literature review process. Evidence related to the FMS™ has been gathered by reviewing current published literature and other sources of relevant information, including a thorough review of the information provided by FMS™ creator Gray Cook. Publications such as *Movement: Functional Movement System Screening, Assessment and Corrective Exercises,* and peer-reviewed publications were a primary source of FMS™ philosophies and rationale. The FMS™ scores were interpreted based on the dysfunction(s) provided in these sources.

The next step required reviewing the list of dysfunctions associated with each movement pattern, and each score (i.e., 1, or 2) for a given movement pattern. The list of dysfunctions that was developed was then used to create a list of exercises hypothesized to improve the identified dysfunctions. These exercises were selected based on published literature, educational texts, and personal athletic training experience. This list of exercises was crosschecked with experienced professionals for credibility and additional suggestions. Individuals that took place in this crosschecking process included a certified athletic trainer with over thirty years of experience at the collegiate level, an academic faculty member that specializes in strength and conditioning with certification in the FMS™ Level 1, and a biomechanist with specialization in biomechanics and knee injury prevention research. The diverse experience of these individuals provided a range of expertise and viewpoints contributing to the strength of the manual.

Once a list of exercises was drafted, the literature search began. This process included searching peer-reviewed databases using a process like the one used when conducting a systematic review. For each exercise from the list created the best possible evidence was accumulated to support the use of the exercise to improve said dysfunction. An electronic search was conducted using OneSearch @ Chico, EBSCO, and PubMed for studies published through December 31, 2018 to identify exercises appropriate for addressing each movement dysfunction. For example, to find exercises to improve ankle dorsiflexion, the search strategy consisted of the following terms: (gastrocnemius stretch* OR ankle mobilization OR talocrural mobilization OR foam roll*) AND (improve dorsiflexion OR tissue extensibility) AND (exercise OR rehabilitation OR treatment). Thirty-four results were found with these search parameters. References cited in articles that were returned from the original search were further reviewed to locate any additional relevant articles not retrieved with primary search. The final list of selected references is reported in the summary and recommendation section of this manuscript as well as detailed in the manual's appendix (see manuscript Appendix A; manual Appendix A and B).

In the manual developed as a result of this project, strength of recommendation taxonomy (SORT) ratings and appropriate references are provided for each exercise, this information provides the reader a quick indication of the level evidence used to support the inclusion of a given exercise. The SORT is an established strength of evidence scale that was developed specifically to create a unified simplistic taxonomy used throughout the medical field to describe the quality, quantity, and consistency of evidence (Ebell et al., 2004). This specific taxonomy system was chosen to assist in the creation of this manual as it has been adopted by the *Journal of Athletic Training,* a journal that serves as a primary source of evidence for members of the National Athletic Trainers' Association. A more thorough description of evidence supporting the use of each exercise is provided in the appendix of the manual (see manuscript Appendix A; manual Appendix A and B).

In order to assist the users of the manual, an introduction and overview of the SORT is also provided in the manual that is similar to the information that follows. First, it is important to understand there are two SORT scales, one for bodies of evidence and another for individual research articles. Both scales will be used to justify exercises included in the manual. Individual studies can be rated using the SORT rating system, in terms of level "one", "two" or "three." As per the SORT system, level "one" evidence consists of patient-oriented evidence, and can be the result of a systematic review, meta-analysis, high quality randomized controlled trial, high quality cohort study for prognosis, validated clinical decision rule in relevant population, or high-quality diagnostic cohort study. Level "two" evidence does have patient-oriented evidence; however, it does not meet the criteria for one of the five study types listed above. Level "three" evidence is either not based on patient-oriented evidence or is based on opinion or bench research. It is preferable to base clinical recommendations in a manual on SORT level “one” evidence (Ebell et al., 2004). In the process of gathering and reading research articles during the development of this manual, determining the level of evidence was an important step in providing support for the use each exercise included in the manual.

Bodies of evidence can also be evaluated. Strength of recommendation is the measure used to describe bodies of evidence and consists of “A”, “B”, and “C.” Ebell and colleagues (2004) present these categories as follows: A) recommendation based on consistent and good-quality patient-oriented evidence, B) recommendation based on inconsistent or limited-quality patient evidence, and C) recommendation based on consensus, usual practice, opinion, disease-oriented evidence, or case series for studies of diagnosis, treatment, prevention or screening. A key to receiving an A is the use of a systematic review or a collection of randomized controlled trails. These are often held as the gold standard in the research community and demonstrate the best evidence to be used in making clinical decisions.

If no evidence of any level (i.e., “one”, “two”, or “three”) could be found to relate the exercise to improvements in functional limitations, the exercise was not included in the final version of the manual. Every attempt was made to include exercises for which SORT level “one” or recommendation A evidence existed. However, if no high-level evidence was found to correct a dysfunction, evidence that existed of any level was included in the manual. The level of evidence was noted so the reader knows of the potential limitations of the exercise.

A check of the initial list of corrective exercises was completed after the project proposal approval. This review process included consulting the previously described committee of experts for additional exercise suggestions, examining the list to identify potential gaps in the manual (i.e., less than three exercises per dysfunction and a variety of exercise approaches), and conducting a broader literature search as needed to identify exercises that improve the targeted dysfunctions. This process was continued until the manual was complete. The manual was considered complete when at least three rehabilitative exercises were presented in the manual for each dysfunction identified by the FMS™ and each movement pattern's scores "one" and "two" had three associated exercises for each limitation with SORT level "one" or recommendation "A" evidence. To ensure accuracy a final review was conducted for each exercise and associated references. It is important to note that some exercises are repeated throughout the manual as multiple movement patterns are related to the same movement dysfunction.

## Description of Manual

For design purposes, a textbook type template was used to create an interactive pdf using Microsoft Word, Adobe InDesign, and Adobe Acrobat Pro. Two forms of the final manual were created for viewing (i.e., print version and interactive version). Appendix A of this manuscript contains the print version and can be read using any pdf reader. For the interactive version of the manual, Adobe Acrobat Reader DC and Flash Player is required on either a desktop computer, iPad, iPhone or Android device to access the video features.

The manual begins with a brief introductory chapter to describe the manual's purpose, layout, and intended use. The introduction also provides an overview of the SORT taxonomy. The seven remaining chapters of the manual are designated to one of each of the seven-movement patterns included in the FMS™. In each chapter a description of the movement pattern is provided, and this is followed by corrective exercise programs for each score (i.e., "one" or "two") and associated dysfunction(s). The table of contents of the manual is interactive, so that the chapter title can direct the user to the beginning of each test maneuver by clicking on the title. At the beginning of each of the seven chapters hyperlinks direct the user to each exercise in the manual. The hyperlinks provided are intended to make for a simple experience for the end-user.

The interactive version of the manual includes video to illustrate the exercises. As one of the last steps of manual construction, video was taken of each exercise prescribed in the manual. The frame of video was frozen to an appropriate image of the movement to create a cover photo that documents the correct performance of each exercise if the manual is to be printed. Due to these technological features of this version of the document, the interactive manual is approximately 1 gigabyte (GB) in size, thus sufficient time should be allotted for initial download. At the end of the manual, a full list of references is provided so that other users can easily access supporting research and an appendix to justify SORT rating for each investigation included.

Material used in the construction of this manual includes and is based on information provided by the trademarked company, FMS™ (Functional Movement Systems Inc., Chatham, VA). This information consists of the objective for each dysfunction and corrections for each score. Material developed by the author includes the corrective exercises that are not provided by the FMS™. All information was cited to the original source and labeled with the "™" symbols for copyright material under the fair use guidelines as appropriate.

## Conclusion

The completion of this project resulted in a manual of corrective exercises to improve scores on the FMS™, the first of its kind in terms of evidence-based suggestions. The manual is able to be immediately used by practitioners for otherwise healthy individuals that have completed the FMS™. After incorporating the manual into an athletic setting, further research can begin to determine whether the exercises presented in the manual are related to improved scores on individual FMS™ tests, decreased injury rates, or changes in views of the FMS™ by sports medicine and strength and conditioning specialists.

# CHAPTER IV

# SUMMARY AND RECOMMENDATIONS

## Summary

The result of this project is a manual of corrective exercises to implement among otherwise healthy individuals who wish to address dysfunctions identified by the FMS™ screening, improve scores on the FMS™, and potentially reduce their risk of injury. Evidence-based research has been a shortcoming in previous attempts to make such a manual, therefore this is the first of its kind. With the addition of the SORT rating scales, the reader (i.e., rehabilitation specialist or athlete) can begin to identify exercises with the strongest quality evidence to support use of the exercise in a rehabilitative corrective exercise program. Practitioners who choose to implement this manual will find that it addresses some of the issues associated with the time burden of implementing injury reduction methods. It also provides an efficient means of developing an individualized exercise program through the use of an algorithm style approach based on FMS™ score. Structurally, the manual is navigated by hyperlink to easily skip to desired exercises based on test maneuver and score. Each exercise is accompanied by written descriptions and video(s) to illustrate how to properly perform each exercise.

The goal of this project was to create a manual that anyone who has FMS™ results can use to improve scores on the FMS™ and ultimately reduce the number and severity of injuries in sport. This manual can confidently be implemented into the clinical setting due to the quality research used to support the inclusion of each carefully selected exercise. The justification for the inclusion of each exercise can be found in table format in the appendix of the manuscript and manual (See manuscript Appendix A; manual Appendix A and B). This table explicitly states details for each investigation used to justify how the SORT ratings were obtained. Then for each testing maneuver, the dysfunctions associated with each score and exercises shown to be affective at correcting these dysfunctions are described. A thorough description including purpose, target tissues, and prescription for each exercise is available throughout the manual itself (see manuscript Appendix A). An outline of exercises associated with each test maneuver and score can be found in the manuscript (Tables 2 through 8).

## Recommendations

The completed manual can be used for any individual scoring either a “one” or “two” to improve scores on the FMS™. It is recommended that the rehabilitation specialist allow time to familiarize the individual user with the exercises and how to locate desired exercises in the manual. After familiarization, the individual should perform all exercises as prescribed in the manual two to three times per week. After a consistent four-week intervention it is recommended that the FMS™ is retested to evaluate performance. Exercise prescription may change at this point if the individual can progress to new, harder exercises or if exercises are no longer necessary for that individual given changes in FMS™ scores.

Exercise prescriptions provided for each exercise were based on the results of high-quality interventions whenever possible. However, some exercises that were chosen for inclusion in the manual were from lower levels of evidence or recommendation studies. These exercises did not include specific prescriptions. In these instances, additional sources were used to determine exercise prescription as seen with multiple references within the SORT section in the manual (see manuscript Appendix A; manual Appendix A and B).

## Conclusion

Evidence related to the FMS™ with regards to injury prediction, validity, and reliability occupies the majority of current literature. However, there is far less evidence regarding corrective exercises for improving FMS™ scores and their associated dysfunctions. Extending the literature search beyond the structured guidelines of the FMS™ was necessary to support how individual exercises could be rationalized to improve FMS™ score. Using this process, a total of fifty-five exercises with SORT rating evidence were included in the resulting manual of this project.

The completed manual can be immediately applied into practice for any individual with FMS™ results. Although the individualized programs it creates have not undergone an implementation period, based on the high-quality evidence used for justification, practitioners can use this manual with confidence. It will allow those who implement the manual, the ability to quickly prescribe individualized programs for a variety of athletes to ultimately reduce the risk of sports-related injuries.

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Table 1. Interpretation of FMS™ test by score (Cook et al., 2014a, Cook et al., 2014b)

| Score | Interpretation |
|---|---|
| **Deep Squat** | |
| 3 | No dysfunction. |
| 2 | Minor limitations for closed kinetic chain dorsiflexion.<br>Minor limitations for thoracic extension. |
| 1 | Gross limitations for closed kinetic chain dorsiflexion.<br>Gross limitations for thoracic extension.<br>Gross limitation hip flexion. |
| 0 | Further evaluation needed. |
| **Hurdle Step** | |
| 3 | No dysfunction. |
| 2 | Minor limitations for ankle dorsiflexion in moving limb.<br>Minor limitation for hip flexion in moving limb. |
| 1 | Relative asymmetric hip immobility.<br>Anteriorly tilted pelvis.<br>Poor trunk stability. |
| 0 | Further evaluation needed. |
| **In-Line Lunge** | |
| 3 | No dysfunction. |
| 2 | Minor limitations in one or both hips' mobility. |
| 1 | Relative asymmetries in one or both hips' mobility and stability. |
| 0 | Further evaluation needed. |
| **Shoulder Mobility** | |
| 3 | No dysfunction. |
| 2 | Pectoralis minor shortening.<br>Latissimus dorsi weakness. |
| 1 | Scapular dyskinesis. |
| 0 | Further evaluation needed. |
| **Active Straight Leg Raise** | |
| 3 | No dysfunction. |
| 2 | Improve hip mobility.<br>Muscle tightness hamstring same side.<br>Muscle tightness iliopsoas opposite side. |
| 1 | Gross limitations for hip mobility. |
| 0 | Further evaluation needed. |
| **Trunk Stability Push-Up** | |
| 3 | No dysfunction. |
| 2 | Minor limitations for trunk stability. |
| 1 | Limited symmetric sagittal plane trunk stability. |
| 0 | Further evaluation needed. |
| **Rotary Stability** | |
| 3 | No dysfunction. |
| 2 | Minor limitations for trunk stability. |
| 1 | Limited asymmetric transverse plane trunk stability.<br>Limited asymmetric sagittal plane trunk stability. |
| 0 | Further evaluation needed. |

Table 2. Deep squat score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Insufficient closed kinetic chain dorsiflexion at the ankle | Slant board gastrocnemius stretch |
| | | Self-mobilization against wall |
| | | Foam roll posterior lower leg |
| | | Self-mobilization on slant board with strap |
| | Limited thoracic extension | Gravity assisted foam roller |
| | | Quadruped thoracic extension |
| | | Prone extension on swiss ball |
| | | Swiss ball bridges |
| Score 1 | Limited hip flexion | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |

Table 3. Hurdle step score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Insufficient closed kinetic chain dorsiflexion at the ankle | Slant board gastrocnemius stretch |
| | | Self-mobilization against wall |
| | | Foam roll posterior lower leg |
| | | Self-mobilization on slant board with strap |
| | Limited hip flexion | Doorway hamstring stretch |
| | | Towel/ Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |
| Score 1 | Hip flexion mobility asymmetry | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |
| | Anterior tilted pelvis | Pelvic lift |
| | | Supine naval draw-in |
| | | Standing pelvic retroversion |
| | | Mirror pelvic posture |
| | | Deadbug |
| | | Birddog |
| | Poor trunk stability | Side bridge (side plank) |
| | | Bridges with leg lifts |
| | | Swiss ball with trunk twists |

Table 4. In-line lunge score, associated dysfunction(s), and assigned corrective exercises

| **Score** | **Associated Dysfunction** | **Corrective Exercise** |
|---|---|---|
| Score 2 | Insufficient hip mobility in both hips | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |
| | | Modified lunge stretches |
| | | Prone leg lifts on bolster |
| Score 1 | Hip mobility asymmetry | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |
| | | Modified lunge stretches |
| | | Prone leg lifts on bolster |
| | Insufficient hip stability | Single leg box dips |
| | | Monster walks with resistance band |
| | | Standing split squat with kettle bell |

Table 5. Shoulder mobility score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Pectoralis minor tightness | Foam roller stretch |
| | | Doorway stretch |
| | | Prone dumbbell fly |
| | Latissimus dorsi weakness | Lat pull-down |
| | | Seated row |
| | | Barbell row |
| Score 1 | Scapulothoracic dysfunction | Coracoid conscious muscle control |
| | | Scapular clock |
| | | Wall push-up |
| | | Prone arm extension |
| | | Forward flexion in side-lying |
| | | External rotation in side-lying |
| | | Prone horizontal abduction with external rotation |
| | | Push-up plus |
| | | Weight shifts |
| | | Wall slides |

Table 6. Active straight leg raise score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Insufficient hip mobility | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Resistance band eccentric training |
| | | Hamstring self-administered PNF |
| | | Resistance band hip flexor strengthening |
| | | Modified lunge stretches |
| | | Prone leg lifts on bolster |
| Score 1 | Lower extremity muscle tightness | Doorway hamstring stretch |
| | | Towel/Resistance band hamstring stretch |
| | | Hamstring foam rolling |
| | | Modified lunge stretches |
| | | Prone leg lifts on bolster |
| | | Piriformis stretch |
| | Insufficient hip stability | Single leg box dips |
| | | Monster walks with resistance band |
| | | Standing split squat with kettle bell |

Table 7. Trunk stability push-up score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Poor trunk stability | Side bridge (side plank) |
| | | Bridges with leg lifts |
| | | Swiss ball with trunk twists |
| Score 1 | Poor symmetric trunk stability in the sagittal plane | Swiss ball knee-up |
| | | Swiss ball roll-out |
| | | Swiss ball superman |

Table 8. Rotary stability score, associated dysfunction(s), and assigned corrective exercises

| Score | Associated Dysfunction | Corrective Exercise |
|---|---|---|
| Score 2 | Poor trunk stability | Side bridge (side plank) |
| | | Bridges with leg lifts |
| | | Swiss ball with trunk twists |
| Score 1 | Poor asymmetric trunk stability in the sagittal plane | Criss-cross "bicycle" |
| | | Hip extension on swiss ball |
| | | Oblique crunch |
| | Poor asymmetric trunk stability in the transverse plane | Skier |
| | | Medicine ball throw |
| | | Mountain climber plank |

# APPENDIX A

California State University, Chico

Department of Kinesiology

# FMS™ Score-Based Rehabilitation Manual

# FMS$^{TM}$ Score-Based Rehabiliation Manual

## California State University, Chico


Chico, CA

# Table of Contents

Chapter 1

# Introduction

The Functional Movement Screen™ (FMS™) was originally created to clear healthy high school football players for participation in strength and conditioning programs. When creator Gray Cook published his screening tool, professional teams, strength and conditioning coaches, and athletic trainers began adopting his approaches to functional testing. He describes that if poor or inefficient movement patterns are reinforced, poor biomechanics—and ultimately an increased potential for chronic and acute injuries—may be the result. In terms of correcting dysfunction, increasing mobility is often the first step to solving most functional movement problem. Therefore, required mobility is the rationale for inclusion of each movement pattern in the screen and the basis for recommendations of corrective exercises in this manual.

The FMS™ was designed to assess dynamic and functional capacity often as part of the pre-participation exam process. It is also used to determine readiness of an athlete to return to sport at the completion of the injury rehabilitation process. The screen is made up of seven individual tests including: the deep squat (DS), hurdle step (HS), in-line lunge (ILL), shoulder mobility (SM), active-straight leg raise (ASLR), trunk stability push-up (TSPU) and rotary stability (RS) tests. Prior to completing the screen three clearing tests for the SM, TSPU and RS tests must be completed pain free to ensure the test itself does not cause injury. These movements are scored on a scale of zero to three based on FMS™ scoring criteria: "*A score of 3 represented the ability to perform the functional movement without compensation. A score of 2 was assigned if the participant performed the movement with compensations. A score of 1 was assigned if the participant was unable to perform the movement according to published guidelines, and a score of 0 was reserved for participants who had pain with the movement or presented with pain while performing a clearing test.*" (Chimera, Smith, & Warren, 2015; Cook, Burton, Kiesel, Rose, & Bryant, 2010).

To benefit after completing the FMS™ screening, the assessment must be followed by an effort to improve the identified areas of dysfunction. Because the screen is designed to assess a large number of athletes at once, prescription of corrective exercises should be just as readily available and easy to use as the screen itself. The need for handouts or a how-to guide will make this process smoother for all parties involved and ultimately provide a higher standard of care for athletic individuals. Some corrective exercise manuals and guides do currently exist; however, they lack evidence-based research to support use of exercises and specificity for the athletes and physically active individuals.

Therefore, the purpose of this manual is to create an athletic trainer and strength and conditioning coach friendly guide to corrective exercises for the FMS™. Background information regarding the FMS™ is presumed to be understood to use this guide as it will not include thorough descriptions of how to properly perform the screen. Rather it will be a tool meant to be used to quickly use the FMS™ score to provide an exercise prescription to athletes that do not receive a perfect score for all individual tests.

Each of the seven following chapters of this manual will be dedicated to one individual movement pattern of the FMS™. A brief description will be provided of each maneuver. Implications for each scoring criteria will be given followed by corrective exercises designed to improve those areas of dysfunction. The results of implementation of these exercises programs have not been researched as a whole for increasing score of the FMS™, however all exercises included in the manual will be accompanied by evidence supporting their efficacy.

It is important to understand this manual is designed for healthy individuals with no current injury or sources of pain with these movements. For individuals with either acute or chronic injury, a more extensive clinical evaluation is needed, and aspects of the rehabilitation plan should be designed to meet the specific needs of that individual to return them to activity as soon as possible. Reference to the Selective Functional Movement Assessment (SFMA) may be useful for these individuals (Cook et al., 2010).

**Strength of Recommendation Taxonomy (SORT)**
The SORT rating system was developed to create a unified simplistic taxonomy meant to be used throughout the medical field to describe quality, quantity and consistency of evidence (Ebell et al., 2014). This specific taxonomy system was chosen to assist in the creation of this manual as it has been adopted by the Journal of Athletic Training, a journal that serves as the primary source of evidence for members of the National Athletic Training

| Recommendation | Description of body of evidence |
|---|---|
| A | Patient-oriented evidence with following criteria:<br>• Cochrane Review with a clear recommendation<br>• USPSTF Grade A recommendation<br>• Clinical Evidence rating of beneficial<br>• Consistent findings from at least two good-quality randomized controlled trails or a systematic review/meta-analysis of same<br>• Validated clinical decision rule in a relevant population<br>• Consistent findings from at least two good-quality diagnostic cohort studies or systematic review/ meta-analysis |
| B | Patient-oriented evidence but does not fulfill one of the above study design criteria. |
| C | Not patient oriented evidence and based on opinion, bench research, a consensus guideline, usual practice, clinical expertise or a case series, but important point of evidence under discussion. |

Figure 1.0 SORT scale for rating groups of studies

| Level | Description of Individual Study |
| --- | --- |
| 1 | Patient-oriented evidence with study design as follows:<br>• Systematic review/meta-analysis of high-quality studies with consistent findings<br>• High-quality randomized controlled trial<br>• High-quality cohort study for prognosis<br>• Validated clinical decision rule in a relevant population<br>• High-quality diagnosis cohort study |
| 2 | Patient-oriented evidence but does not fulfill one of the above study design criteria. |
| 3 | Not patient oriented evidence and based on opinion, bench research, a consensus guideline, usual practice, clinical expertise or a case series, but important point of evidence under discussion. |

Figure 1.1 SORT for rating an individual study

Including SORT ratings makes this the first corrective exercise manual of its kind designed to improve score on the FMS™. Rationale for the included exercises can be found in appendices of this manual with evidence of efficacy of each exercise.

### Exercise Programs:

Through the use of this manual, individualized exercise programs can be created to meet the specific needs of an individual based on FMS™ results. These programs should be implemented 2-3 times per week for four weeks. At four weeks, the FMS™ should be re-administered to determine if new, harder exercises can be added to program or if some exercises can be discontinued.

**Compatible applications:**
In addition to providing SORT ratings, this manual also contains useful technological features. To take advantage of these useful features a device with the capability to run Adobe Reader DC and Adobe FlashPlayer on a compatible device (e.g., Mac, iPhone, iPad, Android, and Cromebook) is needed. These are free applications that can be easily downloaded. The document can also be opened in any portable document format (pdf) reader, but will not include video features.

**How to navigate the manual:**
The manual is powered by cross-reference buttons. For example, the table of contents includes each test maneuver, clicking on the name of a maneuver will take the user to the beginning of the chapter for that maneuver. Once at the beginning of the chapter, the dysfunctions are laid out based on FMS$^{TM}$ score. By clicking the score button the document will jump directly to the prescribed exercises. In some cases, exercises from previous chapters are referenced, these links will also take the user to the desired exercise.

**Video Files:**
Each exercise is accompanied by one or two video files to demonstrate how to perform each exercise correctly. The videos consist of a cover photo to represent the exercise without playing the video. When a video is clicked on it will begin to play within the frame. Controls for play, seek and stop are available for learning and breaking down the exercises as well.

**Equipment requirements:**
- Foam roller
- Swiss ball
- Resistance bands of various resistances
- Dumbbells (5-10 lbs)
- Box Platform
- Barbell

Chapter 2

# Deep Squat

## Description

During the deep squat, the participant is asked to squat as deeply as possible while holding a PVC pipe overhead, maintaining an upright posture, and moving until the femur is below horizontal. This movement pattern is used to assess bilateral mobility of the hips, knees and ankles. To perform the deep squat, closed kinetic chain dorsiflexion at the ankles, flexion at the knees and hips, extension of the thoracic spine, and flexion and abduction of the shoulders is required.

## Implication Based on Score

### Score 3

A score of “three” indicates there is no dsyfunction.

### Score 2

A score of “two” indicates that minor limitations exist with either closed kinetic chain dorsiflexion at the ankle or extension of the thoracic spine.

### Score 1

A score of “one” indicates that gross limitations exist in the same areas mentioned above as well as flexion at the hip.

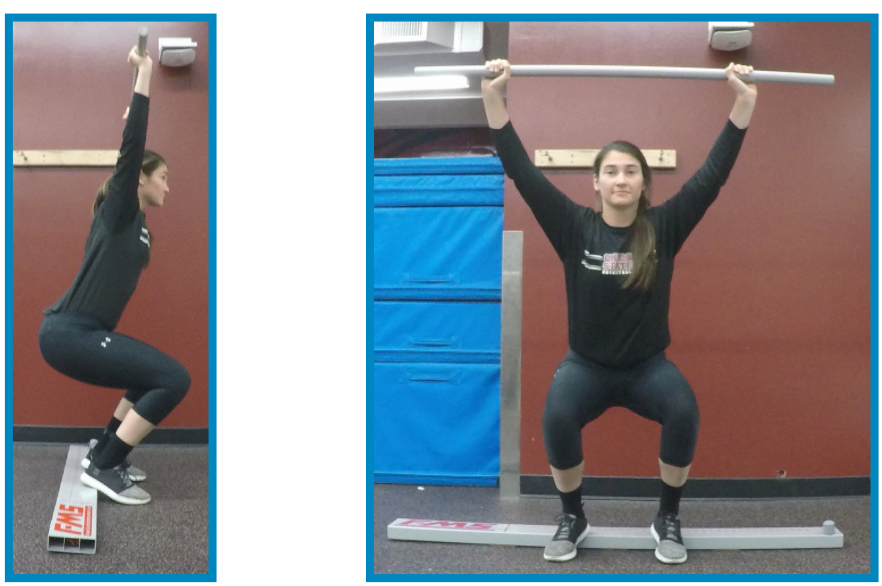


Figure 2.0 a.) Lateral view score 2 , b.) Anterior view score 2

Corrective Exercises

# Slant Board Gastrocnemius Stretch

Score 2

Insufficient closed kinetic chain dorsiflexion at the ankle

**Description:** Stand on a decline slant board with feet positioned towards the incline and knees straight. Lean the whole body forward causing dorsiflexion at the ankles. Be sure to keep entire foot and heel in contact with the board. Once the end range of motion is met hold that position. Optional: The slant board can be adjusted to a greater or lesser incline to create more or less of a stretch, respectively.

**Purpose:** To gain muscular tissue extensibility

**Target Tissue:** Gasttrocnemius, soleus, Achilles' tendon

**Prescription:** 20 seconds x 15 sets

Figure 2.1 Lateral view

Sort: Level 1

Jeon, I., Kwon, O., Yi, C., Cynn, H., & Hwang, U. (2015). Ankle-dorsiflexion range of motion after ankle self-stretching using a strap. *Journal of Athletic Training, 50* (12), 1226-1232.

# Self-mobilizations Against Wall

Score 2

Insufficient closed kinetic chain dorsiflexion at the ankle

Description: Stand facing a wall in a split stance, place toes two inches from the wall. Flex the front knee towards the wall and keep the heel on the floor the ankle is forced into maximal ankle dorsiflexion. A stretch should be felt on the posterior aspect of the ankle. At the end range, small forward and backwards oscillations are made to create a grade IV mobilization. Return to starting position and repeat.

Purpose: Improve posterior talar glide

Target Tissue: Posterior talocrural joint capsule

Prescription: 30 seconds x 10 repetitions

Figure 2.2 Lateral view

Sort: Level 2

Kang, M., Lee, D., Kim, S., Kim, J., & Oh, J. (2015). The influence of gastrocnemius stretching combined with joint mobilization on weight-bearing ankle dorsiflexion passive range of motion. *Journal of Physical Therapy Science*, *27*(5), 1317-1318.

# Foam Roll Posterior Lower Leg

Score 2

Insufficient closed kinetic chain dorsiflexion at the ankle

**Description:** Start in the seated position with the foam roller under the proximal gastrocnemius. One leg is extended and the opposite leg crossed to increase the pressure placed on the posterior leg. Starting at the proximal gastrocnemius-soleus complex and performing small kneading motion continuously moving distally. This should take 30 seconds to reach the distal gastrocnemius-soleus complex.

**Purpose:** Improve muscle recovery and extensibility

**Target Tissue:** Gastrocnemius-soleus complex

**Prescription:** 30 seconds x 3 sets

Figure 2.3 Lateral view

Sort: Level 1

Madoni, S. N., Costo, P. B., Coburn, J. W., & Galpin, A. J. (2018). Effects of foam rolling on range of motion, peak torque, muscle activation, and the hamstring-to-quadriceps strength ratio. *Journal of Strength and Conditioning Research*, *32*(7), 1821-1830.

Okamoto, T., Masuhura, M., & Ikuta, K. (2014). Acute effects of self-myofascial release using a foam roller on arterial function. *Journal of Strength and Conditioning Research*, *28*(1), 69-73.

# Self-mobilizations on Slant Board with Strap

Score 2

Insuffients closed kinetic chain dorsiflexion at the ankle

**Description:** Stand in a split stance on a decline board with the foot towards the incline. Place a strap around the anterior aspect of the talus. Pull the strap with resistance to secure the talus into a fixed position. Flex the front knee to end range of motion. In this position pressure is held constant for 20 seconds followed by 10 seconds of rest. Return to starting position and repeat.

**Purpose:** Improve ankle capsular motion

**Target Tissue:** Posterior talocrural joint capsule

**Prescription:** 20 seconds x 15 repetitions

Figure 2.4 Lateral view

Sort: Level 1

Jeon, I., Kwon, O., Yi, C., Cynn, H., & Hwang, U. (2015). Ankle-dorsiflexion range of motion after ankle self-stretching using a strap. *Journal of Athletic Training*, *50*(12), 1226-1232.

# Gravity Assisted Foam Roller

Score 2

Limited thoracic extension

**Description:** In the supine position, place the foam roller horizontally across the thoracic region. Feet push body up to a bridge position and roll the upper back. One roll through the thoracic region equates one repetition.

**Purpose:** Tissue extensibility and thoracic mobility

**Target Tissue:** Transverse abdominis

**Prescription:** 10 repetitions

Figure 2.5 Lateral view

Sort: Level 3

Katzman, W. B., Vittinghoff, E., Kado, D. M., Schafer, A. L., Wong, S. S., Gladin, A., & Lane, N. E. (2016). Study of hyperkyphosis, exercise and function (SHEAF) protocol of a randomized controlled trail of multimodal spine-strengthening exercise in older adults with hyperkyphosis. *Physical Therapy*, *96*(3), 371-381.

# Prone Extension on Swiss Ball

Score 2

Limited thoracic extension

**Description:** In the prone position, the swiss ball supports the pelvis, feet touch the floor, and trunk is suspended. Starting in a neutral spine position, the trunk extends as far as possible to reach the finish position and holds. Return to starting position and repeat.

**Purpose:** Strengthen back extensor muscles

**Target Tissue:** Erector spinae

**Prescription:** 20 seconds x 10 repetitions

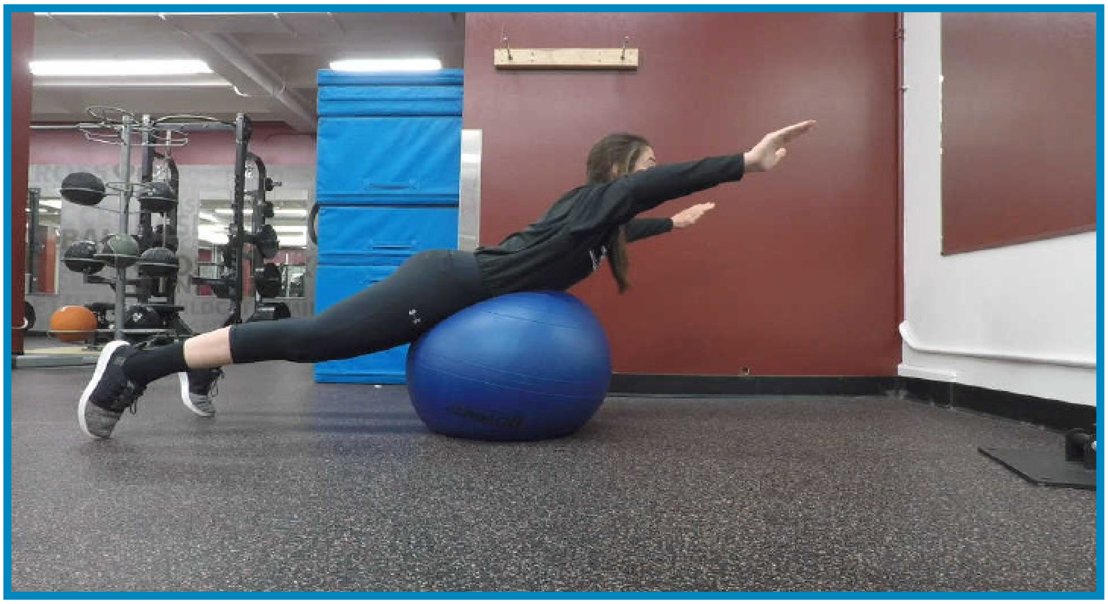


Figure 2.6 Lateral view

Sort: Level 1

Feng, Q., Wang, M., Zhang, Y., & Zhou, Y. (2017). The effect of a corrective functional exercise program on postural thoracic kyphosis in teenagers: A randomized controlled trail. *Clinical Rehabilitation*, *32*(1), 48-56.

# Quadruped Thoracic Extension

Score 2

Limited thoracic extension

**Description:** On hands and knees, sink the back down into thoracic extension. Hold this position for 30 seconds, return to starting position and repeat.

**Purpose:** Improve thoracic spine extension and lengthen anterior chest wall

**Target Tissue:** Thoracic facet joints and pectoralis muscles

**Prescription:** 30 second hold x 2 repetitions

Figure 2.7 Lateral view

Sort: Level 3

Katzman, W. B., Vittinghoff, E., Kado, D. M., Schafer, A. L., Wong, S. S., Gladin, A., & Lane, N. E. (2016). Study of hyperkyphosis, exercise and function (SHEAF) protocol of a randomized controlled trail of multimodal spine-strengthening exercise in older adults with hyperkyphosis. *Physical Therapy*, *96*(3), 371-381.

# Standing Extension Stretch

Score 2

Limited thoracic extension

**Description:** Standing with feet shoulder-width apart, join hands behind head with elbows maximally outreached forward. Maximally extend the spine and hold for 30 seconds, return to starting position, and repeat.

**Purpose:** Restore thoracic spine extension

**Target Tissue:** Thoracic facet joints and erector spinae

**Prescription:** 30 seconds x 5 repetitions

Figure 2.8 Lateral view

Sort: Level 1

Feng, Q., Wang, M., Zhang, Y., & Zhou, Y. (2017). The effect of a corrective functional exercise program on postural thoracic kyphosis in teenagers: A randomized controlled trail. *Clinical Rehabilitation*, *32*(1), 48-56.

# Swiss Ball Bridges

Score 2

Limited thoracic extension

**Description:** Laying supine on the floor with feet on swiss ball. Contract the core and hip extensors to lift the body until a neutral spine is achieved and hold for 20 seconds. Lower the body to the starting position and repeat.

**Purpose:** Strengthen posterior chain and mobilize thoracic spine

**Target Tissue:** Abdominal muscles

**Prescription:** 20 seconds x 10 repetitions


Figure 2.9 Lateral view

Sort: Level 1

Feng, Q., Wang, M., Zhang, Y., & Zhou, Y. (2017). The effect of a corrective functional exercise program on postural thoracic kyphosis in teenagers: A randomized controlled trail. *Clinical Rehabilitation*, *32*(1), 48-56.

# Doorway Hamstring Stretch

Score 1

Limited hip flexion

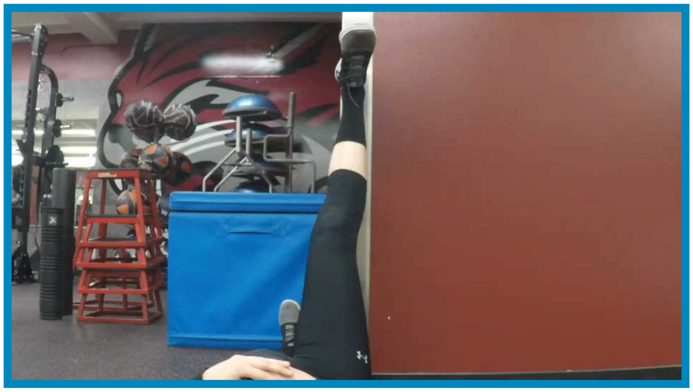
**Description:** Sitting in a doorway, place the the stretching limb in a hip flexed position with the heel on the wall and the opposite leg straight through the doorway. The stretching limb should maintain a fully extended knee, the opposite limb should remain in full extension in contact with the floor, and the pelvis should maintain a neutral position. Optional: To increase or decrease the stretch the body can be moved closer or further away from the wall, respectively.

**Purpose:** Tissue extensibility

**Target Tissue:** Hamstring

**Prescription:** 30 seconds x 3 repetitions

Figure 2.10 a.) Lateral view, b.) Cranial view



Sort: Level 1

Fasen, J. M., O'Connor, A. M., Schwartz, S. L., Watson, J. O., Plastaras, C. T., Garvan, C. W., …, Akuthotoa, V. (2009). A randomized controlled trail of hamstring stretching: A comparison of four techniques. *Journal of Strength and Conditioning Research*, *23*(2), 660-667.

# Towel/Resistance Band Hamstring Stretch

Score 1

Limited hip flexion

**Description:** In the supine position, place a strap around the mid-foot and pull the leg into hip flexion while maintaining a straight knee and a neutral pelvic position. At end range, the leg is held for 30 seconds. Optional: The angle of pull can deviate with the leg in abduction or adduction to target lateral and medial hamstring tightness, respectively.

**Purpose:** Tissue extensibility

**Target Tissue:** Hamstring

**Prescription:** 30 seconds x 3 repetitions

Figure 2.11 a.) Lateral view, b.) Cranial view

Sort: Level 1

Fasen, J. M., O'Connor, A. M., Schwartz, S. L., Watson, J. O., Plastaras, C. T., Garvan, C. W., …, Akuthotoa, V. (2009). A randomized controlled trail of hamstring stretching: A comparison of four techniques. *Journal of Strength and Conditioning Research*, *23*(2), 660-667.

# Hamstring Foam Rolling

Score 1

Limited hip flexion

**Description:** Start seated on the foam roller at the top (proximal) hamstring. Extend the leg and cross the opposite leg to increase the pressure placed on the hamstring. Start at the top (proximal) hamstring and performing a small kneading motion continuously move down (distally). This should take 30 seconds to complete to reach the end (distal) hamstring.

**Purpose:** Tissue extensibility

**Target Tissue:** Hamstring

**Prescription:** 30 seconds x 3 repetitions

Figure 2.12 Lateral view

Sort: Level 1

Madoni, S. N., Costo, P. B., Coburn, J. W., & Galpin, A. J. (2018). Effect of foam rolling on range of motion, peak torque, muscle activation, and the hamstring-to-quadriceps strength ratio. *Journal of Strength and Conditioning Research*, *32*(7), 1821-1830.

# Resistance Band Eccentric Training

Score 1

Limited hip flexion

**Description:** In the supine position, wrap a resistance band around the foot and pull the leg into hip flexion as the hamstring is activated resisting flexion. Continue antagonist action through full range of motion, taking approximately 5 seconds. Lower the leg to starting position and repeat.

**Purpose:** Strengthen and elongate hip extensors

**Target Tissue:** Hamstring

**Prescription:** 5 seconds x 6 repetitions

Figure 2.13 Lateral view

Sort: Level 1

Nelson, R. T., & Brady, W. D. (2004). Eccentric training and static stretching improve hamstring flexibility of high school males. *Journal of Athletic Training*, *39*(3), 254-258.

# Hamstring Self-Administered PNF

Score 1

Limited hip flexion

**Description:** In the standing position, place one heel on a chair or box step. Lean the trunk forward for a 15 second hamstring stretch, followed by a 10 second isometric contraction of the hamstring and another 15 second stretch moving into slightly more hip flexion.

**Purpose:** Increase ROM by autogenic and recipricol inhibition mechanisms

**Target Tissue:** Hamstring

**Prescription:** 45 seconds x 2 repetitions

Figure 2.14 Lateral view

Sort: Level 2

Wicke, J., Gainery, K., & Figueroa, M. (2014). A comparison of self-administered proprioceptive neuromuscular facilitation to static stretching on range of motion and flexibility. *Journal of Strength and Conditioning Research*, *28*(1), 168-172.

# Resistance Band Hip Flexor Strengthening

Score 1

Limited hip flexion

**Description:** In standing position, wrap a resistance band around the anterior thigh and fixed to a stationary object. Against resistance flex the hip for a three second (concentric movement), a two second hold at end range (iso-metric movement), and a three second hip extension (eccentric movement) to complete one repetition.

**Purpose:** Strengthen the hip flexors

**Target Tissue:** Rectus femoris and iliopsoas

**Prescription:** 15 repetitions


Figure 2.15 Lateral view

**Sort: Level 1**

Thorborg, K., Bandholm, T., Zebis, M., Andersen, L. L., Jensen, J. & Holmich, P. (2016). Large strengthening effect of a hip-flexor training programme: A randomized controlled trail. *Knee Surgery*, *Sport Traumatology*, *Arthroscopy*, *24*, 2346-2352.

Chapter 3

# Hurdle Step

## Description

During the hurdle step, the participant is asked to step over the FMS™ test kit that has been adjusted to the height of their tibial tuberosity while maintaining balance and ankle, knee, and hip alignment and holding a PVC pipe across the shoulders. They must simply tap the floor with the heel of the moving limb and return to starting position. This movement is performed and scored separately for each limb. The purpose of the hurdle step is to assess bilateral functional mobility and stability of the hips, knees and ankles. For the stance limb, stability of the ankle, knee and hip, and closed kinetic chain extension of the hip is required. For the moving limb, open kinetic chain dorsiflexion of the ankle and flexion of the knee and hip is required. Therefore, poor performance may be the result of poor stability of the stance limb or poor mobility of the moving limb. A more specific analysis may be required to decipher which dysfunction is present.

## Implication Based on Score

Score 3

A score of "three" indicates there is no dysfunction.

Score 2

A score of "two" indicates minor limitations most often exist with ankle dorsiflexion (see DS score 2) and hip flexion of the moving limb (see DS score 1).

Score 1

A score of "one" indicates relative asymmetric hip flexion immobility may exist (see DS score 1) as well as an anteriorly tilted pelvis and poor trunk stability.


Figure 3.0 a.) Anterior view Score 3, b.) Lateral view Score 3

Corrective Exercises

# Pelvic Lift

Score 1

Anteriorly tilted pelvis

**Description:** In supine position, bend both knees so feet can rest flat on the floor. Outstretch arms laterally for balance and lift the lower extremities to 90 degrees knee flexion. Lift the pelvis a few centimeters off the floor and hold, then return to starting position.

**Purpose:** Body perception training

**Target Tissue:** Sensorimotor systems

**Prescription:** 40 seconds x 5 sets

Figure 3.1 Lateral view

Sort: Level 1

Ludwig, O., Frohlich, M., & Schmitt, E. (2016). Therapy of poor posture in adolescents: Sensorimotor training increases the effectiveness of strength training to reduce increased anterior pelvic tilt. *Cogent Medicine*, *3*,1-11.

# Supine Naval Draw-In

Score 1

Anteriorly tilted pelvis

**Description:** In supine position, maximally abduct arms overhead. Flatten the lower back so that it touches the floor and eliminates lumbar lordosis and return to starting position. Think about drawing in the navel or belly button to the floor.

**Purpose:** Body perception training

**Target Tissue:** Sensorimotor system

**Prescription:** 40 seconds x 5 sets

Figure 3.2 Lateral view

Sort: Level 1

Ludwig, O., Frohlich, M., & Schmitt, E. (2016). Therapy of poor posture in adolescents: Sensorimotor training increases the effectiveness of strength training to reduce increased anterior pelvic tilt. *Cogent Medicine*, *3*,1-11.

# Standing Pelvic Retroversion

Score 1

Anteriorly tilted pelvis

**Description:** While standing, rotate pelvis into a neutral position. To do so think about turning the pelvis backwards like a wheel. In the final position the back should be flatter and standing in a more upright position.

**Purpose:** Body perception training

**Target Tissue:** Sensorimotor system

**Prescription:** 40 seconds x 5 sets

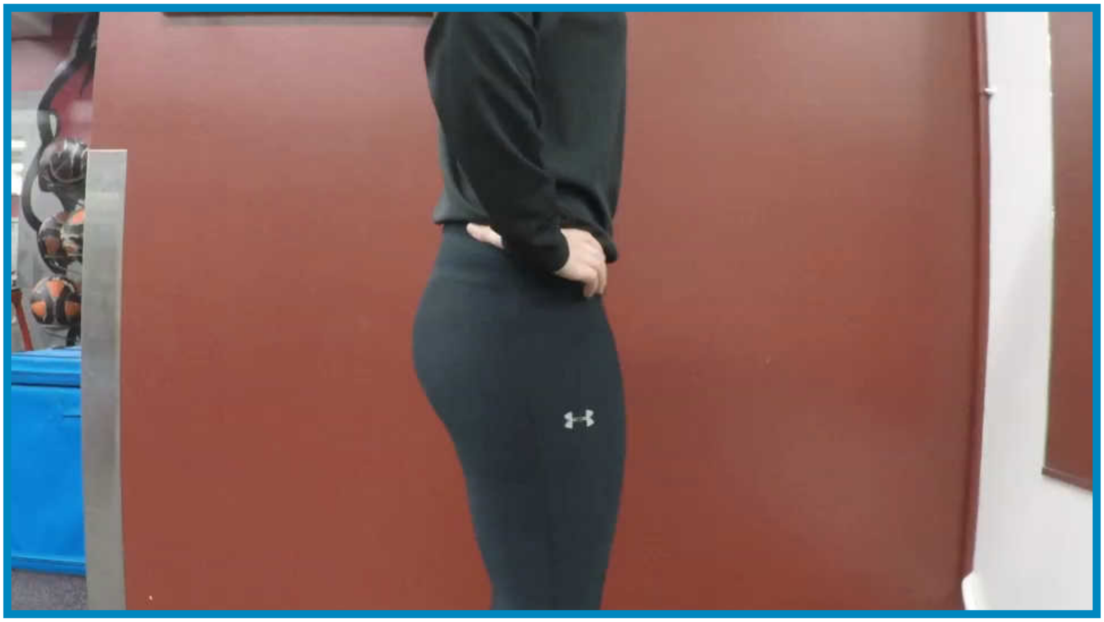


Figure 3.3 Lateral view

Sort: Level 1

Ludwig, O., Frohlich, M., & Schmitt, E. (2016). Therapy of poor posture in adolescents: Sensorimotor training increases the effectiveness of strength training to reduce increased anterior pelvic tilt. *Cogent Medicine*, *3*,1-11.

# Mirror Pelvic Posture

Score 1

Anteriorly tilted pelvis

**Description:** Standing next to a mirror, pelvic posture is corrected. A neutral pelvis and more upright overall posture are achieved while providing visual feedback to changes made.

**Purpose:** Body perception training.

**Target Tissue:** Sensorimotor system

**Prescription:** 40 seconds x 5 sets

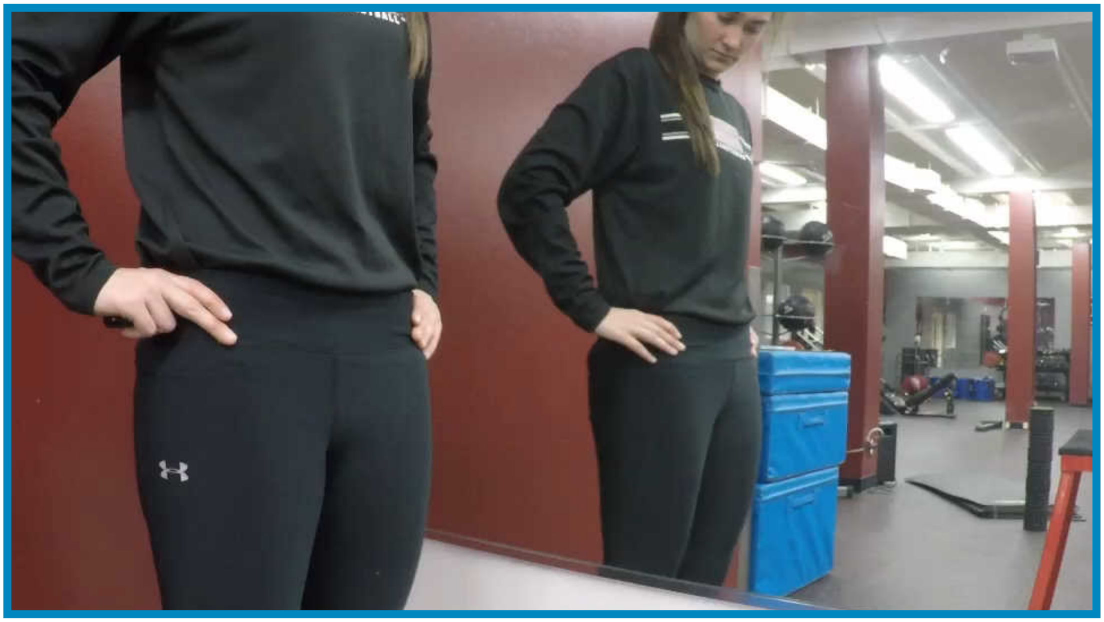


Figure 3.4 Anterior-lateral view

Sort: Level 1

Ludwig, O., Frohlich, M., & Schmitt, E. (2016). Therapy of poor posture in adolescents: Sensorimotor training increases the effectiveness of strength training to reduce increased anterior pelvic tilt. *Cogent Medicine*, *3*,1-11.

# Dead Bug

Score 1

Anteriorly tilted pelvis

**Description:** In the supine position, move the same side arm and leg together as if a rope connects the elbow and knee. As the arm moves into a flexed position, flex the opposite hip and knee into full flexion. Move the limbs to starting position and repeat on opposite limbs. Throughout the maneuver, abdominal muscles stabilize the pelvis in a neutral position.

**Purpose:** Neuromuscular control and core endurance

**Target Tissue:** Transverse abdominis

**Prescription:** 20 repetitions x 2 sets

Figure 3.5 Lateral view

Sort: Level 1

Pereira, I. L., Queiroz, B., Loss, J., Amorim, C., & Sacco, I. C. (2017). Trunk muscle EMG during intermediate Pilates mat exercises in beginner healthy and chronic low back pain individuals. *Journal of Manipulative and Physiological Therapeutics*, *40*(5), 350-357.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Birddog

Score 1

Anteriorly tilted pelvis

**Description:** In the quadruped position, touch opposite side knee and elbow by flexing arm and leg simultaneously. Return limbs to starting position and perform exercise with opposite arm and leg. This is one repetition. Pelvis is in neutral position and lower back is held in a flat position throughout the maneuver.

**Purpose:** Neuromuscular control and core endurance

**Target Tissue:** Transverse abdominis

**Prescription:** 20 repetitions x 2 sets

Figure 3.6 Lateral view

Sort: Level 1

Pereira, I. L., Queiroz, B., Loss, J., Amorim, C., & Sacco, I. C. (2017). Trunk muscle EMG during intermediate Pilates mat exercises in beginner healthy and chronic low back pain individuals. *Journal of Manipulative and Physiological Therapeutics*, *40*(5), 350-357.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Side Bridges (Side Planks)

Score 1

Poor trunk stability

**Description:** In side lying position, the trunk is raised with feet and elbow supporting the body. The core and gluteal muscles are contracted to support this position.

**Purpose:** Strengthen core musculature and improve stability

**Target Tissue:** Core oblique muscles

**Prescription:** 30 seconds x 3 sets each side

Figure 3.7 a.) Anterior view, b.) Cranial view

Sort: Level 1

Chuter, V. H., Janse de Jonge, X. A. K., Thompson, B. M., & Callister, R. (2015). The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: A three-arm randomized controlled trail. *British Journal of Sports Medicine*, *49*, 395-399.

# Bridges with Leg Lifts

Score 1

Poor trunk stability

**Description:** In the supine position, lift the pelvis to assume the bridge position. Extend one leg and hold for 20 seconds. Return to starting position and repeat on opposite leg, alternating sides.

**Purpose:** Neuromuscular control and core strengthening

**Target Tissue:** Gluteus medius and core musculature

**Prescription:** 20 seconds x 5 sets per leg

Figure 3.8 a.) Lateral view, b.) Cranial view

Sort: Level 1

Chuter, V. H., Janse de Jonge, X. A. K., Thompson, B. M., & Callister, R. (2015). The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: A three-arm randomized controlled trail. *British Journal of Sports Medicine*, *49*, 395-399.

# Swiss Ball with Trunk Twists

Score 1

Poor trunk stability

**Description:** Seated on a swiss ball with a neutral pelvic position, grasp a resistance band that is attached to a stationary object to the side. Pulling against resistance move the trunk through a rotational motion. Return to starting position and repeat.

**Purpose:** Improve core stability and endurance

**Target Tissue:** Oblique abdominal muscles

**Prescription:** 15 repetitions x 3 sets each side

Figure 3.9 a.) Anterior view, b.) Lateral view

Sort: Level 1

Chuter, V. H., Janse de Jonge, X. A. K., Thompson, B. M., & Callister, R. (2015). The efficacy of a supervised and a home-based core strengthening programme in adults with poor core stability: A three-arm randomized controlled trail. *British Journal of Sports Medicine*, *49*, 395-399.

Chapter 4

# In-Line Lunge

## Description

During the in-line lunge, the participant is asked to stand in tandem stance on the test kit with the rear toe on the zero marker and front heel on the tibial measurement. While holding a PVC pipe behind the back, maintaining an upright posture, and keeping balance they are asked to lower the rear knee to the test kit and return to starting position. This test was designed to assess hip and ankle mobility and stability involved in closed kinetic chain hip abduction, as well as quadriceps flexibility and knee stability. In terms of functional capacity this test utilizes rotational, deceleration, and lateral movements. Poor performance may indicate imbalance between adductor weakness and abductor tightness in either limb.

## Implication Based on Score

Score 3

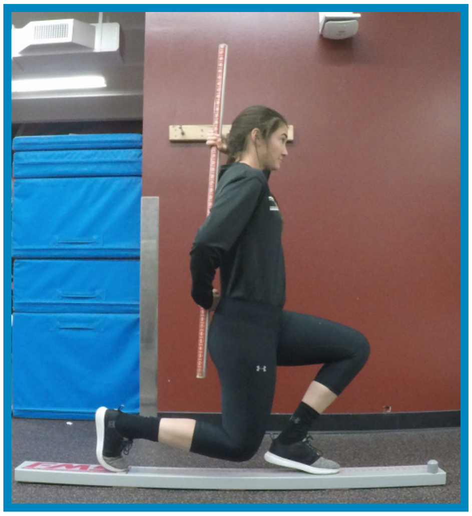
A score of “three” indicates there is no dysfunction.

Score 2

A score of “two” indicates minor limitations often in mobility of one or both hips (See DS hip flexion and add hip flexor stretching).

Score 1

A score of “one” indicates relative asymmetries in mobility or stability in one or both hips (Continue ILL score 2 protocol and see stability exercises).



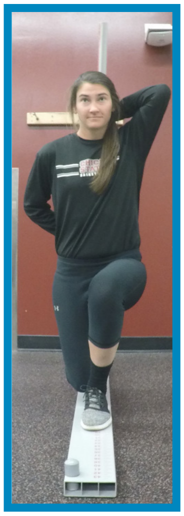


Figure 4.0 a.) Lateral view Score 3, b.) Anterior view Score 3

Corrective Exercises

# Modified Lunge Stretch

Score 2

Insufficient hip mobility in both hips

**Description:** Start in a half-kneeling position, with stretching knee on the ground, trunk erect, and pelvis posteriorly tilted. Lunge forward with the front knee and hip to feel maximal stretch in opposite limb hip flexor. Hold this position for 30 seconds and return to starting position.

**Purpose:** Improve hip extension

**Target Tissue:** Iliopsoas and rectus femoris

**Prescription:** Hold 30 seconds and rest 8 seconds x 10 repetitions

Figure 4.1 a.) Lateral view, b.) Anterior view

Sort: Level 1

Winters, M. V., Blake, C. G., Trost, J. S., Marcello-Brinker, T. B., Lowe, L., Garber, M. B., & Wainner, R. S. (2004). Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: A randomized clinical trial. *Physical Therapy*, *84*(9), 800-807.

# Prone Leg Lift on Bolster

Score 2

Insufficient hip mobility in both hips

**Description:** In the prone position, place a bolster (rolled towel, pillow, half foam roller or full foam roller) under the knee. A stretch should be felt in the hip flexor with leg straight, the position is held for the stretch.

**Purpose:** Improve hip extension

**Target Tissue:** Iliopsoas and rectus femoris

**Prescription:** Hold 30 seconds and rest 8 seconds x 10 repetitions

Figure 4.2 Lateral view

Sort: Level 1

Winters, M. V., Blake, C. G., Trost, J. S., Marcello-Brinker, T. B., Lowe, L., Garber, M. B., & Wainner, R. S. (2004). Passive versus active stretching of hip flexor muscles in subjects with limited hip extension: A randomized clinical trial. *Physical Therapy*, *84*(9), 800-807.

# Piriformis Stretch

Score 2

Insufficient hip mobility in both hips

**Description:** In the supine position, bring the hip to 90 degrees flexion, maximal horizontal adduction and maximal external rotation. Hold at end range of motion for stretch and return to supine position.

**Purpose:** Improve hip flexion, adduction and external rotation

**Target Tissue:** Piriformis

**Prescription:** 30 seconds x 3 sets

Figure 4.3 a.) Cranial view, b.) Lateral view

Sort: Level 2

Gulledge, B. M., Marcellin-Little, D. J., Levine, D., Tillman, L., Harryson, O. L., Osborne, J. A., & Baxter, B. (2014). Comparison of two stretching and optimization of stretching protocol for the piriformis muscle. *Medical Engineering & Physics*, *36*, 212-218.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Single Leg Box Dips

Score 1

Insufficient hip stability

**Description:** Stand on a platform at least 6 inches high with one leg. Flex the knee of the standing limb and maintain a neutral pelvic position. Tap to floor with the opposite foot and return to starting position.

**Purpose:** Strengthen standing limb

**Target Tissue:** Quadriceps and gluteus maximus

**Prescription:** 15 repetitions x 3 sets each leg

Figure 4.4 a.) Lateral view, b.) Anterior view

Sort: Recomendation B

Boren, K., Conrey, C., LeCoguic, J., Paprocki, L., Voight, M., & Robinson, T. K. (2011). Electromyographic analysis of gluteus medius and gluteus maximus during rehabilitation exercises. *The International Journal of Sports Physical Therapy, 6*(3), 206-223.

Crossley, K. M., Zhang, W., Schache, A. G., Bryant, A., & Cowan, S. M. (2011). Performance on a single-leg squat task indicates hip abductor muscle function. *The American Journal of Sports Medicine, 39*(4), 866-873.

Mauntel, T. C., Begalle, R. L., Cram, T. R., Frank, B. S., Hirth, C. J., Blackburn, T., & Pauda, D. A. (2013). The effects of lower extremity muscle activity and passive range of motion on single leg squat performance. *Journal of Strength and Conditioning Research, 27*(1), 1813-1823.

Presswood, L., Cronin, J., Keogh, J. W., & Whatman, C. (2008). Gluteus medius: Applied anatomy, dysfunction, assessment, and progressive strengthening. *Strength and Conditioning Journal*, *30*(5), 41-53.

# Monster Walks with Resistance Band

Score 1

Insufficient hip stability

**Description:** Stand with a resistance band around both feet and in the athletic position. Step forward into the lateral and forward direction alternating stepping limb. Each set includes 8 repetitions for each leg for a total of 16 steps.

**Purpose:** Dynamic strengthening of lower extremity

**Target Tissue:** Tensor fascia latte, quadriceps and gluteals

**Prescription:** 8 repetitions for each leg x 3 sets

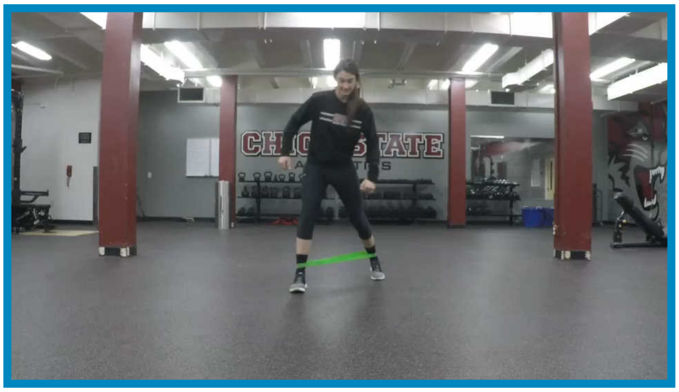
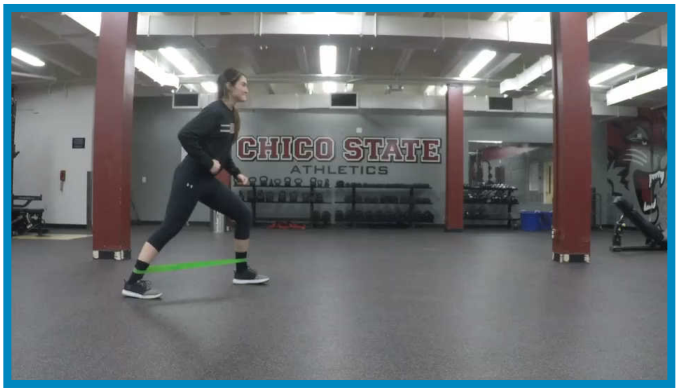


Figure 4.5 a.) Anterior view, b.) Lateral view




Sort: Level 2

Cambridge, E. D., Sidorkewicz, N., Ikeda, D. M., & McGill, S. M. (2012). Progressive hip rehabilitation: The effects of resistance band placement on gluteal activation during two common exercises. *Clinical Biomechanics, 27,* 719-724.

Stastny, P., Tufano, J. J., Golas, A., & Petr, M. (2016). Strengthening the gluteus medius using various bodyweight and resistance exercises. *Strength and Conditioning Journal*, *38*(3), 91-101.

# Standing Split Squat with Kettle Bell

Score 1

Insufficient hip stability

**Description:** Stand in a split stance with one leg on a platform. Hold kettle bell on one side of the body to challenge the opposite side gluteus medius and disturb balance throughout the motion. Bend the front knee into lunge, return to starting position and repeat.

**Purpose:** Strengthen lower leg muscles

**Target Tissue:** Tensor fascia latte, quadriceps and gluteals

**Prescription:** 8 repetitions each leg x 3 sets

Figure 4.6 a.) Lateral view, b.) Anterior view

Sort: Level 3

Stastny, P., Tufano, J. J., Golas, A., & Petr, M. (2016). Strengthening the gluteus medius using various bodyweight and resistance exercises. *Strength and Conditioning Journal*, *38*(3), 91-101.

Chapter 5

# Shoulder Mobility

## Description

A clearing test is performed prior to testing. A participant is asked to place hand on opposite shoulder and move the elbow upward. If pain is felt a score of zero is reported for this side. During the shoulder mobility test, the participant’s hand length is first measured from the distal crease of the wrist to the point of the third digit. Both hands are then placed in a fist, the tested shoulder is asked to be placed in maximal abduction, flexion and external rotation while the opposite extrem-ity is placed in maximal adduction, extension and internal rotation. In this position both fists should be placed along the posterior aspect of the participant's body to be measured. The distance measured between the fists in compar-ison to the hand length is used to determine score. To achieve a “three” fists must be within one hand length. To achieve a “two”, fists must be within one and a half hand lengths. To achieve a “one”, fists are not within one and a half hand lengths. This movement pattern is used to assess bilateral mobility of the shoulder complex.

## Implication Based on Score

### Score 3

A score of “three” indicates there is no dysfunction.

### Score 2

A score of “two” indicates that minor posture changes, including increased development and shortening of the pectoralis minor or latissimus dorsi muscles.

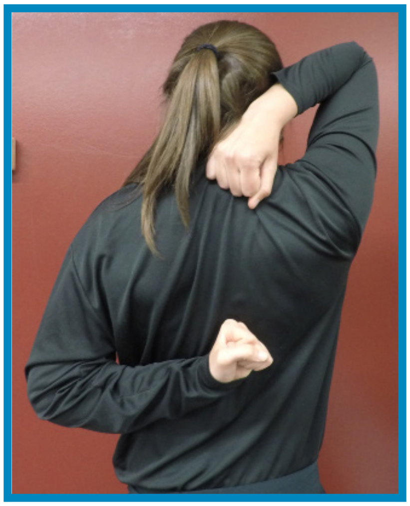


Figure 5.0 Posterior view Score 1

### Score 1

A score of “one” indicates that a scapulo-thoracic dysfunction may exist.

### Score 0

A score of “zero” indicates that pain was present when performing the clearing test and may be indicative of shoulder impingement. Further clinical evaluation is needed.

Corrective Exercises

# Resistance Band Scapular-Retraction

Score 2

Pectoralis minor tightness

**Description:** Hold a resistance band in both hands with shoulders abducted to 90 degrees in the scapular plane and elbows flexed to 90 degrees. Retracting the scapula and stretching the band to maximal resistance.

**Purpose:** Strengthen antagonist muscles of the pectoralis minor

**Target Tissue:** Rhomboids and teres minor

**Prescription:** 10 repetitions x 3 sets


Figure 5.1 a.) Anterior view, b.) Posterior view

Sort: Level 1

Kluemper, M., Uhl, T., & Hazelrigg, H. (2006). Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *Journal of Sports Rehabilitation*, *15*, 58-70.

# Foam Roller Stretch

Score 2

Pectoralis minor tightness

**Description:** In the supine position, place the foam roller along the spine. Stretch arms to 90 degrees of abduction and relax allowing the weight of gravity to pull the shoulders back to stretch the pectoralis minor.

**Purpose:** Stretch the pectoralis minor

**Target Tissue:** Pectoralis minor

**Prescription:** 30 seconds x 2 sets

Figure 5.2 a.) Lateral view, b.) Cranial view

Sort: Level 1

Kluemper, M., Uhl, T., & Hazelrigg, H. (2006). Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *Journal of Sports Rehabilitation*, *15*, 58-70.

# Doorway Stretch

Score 2

Pectoralis minor tightness

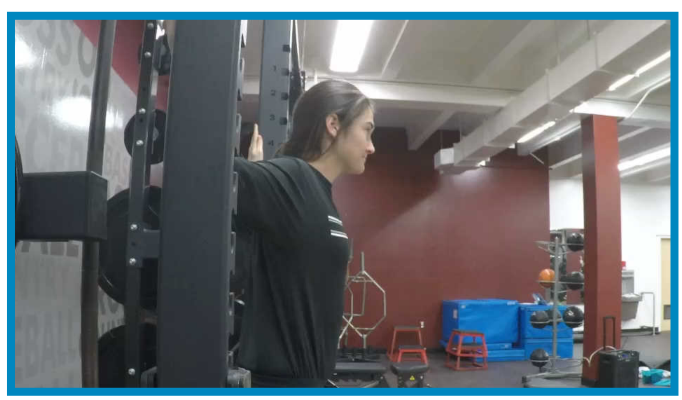
**Description:** In a doorway, abduct shoulders to 90 degrees and flex elbows to 90 degrees. Hold onto the doorframe and lean forward so the arm is extended stretching the pectoralis minor.

**Purpose:** Stretch the pectoralis minor

**Target Tissue:** Pectoralis minor

**Prescription:** 30 seconds x 2 sets


Figure 5.3 a.) Anterior view, b.) Lateral view



Sort: Level 1

Ruivo, R. M., Pezarat-Correia, P., & Carita, A. I. (2017). Effect of resistance and stretching training program of forward head and protracted shoulder posture in adolescents. *Journal of Manipulative and Physiological Therapeutics*, *40*(1), 1-10.

# Lat Pull-Down

Score 2

Latissimus dorsi weakness

**Description:** In standing, attach a resistance band to stationary overhead object. Pull both arms to the chin level in front of the body. A wide grip will optimize the degree the latissimus dorsi is activated.

**Purpose:** Strengthen latissimus dorsi

**Target Tissue:** Latissimus dorsi

**Prescription:** 6 repetitions of 67-85% 1RM x 5 sets

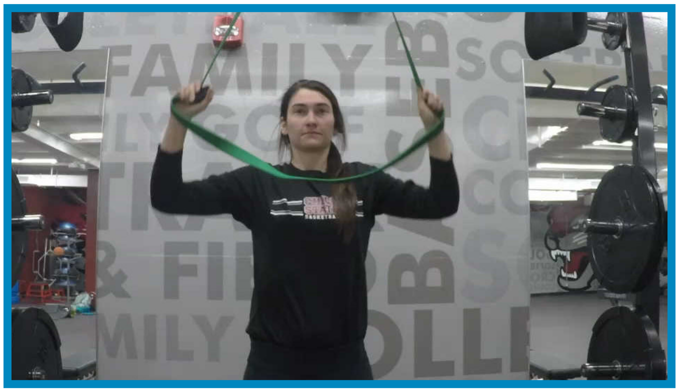
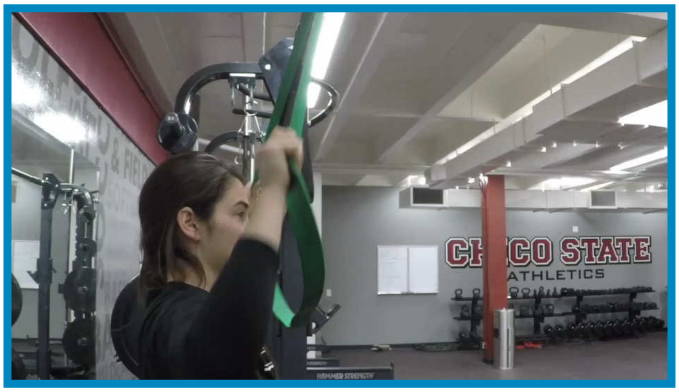


Figure 5.4 a.) Anterior view, b.) Lateral view




Sort: Level 1

Andersen, V., Fimland, M. S., Wiik, E., Skoglund, A., & Saeterbakken, A. H. (2014). Effects of grip width on muscle strength and activation in the lat pull-down. *Journal of Strength and Conditioning Research*, *28*(4), 1135-1142.

Snarr, R., Eckert, R. M., & Abbott, P. (2015). A comparative analysis and technique of the lat pull-down. *Strength and Conditioning Journal*, *37*(5), 21-25.

# Seated Row

Score 2

Latissimus dorsi weakness

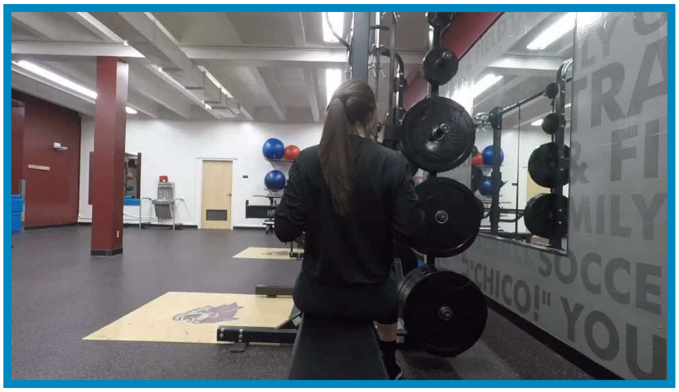
**Description:** Attach a resistance band to a stationary device at shoulder level in the seated position. Grasp resistance band with both hands and pull towards the body, keeping elbows tucked to sides. Pull to maximal resistance or touch the chest and return to starting position.

**Purpose:** Strengthen latissimus dorsi

**Target Tissue:** Latissimus dorsi

**Prescription:** 8 repetitions x 5 reps


Figure 5.5 a.) Lateral view, b.) Posterior view



Sort: Level 1

Ratamess, N. A., Beller, N. A., Gonzalez, A. M., Spatz, G. E., Ross, R. E., … , & Kang, J. (2016). The effects of multiple-joint isokinetic resistance training on maximal isokinetic and dynamic muscle strength and local muscular endurance. *Journal of Sports Science and Medicine*, *15*, 34-40.

# Barbell Row

Score 2

Latissimus dorsi weakness

**Description:** In the standing position, lift a weighted bar to the waist. Bend at the trunk and maintain body position with knees slightly bent. Pull the bar to lower chest/upper abdomen and return to starting position.

**Purpose:** Strengthen upper back, posterior shoulder girdle and shoulder joint muscles.

**Target Tissue:** Latissimus dorsi

**Prescription:** 10 repetitions (60-70% 1RM) x 2 sets

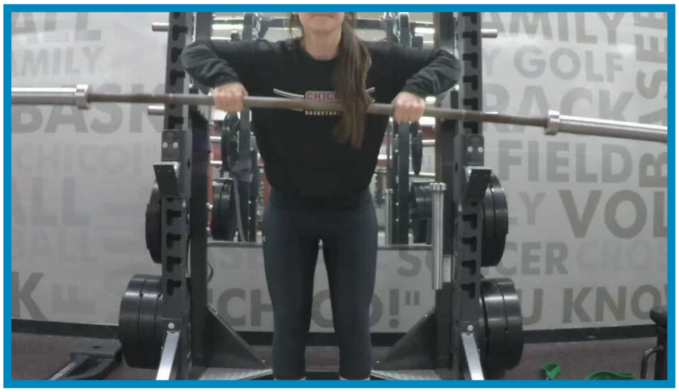


Figure 5.6 a.) Anterior view, b.) Lateral view

**Sort: Level 1**

Ratamess, N. A., Beller, N. A., Gonzalez, A. M., Spatz, G. E., Ross, R. E., … , & Kang, J. (2016). The effects of multiple-joint isokinetic resistance training on maximal isokinetic and dynamic muscle strength and local muscular endurance. Journal of Sports Science and Medicine, *15*, 34-40.

Ronai, P. (2017). The barbell row exercise. *ACSM's Health and Fitness Journal*, *21*(2), 25-28.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Coracoid Conscious Muscle Control

Score 1

Scapulothoracic dysfunction

**Description:** Palpate the coracoid with the contralateral finger. Pull the coracoid away from finger by moving the scapula backwards. Return back to starting position and repeat.

**Purpose:** Improve proprioception and normalize scapular resting position

**Target Tissue:** Anterior chest and posterior shoulder musculature co-contraction

**Prescription:** >20-30 minutes per day, 2-3 days per week

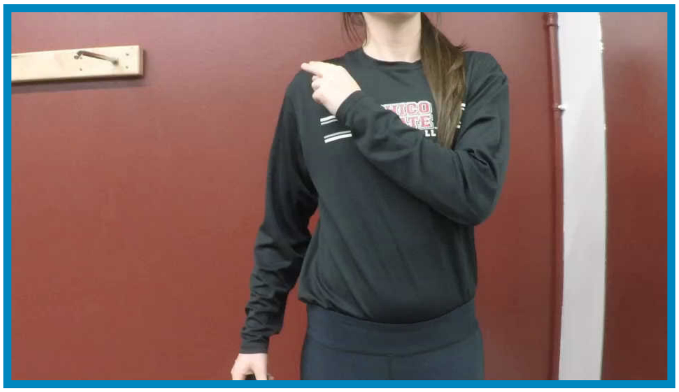
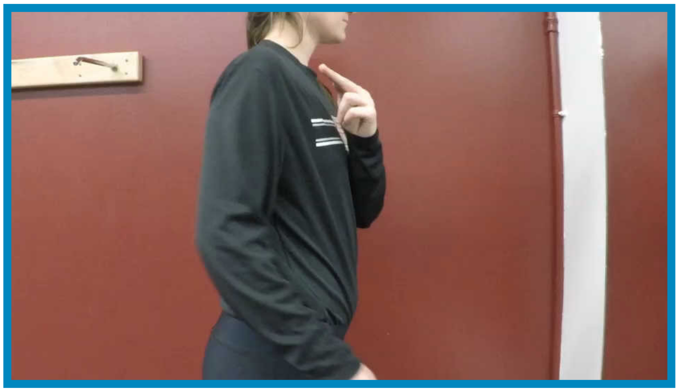


Figure 5.7 a.) Anterior view, b.) Lateral view



Sort: Level 3

Cools, A. M., Struyf, F., DeMey, K., Maenhut, A., Castelein, B., & Cagnie, B. (2014). Rehabilitation of scapular dyskinesis: From the office worker to the elite overhead athlete. *British Journal of Sports Medicine*, *48*, 692-697.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In ACSM's guidelines for exercise testing and prescription (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Scapular Clock

Score 1

Scapulothoracic dysfunction

**Description:** Wrap a resistance band around each wrist and place hands on a wall at shoulder level and shoulder width apart. Resistance band should be taut in this position. Move one limb, primarily at the scapulothoracic joint and keep the other stationary, the resistance band creates the hand to a clock. Each time (in terms of number on a clock 1-12) is touched with the moving hand. One time around signifies one set.

**Purpose:** Scapular stabilization

**Target Tissue:** Scapulothoracic joint and articulating musculature

**Prescription:** 12 repetitions x 3 sets

Figure 5.8 a.) posterior view

Sort: Level 1

Buskurt, Z., Baskurt, F., Gelecek, N., & Ozhan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*, *24*, 173-179.

# Wall Push-Up

Score 1

Scapulothoracic dysfunction

**Description:** Stand facing the wall and place hands at shoulder level and shoulder width apart. Protract and retract the scapula to create push-up motion without bending elbows.

**Purpose:** Scapular stabilization

**Target Tissue:** Scapulothracic musculature

**Prescription:** 10 repetitions x 3 sets

Figure 5.9 Posterior view

Sort: Level 1

Buskurt, Z., Baskurt, F., Gelecek, N., & Ozhan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*, *24*, 173-179.

# Prone Arm Extension

Score 1

Scapulothoracic dysfunction

**Description:** In prone position on table with arms resting at 90 degrees forward flexion holding dumbbells. The shoulders are extended with elbows flexed in the horizontal plane to squeeze the shoulder blades. Return to starting position and repeat.

**Purpose:** Improve lower trapezius endurance

**Target Tissue:** Lower trapezius

**Prescription:** 20 repetitions (20-50% 1 RM) x 2 sets

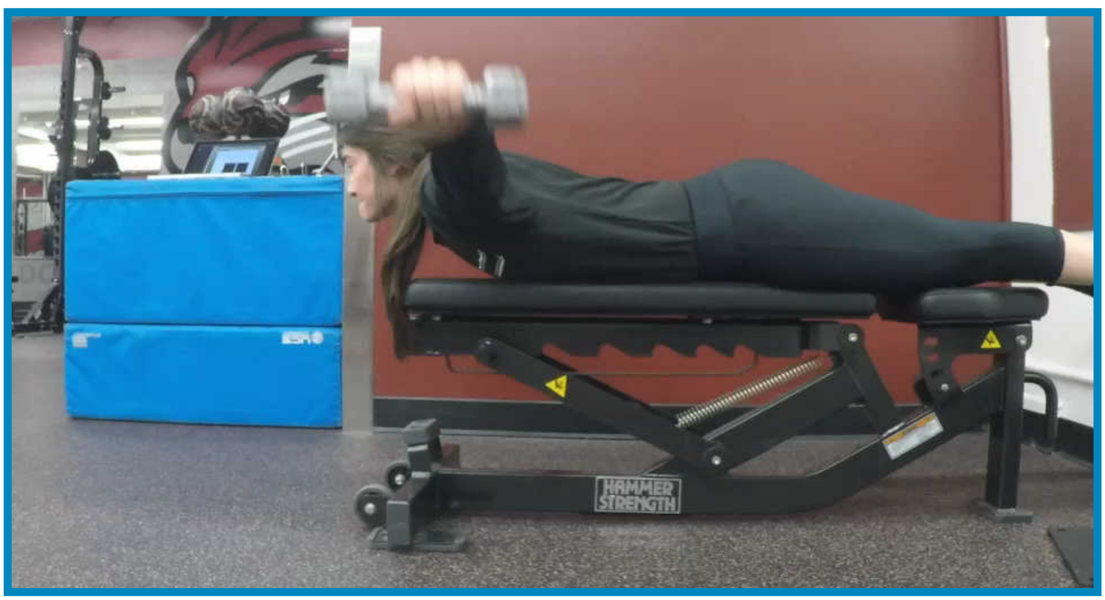



Figure 5.10 Lateral view

Sort: Level 1

Cools, A. M., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., … , & Witvrouw, E. E. (2007). Rehabilitation of scapular muscle balance: Which exercises to prescribe? *The American Journal of Sports Medicine*, *35*(10), 1744-1751.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In ACSM's guidelines for exercise testing and prescription (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Forward Flexion in Side-lying

Score 1

Scapulothoracic dysfunction

**Description:** With dumbbells, in the side-lyng position and shoulder at neutral, perform forward flexion in the horizontal plane to 135 degrees. Return to start-ing position and repeat.

**Purpose:** Improve lower trapezius endurance

**Target Tissue:** Lower trapezius

**Prescription:** 20 repetitions (20-50% 1 RM) x 2 sets

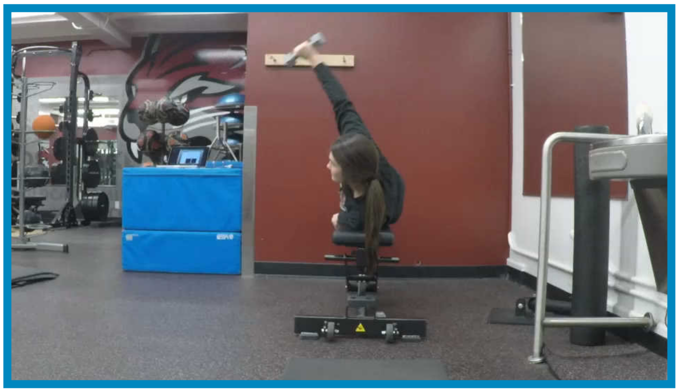
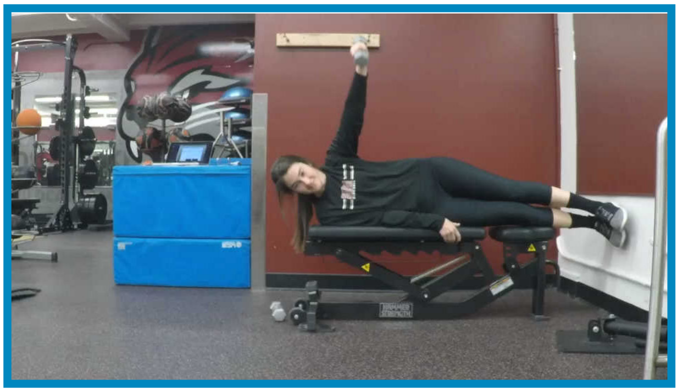


Figure 5.11 a.) Cranial view, b.) Anterior view



Sort: Level 1

Cools, A. M., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., … , & Witvrouw, E. E. (2007). Rehabilitation of scapular muscle balance: Which exercises to prescribe? *The American Journal of Sports Medicine*, *35*(10), 1744-1751.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# External Rotation in Side-lying

Score 1

Scapulothoracic dysfunction

**Description:** In the side-lying position, shoulder at neutral, and elbow at 90 degrees, with one dumbbell externally rotate shoulder. Use a towel between trunk and elbow to avoid compensatory movements.

**Purpose:** Improve lower trapezius endurance

**Target Tissue:** Lower trapezius

**Prescription:** 20 repetitions (20-50% 1 RM) x 2 sets

Figure 5.12 a.) Anterior view, b.) Cranial view

**Sort: Level 1**

Cools, A. M., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., … , & Witvrouw, E. E. (2007). Rehabilitation of scapular muscle balance: Which exercises to prescribe? *The American Journal of Sports Medicine*, *35*(10), 1744-1751.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Prone Horizontal Abduction with External Rotation

Score 1

Scapulothoracic dysfunction

**Description:** In the prone position and shoulder resting at 90 degrees of flexion, horizontally abduct the arm. At end range of horizontal motion externally rotate shoulder. Return to starting position and repeat.

**Purpose:** Improve lower trapezius endurance

**Target Tissue:** Lower trapezius

**Prescription:** 20 repetitions (20-50% 1 RM) x 2 sets

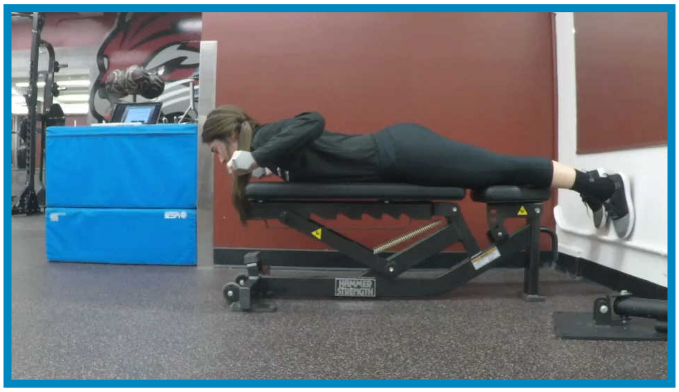


Figure 5.13 a.) Lateral view, b.) Cranial view

Sort: Level 1

Cools, A. M., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., … , & Witvrouw, E. E. (2007). Rehabilitation of scapular muscle balance: Which exercises to prescribe? *The American Journal of Sports Medicine*, *35*(10), 1744-1751.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Push-Up Plus

Score 1

Scapulothoracic dysfunction

**Description:** In the standard push-up position, the body is lifted slightly by protracting scapulae. Return to starting position by retracting the scapulae and repeat. Optional: This exercise can be added to end of push-up or completed on its own.

**Purpose:** Strengthen serratus anterior

**Target Tissue:** Serratus anterior

**Prescription:** 10 repetitions x 3 sets

Figure 5.14 a.) Lateral view, b.) Cranial view

Sort: Level 1

Buskurt, Z., Baskurt, F., Gelecek, N., & Ozhan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*, *24*, 173-179.

# Weight Shifts

Score 1

Scapulothoracic dysfunction

**Description:** In the standard push-up position, slowly shift weight between left and right arm. Maintain scapular position throughout movements. Shift to both left and right to complete one repetition and repeat.

**Purpose:** Strengthen serratus anterior

**Target Tissue:** Serratus anterior

**Prescription:** 10 repetitions x 3 sets

Figure 5.15 a.) Cranial view, b.) Lateral view

Sort: Level 1

Buskurt, Z., Baskurt, F., Gelecek, N., & Ozhan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*, *24*, 173-179.

# Wall Slides

Score 1

Scapulothoracic dysfunction

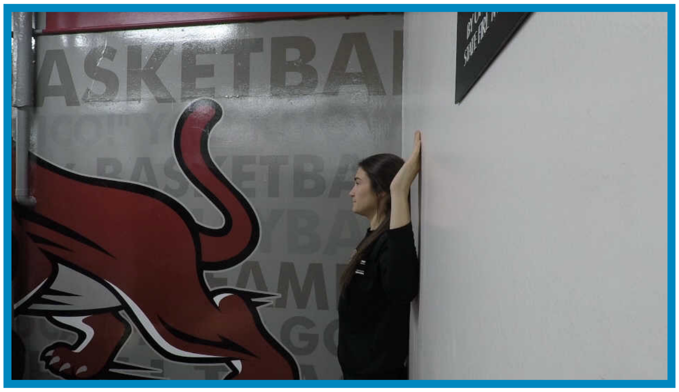
**Description:** Standing with back against the wall, raise arms to 90 degrees shoulder abduction and 90 degrees elbow flexion. Maintaining arm contact with the wall extend elbows as far as you can keeping back against the wall, return to starting position and repeat.

**Purpose:** Strengthen serratus anterior

**Target Tissue:** Serratus anterior

**Prescription:** 10 repetitions x 3 sets

Figure 5.16 a.) Anterior view, b.) Lateral view



Sort: Level 1

Buskurt, Z., Baskurt, F., Gelecek, N., & Ozhan, M. H. (2011). The effectiveness of scapular stabilization exercise in the patients with subacromial impingement syndrome. *Journal of Back and Musculoskeletal Rehabilitation*, *24*, 173-179.

Chapter 6

# Active Straight Leg Raise

## Description

During the active straight leg raise, the participant is placed in supine position and a vertical dowel is placed at the mid-point between the ASIS and patella. The participant is asked to actively raise one leg as high as they can, while maintaining contact with the table with the opposing limb and head. Score is based on malleolus position of the moving leg. A score of "three" is achieved if the malleolus is between the mid-thigh and the ASIS. A score of "two" is given if the malleolus is between the mid-thigh and the knee. A score of "one" is given if the malleolus is below the knee. This movement pattern is primarily used to examine mobility limitations specifically those created by muscle shortening in the lower extremity. To perform the active straight leg raise the participant must have functional hamstring, gluteal and iliotibial band flexibility as well as hip mobility in the opposing leg and pelvic and core stability.

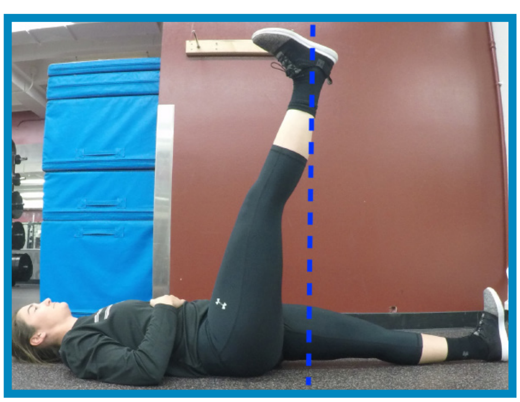
## Implication Based on Score

### Score 3

A score of "three" indicates there is no dysfunction.

### Score 2

A score of "two" indicates minor asymmetric hip mobility limitations (see ILL hip mobility), moderate isolated, unilateral muscle tightness may exist (see DS and ILL muscle tightness) or stability dysfunction of the non-moving limb (see ILL stability exercises).



### Score 1

A score of "one" indicates gross hip mobility limitations [Continue all score 2 exercises (see above)]

Figure 6.0 Lateral view Score 2

Chapter 7

# Trunk Stability Push-Up

## Description

A clearing test is performed at the end of testing in which the participant is asked to do a press-up from push-up position. If this spinal extension exercise elicits pain, a score of "zero" is given for this movement pattern and further clinical evaluation is needed. During the trunk stability push-up, the participant is asked to do a push-up relative to hand position. Men will start with thumbs positioned at forehead level, while women will start with thumbs positioned at chin level. If a push-up can be performed completely with no lag, participants will be given a "three". If compensation is needed men will move their hand position to chin level, while women will move to clavicle level. At this level if they are able to compete the push-up with no lag they will be given a "two". If not able to perform they will be given a "one". To perform the trunk stability push-up, trunk stability in the sagittal plane is the primary requirement. This involves  strength from the upper and lower abdominals. A lag suggests that isometric contraction of these muscles cannot be sustained resulting in spinal hyperextension.

## Implication Based on Score

### Score 3

A score of "three" indicates there is no dysfunction.

### Score 2

A score of "two" indicates poor trunk stability in the presence of trunk extension force (see HS trunk stability exercises).

### Score 1

A score of "one" indicates poor trunk stability when activated symmetricly and in the sagittal plane.

### Score 0

A score of "zero" indicates pain with spinal extension clearing test. Further evaluation is needed to determine exact clinical diagnosis.

Figure 7.0 Lateral view Score 3

Corrective Exercises

# Swiss Ball Knee-Up

Score 1

Poor symmetric trunk stability in the sagittal plane

**Description:** In the plank position with feet on swiss ball, pull knees towards the chest. Extend back to starting position to complete one repetition and repeat.

**Purpose:** Strengthen core in trunk flexion

**Target Tissue:** Abdominal muscles

**Prescription:** 10 repetitions x 2 sets

Figure 7.1 Lateral view

Sort: Level 1

Clark, A. W., Gedeke, M. K., Cunningham, S. R., Rockwell, D. E., Lehecka, B. J., Manske, R. C., & Smith, B. S. (2017). Effects of pelvic and core strength training on high school cross-country race time. *Journal of Strength and Conditioning Research*, *31*(8), 2289-2295.

# Swiss Ball Roll-out

Score 1

Poor symmetric trunk stability in the sagittal plane

**Description:** In the kneeling position, with elbows placed on swiss ball, roll out on the swiss ball and maintain tight abdominal muscles keeping the pelvis and trunk straight. Return to starting position and repeat.

**Purpose:** Strengthen core in trunk flexion

**Target Tissue:** Abdominal muscles

**Prescription:** 10 repetitions x 2 sets

Figure 7.2 Lateral view

Sort: Level 1

Clark, A. W., Gedeke, M. K., Cunningham, S. R., Rockwell, D. E., Lehecka, B. J., Manske, R. C., & Smith, B. S. (2017). Effects of pelvic and core strength training on high school cross-country race time. *Journal of Strength and Conditioning Research*, *31*(8), 2289-2295.

# Swiss Ball Superman

Score 1

Poor symmetric trunk stability in the sagittal plane

**Description:** In the prone position, place pelvis on swiss ball. Suspend legs and upper body in the air while maintaining balance. Hold this position by isometrically contracting in extended position. Return to starting position and repeat.

**Purpose:** Isometric trunk strength

**Target Tissue:** Rectus abdominis and erector spinae

**Prescription:** isometric hold time

Figure 7.3 Lateral view

Sort: Level 2

Comfort, P., Pearson, S. J., & Mather, D. (2011). An electromyographical comparison of trunk muscle activity during isometric trunk and dynamic strengthening exercises. *Journal of Strength and Conditioning Research*, *25*(1), 149-154.

*Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

Chapter 8

# Rotary Stability

## Description

A clearing test where the individual is asked to perform spinal flexion by leaning back from the quadruped position so the buttock touches the heel and arms are outstretched (similar to child's pose) is required. If pain is elicited, further clinical evaluation is needed and a score of "zero" is given for bilateral results. During the rotary stability test, the individual is in a quadruped position and asked to flex the shoulder and extend the hip and knee on the same side. Once raised above the floor to six inches they are asked to extend the shoulder and flex the hip and knee until the elbow and knee touch. If they are able to complete this movement while maintaining balance and a flat back they receive a "three". If not, they switch to performing the movement in a diagonal pattern, using opposite sides for leg and shoulder. If able to perform in this manner they receive a "two" and if not, they receive a "one". This movement pattern is assessed bilaterally. To perform the rotary stability test neuromuscular coordination and multi-planar trunk stability of both the upper and lower extremity is required.

## Implication Based on Score

### Score 3

A score of "three" indicates there is no dysfunction.

### Score 2

A score of "two" indicates poor trunk stability in the presence of trunk extension force (see HS trunk stability exercises).

### Score 1

A score of "one" indicates asymmetric trunk stability in the sagittal plane and transverse plane.

### Score 0

A score of "zero" indicates pain with spinal flexion clearing test. Further evaluation is needed to determine exact clinical diagnosis.

Figure 8.0 a.) Phase one Score 3,
b.) Phase two Score 3

Corrective Exercises

# Criss-cross “Bicycle”

Score 1

Poor asymmetric trunk stability in the sagittal plane

**Description:** In the supine position arms and legs move in opposition in the sagittal plane. Clasp hands behind the head and flex legs to perform a pedaling motion.

**Purpose:** Lumbopelvic stabilization and core endurance

**Target Tissue:** Rectus abdominis, oblique abdominals, and multifidus

**Prescription:** 20 repetitions x 2 sets

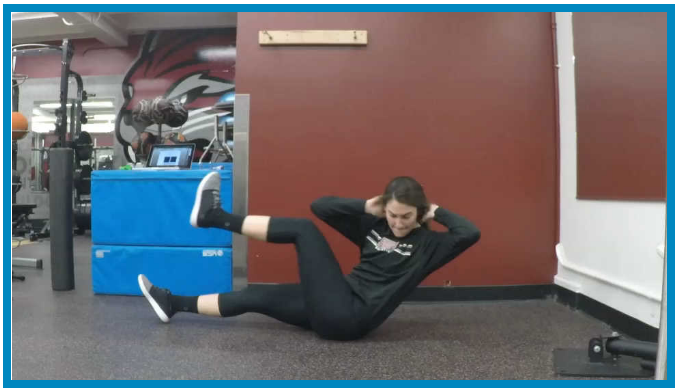


Figure 8.1 a.) Lateral view, b.) Cranial view

Sort: Level 1

Pereira, I. L., Queiroz, B., Loss, J., Amorim, C., & Sacco, I. C. (2017). Trunk muscle EMG during intermediate Pilates mat exercise in beginners healthy and chronic low back pain individuals. *Journal of Manipulative and Physiological Therapeutics*, *40*(5), 350-357.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Hip Extension on Swiss Ball

Score 1

Poor asymmetric trunk stability in the sagittal plane

**Description:** In plank position with feet on the swiss ball, one leg is maximally extended creating an asymmetric exercise. The leg is lowered to the swiss ball and movement is repeated with opposite limb. This is considered one repetition.

**Purpose:** Improve core stability, hip extensor development, and proprioception

**Target Tissue:** Rectus abdominis, external and internal obliques

**Prescription:** 20 repetitions x 2 sets

Figure 8.2 Lateral view

Sort: Level 1

Escammila, R. F., Lewis, C., Bell, D., Bramblet, G., Daffron, J., Lambert, S., … , & Andrews, J. (2010). Core muscle activation during swiss ball and traditional abdominal exercises. *Journal of Orthopedic & Sports Physical Therapy*, *40*(5), 265-276.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Oblique Crunch

Score 1

Poor asymmetric trunk stability in the sagittal plane

**Description:** In supine position on the floor, the knees are flexed. One arm is extended to opposite thigh and the contralateral scapula is raised off the ground in trunk flexion. Return to starting position and repeat.

**Purpose:** Strengthen core musculature

**Target Tissue:** Rectus abdominis and external oblique

**Prescription:** 20 repetitions x 2 sets

Figure 8.3 a.) Lateral view, b.) Cranial view

Sort: Level 1

Gottschall, J. S., Mills, J., & Hastings, B. (2013). Integration core exercises elicit greater muscle activation than isolation exercise. *Journal of Strength and Conditioning Research*, *27*(3), 590-596.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Skier

Score 1

Poor asymmetric trunk stability in the transverse plane

**Description:** In the plank position with feet on the swiss ball, pull knees to either right or left side. Return legs to fully extended position and repeat on alternate side.

**Purpose:** Improve core stability and endurance

**Target Tissue:** External and internal obliques

**Prescription:** 20 repetitions x 2 sets

Figure 8.4 Lateral view

Sort: Level 1

Escammila, R. F., Lewis, C., Bell, D., Bramblet, G., Daffron, J., Lambert, S., … , & Andrews, J. (2010). Core muscle activation during swiss ball and traditional abdominal exercises. *Journal of Orthopedic & Sports Physical Therapy*, *40*(5), 265-276.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Medicine Ball Throw

Score 1

Poor asymmetric trunk stability in the transverse plane

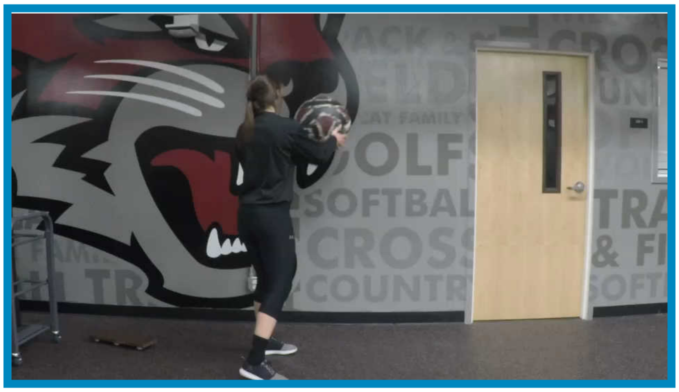
**Description:** Stand perpendicular to wall with medicine ball in hand, throw the ball laterally by twisting the upper body and swinging the arms. Catch the ball and repeat the motion.

**Purpose:** Strengthen abdominal musculature using plyometric exercise

**Target Tissue:** Rectus abdominis and external oblique

**Prescription:** 20 repetitions x 2 sets

Figure 8.5 a.) Anterior view, b.) Lateral view



Sort: Level 1

Vera-Garcia, F. J., Ruiz-Perez, I., Barbado, D., Juan-Recio, C., & McGill, S. M. (2014). Trunk and shoulder EMG and lumbar kinematics of medicine-ball side throw and side catch and throw. *European Journal of Human Movement*, *33*, 93-109.

Riebe, D., Ehrman, J., Liguori, G., & Magal, M. (2018). General principles of exercise prescription. In *ACSM's guidelines for exercise testing and prescription* (10th ed., pp. 143-179). Philadelphia, PA: Wolters Kluwer Health.

# Mountain Climber Plank

Score 1

Poor asymmetric trunk stability in the transverse plane

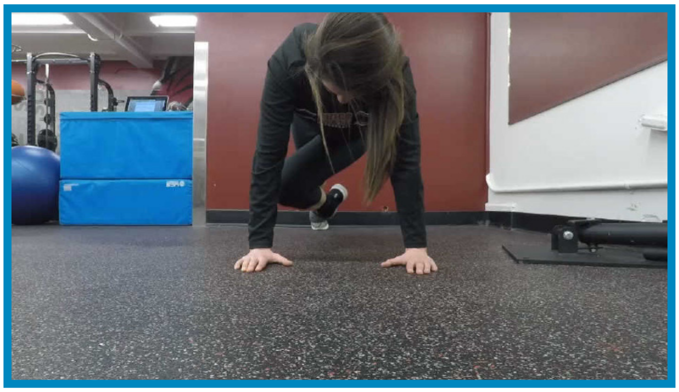
**Description:** In the plank position, flex one knee and hip to opposite side elbow while maintaining balance. Return flexed limb to starting position and alternate sides.

**Purpose:** Core strengthening and dynamic balance training

**Target Tissue:** Rectus abdominis and external oblique

**Prescription:** 20 repetitions x 2 sets

Figure 8.6 a.) Lateral view, b.) Cranial view



Sort: Level 1

Gottschall, J. S., Mills, J., & Hastings, B. (2013). Integration core exercises elicit greater muscle activation than isolation exercises. *Journal of Strength and Conditioning Research*, *27*(3), 590-596.

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Clark, A. W., Gedeke, M. K., Cunningham, S. R., Rockwell, D. E., Lehecka, B. J., Manske, R. C., & Smith, B. S. (2017). Effects of pelvic and core strength training on high school cross-country race time. *Journal of Strength and Conditioning Research*, *31*(8), 2289-2295.

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# Index

**Appendix A. SORT citation ratings for individual studies**

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **The middle grip (1-2x bi-acromial distance) is advantageous to activate the latissimus dorsi and improve strength.** | Anderson et al., 2014 | Patient-oriented (EMG activation) | Randomized, cross-over experimental design<br><br>Allocation concealed: Yes<br>Blinding:<br>Sample size: 16<br>Follow-up: 100% | 1 |
| **Scapular stabilization improves muscle strength, joint position sense, and prevent scapular dyskinesis.** | Buskurt et al., 2011 | Patient-oriented (Strength of RT cuff and scapular [hand held dynamometer] and joint position sense [inclinometer]). | Quasi-experimental design<br><br>Blinding: No<br>Sample size: 50<br>Follow-up: 80% | 1 |
| **Monster walks with resistance band placed around the feet create the highest gluteus medius activation.** | Cambridge et al, 2012 | Patient-oriented (EMG activation of gluteus medius and gluteus maximus) | Randomized, cross-sectional observational design<br><br>Sample size: 9<br>Follow-up: 100% | 2 |
| **Home-based core exercise (side bridge, bridge with leg lifts, swiss ball with trunk twists) programs increase trunk stability.** | Chuter et al., 2015 | Patient-oriented (core endurance [Sahrmann and SEBT] and dynamic stability [side bridge, flexor and Sorenson]) | Three-arm randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 78<br>Follow-up: 100% | 1 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **Swiss ball knee-up, roll out, and hip extension improve trunk stability.** | Clark et al., 2017 | Patient-oriented (isometric strength [hip abductor, hip adductor, hip extension, and core musculature]) | Randomized controlled trial (test-retest design)<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 35<br>Follow-up: 94% | 1 |
| **Superman produces high isometric erector spinae activation.** | Comfort et al., 2011 | Patient-oriented (EMG activity [rectus abdominis and erector spinae]) | Repeated-measures design<br><br>Allocation concealed: No<br>Blinding: No<br>Sample size: 9<br>Follow-up: 100% | 2 |
| **Prone arm extension, forward flexion in side-lying, external rotation in side-lying, and prone horizontal abduction with external rotation are superior exercises to balance upper/lower intramuscular trapezius strength ratio.** | Cools et al., 2007 | Patient-oriented (EMG activity [trapezius and serratus anterior]) | Cohort observational study<br><br>Sample size: 45<br>Follow-up: 100% | 1 |
| **Lack of flexibility and muscle dysfunction of the serratus anterior and lower trapezius are related to scapular dyskinesis.** | Cools et al., 2014 | N/A | Review | 3 |
| **Skier on swiss ball produce high (41-60%) MVIC EMG for abdominal obliques muscles.** | Escammila et al., 2010 | Patient-oriented (EMG activity [upper and lower rectus abdominus, external and internal obliques, latissimus dorsi, lumbar paraspinals, and rectus femoris]) | Repeated-measures design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 18<br>Follow-up: 100% | 1 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **Doorway hamstring stretch and towel/resistance band hamstring stretch improve hamstring tightness.** | Fasen et al., 2009 | Patient-oriented (hamstring length [knee flexion angle]) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 100<br>Follow-up: 87% | 1 |
| **Prone extension on swiss ball and swiss ball bridges improve thoracic kyphosis.** | Feng et al., 2017 | Patient-oriented (thoracic kyphosis angle) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 181<br>Follow-up: 91% | 1 |
| **Oblique crunch and mountain climber plank activate distal trunk musculature.** | Gottschalle et al., 2013 | Patient-oriented (EMG activity [anterior deltoid, rectus abdominus, external obliques, lumbar erector spinae, thoracic erector spinae, and gluteus maximus]). | Randomized, repeated-measures design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 20<br>Follow-up: 100% | 1 |
| **External rotation and adduction elongate the piriformis muscle.** | Gulledge et al., 2014 | Patient-oriented (hip joint ROM and piriformis length) | Cross-over experimental design<br><br>Allocation concealed: No<br>Blinding: No<br>Sample size: 7<br>Follow-up: 100% | 2 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **Static stretching and ankle self-stretching using a strap both improve ankle dorsiflexion.** | Jeon et al., 2015 | Patient-oriented (Active dorsiflexion ROM and passive dorsiflexion ROM) | Randomized controlled clinical study<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiners)<br>Sample size: 32<br>Follow-up: 100% | 1 |
| **Gastrocnemius stretching combined with talocrural joint mobilizations improve ankle dorsiflexion.** | Kang et al., 2015 | Patient-oriented (weight-bearing ankle dorsiflexion passive ROM) | Cross-sectional observational design<br><br>Sample size: 11<br>Follow-up: 100% | 2 |
| **Gravity assisted foam roller and quadruped thoracic extension reduce thoracic-kyphosis.** | Katzman et al., 2016 | Patient-oriented (angle of kyphosis [thoracic flexion]) | Randomized controlled trail (proposal) | 3 |
| **Foam roller stretch and prone dumbbell fly improve forward shoulders via lengthening the pectoralis muscles.** | Kluemper et al., 2017 | Patient-oriented (shoulder posture [distance acromion to wall] | Quasi-experimental design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 39<br>Follow-up: 100% | 1 |
| **Sensorimotor exercises improve effectiveness of strength training to improve anterior pelvic tilt.** | Ludwig et al., 2016 | Patient-oriented (anteversion angle of the pelvis) | Quasi-experimental design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 54<br>Follow-up: 100% | 1 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **Foam rolling improves tissue extensibility and ROM.** | Madoni et al., 2018 | Patient-oriented (hamstring ROM range of motion at hip joint) | Randomized, cross-over experimental design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 22<br>Follow-up: 100% | 1 |
| **Eccentric training improves hamstring flexibility.** | Nelson et al., 2004 | Patient-oriented (hamstring flexibility [90/90 test for knee extension]) | Randomized controlled trail (test-retest design)<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 81<br>Follow-up: 85% | 1 |
| **Foam rolling reduces arterial stiffness and improves vascular endothelial function.** | Okamoto et al., 2014 | Disease-oriented (brachial ankle pulse wave velocity, blood pressure, heart rate, and plasma nitric oxide concentration) | Randomized, cross-over experimental design | 3 |
| **The deadbug, birddog and criss-cross exercise activate trunk stability musculature.** | Pereira et al., 2017 | Patient-oriented (EMG activation [rectus abdominis, internal oblique, external oblique, multifidus]) | Cross-sectional observational design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 19<br>Follow-up: 100% | 1 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **The seated row and bent-over row increase latissimus dorsi strength.** | Ratamess et al., 2016 | Patient-oriented (peak isokinetic force for chest press and seated row) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 17<br>Follow-up: 100% | 1 |
| **Bar bell row increases strength and muscle development in upper back, posterior shoulder girdle and shoulder joint.** | Ronai et al., 2017 | N/A | Clinical recommendation | 3 |
| **Doorway pectoralis stretch improves forward head posture.** | Ruivo et al., 2017 | Patient-oriented (sagittal head, cervical and shoulder angle) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 130<br>Follow-up: 88% | 1 |
| **Lat-pull down is performed for 6 repetitions at 67-85% 1RM for 5 sets to improve strength.** | Snarr et al., 2015 | N/A | Review and clinical recommendation | 3 |
| **Monster walks and standing split squat exercises improve hip stability.** | Stastny et al., 2016 | N/A | Recommendations | 3 |
| **Resistance band hip flexor exercise improves hip flexor strength.** | Thorborg et al., 2016 | Patient-oriented (isometric hip flexor strength) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 33<br>Follow-up: 94% | 1 |

| Main Findings | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|
| **Medicine ball twist activates trunk musculature asymmetrically.** | Vera-Garcia et al., 2014 | Patient-oriented (EMG activity [seven trunk muscles, anterior deltoid, and pectoralis major]) | Cross-over experimental design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 13<br>Follow-up: 100% | 1 |
| **Self-administered hamstring PNF improves hip ROM.** | Wicke et al., 2014 | Patient-oriented (hip ROM) | Cross-over experimental design<br><br>Allocation concealed: Yes<br>Blinding: No<br>Sample size: 25<br>Follow-up: 76% | 2 |
| **Passive and active hip flexor stretching improve hip extension.** | Winters et al., 2004 | Patient-oriented (hip extension ROM [Thomas test]) | Randomized controlled trial<br><br>Allocation concealed: Yes<br>Blinding: Yes (examiner)<br>Sample size: 41<br>Follow-up: 80% | 1 |

**Appendix B. SORT citations' ratings scale for groups of studies**

| Main Findings | | Citation | Evidence Type (Dependent Variable) | Study Design | SORT |
|---|---|---|---|---|---|
| **Four Study Recommendation** | | | | | B |
| **The single leg squat improves hip stability.** | Single leg squat recruits high gluteal EMG activity and strengthens the muscle. | Boren et al., 2011 | Patient-oriented (EMG activation [gluteal medius and maximus]). | Cross-sectional observational design<br><br>Sample size: 24<br>Follow-up: 100% | 2 |
| | Single leg squat requires hip abductor function to perform well. | Crossley et al., 2011 | Patient-oriented (EMG activity [hip abduction, external rotation, trunk side bridge, and gluteus medius]) | Cohort observational design<br><br>Blinding: Yes<br>Sample size: 34<br>Sample spectrum: Broad<br>Consistent reference: Yes | 1 |
| | Single leg squat requires gluteal medius and maximus activation. | Mauntel et al., 2013 | Patient-oriented (Passive hip ROM and lower extremity muscle activation) | Quasi-experimental design<br><br>Allocation concealed: No<br>Blinding: No<br>Sample size: 40<br>Follow-up: 100% | 2 |
| | Single leg squat is performed for 8 repetitions on each leg for 3 sets to improve strength. | Presswood et al., 2008 | N/A | Review and clinical recommendations | 3 |