Season-Long Changes in Performance Outcome Measures Using a Functional Preparticipation Examination

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Abstract

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Background: The traditional preparticipation examination (PPE), which is required for high school athletes, has been implemented for decades to assist the safe participation of athletes in sport. The PPE is a multifaceted screen that includes a previous medical history review and a general health examination. The general health examination includes cardiovascular, neurologic and musculoskeletal assessments. The musculoskeletal assessment aims to detect predisposing factors of injury; however, it has been shown to only have 51% sensitivity. To help predict injury risk factors more accurately a functional preparticipation examination (F-PPE) was proposed. Purpose: The purpose of this study was to determine if there is a change in the F-PPE measures over the course of a season (pre-, mid-, and postseason). Methods: The F-PPE includes the impression Landing Error Scoring System (iLESS), Single-Leg Anterior Reach (SLAR), Single-Leg Hop (SLHOP) and ankle dorsiflexion range of motion (ROM) tests. This investigation used these 4 tests, and implemented them 3 separate times during an athletic season (pre, mid, post) to determine if they are sensitive to change over time. Results: The F-PPE was able to identify increases in dynamic postural stability, unilateral balance, trunk stabilization and flexibility in the SLAR and SLHOP tests. ROM did not change significantly and iLESS scores showed consistency throughout the athletic
season. **Conclusion:** The F-PPE should be added to preparticipation physicals and athletic programs to assist coaches and athletes in measuring performance during an athletic season.
Preface

Chapter 3 contained within the thesis document serves as a prepublication manuscript. This manuscript has been formatted to meet the guidelines set forth by the *Journal of Athletic Training* and Thesis and Dissertation Services at Ohio University. The heading and reference citation styles follow the guidelines of the AMA Manual of Style (10th ed., 2007).
Dedication

To my parents, John and Denise Sabol
Acknowledgements

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Chapter 1: Introduction

Preparticipation examinations (PPEs) in the high school setting involve a multifaceted approach designed to detect conditions and abnormalities in athletes that may predispose them to further injury.\(^1\) Most PPEs include a previous medical history screen and general health examination.\(^1\) Typically, the general health examination includes a cardiovascular, neurologic, and musculoskeletal assessment.\(^1\) According to the National Athletic Trainers Association (NATA) position statement, if an accurate history is taken, up to 90\% of musculoskeletal injuries can be identified.\(^1\) Traditionally, due to time and financial constraints, the functional aspect of the orthopedic examination has been quick and un-reliable.\(^1\)–\(^3\) To more accurately determine injury predispositions in athletes and measure performance changes throughout a season, a functional preparticipation exam (F-PPE) has been proposed.\(^1\)

The National Federation of State High School Associations recommends the use of PPEs as a routine part of all preseason examinations.\(^3\) This recommendation has been implemented across the United States, but little information is available to support its validity.\(^3\) This gap in the literature for the orthopedic screen presents an opportunity for athletic trainers to improve prediction and prevention practices.\(^3\)\(^4\) In an effort to bridge the gap in the literature, 4 functional screening examinations have been proposed to improve the accuracy of injury prediction while providing additional information to create successful injury prevention programs.\(^5\) The 4 functional assessments in the F-PPE include: the single-leg anterior reach (SLAR), single-leg hop for distance (SLHOP), the impression Landing Error Scoring System (iLESS), and ankle dorsiflexion range of
motion (ROM), each being the most validated test in its area after extensive research and comparison to other injury screening tests.  

**STATEMENT OF THE PROBLEM**

The current PPE format does not adequately identify injury risk in high school athletes. The tests being used are not reliable and have no data supporting their use. To be useful, PPE tests should be reliable and valid, cost effective and time sensitive; only then will PPE more accurately identify athletes who are at higher risk of injury and assure accurate measurement of performance throughout an athletic season.

**PURPOSE**

The purpose of this study was to determine if F-PPE values change over the course of a season (pre-, mid-, and postseason).

**RESEARCH QUESTIONS AND HYPOTHESIS**

1. Will outcomes measured by F-PPE tests change throughout the course of an athletic season?  
   a. Outcome measures will not change throughout a season.  
   b. iLESS (0-fail, 1-pass).  
   c. SLAR distance (cm % of limb length).  
   d. SLHOP distance (cm % of limb length).  
   e. ROM distance (cm % of limb length).  

**INDEPENDENT VARIABLES**

1. Time  


d. Group.

e. Football.

f. Volleyball.

**DEPENDENT VARIABLES**

1. iLESS (0-1).
   a. Bilateral SLAR (cm % of limb length).
   b. Bilateral SLHOP (cm % of limb length).
   c. Bilateral dorsiflexion ROM (cm % of limb length).
   
a. For single-leg tests, peak performance leg will be used for analysis.

**ASSUMPTIONS**

1. Participants will be honest in all questionnaires.
2. Participants will give their best effort in each test during all 3 testing trials.
3. Participants will not knowingly change their biomechanical motions during any of the functional tests.
4. The instructions will be given verbally and consistently to each participant before practice trials commence.
5. Real-time analysis of iLESS will be consistent for each participant by a trained clinician.
6. Test implementation will occur approximately at same time of day for each session.
LIMITATIONS

1. The results of this study cannot be generalized to collegiate or professional athletes.

2. All raters were not available for all data collection.

DELIMITATIONS

1. Participants were athletes at New Lexington High School who were healthy active members of their sports teams.

2. Measurements were obtained during 3 separate testing sessions.
Chapter 2: Review of the Literature

INTRODUCTION

Preparticipation examinations (PPEs) in the high school setting involve a multifaceted approach to detect conditions and/or abnormalities in athletes that may predispose them to further harm. Most PPEs include a previous medical history screen and general health examination. Typically, the general health examination includes some combination of cardiovascular, neurologic, and orthopedic assessments. According to the NATA position statement, during the orthopedic screening, if clinicians take an accurate history, 90% of musculoskeletal injuries can be detected. Traditionally the functional part of the orthopedic examination has been quick and unreliable. In order to more accurately determine injury predispositions in athletes and measure performance throughout a season, a functional preparticipation exam (F-PPE) has been proposed. This literature review will discuss the traditional PPE and its detriments, the proposed F-PPE, including all its components and, finally, how the data collected will help the sports medicine field.

TRADITIONAL PREPARTICIPATION EXAMINATION

The traditional PPE is used in many states for detecting and preventing injuries. While it is widely used and implemented at all levels of competition, its effectiveness and ability to generate valid results has little evidence. The lack of supporting evidence for the PPE is compounded by the lack of consistent implementation. The PPE does not have a standardized format for implementation, a problem that has raised questions by experts and medical professionals alike. Some of the issues with inconsistency include:
training of professionals conducting the examinations; paper questionnaires used during the previous medical history screen; and, mandating PPEs in every state at all levels of competition. A study conducted by Matheson et al.\textsuperscript{3} gathered histories of 1693 NCAA D-1 athletes to help determine the effectiveness of injury detection during the medical history screen. Researchers collected information about unresolved injuries at the time of screen, total time lost due to injuries, and frequency of positive responses to the American Heart Association (AHA) questions.\textsuperscript{3}

Out of the large number of athletes who participated, 78.3\% reported having a current or recently resolved injury.\textsuperscript{3} In all, 3126 injuries were reported to be present at the time the health questionnaire was given.\textsuperscript{3} In addition to the large number of injuries reported, 11\% of all injuries were claimed to not be resolved.\textsuperscript{3} With so many injuries at the time of implementation, many of which were unresolved and 9\% of which were head injuries, it is difficult to assess these athletes accurately using the traditional PPE because they already will have deficits at the time of testing.\textsuperscript{3} In an ideal world, athletes would be symptom free at the time of implementation, but this is not the reality. The report by Matheson et al.\textsuperscript{3} showed that PPE questionnaires are not reliable and are poor in predicting injury and prevention. This due, at least in part, to the high possibility that an injury is already present. This calls for a more specifically worded questionnaire to help athletes and health care professionals alike to evaluate athletes in the preseason.

A consensus statement involving the American College of Sports Medicine and International Federation of Sports Medicine, also expressed concern for the lack of standardization of the implementation of PPEs.\textsuperscript{8} They discussed the problems with how
the examinations are conducted and also referred to other problems. Recently, the updated PPE was presented (PPE-4) in order to help with the standardization issue; while some states have complied with haste, others have been slow or refuse to change. The varied responses could be due to many factors including but not limited to: socioeconomic status, cost of screening, access to health care providers, level of participation, and regulations of the state or region. While much discussion has centered on echocardiogram screening, other parts of the exam need to be addressed as well. Specifically the orthopedic screen during the PPE is simply a 2-minute evaluation with a toe-walk, duck-walk, and heel-walk to determine “functional” ability of the athlete. The orthopedic examination is a vital aspect of the PPE for athletics, aiming to help keep athletes on the field rather than not knowing what they are at a higher risk for and allowing them to sustain more injuries.

An ideal PPE will be athlete focused and designed to detect and properly treat important conditions in a cost effective manner. The functional portion of the orthopedic examination is not extensive enough to detect and therefore prevent injuries. The issue with orthopedic examination is that this part of the examination has a low sensitivity and high specificity, meaning that even if the orthopedic examination notes the absence of a condition, there is still a high possibility that it could be present. If the test has a high specificity, when it rules in a condition, it is likely the condition is present. A PPE needs to have both high sensitivity and high specificity to be a valid preseason diagnostic tool for medical professionals. To this point in the literature, there is little evidence supporting the validity of the traditional 2-minute PPE to predict and, more importantly, prevent
injuries.\textsuperscript{2,5–7} In addition, there is no literature examining the changes in performance of high school athletes using a functional screening examination. If implemented correctly, it can be a used to improve patient outcomes and even track how athletes’ bodies are sustaining the everyday load of sport throughout a season.\textsuperscript{6} No expenditures are needed to create this type of screen. A few tests that are valid, reliable and have data backing up their accuracy need to be used in order to answer the questions put forth in the consensus statement.\textsuperscript{2}

**FUNCTIONAL PREPARTICIPATION EXAMINATION**

The National Federation of State High School Associations aims for PPEs to be a routine part of all preseason examinations for athletes.\textsuperscript{5} As stated earlier, there is little information to support the efficacy of the traditional PPE and its ability to detect and prevent injuries.\textsuperscript{5} This lack of support presents a chance for change; the consensus statement made clear that it is needed.\textsuperscript{4,5,8} Meister et al\textsuperscript{5} proposed the aforementioned four functional tests to improve the effectiveness of PPEs and overall increase the accuracy of prospective injury prediction and, in case a predisposition is found, a more individualized prevention plan. The F-PPE includes: the single-leg anterior reach (SLAR), single-leg hop for distance (SLHOP), the impression Landing Error Scoring System (iLESS), and ankle dorsiflexion range of motion (ROM) assessment, will each be described and discussed.

**Landing Error Scoring System (LESS)**

The biomechanics in sport-specific activities can be indicative of whether or not an injury will be sustained.\textsuperscript{9} The iLESS is based on the LESS test, which was developed
to assess biomechanics during jumping. It is important to support the validity of this test because the scored errors from each athlete’s jump are subjective based on the discretion of the clinician. A systematic review of numerous articles involved in the accuracy of the LESS test aimed to determine if clinicians can score the LESS test reliably in individuals who perform a jump landing. In the search criteria, investigators limited the results to English studies conducted in the past 5 years and studies that specifically investigated the interrater reliability of LESS. Only 3 studies met the search criteria because they had to have a level 3 of evidence or higher. Of the 3 studies, 2 used video data analysis, while 1 used the iLESS in real-time. When determining the interrater reliability of a diagnostic test, an intraclass coefficient (ICC) is computed, which describes the amount of variability that occurs between scores. This ICC is presented on a numbered scale between 0.0 and 1.0. On this scale, anything above .8 is very good, .4 to .8 is good and below .4 is poor.

As stated previously, the LESS is subjective, but each of the 3 studies determined that clinicians are reliable at scoring the LESS while having excellent validity. To perform the LESS test, the drop jump must be performed from a box at least 30 cm high. After landing on a designated platform, an immediate vertical jump for height is performed and it is from this point the observation takes place with no instruction or feedback from the clinician. Each landing style is graded on 17 different aspects, each of which is graded with a 0-3 score and then tallied to elicit an overall score. Anything lower than a final score of 4 is considered excellent, while scores above 6 are poor and identify individuals who were more at risk for sustaining injury.
al showed that the LESS is an adequate screening tool to identify individuals at higher risk for sustaining lower-extremity injury, especially anterior cruciate ligament (ACL) injuries. All 3 studies showed that LESS has high validity when aiming to identify the high-risk individuals. These studies reported that the overall LESS-real-time (LESS-RT) scores had good interrater reliability (ICC 0.72–0.81) and precision. The standard error of measure (SEM) ranged from 0.69 to 0.79.

As stated previously, the LESS is a valid way of identifying lower extremity injury and, specifically, it can identify athletes who are more likely to sustain an injury to the ACL. ACL injuries are common in athletes in all sports and can be more common in individuals with other predisposing factors such as age, gender, anatomical structure, and biomechanics. A study performed by Padua et al10 aimed to further dissipate the need for a standardized tool to screen for ACL injuries by validating the LESS in its ability to detect abnormalities in movement. The authors, using the LESS, hypothesized that they would be able to differentiate between normal and abnormal joint kinematics in the 3 major directional planes (sagittal, coronal and transverse). As with other studies, they analyzed the jumps using 2-D video analysis. Each participant was required to jump from the standard height of 30 cm onto a force platform. This particular study also required participants to jump away from the platform to a distance of 50% of their height followed by a maximum vertical jump. The researchers gave no feedback on landing technique, unless the movement was performed incorrectly. A successful jump was considered to be one that included all of the following: jumping forward off box with both feet, landing on the force plate from which a maximal vertical jump is conducted.
immediately, and landing with dominant foot on the force plate and nondominant foot off the force plate.\textsuperscript{10}

After video analysis, Padua et al separated the participants’ results into excellent, good, moderate and poor. The distinction was based on the results of the LESS score associated with each participants’ performance and ability to jump and land correctly.\textsuperscript{10} The values associated with each labeling corresponded as follows: a poor score was anything greater than 6; a moderate score was between 5 and less than or equal to 6; a good score was greater than 4 or less than or equal to 5; and a score of less than 4 was considered excellent.\textsuperscript{10} The authors wanted an unbiased interrater and intrarater reliability of the LESS so they had 50 participants (25 male, 25 female). To determine intrarater reliability, they had one rater (who was blinded to the original data) grade the LESS scores based on the video analysis.\textsuperscript{10} To determine the interrater reliability, they took a second rater to determine the LESS scores based on the same data as the first rater. This rater was also blinded to the previously recorded data. After video and data analysis, the ICC and SEM values for intrarater and interrater reliability were 0.91, 0.42 and 0.84 and 0.71, respectively.\textsuperscript{10} These figures indicate that the interrater reliability was good, and the intrarater reliability was excellent. The actual numerical data involving the LESS scores indicated a few important findings. The overall mean of LESS scores was 4.92 for the entire sample. The female sample in the study was found to have worse LESS scores than the men. Of the entire sample of women, only 14% were in the excellent LESS score group whereas 36% of women were in the poor group, significantly higher than the 23% of men in the poor group.\textsuperscript{10} This study supports the validity of the LESS scoring system.
It also brings attention to the performance of women versus men during these testing screens, not for this test specifically but overall for the entire study.

**Impression Landing Error Scoring System (iLESS)**

The previous information illustrated that the LESS is reliable and valid. The iLESS is a simplified version of the LESS in which the rater gives a score based on real-time analysis and gives a simplified score of a 0 or 1. Cortes and Onate\textsuperscript{11} discussed the differences between iLESS and LESS. The iLESS is scored numerically like the LESS, but the analysis is different. As described in previous literature the LESS is analyzed in the sagittal and frontal planes with a 2-D camera.\textsuperscript{5,9,10,11} The iLESS, in contrast, involves real-time analysis. This is the direct assessment by the clinician without the use of video cameras.\textsuperscript{11} While it may be a negative concept to not have the benefits of a video camera, in sports PPE settings, this method is more efficient in its ability to screen many athletes in a short time period. The assignment of correlated scores during analysis of the iLESS are dichotomous and are 0 and 1; this simplified scoring system adds to the efficiency of the test. Cortes and Onate\textsuperscript{11} aimed to assess the ability of the iLESS in comparison to the standard LESS using expert and novice raters.\textsuperscript{11} The methodology of the drop jump landing was similar to Padua et al.\textsuperscript{10} From a larger pool of previously collected data, they took a sample of 20 Division 1 soccer athletes video analyses from the LESS. The iLESS analysis, which aims to be concise, only took a quick view of the frontal plane videos. After a quick analysis, the researchers gave either a 1 or 0 rating, the majority of which was based on the amount of movement at the knee (due to increased knee valgus angles correlation with higher risk of ACL sprains). To determine agreement in the iLESS
scoring, the novice and expert raters both evaluated the videos separately and without communication.

A kappa statistic was used to grade the agreement rate between raters. During the iLESS analysis, there was only a difference in score for two of the participants, whereas the differences in scores on LESS scoring differed in five instances.\textsuperscript{11} The kappa scores for the iLESS compared to the LESS for expert (iLESS vs LESS) and novice (iLESS vs LESS) were: 0.692 compared to 0.500, and 0.600 compared to 0.583, respectively.\textsuperscript{11} Lower kappa levels show a higher level of agreement and this study showed that the highest agreement was for the iLESS (90\%) and the lowest for the LESS (80\%).\textsuperscript{11} This study was beneficial in verifying the consistency for both the LESS and iLESS. Although the expert rater in this study was one of the creators of the LESS, they did various things to blind the researchers and keep the bias level to a minimum.\textsuperscript{11} The study also shows that with basic amounts of training, a novice rater with little prior knowledge of the test is able to learn what is important to look for during video analysis.\textsuperscript{11} The training session required for the novice rater only took 60 minutes; therefore, it was time efficient without sacrificing quality.\textsuperscript{11} This study repeatedly referred to the time constraints of the LESS compared to the iLESS. These time constraints deter researchers from collecting data in short periods of time, so moving forward it needs to be determined in each specific setting which scoring system is most beneficial.\textsuperscript{11}

Harris-Hayes et al\textsuperscript{12} found similar results in the ability of novice raters to reliably analyze the lower extremity movement patterns during a drop-jump task. The kappa statistics for each clinician ranged from 0.80 to 0.90 and 0.75 to 0.90, respectively.\textsuperscript{12}
Throughout the study, although the clinicians with more experience had higher intrarater reliability, there was much agreement between the novice and experienced clinician, indicating the novice raters are capable of accurate data collection.\textsuperscript{12} This study has many conclusions similar to previous literature. They state that the interrater reliability is only valid when the standardized method of analysis is being used (iLESS). The standard training for iLESS is time efficient and can be learned quickly by a clinician familiar with the sports medicine field.\textsuperscript{12} Due to the accessibility and ease of analysis education, it makes this a feasible method of assessment in large research studies and screens.

**Single-Leg Anterior Reach (SLAR)**

The SLAR aims to assess postural stability. This assessment has been adopted from the traditional Star Excursion Balance Test (SEBT).\textsuperscript{5} The SEBT, which has a strong interrater and intrarater reliability, has been used as a valid method of detecting chronic ankle instability and functional ROM deficits.\textsuperscript{5} The original SEBT consisted of 8 parts, of which only anterior, posterior, medial and lateral directions were found to stress postural control.\textsuperscript{5} A study conducted by Plisky et al\textsuperscript{13} found that high school basketball players who had an anterior reach length of 94\% or less of their limb length were at an increased risk of 6.5 times that of someone who did not.\textsuperscript{13} In addition, in the same cohort of athletes, they found that athletes who had 4 cm or greater difference between right and left reach distances had a 2.5 times greater chance of sustaining an injury.\textsuperscript{5,13} Therefore, it has been established that for a large-scale research project or screen using only the anterior reach portion of the SEBT and Y-Balance Test is a valid, concise, and time efficient way of assessing many participants while being concise.
Plisky et al\textsuperscript{13} surveyed boys and girls in 7 high schools. Each participant was given a questionnaire, which revealed any pertinent information while also viewing a video describing the correct method of performing the SEBT. In previous studies\textsuperscript{13–17} a learning effect was found when participants were given 6 trials or more, which was followed by a plateau. The SLAR results for each participant were recorded and the best of 3 trials were used for data collection. The results were not recorded if the participants committed one of the following errors: failing to keep one-legged balance, moving of stance foot from designated area, completely weight bearing of reach foot or failing to reach back to starting position.\textsuperscript{13} All measures used for data collection were compared to each individual’s leg length, bilaterally.\textsuperscript{16} The purpose of Plisky’s study was to determine if the SEBT would be able to predict injuries in high school athletes, specifically lower extremity (LE). They found that when the right reach distance was decreased in relation to left distance in the anterior direction, there was a higher prediction of LE injury. The findings were consistent with a previous study\textsuperscript{18} but inconsistent with others.\textsuperscript{14,15,17,18} A possible explanation is the assumption that an imbalance in one limb is correlated with a higher risk of injury in that limb, as in the contralateral limb too. This assumption was made due to the implications that an unstable limb has on higher injury risk. An unstable limb has decreased ability to react, creates an unstable base, and is subjected to a more excessive force due to the biomechanical compensations made by the kinetic chain.\textsuperscript{16} The other reason for the inconsistency between studies could be due to that lack of consideration of other factors for each participant. Other biomechanical factors such as flexibility, strength or previous injury need to be considered. It is also important to
remember that these factors and the data collected need to be compared by sex. Differences in males and females did exist. Females who had a reach of 94% or less of the leg length were 6 times more likely to sustain a LE injury, whereas the identical measure in males was not significant.\textsuperscript{16} This finding is important in the factor of neuromuscular control. Previous literature has shown,\textsuperscript{13–16} especially in high school basketball, that females are much more likely to sustain an injury when compared to their counterparts. This high rate of injury has been identified by the previous literature as a problem associated with neuromuscular control. Based on the literature, and the findings in this study, the SEBT is a reliable device in measuring neuromuscular control, in addition to the other measurements already discussed in this review.\textsuperscript{16}

In a systematic review conducted by Gribble et al,\textsuperscript{14} literature supports the use of the SEBT to effectively screen for lower extremity postural control deficits. It has been shown to exploit deficits from use of external devices, fatigue and intervention programs. Its effectiveness in predicting lower extremity injury and sensitivity to the aforementioned factors allow it to be a tool for implementation in the clinic. In addition to being reliable, its efficiency in time also adds to the practicality of use in the clinic or large screens.\textsuperscript{14} It is also important to consider the variability in sport, age, sex and competition level. If more research in the future focuses in this area, the data can help normalize results found in studies and reviews such as this.\textsuperscript{14}

**Single-Leg Hop (SLHOP)**

The SLHOP test described by Noyes et al\textsuperscript{19} is a standardized test that assesses the patient’s ability to jump from a single-legged position and maintain postural stability
throughout the movement. The test itself is an objective measurement in order examine lower extremity functional deficiencies.\textsuperscript{19} In all single-leg tests, a limb symmetry index of 85\% or more was considered normal for both males and females. This index does not consider side dominance, activity level and or specific sport of play. Noyes et al\textsuperscript{19} aimed to further evaluate the SLHOP and its sensitivity level with a higher sample size. They also aimed to compare this test with a timed-hop, triple hop and cross-over hop test. Lastly, they aimed to determine the most sensitive tests to use in correlation with manual muscle test, ligamentous tests, and selective tissue tests to better advance the evaluation process. They tested 67 patients, out of which 52\% presented with abnormal limb symmetry on the SLHOP. Of the 67 participants, when the timed hop test was administered, 49\% demonstrated abnormal limb symmetry. This showed that when only one test was considered, the participants that had abnormal limb symmetry ranged from 49-52\%, whereas when both tests were considered the percentage increased to 62\%. This gives evidence that during an evaluation process, a number of tests should be considered to rule in or rule out a condition, based on their sensitivity and specificity.\textsuperscript{19} Based on the sensitivity and specificity of the SLHOP and timed hop, they should only be used as confirmation tests to rule in a condition. The specificity, false-negative rate, false-positive rate, positive predictive value and negative predictive value were all reported for the SLHOP. They were reported as 97\%, 48, 3, 92 and 74, respectively.\textsuperscript{19} These numbers indicate that the SLHOP is able to detect limb abnormalities and lower extremity deficiencies, but is not able to detect the specific abnormality or deficiency. Overall, Noyes et al\textsuperscript{19} found that the high specificity and low false-positive rates allow this test to
confirm limb abnormality. In a study examining the differences in SLHOP scores based on sex, Harrison et al. aimed to measure the differences between males and females on the SLHOP test. Impaired biomechanics and neuromuscular control have been proposed as links to patellofemoral pain syndrome in young athletes. They tested 109 healthy high school aged soccer players; 49 of whom were girls and 60 boys. Their tasks for this study were to kick a soccer ball as far as possible and perform repeated vertical jumps. They were given an adequate amount of practice trials. A counterbalance testing order was conducted to avoid any potential order effect. The results of the study showed significant single-leg force production and force attenuation differences between the sexes. The ground reaction forces for the females were much higher in the dominant leg than the males in addition to the females experiencing greater force loading during the tasks. The results of this study showed that healthy female athletes experienced difficulty with force attenuation while exposing themselves to higher ground reaction force during activity. These two factors put females at a higher risk for injury and highlight the need for increased research in this area in addition to increased neuromuscular training in healthy and unhealthy female populations.

Logerstedt et al. examined the SLHOP’s ability to predict self-reported knee function 1 year after ACL surgery. The SLHOP is a performance-based measure to assess the strength, coordination and postural control of the body. Single-leg tests have also been able to show if athletes are able to return to their previous level of play after an ACL reconstruction. Other information single-leg tests can give is limb deficits and the
difference in performance bilaterally. The purpose of their study was to determine the ability of single-leg tests to predict self-reported knee function after ACL construction.\textsuperscript{21}

They used 120 participants who all underwent reconstruction and were involved in initial rehabilitation to address muscle impairments. After the preoperative rehabilitation was finished, they conducted 4 single-leg hop tests. As Harrison et al\textsuperscript{20} stated, these single-leg hop tests have been found to be reliable test-retest measures in young adults and normal populations. This study found that the preoperative hop tests did not significantly predict the self-reported knee function after 1 year post-op. However, the hop tests conducted 6 months after the surgery had a significant effect on the predicted self-reported knee function. This study is helpful to validate these single-leg hop tests because self-reporting measures are used commonly to measure knee function. Low knee function on questionnaires has been correlated with athletes’ fear of a return to play and fear of reinjury. Overall, these tests have implications for how decisions are made in the clinic when used in the correct manner.

A similar study conducted by Reid et al\textsuperscript{23} found similar results while testing 4 hop tests during 3 separate points. They emphasized the importance, in standardized testing of producing standardized outcome measures for clinicians to make valid decisions. With the help of these 4 tests, and limb symmetry index, individuals who are lacking dynamic knee stabilization can be identified. These can be used at all points of the rehabilitation process as a tool for measurement and progress tracking. The authors used a prospective observational study with repeated measures. The study included 42 participants who underwent unilateral ACL surgery using a semitendinosus graft.\textsuperscript{23} Each of the
participants were tested using the 4 hop tests 3 times within 16 weeks of surgery. They completed a fourth testing session 22 weeks post-op. The SLHOP had an ICC of .92 with an SEM of 3.49. The reliability for the SLHOP reported in the study via SEM and ICC were both very high. Among the hop tests assessed, the SLHOP is a reliable means of gaining information about any athlete in their function and self-reported symptoms.\textsuperscript{23}

**Ankle Dorsiflexion Range of Motion (ROM)**

Lateral ankle sprains are a very common lower extremity injury that also has a high reinjury rate.\textsuperscript{23–27} These injuries are accompanied by pain, decreased range of motion, swelling, and functional impairments. These impairments in static and dynamic balance can affect athletes performance and cause chronic ankle instability (CAI).\textsuperscript{28} The authors of this study aimed to assess the relationship between the weight bearing ankle dorsiflexion ROM test and portions of the SEBT. They recruited 45 participants who reported unilateral or bilateral CAI. Following the administration of questionnaires, the same researchers were used to determine the consistency of ratings while conducting the ROM and SEBT. Ankle dorsiflexion has been shown to affect dynamic balance. The variance in results of the SEBT and ROM could not be explained solely by ankle dorsiflexion, meaning other factors must come into play. Other factors that may be affecting these tests are hip and knee ROM and strength, and neuromuscular control. Many things must cooperate to allow proper lower extremity biomechanics, but decreased dorsiflexion is a major contributor to an increased risk of injury. Asymmetry of 4 cm or more when compared bilaterally has been shown to be a threshold for higher injury risk. This study provides some insight into relationships between ROM and
dynamic balance, but cannot be generalized to an entire population.

The weight-bearing lunge test has shown a relationship between ROM and dynamic balance as stated by Reid et al. A study conducted by Chisholm et al. aimed to validate the ROM test. Participants were recruited from physical therapy offices; all were above 18 years of age. During the first visit, the participants were given a demographic sheet to record pertinent information. The dorsiflexion ROM test was conducted with descriptive detail, including having the unaffected foot placed forward, with the big toe in the middle of the tape measure. While having 2 hands on the wall, and 2 stationary feet and with the heel constantly being in contact with the ground, the participant aimed for the knee to contact the wall while lunging forward. It was considered successful if the knee contacted the wall without the heel moving. If the movement was successful the foot would be moved back and the attempt would be conducted again. Up to 5 trials would be given for each participant and the farthest distance reached would be recorded as a single measurement for data collection. The participants were also given 2 reports of self-measurement with each session to give the researchers more information about their functionality. Three sessions occurred to allow the authors to evaluate the test-retest reliability. On the affected leg, the mean ICC of the three tests was .99 while on the unaffected leg it was .94. The validity of the ROM test was based on effect size and SRM scores, which ranged from 0.70-0.73 and 0.99-1.00, respectively. This study has shown that the ROM test is efficient in obtaining a reliable score for the lunge test.
Chapter 3: Season-Long Changes in Performance Outcome Measures Using Functional Preparticipation Examination

**Context:** The current preparticipation (PPE) format does not adequately identify injury risk in high school athletes. If tests were found to be reliable and valid, cost effective and time sensitive, the PPE could more accurately determine athletes who are at higher risk of injury and performance values could be measured throughout an athletic season.

**Objective:** To determine if there is a change in the functional preparticipation examination (F-PPE) measures over the course of a season (pre-, mid-, and postseason).

**Design:** Repeated measures.

**Setting:** High school.

**Participants:** During the fall data collection period, seventeen male football players (16.3 ± 1.1 years, 177.6 ± 7.4 cm, 83.6 ± 14.2 kg) and 13 female volleyball players (15.4 ± 0.9 years, 162.8 ± 7.7 cm, 68.3 ± 19.5 kg) participated in 3 testing sessions. Individuals who sustained a time-loss injury during the season were excluded.

**Data Collection and Analysis:** The F-PPE includes the impression Landing Error Scoring System (iLESS), Single-Leg Anterior Reach (SLAR), Single-Leg Hop (SLHOP) and Ankle dorsiflexion range of motion (ROM) tests. This investigation will use these 4

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1 This chapter represents a prepublication manuscript to be submitted to the Journal of Athletic Training (May 2017). Authors are: Todd C. Sabol, AT (School of Applied Health Sciences and Wellness, Ohio University, Athens); Dustin Grooms, PhD, AT, CSCS (School of Applied Health Sciences and Wellness, Ohio University, Athens); Jae Yom, PhD, CSCS (School of Applied Health Sciences and Wellness, Ohio University, Athens); James Onate, PhD, AT, ATC, FNATA (School of Health and Rehabilitation Sciences, The Ohio State University, Columbus); Janet Simon, PhD, AT (School of Applied Health Sciences and Wellness, Ohio University, Athens).
tests, implement them 3 separate times during an athletic season (pre, mid, post) to determine if they change throughout the fall season.

**Results:** The SLHOP improved by 7% for both right and left legs, and the SLAR improved 10% for the left leg and 11% for the right leg. These changes were noted between pre- and postseason time points. All other comparisons did not reach statistical significance.

**Conclusions:** The F-PPE was able to identify increases in dynamic postural stability, unilateral balance, trunk stabilization and flexibility in the SLAR and SLHOP tests. ROM did not change significantly and iLESS scores showed consistency throughout the athletic season.

**Key Words:** single-leg hop, SLHOP, single-leg anterior reach, adolescent athlete

**Key Points**

- Single-leg hop improved for both right and left legs over the course of one athletic season.

- Single-leg anterior reach improved for both right and left legs over the course of one athletic season.

- Adolescent males performed better on the single-leg hop and anterior reach compared to female adolescents.
Preparticipation examinations (PPEs) in the high school setting involve a multifaceted approach designed to detect conditions and abnormalities in athletes that may predispose them to further injury.\(^1\) Most PPEs include a previous medical history screen and general health examination.\(^1\) Typically, the general health examination includes cardiovascular, neurologic, and musculoskeletal assessments.\(^1\) According to the National Athletic Trainers Association (NATA) position statement, if an accurate history is taken, up to 90\% of musculoskeletal injuries can be identified.\(^1\) Traditionally, due to time and financial constraints, the functional aspect of the orthopedic examination has been quick and unreliable.\(^1\)–\(^3\) To more accurately determine injury predispositions in athletes and measure performance changes throughout a season, a functional preparticipation exam (F-PPE) has been proposed.\(^1\)

The National Federation of State High School Associations recommends PPEs be a routine part of all preseason examinations.\(^3\) While this recommendation is implemented across the United States, little information is available to support its validity.\(^3\) This gap in the literature for the orthopedic screen presents an opportunity for athletic trainers to improve prediction and prevention practice.\(^3\) In an effort to bridge the gap in the literature, 4 functional screening examinations have been proposed by Meister et al\(^4\) to improve the accuracy of injury prediction while providing additional information to create successful injury prevention programs. The 4 functional screens encompassing the F-PPE include: the single-leg anterior reach (SLAR), single-leg hop for distance (SLHOP), the impression Landing Error Scoring System (iLESS), and ankle dorsiflexion
range of motion (ROM) assessment, each being the most validated test in its area after extensive research and comparison to other injury screen tests.4

The current PPE format does not adequately identify injury risk in high school athletes. The tests being used are not reliable and have no data supporting their use. If tests were found to be consistent in implementation, cost effective and time sensitive, the PPE could more accurately determine athletes who are at higher risk of injury and performance values could be measured throughout an athletic season. The purpose of this study was to determine if F-PPE is able to assess measures over the course of a season (pre-, mid-, and postseason).

METHODS

Participants

During the fall data collection period, 17 male football players (16.3 ± 1.1 years, 177.6 ± 7.4 cm, 83.6 ± 14.2 kg) and 13 female volleyball players (15.4 ± 0.9 years, 162.8 ± 7.7 cm, 68.3 ± 19.5 kg) participated in 3 testing sessions. In the football participant group, there were 7 seniors, 7 juniors, 2 sophomores, and 1 freshman. In the volleyball participant group there were 5 freshmen, 4 sophomores, 3 juniors, and 1 senior. Individuals who sustained a time-loss injury during the season were excluded or underwent a lower extremity surgery within the previous 6 months were excluded from the study.

Procedures

Data collection period occurred between August and November 2016. Fall sports including football and volleyball were used for data collection. Four assessments were
completed called the F-PPE. The F-PPE contains 4 functional tests, which have been validated to use as predictors of injury: the SLAR, SLHOP, iLESS, and ROM. The implementation order of each test was randomized for each participant. They were given a medical history sheet to provide information about past injuries. This form was adopted from the Ohio High School Athletic Association form. The assent and parent consent forms were obtained for those under 18 and informed consent for anyone aged 18. Ohio University’s IRB approved this study. Demographic information including age, sex and sport were provided on a demographic questionnaire. Bilateral limb length was taken via the true leg length special test.5

The iLESS test assessed jump-landing mechanics of the athletes. The participants were instructed to drop down from the elevated surface onto a specified area on the floor, where they must immediately jump straight up with maximal effort (see Figure 1).4 Three trials were given and a trained clinician analyzed drop-jump landings. High level of agreement for both tests between an expert (E) and novice (N) yielded these results: iLESS (E vs N) 90%; LESS (E vs N) 80%; Expert (iLESS vs LESS) 75%; Novice (iLESS vs LESS) 85% agreement. Therefore the iLESS is a valid means of assessing functional performance without the need for the rater or participant to have an extensive training background.4
The SLAR assessed single-leg dynamic postural control. It was conducted 3 times; the maximum performance was used for analysis. The participant had 1 foot planted on a designated area; when instructed, the participant reached anteriorly to maximal reach distance while keeping balance. While reaching forward the participant maintained balance and did not transfer weight onto the reach foot, only tapping the toe and returning to the starting position while maintaining postural stability throughout (see Figure 2). This measurement was repeated 2 more times; the scores were normalized to limb length (anterior iliac spine to the center of the ipsilateral medial malleolus). Participants completed the test bilaterally. The intrarater reliability ranged from 0.85-0.91, while interrater reliability 0.99-1.0, showing good-to-excellent reliability when using standardized equipment and methods.
The SLHOP assessed single-leg power production and landing ability. It was performed 3 times and was performed bilaterally. The participant aimed to jump forward on 1 leg to maximal distance, but if the balance was lost, or other leg or arm touched the ground, the attempt was not counted (see Figure 3). The SLHOP has an ICC between 0.82-0.93.\textsuperscript{6} Series of hop tests provide a reliable and valid performance based outcome measure.\textsuperscript{6}

\textbf{Figure 3.} Single-leg hop procedure.

The ROM test assessed closed chain ankle range of motion. Participants were barefoot and asked to face and stand a few inches away from a wall marked with a tape measure; the great toe and heel were aligned with the tape measure, while the contralateral ankle was behind it in a tandem stance position.\textsuperscript{4} Participants were instructed to lunge towards wall with goal of hitting the anterior portion of the knee on the wall while keeping the associated heel on the ground.\textsuperscript{4} If achieved, the participant moved back 1 cm and the same procedures were repeated (see Figure 4).\textsuperscript{4} The ROM measurement was taken 3 times. The farthest distance was used for data collection.\textsuperscript{4,7} The ROM test has an ICC: 0.91, standardized response mean (SRM) 0.99-1.00.\textsuperscript{8}
Figure 4. Ankle dorsiflexion ROM procedure.

Statistical Analysis

The dependent variables were SLAR-normalized distance for right and left legs, SLHOP-normalized distance for right and left legs, ankle ROM for right and left legs, SLAR symmetry, SLHOP symmetry, and ankle ROM symmetry. The independent variables were time (pre-season, mid-season, and post-season) and group (football and volleyball). Two separate multivariate repeated measures ANOVA were conducted. The first multivariate repeated measures ANOVA was conducted for SLAR-normalized distance for right and left legs, SLHOP-normalized distance for right and left legs, and ankle ROM for right and left legs. The second multivariate repeated measures ANOVA was for SLAR symmetry, SLHOP symmetry, and ankle ROM symmetry. Follow up one-way repeated measures ANOVAs were conducted if the individual multivariate test was significant. The alpha level was set a priori at $P < 0.05$ for all analyses.

RESULTS

SLAR, SLHOP and ROM

The multivariate repeated measures ANOVA for normalized SLAR, SLHOP, and ankle ROM was significant for time ($F = 4.83_{(12,17)}, P = 0.002$) and group ($F = 3.11_{(6,23)},$
The interaction time*group was not significant ($P = 0.585$). Descriptive statistics for SLAR, SLHOP and ROM over time are presented in Table 1 and by group in Table 2. Follow up one-way repeated measures ANOVAs indicated 4 dependent variables were significant for time between testing sessions 1 and 3. The 4 variables were: SLAR_Right ($F = 10.82_{(2)}$, $P = 0.001$, $1-\beta = 0.98$), SLAR_Left ($F = 14.751_{(2)}$, $P = 0.001$, $1-\beta = 0.99$), SLHOP_Right ($F = 12.61_{(2)}$, $P = 0.001$, $1-\beta = 0.97$) and SLHOP_Left ($F = 10.09_{(3)}$, $P = 0.001$, $1-\beta = 0.98$). The percentage change for each variable from session 1 to session 3 was as follows: SLAR_Right increased 11.04%; SLAR_Left increased 10.24%; SLHOP_Right increased 7.03%; and, SLHOP_Left increased 7.12%. There were no statistically significant results for either ROM_Right or ROM_Left ($P > 0.05$). Overall, the football athletes had further reach distances and jumped further when compared to the volleyball athletes.

**Table 1.** Descriptive Statistics for SLAR, SLHOP, and ROM Over Time

<table>
<thead>
<tr>
<th>Variable</th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
<th>Percentage change</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAR_R % LL</td>
<td>74.31 ± 10.29</td>
<td>75.23 ± 13.23</td>
<td>82.99 ± 14.29*</td>
<td>11.04</td>
</tr>
<tr>
<td>SLAR_L % LL</td>
<td>74.69 ± 11.87</td>
<td>74.32 ± 13.23</td>
<td>82.75 ± 14.23*</td>
<td>10.24</td>
</tr>
<tr>
<td>SLHOP_R % LL</td>
<td>173.15 ± 33.02</td>
<td>177.81 ± 34.88</td>
<td>185.77 ± 36.84*</td>
<td>7.03</td>
</tr>
<tr>
<td>SLHOP_L % LL</td>
<td>171.89 ± 35.52</td>
<td>175.12 ± 37.69</td>
<td>184.59 ± 40.88*</td>
<td>7.12</td>
</tr>
<tr>
<td>ROM_R cm</td>
<td>9.43 ± 2.57</td>
<td>8.61 ± 2.38</td>
<td>8.71 ± 2.05</td>
<td>-</td>
</tr>
<tr>
<td>ROM_L cm</td>
<td>9.55 ± 2.17</td>
<td>8.75 ± 2.22</td>
<td>9.75 ± 2.56</td>
<td>-</td>
</tr>
</tbody>
</table>

*Significant difference between time 1 and time 3 ($P < 0.05$).
R = right, L = Left
Table 2. Descriptive Statistics for SLAR, SLHOP, and ROM by Group

<table>
<thead>
<tr>
<th></th>
<th>Football</th>
<th>Volleyball</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAR_R % LL</td>
<td>81.57 ± 13.23</td>
<td>73.45 ± 11.31*</td>
</tr>
<tr>
<td>SLAR_L % LL</td>
<td>81.75 ± 12.27</td>
<td>72.76 ± 10.37*</td>
</tr>
<tr>
<td>SLHOP_R % LL</td>
<td>200.14 ± 27.08</td>
<td>162.34 ± 28.12*</td>
</tr>
<tr>
<td>SLHOP_L % LL</td>
<td>196.35 ± 32.84</td>
<td>161.37 ± 29.65*</td>
</tr>
<tr>
<td>ROM_R cm</td>
<td>9.39 ± 2.55</td>
<td>8.43 ± 2.04</td>
</tr>
<tr>
<td>ROM_L cm</td>
<td>9.33 ± 2.38</td>
<td>9.25 ± 1.68</td>
</tr>
</tbody>
</table>

*Significant difference between groups ($P < 0.05$).
R = right, L = Left

SLHOP, SLAR, and Ankle ROM Symmetry

The multivariate repeated measures ANOVA for SLAR, SLHOP, and ankle ROM symmetry was not statistically significant for time ($P = 0.24$), group ($P = 0.34$), or the interaction time*group ($P = 0.91$). Descriptive statistics for SLHOP, SLAR, and ankle ROM symmetry over time and by group are in Table 3 and 4.

Table 3. Descriptive Statistics for SLAR, SLHOP, and ROM Symmetry Over Time

<table>
<thead>
<tr>
<th></th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAR_SYM %</td>
<td>95.5 ± 3.1</td>
<td>95.1 ± 3.6</td>
<td>91.3 ± 3.7</td>
</tr>
<tr>
<td>SLHOP_SYM %</td>
<td>95.1 ± 6.1</td>
<td>94.2 ± 4.6</td>
<td>94.6 ± 5.3</td>
</tr>
<tr>
<td>ROM_SYM %</td>
<td>91.3 ± 6.1</td>
<td>92.6 ± 6.4</td>
<td>95.8 ± 1.2</td>
</tr>
</tbody>
</table>
iLESS

A frequency table (see Table 5) was constructed for the iLESS statistics to look for agreement and consistency over the 3 testing trials. The test is graded on a binary scale, scoring either a 0 for a low-risk movement pattern, or a 1 for a high-risk movement pattern. Kendall’s Tau was calculated 3 times (time 1 vs time 2, time 1 vs time 3, and time 2 vs time 3) to evaluate change in the iLESS scores.

Table 4. Descriptive Statistics for SLAR, SLHOP, and ROM Symmetry by Group

<table>
<thead>
<tr>
<th></th>
<th>Football</th>
<th>Volleyball</th>
</tr>
</thead>
<tbody>
<tr>
<td>SLAR_SYM %</td>
<td>95.9 ± 3.1</td>
<td>95.9 ± 3.6</td>
</tr>
<tr>
<td>SLHOP_SYM %</td>
<td>93.4 ± 5.3</td>
<td>95.8 ± 7.7</td>
</tr>
<tr>
<td>ROM_SYM %</td>
<td>91.2 ± 6.8</td>
<td>88.6 ± 4.8</td>
</tr>
</tbody>
</table>

Table 5. Frequencies for the iLESS Over Time

<table>
<thead>
<tr>
<th></th>
<th>Time 1</th>
<th>Time 2</th>
<th>Time 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>9</td>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>1</td>
<td>21</td>
<td>20</td>
<td>19</td>
</tr>
</tbody>
</table>

Based on the frequencies from each trial, a kappa coefficient (κ) was calculated to determine the interrater reliability level. From the preseason to postseason trials, only 2 participants’ scores changed, both of which were football players. One individual scored a 1 during the initial trial, a 0 at the midseason trial and stayed 0 at the postseason trial.
The second individual scored a 1 during the initial trial, a 1 at the midseason trial and a 0 at the postseason trial.

The $\kappa$ aims to show consistency in interrater reliability. The $\kappa$ for T1 vs T2, T1 vs T3 and T2 vs T3 were 0.89, 0.81 and 0.91, respectively. These data show a very high level of agreement. This high level of agreement shows that the iLESS is a tool that can be implemented with confidence that any rater with acceptable knowledge of kinesiology, biomechanics, jumping mechanics and landing mechanics could accurately rate the iLESS.

**DISCUSSION**

The purpose of this study was to determine if there is a change in the F-PPE measures over the course of a season (pre-, mid-, and postseason). The results showed a statistically significant increase in performance for the SLAR, and SLHOP tests in both football and volleyball athletes and on both limbs. This symmetrical change shows that the functional tests are reliable in their measurements, as the performance changes increased symmetrically regardless of sport, time or rater implementing the tests. The specific reasons for the increase are not known, as neither team participated in an in-season strength straining program or performed any extra plyometric or agility training throughout the fall. One variable that may have had an effect is the number of times each participant performed each task, and over time developed a learning effect.

**SLAR**

The increase in performance from T1 to T3, for the right (11.04%) and left (10.24%) cannot be compared to other repeated measures studies using the SLAR,
because, to the knowledge of the author of the current study, there are none. However, in previous studies,\textsuperscript{5,9–12} when participants were subjected to 6 trials or more of the SEBT, a learning effect took place and they began improving their scores. This is an acceptable reason for the drastic increase from T1 to T3, because participants were becoming more familiar with the test after having 3 practice trials in addition to 3 recorded trials for each session. The 6-trial mark for the learning effect was exceeded after T2.

The SLAR examined the integrity of dynamic postural stability and functional ankle mobility and flexibility of musculature surrounding the shank. The increase in performance measures is not a foreign idea. In multiple studies,\textsuperscript{13–18} there was found to be either a maintenance or increase in various performance factors in upper or lower extremity, depending on the specific sport. Conversely, there can also be a decrease in performance over an athletic season or period of time from different factors.\textsuperscript{13–20}

A study by Schmidt et al\textsuperscript{17} found that collegiate wrestlers’ body mass, body composition and muscular power all stayed very consistent throughout the wrestling season; in contrast, muscular strength decreased. This was consistent with McLean et al,\textsuperscript{18} who found that female collegiate soccer players who were starters decreased their performance levels, while nonstarters and athletes who did not receive much playing time stayed consistent. The wrestlers’ fatigue was attributed to high levels of intense training and weight cutting, whereas the soccer players’ fatigue and decreased performance levels were mainly associated with extended minutes on the pitch in competition and practice. Those athletes who did not have to cut high degrees of weight and who did not receive as much playing time did not have as high levels of performance decreases or could
maintain performance levels. In the current study, participants’ playing time and level of in-game exposure were not documented, so inquiry from these results could not be specifically applied to the results. But muscular fatigue did not seem to be a factor as SLAR performance increased over time and was symmetrical.

Burk et al\textsuperscript{14} reported that in collegiate soccer, volleyball and recreational athletes increased Balance Error Scoring System (BESS) scores over a 90-day period. Another study\textsuperscript{13} found an increase in upper extremity performance (maximal concentric upper-body strength and handball throwing velocity) while finding no increase or decrease in lower extremity measures (maximal sprint and endurance running in handball athletes). These results show that strength training, sport-specific training, and competition in sport can have a positive effect on performance.\textsuperscript{13} The participants in the current study were not involved with a consistent strength training program, though they were active in their respective sport 5-6 days per week. This amount of exposure time in addition to the numerous trials of each functional exam at each testing session could have given the participants many opportunities to become increasingly effective with dynamic postural stability, force attenuation and flexibility, all of which were tested in each session.

The difference between the higher scores for volleyball and football are mainly due to the sex-related differences between male and females. There were no female football players during this study as well as no male volleyball players. In functional screenings previously,\textsuperscript{21} females were shown to perform better than males in movements requiring flexibility and balance, but perform worse in movements that require trunk/core strength, in addition to having higher symmetry in the anterior reach portion of the SEBT.
However, the results in Table 2 and 3 show the changes over time and symmetry between football (males) and volleyball (females). The change over time shows that the football participants had a significantly higher performance level (81.57 ± 13.23, 81.75 ± 12.27) than that of the volleyball participants (73.45 ± 11.31, 72.76 ± 10.37) when compared by right and left foot, respectively. Table 3 highlights that the football team and volleyball team had 95.9% symmetry, showing that at least in the current study, symmetry was virtually equal (although the football team SD was lower).

**SLHOP**

The single-leg hop functional exam requires the most coordination, postural stability, and force attenuation of the 4 exams. The degree of difficulty is the highest because these factors are stressed simultaneously. Distance, ability to land and maintain balance and consistency are required when performing this functional test; without them, limb symmetry and overall data would not be reliable.

The SLHOP showed significant increases in distance over time from T1 to T3 for both right (7.03%) and left foot (7.12%). This is consistent with other literature\(^5,9\) reporting a learning effect, which becomes evident after numerous trials of the same examination. The learning effect threshold was surpassed in the current study’s methodology by double. The previous studies noted a learning effect after 6 trials. In the current study, 18 trials (including practice trials) were performed, so the associated increase in performance can be attributed in some capacity to the learning effect. Significant differences were also found in the SLHOP scores when compared by group. The football players had much further distance scores than the volleyball players, but
their limb symmetry was inferior to that of the volleyball players. This finding is indicative of future injury risk as reported by Logerstedt et al\textsuperscript{22} because of limb asymmetry indicates contralateral muscle weaknesses.\textsuperscript{23–26}

Noyes et al\textsuperscript{27} described that all single-legged tests must have a symmetry index of at least 85\% to be considered normal for both males and females. During data collection when comparing the test trials from T1-T3, the SLHOP symmetry never dropped below 94.2 ± 4.6. When comparing football to volleyball, the SLHOP symmetries were 93.4 ± 5.3 and 95.8 ± 7.7, respectively. This shows that regardless of foot dominance, sport or sex, a high level of foot symmetry can be maintained. As we saw in the current study, the results revealed that leg dominance was not an important factor regarding performance because increases were noted for both limbs, regardless of dominance. These findings for both football and volleyball were symmetrical as well, so leg dominance and possible muscle imbalances contralaterally did not affect the increases.

**ROM**

The dorsiflexion ROM test was the only test that was not significant over time, or between groups. The symmetry numbers when compared by group were not as high as the other functional exams. However, the ROM test proved to be reliable and valid as previous literature show.\textsuperscript{8,28–32} Specifically, Chisholm et al\textsuperscript{8} found that dorsiflexion ROM measures should be used on initial assessment screens and following screens in order to accurately assess change. This functional exam can be used to assess dynamic balance measures and overall injury risk if proper minimum distances are not met, or if a degree of symmetry cannot be achieved. This test, in addition to the SLAR and SLHOP, can
provide insight into single-leg joint mobility and flexibility of the surrounding musculature.

Previous literature\textsuperscript{33–35} examining sex-related differences in functional performance evaluation have shown females to be at a disadvantage with force attenuation due to greater ground reaction forces and reduced muscle mass.\textsuperscript{36} Females have been shown to perform better than males in examinations requiring flexibility and mobility. The results in the current study do not support those findings. Reasons for this may be varied; however, the average leg length for the male participants was much greater than that of females, which may have had some affect. In addition, the volleyball players did not participate in a traditional static stretching protocol before practices and games. The warm-up consisted of dynamic and sport-specific warm-up in contrast to the male football players whose warm-up included a dynamic warm-up followed by a static stretching period. The compound effect of static stretching over the period of the athletic season as well as previous years of sport participation in the participating school district may have attributed to the inconsistent results from previous literature. The methods of sport preparation are very similar throughout elementary, middle, and high school; therefore, these methods of flexibility training may have contributed to the female volleyball players not performing in the ROM test as previous research had reported.

\textbf{iLESS}

There was a slight increase in 0’s (good landing mechanics), while the corresponding decrease in 1’s. This consistency in scores shows that the iLESS is an acceptable tool for measuring athletes’ performance levels during various points
throughout an athletic season. The results show that with an n = 30 between two athletic teams, regardless of the everyday demands of sport, the iLESS can accurately and consistently show participants’ performance levels in jump landing, force attenuation and landing mechanics.

These findings are consistent with that of Cortes and Onate, who found that the iLESS was an acceptable alternative to the LESS because the validity and reliability for participant and rater was satisfactory. In their study, they found an agreement level of 90%, which is consistent with the data presented.

Another study which supports the idea of visual assessment of movement patterns examined whether or not visual assessment in real-time was a valid and reliable means of screening movement patterns. Although this study did not assess the exact functional movements that the former study did, they found that a rater can reliably analyze movement in real-time. The current study did not assess the interrater reliability in iLESS as only one rater was used for the entirety of data collection, but both studies show that a novice and expert rater are equipped to do initial screens such as a preparticipation screen.

The volleyball players, in comparison with the football players, scored more 1’s, which are correlated with poor landing mechanics and high ground reaction forces. Harrison et al and Chimera et al showed that females are not able to perform as well in activities that test core/trunk stability and that stress landing mechanics, which in this case were valgus landing position and higher ground reaction forces (indicated from loud landing noise).
Skeletal Maturity

Between the SLAR and SLHOP we found significant increases in performance throughout the athletic season. These findings were consistent with only one study we found by Burk et al.\textsuperscript{14} However, between this study and the other studies\textsuperscript{17,18} that we compared our results to, the demographic characteristics of the participant groups that were used were not consistent with ours. Studies by McLean et al\textsuperscript{18} and Schmidt et al\textsuperscript{17} found significant decreases in performance throughout the course of an athletic season. However, in both studies, collegiate athletes were used. This difference between collegiate and high school athletes in the current study may have influenced the increases in performance throughout the athletic season. High school aged athletes are much more immature in their musculoskeletal and nervous systems, which allows their ceiling for performance enhancement to be much higher than that of collegiate athletes who are more mature physically and more than likely have had more practice in such activities. Previous literature\textsuperscript{48} using the SLAR reported no significant differences between high school and collegiate athletes, whereas Myers et al\textsuperscript{39} found collegiate athletes performed significantly better than high school athletes.\textsuperscript{39} Therefore, we can hypothesize that the skeletal immaturity may have been a factor in the drastic improvement in high school athletes’ performance compared to more mature athletes.

Limitations

Our study had a few limitations, the first being that this study was conducted in the high school setting and had a relatively small sample size of athletes from 2 fall sports. The results of the study cannot be directly applied to collegiate or professional
athletes. High school athletes’ performance on these functional exams may have varied due to motivation, physical maturity level or level of athleticism. Another limitation was the availability of raters. Although the data collected and overall results showed consistency in rating, performance, and symmetry, for each testing session there was a “mass testing” day where 5 raters were at each station (one station for leg length measurement and PMHx questionnaire distribution) for efficiency in test implementation. However, many athletes did not attend and had to come at a later date where all functional tests were implemented by the primary researcher.

**Future Research**

Further research should examine whether these functional tests reflect consistent increases in performance throughout the athletic seasons of different sports with a larger sample size and at different levels of competition. Additional research needs to explore reasoning for the increases in performance over time. Additionally, researchers could use these tests throughout an athletic season with concurrent strength training or flexibility programs to identify further increases or decreases in performance. These findings would provide further evidence for the reliability and validity of these tests, in addition to the specific performance changes in male and female athletes of all levels of performance.

**CONCLUSION**

Functional testing at separate points during an athletic season can show increases in performance. The symmetry of these increases between male and female fall sport athletes show that the selected tests of the F-PPE are consistent in assessing performance changes during an athletic season. The statistics reported in this study can provide sports
medicine professionals with information vital to the health and safety of high school athletes over time. The findings can assist professionals working with this demographic of athletes to implement or modify pre-season, in-season, and off-season training protocols to maximize in-season performance.

REFERENCES


40. McCann RS, Kosik KB, Beard MQ, Terada M, Pietrosimone BG, Gribble PA.

Chapter 4: Conclusion

Although this study found an increase in performance levels for SLAR and SLHOP over an athletic season in fall sport, high school athletes, there were no statistically significant increases in ROM or significant changes in iLESS performance during that same period. The level of consistency was encouraging, indicating that when implementing the F-PPE, a minimal amount of training is needed for raters to become adequate in assessment. The significant changes in SLAR and SLHOP over time show that more research needs to be done to determine the specific reasons for the increase.

Overall the statistics presented in this article give health care professionals additional data regarding how high school athletes’ performance changes using 4 functional exams highlighted in the F-PPE. These exams can be used to track performance, progress after an injury, and provide information for improvements and modifications of in-season training loads for athletes. This information can be incorporated into programs for athletic trainers, strength and conditioning professionals, and coaches to assist their athletes in achieving peak performance at vital times during in-season competition.
References


42. Myer G, Paterno M, Ford K, Quatman C, Hewett T. Rehabilitation after anterior cruciate ligament reconstruction: criteria-based progression through the return-to-


Appendix A: Specific Aims

Pre-participation examinations (PPE) in the high school setting involve a multifaceted approach to detect conditions or abnormalities that may predispose athletes to further harm. Most PPE’s include a medical history screen, and general health examination. Typically; the general health examination includes some form of a cardiovascular, neurologic, and orthopedic assessment. According to the NATA position statement, during the orthopedic screening, if clinicians take an accurate history, 90% of musculoskeletal injuries can be detected. The issue with orthopedic examination is that this part of the exam has a low sensitivity and high specificity, meaning that even if the orthopedic examination finds a condition to not exist, there is still a high possibility that it could have been missed. If the test has a high specificity, when it rules in a condition, it is likely the condition is present. A PPE needs to be more sensitive while maintaining a high specificity in order to be a valid preseason diagnostic tool for medical professionals.

To this point in the literature, there is little evidence supporting the validity of the traditional two-minute PPE to predict and more importantly, prevent injuries. Recently, research has recommended using a functional PPE (F-PPE) to bridge the gaps in literature concerning the validity of the traditional PPE. Instead of using the current PPE which only uses a duck-walk or single-leg hop to screen for injuries, this study will use four functional tests; the single-leg anterior reach (SLAR), single-leg hop for distance (SLHOP), the Landing Error Scoring System (iLESS), and ankle dorsiflexion range of motion (ROM) assessment. These four tests will be conducted by a researcher trained in implementation of the tests. The F-PPE tests will aim to observe changes in functional capacity of high school athletes throughout the season.

We propose to use the F-PPE at New Lexington High School in New Lexington, Ohio. The participation groups will include New Lexington sanctioned sports teams in the fall of 2017. Using the combination of men and women’s sports, we propose to test each athlete at the beginning of the season to detect any predisposing orthopedic factors. We also propose to test them two additional times throughout the athletic season (mid, and post season). Not only do we hope to further solidify the F-PPE as a valid screening tool, but we also hope to use the tests to establish their sensitivity in measuring change over time. This study aims to give insight into the accuracy of the F-PPE tests and the amount of change the athletes sustain throughout the year. We propose the following specific aim.

Aim 1: Using the F-PPE to determine changes throughout an athletic season in the same cohort of athletes.
## Appendix B: Data Collection Sheet

Data Collection Sheet

<table>
<thead>
<tr>
<th>Subjct #</th>
<th>Limb Lengt</th>
<th>Ankle DF ROM</th>
<th>SIAR (cm)</th>
<th>SIHOP (cm)</th>
<th>TTT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>h (left)</td>
<td>L R L 2 3 3</td>
<td>L R L 2 3</td>
<td>L R L 2 3</td>
<td>T 1</td>
</tr>
<tr>
<td></td>
<td>h (right)</td>
<td>L R L 2 3 3</td>
<td>L R L 2 3</td>
<td>L R L 2 3</td>
<td>T 2</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T 3</td>
</tr>
</tbody>
</table>

School: New Lexington HS
School #: __________
Clinician: __________

Ohio University F-PPE
Appendix C: Data Collection Forms

Previous Medical History Evaluation (Preseason)

General Information

Participant # ____________________ Mass (lbs) ____________________ Date __________
Age________ DOB________ Sex_____________ Grade_____________________________
Sport(s)___________________ Position ________________

<table>
<thead>
<tr>
<th>Medical History Questionnaire</th>
<th>Response:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Have you suffered a lower extremity (LE)* injury that caused you to miss practice or competition within the last 30 days?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>2. Have you suffered a lower extremity injury that required surgery within the last six months?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>3. Have you ever fractured or broken any bones?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>4. Have you dislocated any joints?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>5. Have you suffered an injury that required imaging such as x-ray, MRI or CT Scan?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>6. Have you suffered an injury that required the use of an ambulatory device (Crutches, canes etc.)?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>7. Have you ever suffered a stress fracture?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>8. Do you currently use a brace, orthotics or other prophylactic device?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>9. Do you currently have an injury/problem that is bothering you?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>10. Do you experience any redness, swelling or discomfort in your joints?</td>
<td>□ Yes  □ No</td>
</tr>
<tr>
<td>11. Have you been diagnosed with any juvenile conditions/diseases?</td>
<td>□ Yes  □ No</td>
</tr>
</tbody>
</table>

If yes was answered to any of the above questions please expand:

Please add any other information you feel the clinician should know:

*Lower extremity (LE) is defined as anything below the hip level, including, but not limited to the hip joint, knee joint and ankle joint.
Previous Medical History Evaluation (Mid/Postseason)

**General Information**

Participant # ____________________  Mass ____________________  Date __________

Age_________  DOB______________  Sex______________  Grade_________________

Date________________________________________________________

Sport(s)__________________________  Position_______________________________

<table>
<thead>
<tr>
<th>Medical History Questionnaire</th>
<th>Response:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.  Have you suffered an lower extremity (LE)* injury since the last testing session that</td>
<td>□ Yes</td>
</tr>
<tr>
<td>caused you to miss practice or competition within the last 30 days?</td>
<td>□ No</td>
</tr>
<tr>
<td>2.  Have you suffered a lower extremity injury since the last testing session that</td>
<td>□ Yes</td>
</tr>
<tr>
<td>required surgery within the last six months?</td>
<td>□ No</td>
</tr>
<tr>
<td>3.  Have you fractured or broken any bones since the last testing session?</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
</tr>
<tr>
<td>4.  Have you dislocated any joints since the last testing session?</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
</tr>
<tr>
<td>5.  Have you suffered an injury that required imaging such as x-ray, MRI or CT Scan since</td>
<td>□ Yes</td>
</tr>
<tr>
<td>the last testing session?</td>
<td>□ No</td>
</tr>
<tr>
<td>6.  Have you suffered an injury that required the use of an ambulatory device since the last</td>
<td>□ Yes</td>
</tr>
<tr>
<td>testing session (Crutches, canes etc.)?</td>
<td>□ No</td>
</tr>
<tr>
<td>7.  Have you suffered a stress fracture since the last testing session?</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
</tr>
<tr>
<td>8.  Have you began using a brace, orthotic or other prophylactic device since the last</td>
<td>□ Yes</td>
</tr>
<tr>
<td>testing session?</td>
<td>□ No</td>
</tr>
<tr>
<td>9.  Do you currently have an injury/problem that is bothering you?</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
</tr>
<tr>
<td>10. Do you experience any redness, swelling or discomfort in your joints?</td>
<td>□ Yes</td>
</tr>
<tr>
<td></td>
<td>□ No</td>
</tr>
<tr>
<td>11. Have you been diagnosed with any juvenile conditions/diseases since the last testing</td>
<td>□ Yes</td>
</tr>
<tr>
<td>session?</td>
<td>□ No</td>
</tr>
</tbody>
</table>

If yes was answered to any of the above questions please expand

Please add any other information you feel the clinician should know:

*Lower extremity (LE) is defined as anything below the hip level, including, but not limited to the hip joint, knee joint and ankle joint.*
Appendix D: Instrument Reliability

Below is a summary of the reliability data collected (n=6; male=3, female=3).

The peak leg was used for analyses.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsiflexion ROM</td>
<td>ICC (_{(1,k)})=0.97 (0.85, 0.99)</td>
</tr>
<tr>
<td>Single Leg Anterior Reach</td>
<td>ICC (_{(1,k)})=0.96 (0.79, 0.99)</td>
</tr>
<tr>
<td>Single Leg Hop</td>
<td>ICC (_{(1,k)})=0.98 (0.87, 0.99)</td>
</tr>
<tr>
<td>Impression Landing Error Scoring System</td>
<td>(\kappa = 1.0) (p=0.01)</td>
</tr>
</tbody>
</table>

Day to Day Reliability for Scale and Dichotomous Variables
Appendix E: Power Analysis

Contrary to a traditional power analysis the whole population of football and volleyball athletes at New Lexington High School will be used. An approximation of 125 student-athletes will be participating in this study.
Appendix F: Pilot Data

Below is a summary of the pilot data collected (n=6; male=3, female=3). The peak leg was used for analyses.

Summary of Descriptive Statistics for Scale Variables

<table>
<thead>
<tr>
<th>Measure</th>
<th>Mean ± Standard Deviation</th>
<th>Minimum; Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dorsiflexion ROM</td>
<td>14.66±4.23</td>
<td>10.00; 21.00</td>
</tr>
<tr>
<td>Single Leg Anterior Reach</td>
<td>73.67±10.91</td>
<td>60.00; 87.00</td>
</tr>
<tr>
<td>Single Leg Hop</td>
<td>186.33±48.82</td>
<td>119.00; 234.00</td>
</tr>
</tbody>
</table>

Summary of Frequencies for Dichotomous Variable

<table>
<thead>
<tr>
<th>Impression Landing Error Scoring System</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>n=2</td>
</tr>
<tr>
<td>1</td>
<td>n=4</td>
</tr>
</tbody>
</table>