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original research

Landing Error Scoring System Differences Between Single-Sport and Multi-Sport Female High School–Aged Athletes

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Context: Single-sport specialization (SSS) is becoming more prevalent in youth athletes. Deficits in functional movement have been shown to predispose athletes to injury. It is unclear whether a link exists between SSS and the development of functional movement deficits that predispose SSS athletes to an increased risk of knee injury.

Objective: To determine whether functional movement deficits exist in SSS athletes compared with multi-sport (M-S) athletes.

Design: Cross-sectional study.

Setting: Soccer practice fields.

Patients or Other Participants: A total of 40 (21 SSS [age = 15.05 ± 1.2 years], 19 M-S [age = 15.32 ± 1.2 years]) female high school athlete volunteers were recruited through local soccer clubs. All SSS athletes played soccer.

Intervention(s): Participants were grouped into 2 categories: SSS and M-S. All participants completed 3 trials of the standard Landing Error Scoring System (LESS) jump-landing task. They performed a double-legged jump from a 30-cm platform, landing on a rubber mat at a distance of half their body height. Upon landing, participants immediately performed a maximal vertical jump.

Main Outcome Measure(s): Values were assigned to each trial using the LESS scoring criteria. We averaged the 3 scored trials and then used a Mann-Whitney *U* test to test for differences between groups. Participant scores from the jump-landing assessment for each group were also placed into the 4 defined LESS categories for group comparison using a Pearson χ^2 test. The α level was set a priori at .05.

Results: Mean scores were 6.84 ± 1.81 for the SSS group and 6.07 ± 1.93 for the M-S group. We observed no differences between groups ($z = -1.44$, $P = .15$). A Pearson χ^2 analysis revealed that the proportions of athletes classified as having excellent, good, moderate, or poor LESS scores were not different between the SSS and M-S groups ($\chi^2_3 = 1.999$, $P = .57$).

Conclusions: Participation in soccer alone compared with multiple sports did not affect LESS scores in adolescent female soccer players. However, the LESS scores indicated that most female adolescent athletes may be at an increased risk for knee injury, regardless of the number of sports played.

Key Words: knee, injuries, movement assessment

Key Points

- Participation in a single sport compared with participation in multiple sports did not affect Landing Error Scoring System scores in adolescent female soccer players.
- Most study participants may be at an increased risk of knee injury because of deficits in functional movements.
- Adolescent athletes should participate in training that effectively addresses these functional movement deficits to reduce injury risk.

Single-sport specialization (SSS), characterized by year-round participation in a single sport to the exclusion of other sports and activities, is becoming more prevalent in youth athletes.[1,2] In a *New York Times* article, Belluck[3] reported on a small town in Minnesota where the basketball coach wanted to start a competitive basketball "traveling squad" for second graders. This highlights the change in sport culture whereby youth athletes are specializing in their sport very early in their development and excluding themselves from participating in a multitude of different sporting activities.

Specialization in a single sport not only has the potential to place young athletes at greater risk of injury and repetitive trauma but also increases the probability of developing sport-specific strength and flexibility imbalances, which could lead to overuse injuries.[4–6] By changing sports throughout the year and participating in multiple sports, young athletes gain a wider range of skills and potentially provide their bodies with the rest periods they need from repetitive single-sport activity.[7] Each sport has different demands and requirements of both the cardiovascular system and the musculoskeletal system[7]; therefore, participating in multiple sports gives the body breaks in sport-specific training. Excessive stress or overload can lead to tissue breakdown and injury, especially when sufficient recovery time is not provided. To realize maximum gains, athletes must correctly identify and train just below the threshold for injury.[8] Including a multitude of exposures allows breaks in training and results in multi-sport

(M-S) athletes developing a balance in overall muscular strength and flexibility. Consequently, athletes who are active in a variety of sports are theorized to have a lower incidence of injuries and participate in sports longer than those who specialize before puberty.[8,9] Early sport specialization has been linked to an increased injury risk in children and adolescents,[2] and whereas the exact mechanisms for this higher risk of injury are not completely understood, researchers[10] think that given its year-round specialization, single-sport participation potentially could lead to deficits in functional movement patterns, which may predispose athletes to injury.

Soccer is a total-body sport, involving simultaneous dynamic movements of both the upper and lower extremities, and is a sport with increased specialization in the female youth setting.[11,12] Because of the dynamic nature of soccer, female athletes are generally at greater risk of acute injury in this sport than in other female sports, but high rates of overuse injury have also been reported in women's soccer.[13] Females have a higher risk of anterior cruciate ligament (ACL) injury than males performing the same activities,[14] and in multiple sports, the risk of noncontact ACL injury for females is more than twice that for males.[15,16] Furthermore, when controlling for activity and playing time, females experience more sports injuries than males.[17] Movement patterns associated with ACL and other lower extremity injuries include decreased flexion of the knee, hip, and trunk combined with increased knee valgus and leg rotation.[18] These errors are common in participants performing poorly on the Landing Error Scoring System (LESS).

The LESS is 1 approach to screening athletes for biomechanical errors that may increase the risk of knee injury. Through video analysis of frontal and side views, it allows the clinician to assess lower extremity and trunk positioning during a jump-landing task. In a prospective study of 2691 college-aged participants, Padua et al[18] found that the LESS was a valid and reliable tool for identifying high-risk movement patterns. Deformation of the ACL is commonly seen with femoral internal rotation, increased knee valgus, and knee flexion.[18] Interestingly, poor LESS scores have been associated with increased knee valgus, hip-adduction angle, and knee and hip internal-rotation moment.[18] The LESS can easily identify these positions through the functional movement task, and, therefore, is an effective screening tool for athletes who may be at increased risk for injury. However, poor LESS scores do not necessarily correlate with increased injury rates. Rather, they merely identify individuals who have high-risk mechanics that may be related to an increased risk of lower extremity injury. Therefore, the purpose of our study was to determine whether functional movement deficits exist in SSS female athletes compared with M-S female athletes. We hypothesized that SSS athletes would demonstrate more errors (ie, higher scores) on the LESS than M-S athletes.

METHODS

Participants

Forty female athletes (21 SSS [age = 15.05 ± 1.2 years], 19 M-S [age = 15.32 ± 1.2 years]) were recruited through local soccer clubs and the Olympic Development Program. This sample size was based on an a priori power analysis that specified the minimum inclusion of 18 participants per group with the desired statistical power established at 0.80 and the α level set at .05. The SSS and M-S groups were assigned based on a self-report questionnaire about sport participation. Athletes in the SSS group had specialized competitively in only 1 sport for at least 1 year. Athletes in the M-S group had participated competitively in more than 1 sport for at least 1 year. Previous knee injury was not an exclusion criterion for this study; however, participants were required to have no orthopaedic injury that prevented them from being active in sport at the time of testing. All participants provided written informed assent, and parents or guardians provided written informed consent. The study was approved by the University of Utah Institutional Review Board.

Instrumentation

We used 2 commercially available high-definition video cameras (Sony Handycam; Sony Corporation of America, New York, NY) to record the test trials of each participant. The cameras were mounted on tripods and placed in front and to the side of the plyometric box and rubber landing mat. The lens height of each camera was 48 in (121.92 cm) from the floor and 136 in (345.44 cm) away from the front edge of a rubber landing mat. A 30-cm plyometric box was positioned behind the landing mat (Figure 1).

Procedures

Before testing, recruits completed a brief questionnaire to determine the sports in which they participated and their knee-injury history (Table 1). Next, we instructed participants on the LESS testing procedures. As noted, the LESS evaluates mechanics during a jump-landing test. We used the standardized LESS protocol, with participants performing a double-legged jump from a 30-cm platform and landing on a rubber landing mat placed in front of them at a distance of half their body height. Upon landing from the platform, they immediately performed a maximal vertical jump (Figure 2). Emphasis was placed on the participants jumping as high as possible when landing from the box. They were provided no coaching about the jump unless it was performed incorrectly, and they were allowed 3 practice trials. After the practice trials, they were video recorded in the frontal and sagittal planes for all 3 test trials. We scored the recorded trials at a later date.

Assessment of Jump-Landing Task and LESS

The LESS has 17 scored items to evaluate the landing from both the sagittal and frontal views (Table 2). The LESS score is a count of errors on a range of easily observable items of the jump-landing movement. A higher LESS score indicates more errors and, thus, a poorer jump-landing technique. In accordance with previous research,[18] the LESS scores are divided into categories for the specific population observed and are defined as *excellent* (0–3 errors), *good* (4–5 errors), *moderate* (6 errors), and *poor* ($\geq$7 errors). Only the principal investigator scored video trials to ensure the reliability of measures. Intrarater reliability for the LESS scores was excellent (intraclass

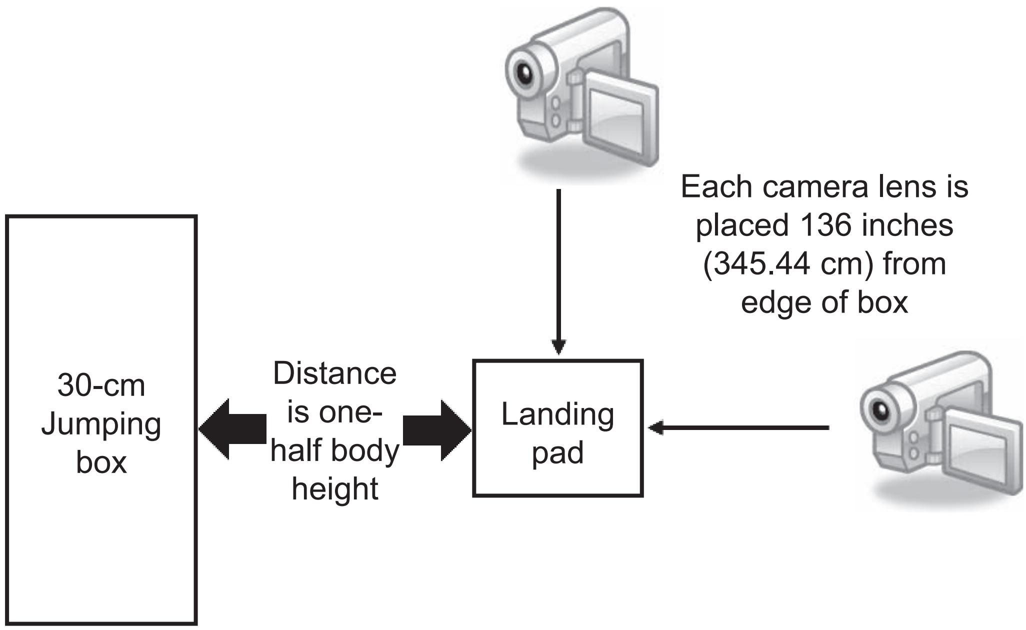

Figure 1. Landing Error Scoring System instrumentation data-collection setup.

correlation coefficient [2,1] = 0.91, SEM = 0.48). In addition, the principal investigator was blinded to group when scoring the videos. The videos were paused at the corresponding scoring time (ie, initial foot contact) to improve the quality of scoring. The scorer watched the trials as many times as needed to feel confident about an accurate assessment.

Statistical Analysis

The scores from the 3 trials for each participant were averaged and counted as the LESS score. A Mann-Whitney *U* test was used to test for differences between groups. Participant scores from the jump-landing assessment for each group were also placed into the 4 defined LESS categories for group comparison using a Pearson χ^2 test. In addition, we visually compared category distributions by group. The α level was set a priori at .05 for all statistical analyses. We used SPSS (version 20.0; IBM Corporation, Armonk, NY) to analyze the statistics.

RESULTS

The overall mean LESS score for both groups combined was 6.48 ± 1.89. The mean LESS scores were 6.84 ± 1.81 for the SSS group and 6.07 ± 1.93 for the M-S group. The results of the Mann-Whitney *U* test indicated no differences between groups for the LESS scores ($z = -1.44$, $P = .15$).

The Pearson χ^2 analysis revealed that the proportions of athletes classified as having excellent, good, moderate, or poor LESS scores were not different between the SSS and M-S groups ($\chi^2_3 = 1.999$, $P = .57$).

Visual comparison of category distributions by group demonstrated that the participants in the SSS group received a greater number of poor scores on the LESS than the M-S group. Specifically, the SSS group contained 2 participants (10%) in the excellent, 3 (14%) in the good, 4 (19%) in the moderate, and 12 (57%) in the poor category. In the M-S group, 4 participants (21%) were in the excellent, 3 (16%) in the good, 5 (26%) in the moderate, and 7 (37%) in the poor category.

Descriptive information retrieved from the demographic questionnaire revealed that 11 (6 SSS, 5 M-S) participants reported sustaining knee injuries that required them to miss at least 1 game and 3 (2 SSS, 1 M-S) participants sustained ACL injuries. In addition, 16 (11 SSS, 5 M-S) participants indicated they had completed specific exercises to reduce their risk of ACL injury in the past. The M-S group stated that the most common sport played other than soccer was basketball. All SSS athletes played soccer and had specialized in only this sport for an average of 7.3 years. The M-S athletes had been involved in M-S participation for an average of 8.8 years. In addition, we observed no differences between groups for Olympic Development Program involvement or number of soccer practices and games played per week ($P \geq .05$).

DISCUSSION

The purpose of our study was to determine whether functional movement deficits existed in SSS female athletes

Table 1. Demographic Questionnaire

Questions
Do you participate in any organized sport(s) other than soccer? If yes, which sport(s) and number of years participated for each?
How many years have you played organized soccer and what is the average number of soccer practices and games per week this season that you have participated in?
Have you ever sustained a knee injury while playing soccer that caused you to miss practice or games?
Have you ever been told you tore your ACL? If yes, which knee and did you have surgery to repair your ACL?
Do you knowingly perform exercise to reduce your risk of ACL injury as a part of training or practice for soccer?

Abbreviation: ACL, anterior cruciate ligament.

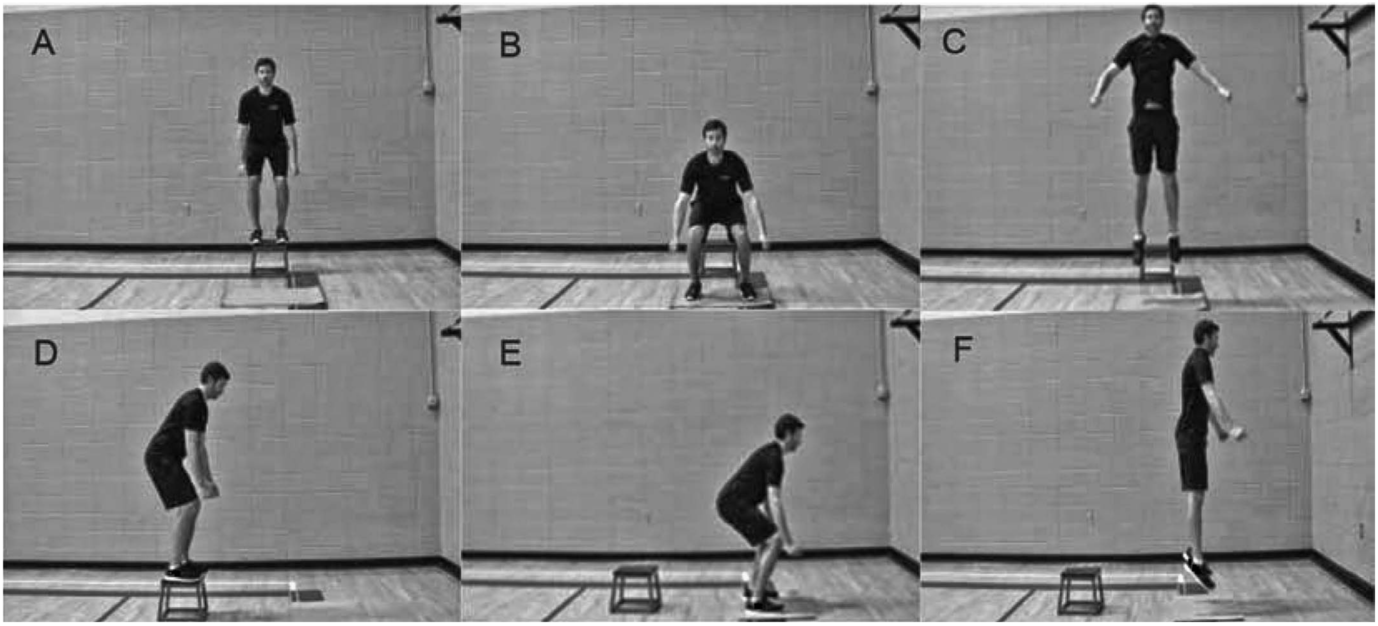

Figure 2. Landing Error Scoring System test. Frontal-plane view of the A, starting position, B, landing position, and, C, maximal vertical jump. Sagittal-plane view of the D, starting position, E, landing position, and, F, maximal vertical jump. Note that the initial landing position is used for Landing Error Scoring System scoring.

compared with M-S female athletes. We observed no differences in LESS scores between SSS and M-S female athletes. However, when we visually compared category distributions by group, we noted that the SSS group received a greater number of poor scores on the LESS than the M-S group. The SSS group had more participants in the poor LESS category than the M-S group did, thereby supporting our hypothesis that SSS athletes would have higher LESS scores (more errors) than M-S athletes. However, as noted, despite this speculation that SSS athletes may be at increased risk of injury, movement patterns did not differ.

These observations suggested that SSS potentially could lead to deficits in functional movement patterns, which may predispose the athlete to a greater risk of injury. Therefore, we surmise that athletes who specialize in 1 sport have the risk of developing altered lower extremity mechanics that could predispose them to deficits in their functional movement patterns, whereas athletes who participate in many sports generally would have a balance in their overall musculoskeletal system and, therefore, would be less likely to have functional movement deficits.

Analyzing the presence of injury history was not a purpose of this study, but when comparing the LESS scores

Table 2. Landing Error Scoring System Chart

Sagittal View	Frontal View
Hip-flexion angle at contact: hips are flexed Yes = 0, no = 1	Lateral (side) trunk flexion at contact: trunk is flexed Yes = 0, no = 1
Trunk-flexion angle at contact: trunk in front of hips Yes = 0, no = 1	Knee-valgus angle at contact: knees over midfoot Yes = 0, no = 1
Knee-flexion angle at contact: greater than 30° Yes = 0, no = 1	Knee-valgus displacement: knees inside of large toe Yes = 1, no = 0
Ankle plantar-flexion angle at contact: toe to heel Yes = 0, no = 1	Foot position at contact: toes pointing out >30° Yes = 1, no = 0
Hip flexion at maximum knee-flexion angle: greater than at contact Yes = 0, no = 1	Foot position at contact: toes pointing out <30° Yes = 1, no = 0
Trunk flexion at maximum knee flexion: trunk in front of hips Yes = 0, no = 1	Stance width at contact: <shoulder width Yes = 1, no = 0
Knee-flexion displacement: >30° Yes = 0, no = 1	Stance width at contact: >shoulder width Yes = 1, no = 0
Sagittal-plane joint displacement Large motion (soft) = 0, average motion = 1, small motion (loud/stiff) = 2	Initial foot contact: symmetric Yes = 0, no = 1 Overall impression Excellent = 0, average = 1, poor = 2

between participants with and without a history of knee injury, we observed that the average LESS scores were 7.5 (poor) for the 6 SSS athletes with knee-injury histories and 6.17 (moderate) for the SSS athletes without knee-injury histories. Furthermore, the average LESS scores were 6.5 (moderate) for the 5 M-S athletes with a history of knee injury and 5.4 (good) for the M-S athletes without a history of knee injury. No athlete had symptoms of an injury that limited participation at the time of the jump-landing–task assessment; however, these observed differences in average LESS scores between participants with and without a history of injury for both groups perhaps suggest that previous knee injury influenced the lower extremity mechanics demonstrated and LESS scores obtained. Again, we did not analyze the presence of injury history, so these observations need investigation in future studies.

When comparing our results with those from previous studies in which the LESS has been used in similar populations, we observed higher LESS scores in our study for both the SSS and M-S groups, whereby our participants displayed greater movement errors than those reported by DiStefano et al.[19,20] However, the populations in the comparative studies were younger and included male athletes, which may account for the differences in scores.

Female participation in youth soccer has grown tremendously over the past 30 years.[11] Just 3 decades ago, the US Youth Soccer organization counted its membership at 100 000. Today, municipal parks are filled with millions of young soccer players, and the organization counts more than 3 million young players.[12] With this increase in participation, sport specialization, and the likelihood of female athletes sustaining ACL injuries when compared with male athletes, more attention must be paid to identifying at-risk athletes.

The LESS test is a valid and reliable indicator of poor jump-landing mechanics, a key factor in noncontact ACL injury.[21,22] Whereas our results were not different between groups, our overall results indicated that most female adolescent athletes included in the study may be at an increased risk for knee injury, regardless of the number of sports played, because of the movement errors present in their mechanics. This finding highlights the need for greater implementation of programs, such as the Prevent Injury and Enhance Performance (PEP) and Sportsmetrics ACL injury-prevention programs, that have been shown to reduce the risk of knee injury in soccer players.[23] To address this public health concern, these programs should be conducted in local community soccer clubs and through regional and national youth soccer organizations as a valuable way to reduce time missed from competition because of injury. At the time of this writing, the US Youth Soccer Web site[12] discusses knee injuries and highlights the 11+ program from Fédération International de Football Association under the link "Health and Safety Resources Center." However, the way the group promotes and brings attention to this program is not apparent.

These ACL injury-prevention programs are designed to target risk-factor movements and associated musculature to help prevent injury. They are easy to perform, are inexpensive, and take approximately 15 to 20 minutes to complete per session, and the evidence supporting their benefits is growing.[20,23] However, fewer than half of the participants in our study reported performing specific exercises to reduce this risk. When considering the results of DiStefano et al[20] that athletes who displayed the greatest LESS scores improved the most after an ACL injury-prevention program and considering that our study revealed most female adolescent athletes demonstrated poor mechanics, we recommend that all female adolescent athletes within youth sport participation receive injury-prevention training, regardless of whether they are SSS or M-S athletes.

The National Athletic Trainers' Association[24] recently published a position statement about injuries in adolescent athletes. It called attention to the lack of research in this population and addressed the need for high-quality prospective studies aimed at athlete risk-factor identification, followed by the implementation of injury-prevention strategies in high school athletes.[25] Furthermore, this lack of research clearly highlights the need for more attention to be focused on female youth athletes at risk for ACL injury, especially considering the relationship between ACL injury and the onset of posttraumatic knee osteoarthritis at an early age.[26]

Health professionals, and athletic trainers in particular, need to take a leading role in the broad implementation of screening for functional movement deficits among athletes (specifically female athletes) to reduce the likelihood of injury occurrence. Coaches and parents should also be educated about the importance of injury-risk reduction and the financial effect of musculoskeletal injuries. Poor LESS scores do not necessarily correlate with increased injury rates. Rather, they simply identify athletes who have high-risk mechanics that are related to placing the lower extremity in a vulnerable position. More long-term epidemiologic research is needed to correlate poor LESS scores with increased injury rates.

Our study had limitations that should be considered when interpreting our results. Participants jumped off a box that was approximately shoulder width in size, so this could have influenced how each participant landed. Using a wider box would have allowed participants to start with a wider stance and might have produced different LESS score results. Furthermore, some participants were tested at the end of a soccer practice session, so fatigue could have played a role in the landing scores measured. This could have been controlled by having all athletes perform the task before practice. In addition, some participants had performed the LESS test maneuver in previous studies, resulting in the possibility of a test learning effect. Finally, additional factors, such as injury history and the performance of knee injury-prevention exercises, may have influenced the LESS scores for those athletes.

CONCLUSIONS

Participation in soccer alone compared with participation in multiple sports did not affect LESS scores in adolescent female soccer players. However, the LESS scores in our study indicated that most female adolescent athletes, regardless of the number of sports played, demonstrated poor landing mechanics that may place them at increased risk for knee injury. Given the overall results of our study and the consensus of current literature, we recommend that all female adolescent soccer players be encouraged to participate in some form of knee and ACL injury-prevention program. This may consist of jump-landing mechanics, resistance training, stretching, or neuromuscular coordination training. Moreover, we recommend using the LESS to identify individuals who display altered lower extremity mechanics, which may lead to an increased risk of lower extremity injury.

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