EFFECT OF LANDING SURFACE AND UPPER EXTREMITY CONSTRAINT ON BIOMECHANICS GRADED BY THE LANDING ERROR SCORING SYSTEM

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The purpose of this study was to compare jump-landing biomechanics across 1) landing surface condition; and 2) upper extremity constraint condition as graded by the Landing Error Scoring System (LESS). Recreational athletes (N=40; 21M, 19F) performed three jump-landings with three surface (Grass (GS), Court (CS), and Tile (TS)) and upper extremity constraint conditions (unconstrained (UN), football (AF), and lacrosse stick (LS)). The jump-landings were recorded via 2D videography and graded using the LESS. No differences were observed by surface (GS=5.01±1.40; CS=4.83±1.31; TS=5.09±1.86, p=0.52) or constraint condition (UN=5.09±1.86; FB=4.76±1.65; LS=4.86±1.76; p=0.21). The results indicate that the LESS is a robust instrument biomechanical screening in different landing environments and with sports with different upper extremity equipment.

KEY WORDS: ACL injury, injury risk screening, jump landing biomechanics

INTRODUCTION: Anterior cruciate ligament (ACL) rupture is a common sports injury, and is associated with reduced sports performance, loss of function, and long-term sequelae such as osteoarthritis (Dugan, 2005). Neuromuscular characteristics during high-risk sporting tasks such as jump-landing and cutting have been shown to be the compelling risk factors for ACL injury (Dai, Herman, Liu & Garrett, 2012a). Neuromuscular characteristics during these tasks associated with a high risk for injury include smaller knee flexion angles, greater knee valgus angles, greater hip adduction angles, and small trunk flexion angles; these patterns have been demonstrated to increase loading on the ACL and be predictive of injury (Dai et al., 2012a).

Injury prevention training programs targeting these characteristics have been shown to reduce injury risk (Dai, Herman, Liu & Garrett, 2012b); however, these programs may require extensive resources and may not be practical to implement for all athletes on a team. Alternatively, higher intensity neuromuscular training may be beneficial for athletes who are at particularly high risk (Myer, Ford, Brent & Hewett, 2005). As such, the ability to efficiently and effectively screen for athletes at high-risk for ACL injuries could lead to better resource allocation and focus on high-risk athletes to prevent these injuries through targeted application of injury prevention programs.

The Landing Error Scoring System (LESS) is a clinical tool that evaluates biomechanical performance during a jump-landing task with particular focus on aspects related to an increased risk for ACL injury. The LESS has been proven to be reliable at identifying athletes with high-risk biomechanics by using a 17 criterion list that assesses the subject's biomechanics with the use of standard videography (Padua et al., 2009). A higher LESS score indicates a higher number of errors during jump landing and hence poorer neuromuscular technique during landing.

Clinically, the use of the LESS has great potential; however, validation studies have only been conducted in the laboratory environment. When used as intended in the field or clinical office setting, the subjects' performance may be influenced by differences in the environment. One such modifying factor may be the landing surface used for the LESS assessment. Prior research has indicated that different surface types may influence landing and cutting biomechanics (Dowling, Corazza, Chaudhari, & Andriacchi, 2010); however, there is currently no research on the effect of different landing surfaces on LESS scores. Similarly, research has demonstrated that different upper extremity constraint conditions such as when an athlete is or is not encumbered with athletic equipment may alter biomechanics during athletic tasks (Chaudhari, Hearn, & Andriacchi, 2005). The standard LESS methodology used an unconstrained upper extremity limb condition; however, this is not necessarily representative of the in-competition demands of a given sport or positional players within a given sport during jump-landing tasks. Even a one or two point difference in LESS grading could affect the injury risk categorization of a given subject and therefore whether or not a training program is implemented or additional training is offered. Understanding how a LESS score can vary on different *in situ* surfaces is crucial for making the best possible decisions regarding injury risk and thus making the most efficient and effective use of resources available.

The aim of this study was to determine the influence of 1) landing surface and 2) upper extremity constraint condition on Landing Error Scoring System grades. We hypothesized that 1) LESS grades will increase from court to tile to grass surface conditions, and 2) LESS grades will increase from unconstrained to one-limb constrained to two-limb constrained conditions.

METHODS: 40 (21M, 19F) college-aged recreational athletes with experience in landing/cutting sports were recruited (Table 1). A recreational athlete was defined as one who participates in a relevant sport such as basketball, soccer, volleyball, or football 1-3 per week or who played such sports at the high school varsity level and who currently plays at least once per month.

Table 1

Subject Demographics. Means and standard deviation (SD) are shown.

	Mean	SD
1. Age (yrs)	23.8	2.4
2. Height (m)	1.75	0.11
3. Mass (kg)	69.8	12.7

The data collection methods for the Landing Error Scoring System were per the original protocol as described by Padua et al. (2009). The subjects were instructed to stand on a 0.030m high box with their feet shoulder width apart and with their toes at the edge of the box. They were then to jump with both legs to a 0.075m x 0.045m landing target positioned at a distance of 50% of each of the subjects' respective heights away from the box. Upon landing, the subjects immediately completed a vertical jump at maximal effort. The subjects were not provided any feedback or coaching on their technique unless the task is not completed correctly (e.g. landing outside of the target area). Three successful jump landings were then recorded for the given surface condition and each upper extremity constraint condition using standard two-dimensional videography. A successful jump is characterized by: 1) Jumping off of both feet at the same time; 2) Jumping forward, but not vertically, to the landing target; 3) Landing with each foot entirely within the landing target; 4) Landing with no more than one-half the length or width of each foot outside of the landing target during the second landing; and 5) Completing the task in a single fluid motion. The video cameras were placed 4.115m from the landing target in front of (frontal plane) and to the dominant side of the subject (sagittal plane) to record the landing.

The three landing surface conditions were a natural outdoor grass field, a basketball court at an indoor facility, and a tile surface in our biomechanics laboratory. The upper extremity constraint conditions included a hands-free unconstraint condition, a one-arm constraint condition in which the subject was instructed to hold an American football in a tucked manner in their dominant upper extremity, and a two-arm constraint condition in which the subject was instructed to hold a lacrosse stick with the net end in their dominant hand. The three upper extremity constraint conditions were performed exclusively on the tile surface. The tasks were completed on the three surfaces as assigned by a Latin Square design (Hinkelmann & Kempthorne, 2008).

The video data were subsequently independently scored by two different investigators via the criteria as described in Padua et al. (2009). Separate analyses of variance were performed to analyse surface and upper extremity constraint main effects. Correlational analyses between the landing conditions were performed using Pearson's R. Intrarater reliability was assessed via an intrarater correlational coefficient. Alpha was set *a-priori* at 0.05. All data analysis was performed using the Statistical Package for the Social Sciences (SPSS, v. 21).

RESULTS: Demographic data are listed in Table 1. The ICC value between the two raters was 0.932, indicating very strong agreement in LESS grading between the raters. With respect to surface condition, no significant within subject differences were found (Table 2). Similarly, with respect to the upper extremity constraint conditions, no significant within subject differences were found (Table 3). Strong correlations were observed between both the landing conditions (Table 4) and the upper extremity constraint conditions (table 5).

Table 2

Landing Error Scoring System Grades – Surface Conditions (p=0.52) Means and standard deviation (SD) are shown.

	Mean	SD
1. Grass Surface	5.01	1.40
2. Court Surface	4.83	1.31
3. Tile Surface	5.09	1.86

Table 3

Landing Error Scoring System Grades – Upper Extremity Constraint Conditions (p=0.21) Means and standard deviation (SD) are shown.

	Mean	SD
1. Unconstrained	5.09	1.86
2. Football	4.76	1.65
3. Lacrosse Stick	4.86	1.76

Table 4

Landing Error Scoring System Grades – Surface Correlations

	Pearson's R	P Value
1. Tile vs Grass	0.587	<0.001
2. Court vs Grass	0.608	<0.001
3. Court vs Tile	0.611	<0.001

Table 5

Landing Error Scoring System Grades – Upper Extremity Constraint Correlations

	Pearson's R	P Value
1. Unconstrained vs Football	0.820	<0.001
2. Unconstrained vs Lacrosse Stick	0.763	<0.001
3. Football vs Lacrosse Stick	0.762	<0.001

DISCUSSION: We hypothesized that LESS grades would be different across landing surface conditions and upper extremity constraint conditions. As there were no differences in LESS grades in either scenario, our study hypothesis is rejected. An element that further strengthens this result is the high correlation between the conditions in each scenario. Correlations between the surface conditions demonstrated a strong positive relationship, whereas the different upper extremity constraint conditions demonstrated a very strong positive relationship. This indicated that within-group means and individual subject scores did not vary much between the conditions. We also note that the mean values of this study are very similar to that of prior studies using college-aged athletes (Smith et. al., 2012; Lam & McLeod, 2014).

These results indicate that the Landing Error Scoring System is a robust clinical tool for biomechanical screening across multiple use environments. The LESS was created to reduce the need for expensive equipment and highly trained personnel and to be feasible for use in multiple environments and sports featuring large numbers of athletes. Potential clinical use scenarios may include conducting screening testing in a community soccer league at a practice field, screening basketball players attending a skills camp in a gymnasium, and screening athletes in a sports medicine clinical facility during pre-participation evaluations. If a standard set of guidelines for ACL injury risk based on the magnitude of LESS grading is to be meaningful, it is imperative that the LESS be reliable for use in a variety of scenarios such as these. Similarly, the LESS needs to be representative of the biomechanics used during jump landing tasks across a robust set of sports. If a standard set of guidelines for ACL injury risk are based on athletes from sports without significant constraints on their upper extremities (e.g soccer), it is important to verify that LESS grades are not significantly affected by constraint conditions so they may be applied to sports with such conditions (e.g. lacrosse). The results indicate that LESS grades do not change significantly in these conditions, and as such may be applied with confidence in such scenarios. This is important for the further clinical development of the LESS and for the further study of variations of the LESS using different populations.

Some important limitations to this study should be noted. Although the conditions used in this study were considered by the authors to be representative of common potential clinical use scenarios, not all circumstances were explored in this study. Perhaps most notable would be more extreme cases of high or low shoe-surface coefficients of friction, such as using a high-grip shoe on a carpeted or tacky surface. Upper extremity constraint was tested on only one surface selected by the investigators; however, we feel the lack of difference between upper extremity conditions is likely to hold across surfaces. Finally, these conditions may have a different magnitude of effect when applied to pediatric populations, particular those in puberty.

CONCLUSION: Landing Error Scoring System grading does not significantly vary by landing surface condition or by upper extremity constraint. This indicates that the Landing Error Scoring System is a robust clinical biomechanical screening tool for using in a variety of environmental setting and with a variety of sports and player positions. Additional research is needed to determine if a similar magnitude of effect of is observed in the paediatric athlete.

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