THE EFFECT OF LANDING ERROR SCORING SYSTEM PERFORMANCE ON FEMORAL ARTICULAR CARTILAGE DEFORMATION IN RECREATIONALLY ACTIVE FEMALES

by

Lily Szwejbka

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Lily K. Szwejbka

Greenville, NC

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Approved by:

Dr. Anthony S. Kulas

Department of Kinesiology, College of Health and Human Performance

Abstract

The Landing Error Scoring System [LESS] is a valid and reliable standardized tool used to assess biomechanical movements during jumping and landing activities thought to be high-risk for sustaining anterior cruciate ligament [ACL] injuries. A poor LESS score suggests a high risk for ACL injuries. The effect of LESS scores on femoral articular cartilage [FCT] deformation is not clear. The purpose was to investigate the effect of poor landing performance, as defined by the LESS, on FCT deformation in healthy, recreationally active females.

The study consisted of 11 recreationally active female subjects aged 18 to 25 years old with no history of diagnosed knee or lower extremity injury or surgery. After obtaining informed consent from the subject, ultrasound images were taken of the FCT. Using video cameras placed in the sagittal and frontal plane, 2 sets of 10 drop jumps from a height of 30 cm were recorded and analyzed. Ultrasound images were taken again amid the two bouts of drop jumps, and again at the end. Using Kinovea software, the 17 biomechanical components of landing in the LESS were assessed, and observed errors were recorded. A high LESS score indicated a high number of landing errors, which implied poor overall landing technique. 5 subjects obtained a score of 4 errors and 6 subjects obtained a score of 5 errors according to the LESS. There were no differences in cartilage deformation when comparing subjects who landed with a LESS score of a 5 versus those who scored a 4 ($P > 0.05$). The observed statistical power was 0.658.

Due to insufficient statistical power, further studies should examine if poor landing technique affects articular cartilage deformation after drop-jumping activities. Thus, the ultimate goal is to determine if landing technique increases risk of articular cartilage injury and joint conditions. The focal point of future research projects could be the long-term effects of regular exercise with poor impact technique on FCT deformation by continuing to study the participants

and finding predictive patterns in development of osteoarthritis, ACL injuries, and other lower extremity conditions.

Background

Knee Cartilage and Ligament Injury in Young, Active Individuals

Young, recreationally active individuals experience high incidences of injuries to cartilage and joint conditions in the lower extremities. Hyaline cartilage injuries of the knee include meniscus and articular cartilage tears, osteochondritis, osteoarthritis, overuse inflammation (Osgood-Schlatter), and fissures. When participating in recreational or competitive sports during development, the cartilage within the joint can be acutely or chronically impacted, compressed, torn, and twisted. This is of interest because physical activity should optimize joint development, starting in childhood; increasing volume of cartilage obtained during development should reduce risk of developing joint conditions such as osteoarthritis later on in life (Jones, 2003).

The of anterior cruciate ligament [ACL] injury, is 4-to-6 times greater in female athletes than male athletes for a variety of reasons: neuromuscular control and development, increased tendency for valgus motion, and changes in anterior knee laxity during the menstrual cycle (Hewett, 2010). The risk also increases if the individual specializes in a single sport, with men's spring football, women's gymnastics, and women's soccer having the greatest ACL injury rates in a 15-sport, 16-year study in the National Collegiate Athletic Association (Hootman, 2007). ACL injuries are of special concern because of the increased risk for re-rupture and potentially permanent removal from practicing the sport. The rate of ACL re-rupture averages to 11% of cases in athletes; of those, revision surgery is performed in about 3.5% of them, with a return-to-play rate of 50% (Gans, 2018). Despite the high incidence rate, proper rehabilitation and prevention programs and improved surgical techniques reduce the risk of recurrent ACL injury. In the 10-year study in the NCAA with Gans (2018), the overall rate of change per year for recurrent ACL tears was 0.85%, with a stronger rate of decrease in females. However, the incidence rates of ACL injuries remain high overall and since ACL injuries carry a long-term burden of early onset knee osteoarthritis (Lohmander, 2007), it is also clear that a better understanding of how joint loading is affected during movements that have been known to cause ACL injuries is needed.

Biomechanics Affecting Knee Joint Loads

Repetitive and high compressive loads from improper biomechanics can cause irreversible damage to the body, especially in landings that are more erect. Although femoral articular cartilage [FCT] deformation normally occurs in acute amounts daily (Kilic, 2014), landing technique affects knee joint loads leading to greater FCT deformation (Harkey, 2018).

While there is little known about how landing technique affects FCT deformation, landing technique has been shown to potentially increase loads on the ACL which can predispose the person to injury. A study investigating landing biomechanics in males versus females found that females tend to have less knee and hip displacement and greater ground reaction forces than their male counterparts (Schmitz, 2007). In the sagittal plane, the decreased flexion increases the load on the knee joint, thus it is more difficult for energy to be absorbed by the muscles surrounding the joint and the vertical ground reaction force response is greater. When a greater range of motion is obtained in the landing of a jump, there is less emphasis on the knee joint tissues and it is dispersed to the muscles. In the frontal plane, a common biomechanical predictor of ACL injury is knee abduction, otherwise known as valgus. This describes movement of the knee towards the midline while the lower leg and foot move away from the midline. Hewett's study (2005) on female athletes found 20% greater ground reaction forces in those with an ACL injury compared to those without and knee abduction predicted ACL injury status.

Proper technique in repetitive, high compressive load activity is important both in preventing injury and in surgery rehabilitation. Individualized post-operative rehabilitation plans for athletes who had knee cartilage repair should have a knowledgeable coach, athletic trainer, or physical therapist who will help with progressively strengthening the surrounding muscles - such as the quadriceps and glutes (Mithoefer, 2012). Overall, while landing technique is influential in determining the lower extremity positions that predisposes a person to ACL injury such as knee valgus, it is unclear if landing technique influences femoral articular cartilage deformation. Repetitions of high impact movements typically lead to cartilage deterioration, and the effect is greater when movements are completed with poor, erect technique.

The Landing-Error Scoring System

The LESS was developed in 2009 as a standardized tool to assess movement patterns determined to be risk factors for ACL injury. The system is composed of 17 observable and evaluative elements of a drop-jump landing kinematics in the sagittal, frontal, and transverse planes (Figure 1). Errors in the sagittal plane include decreased knee and hip flexion, frontal plane errors include increased knee valgus and hip adduction, and errors in the transverse plane show increased internal knee and hip rotation moment. In the JUMP-ACL study used in the determination of the validity and reliability of the LESS, it was determined that the LESS properly identified risk factors for ACL injury in landing technique, as well as greater incidence of poor performance and less incidence of excellent performance in females compared to males.

Thus, it was concluded the LESS could be used in larger-scale studies as an efficient injury-prevention and injury-risk screening tool for noncontact ACL and lower extremity injury.

Padua further implemented the LESS in 2015 in a study with elite-youth soccer athletes, in which it was determined that participants with a score of 5 or more had greater risk of ACL injury than participants with a score less than 5. Given that the LESS is a reliable tool to evaluate landing performance and it appears to add additional insight into knee injury risk, specifically ACL injuries, its ability to determine the extent of FCT deformation in poor versus good performances is unknown and could potentially extend the clinical utility of the LESS.

Purpose and Hypothesis

Purpose

The purpose of the project was to investigate the effect of poor landing performance, as defined by the LESS, on FCT deformation in healthy, recreationally active females.

Hypothesis and Significance

It was hypothesized that subjects with poorer landing technique scores (≥ 5 errors) according to the LESS would have greater amounts of FCT deformation than those with good LESS scores (≤ 4 errors). Should the results show that poor LESS scores lead to higher FCT deformation, future studies should examine whether poor landing technique may incline individuals to possess increased risk of articular cartilage injury and joint conditions.

Methods

The IRB approved study consisted of 11 recreationally active female subjects aged 18 to 25 years old. The subjects did not have any current diagnosed knee or lower extremity injury, previous diagnosed knee injury, or history of knee surgery. Data collection, reduction, and analyzation all occurred in the Performance Optimization Lab of the Ward Sports Medicine Building at East Carolina University.

Procedures

Upon arrival to the Performance Optimization Lab, the subjects completed an informed consent process. Then, they completed the Knee Injury and Osteoarthritis Outcome Score (KOOS) was used to quantify the subject's knee health in the week leading up to participation. The Tegner Activity Score Sheet was also used to assess the subject's physical activity level with a scale of 1 to 10 ranging from sedentary to professional athlete, respectively. After the surveys were completed, height and weight were recorded.

Subjects laid supine on an examination table and laid down with one knee flexed to 140°, verified with a goniometer. Two images of the superior surface of the patella were captured using ultrasound, which displayed the space of the femoral articular cartilage in the medial condyle, intercondylar notch, and the lateral condyle (Figure 1). Then the knee was fully extended and then repositioned to the flexed position, followed by two more images of the superior surface of the patella and were used as the control images. The same procedure was performed for the opposite leg as well.

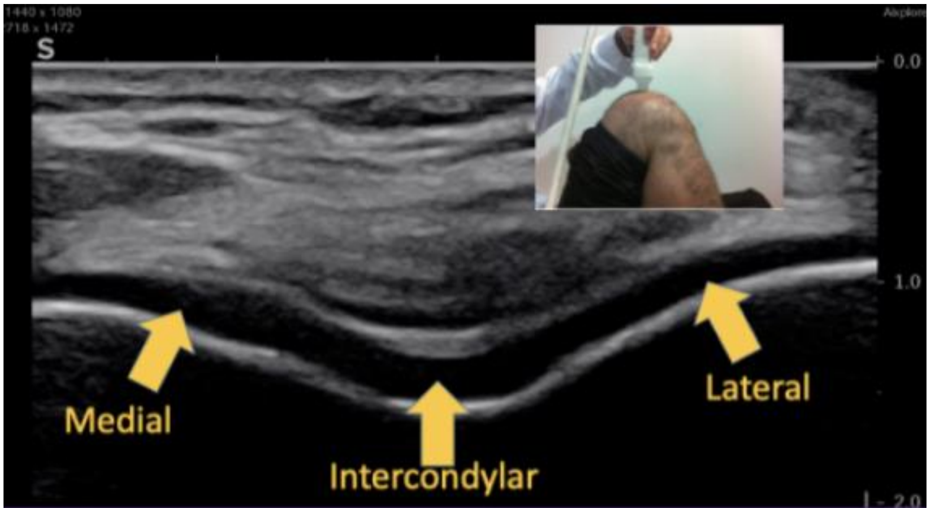

Figure 1. Pre-analysis ultrasound image of femoral cartilage and location of probe.

After the control images were captured, the performed the first round of 10 drop jumps. A research team member would demonstrate for the subject how to perform a drop jump, since the subject would not be allowed to have a "practice jump" which could cause alterations to the femoral articular cartilage. Using video cameras placed in the sagittal and frontal planes, 10 maximal effort drop jumps from a height of 30 cm were recorded. Then, the subject returned to the examination table to capture 2 more ultrasound images of each knee, positioned the same as in the control image. The subject completed 10 more maximal effort drop jumps followed by 2 more images of each knee. The total time for the in-lab procedures is approximately 45 minutes.

Data Reduction Procedures

The sagittal and frontal plane recordings of the drop jump landing task were exported from the video cameras to a computer equipped with Kinovea software for LESS analysis. After viewing the 20 total jumps, 3 jumps representing the most consistent performance of the subject were used for analysis with the LESS. The 3 jumps selected were not from the first 3 jumps performed in each set of 10 due to potential inconsistency in subject performance. Using Kinovea software, the frontal and sagittal view of the same jump trial were synchronized and the frame position of initial contact, full contact, maximum knee flexion, and maximum knee valgus were recorded (Figure 2).

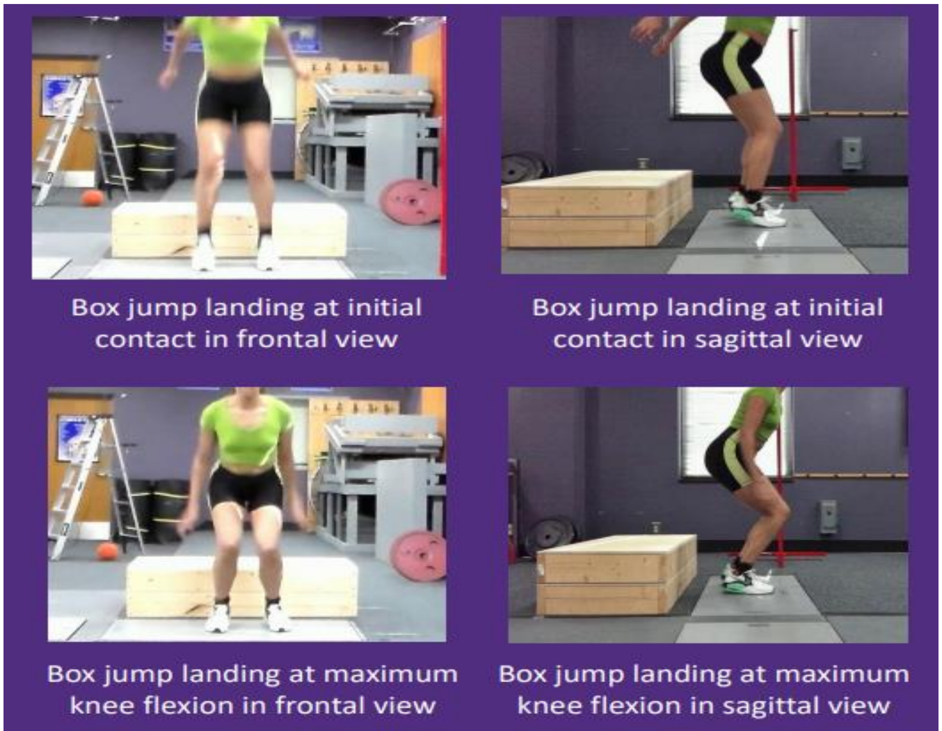

Figure 2: Analysis of landing

Then, the 17 biomechanical components of landing in the LESS were assessed, beginning with errors at initial contact (Figure 3). Some of the reviewed biomechanical components required using Kinovea's goniometer feature to determine degrees of flexion and line drawings were used to observe alignment. Any observed errors according to the LESS criteria were recorded in an Excel file and the number of errors for the jump was recorded. The same procedure was repeated for the other two consistent jumps, followed by determining the final error score of the subject. To be considered an overall landing technique error, the errors recorded had to be present in at least 2 of the 3 consistent jump trials. A high LESS score indicated a high number of landing errors, which implied poor overall landing technique.

LESS Item

Knee flexion at IC > 30°
Hip flexion at IC
Trunk flexion at IC
Plantarflexion at IC
No knee valgus at IC
No lateral trunk flexion at IC
Non-wide stance at FC
Non-narrow stance at FC
Foot internal rotation < 30° from IC --> MKF
Foot external rotation < 30° from IC --> MKF
Symmetric feet landing
Knee flexion displacement > 45° IC --> MKF
> Hip flexion at MKF than IC
> Trunk flexion at MKF than IC
No knee valgus at MKV
Big trunk, hip, & knee displacement IC -> MKF
Soft land & no frontal plane knee movement

MKF = maximum knee flexion, MKV = maximum knee valgus, IC = initial contact, FC = full contact

Figure 3. Landing Error Scoring System [LESS] criteria

Results

In the qualitative analysis using the LESS 5 subjects averaged with a score of 4 errors over 3 consistent drop-jump trials and 6 subjects averaged with a score of 5 errors. According to the LESS criteria, a score of 5 or more signifies the subject is at greater risk of sustaining ACL injuries and may be targeted for ACL-injury prevention techniques. Thus, 54.5% of subjects were considered to have poor landing technique. The remaining subjects were scored as a 4 and were considered to have good landing technique.

In terms of the quantitative analysis of the femoral articular cartilage thickness, the data collected was run through the Statistical Package for the Social Sciences (SPSS). Figure 4a displays the analysis of the right limb cartilage thickness and Figure 4b displays the results of the left limb, with the darker bars representing LESS scores of 4 and the lighter bars representing LESS scores of 5 with the numbers above the bars respresenting the standard deviations. "RC" and "LC" represent the control measurements, which is an average of the measurements of C1 and C2 ultrasound images. "RC4" and "LC4" represent the ultrasound measurements after the subject's complete in-lab procedure. The SPSS found that there was no significant difference in cartilage thickness changes from the control condition measurements to the post-landing measurements when comparing LESS scores of 4 with LESS scores of 5. The only area of significant FCT deformation (P > 0.05) was in the left lateral condyle following the full drop-jump procedure and this change occurred in both groups; those who landed with LESS scores of 5 and those who landed with LESS scores of 4.

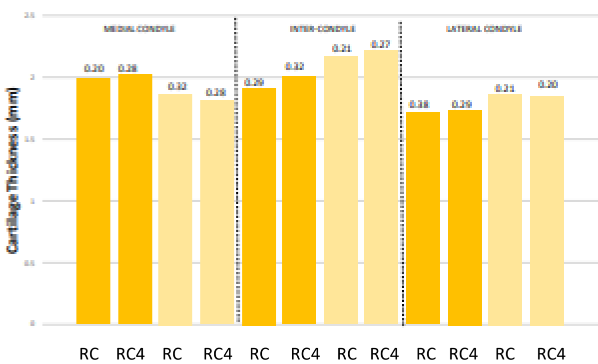

Figure 4a. Analysis of right limb cartilage thickness

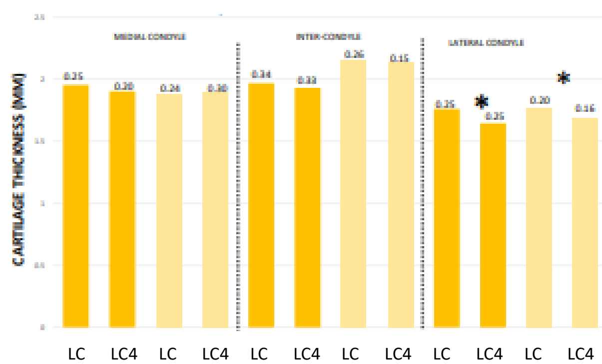

Figure 4b. Analysis of left limb cartilage thickness

Discussion and Limitations

There was no difference in FCT deformation in subjects who landed with good technique at a LESS score of 4 versus subjects who landed with poor technique at a LESS score of 5. There was little difference between the two groups of LESS score outcomes, as opposed to if a subject had a LESS score of 2 versus 8. Future research should seek to address the effect of landing performance on FCT deformation in subjects with a wider range of landing performance scores according to the LESS.

The primary limitation of this research project was having less than enough subjects to obtain statistical power thus far. The observed power for left lateral femoral articular cartilage thickness was 0.658 for 11 subjects. The goal for observed power is 0.8 for reliability and the project would require at least 20 subjects to have appropriate statistical power The limitation of the number of subjects is creditable to the requirements the subjects had to meet to be able to participate: female aged 18 to 25, no past or present history of knee or lower extremity injury, and recreationally active for 4 days per week. Future testing is determining the possibility of expanding the research project to include male subjects as well.

Another limitation was the restrictive and dichotomous criteria of the LESS. Error was defined by either a "yes" or a "no" in regard to meeting the criteria for the majority of the 17 biomechanical components. While this is valid in determining whether or not there is technical error, it does not consider the degree of the error. For example, the bottom-left image of Figure 2 appears at first glance to have no apparent knee valgus. However, since the center of the patella is aligned more medially than the great toe, it is graded as an error. While this is true, it does not create distinction in the analysis process between those who have slight knee valgus and those whose knees "knocked" in the valgus position. Additionally, some subjects with extensive athletic experience may have trained to land specifically for their sport, which requires different technique than the drop jumps. For example, participants trained as dancers are taught entirely different biomechanics for jumping in which the legs and feet are externally rotated. Thus, having the subjects perform drop jumps with their legs and feet aligned straight forward require irregular neuromuscular activation, which affects their error results.

Conclusions

The results did not support the hypothesis that poor landing technique causes greater femoral articular cartilage deformation. Since cartilage deformation occurred on the left lateral condyle in both outcome groups (LESS score of 4 versus 5), there was no evidence from the results suggesting landing performance influences FCT deformation. The inconclusiveness was likely due to low statistical power. All of the subjects scored either a 4 or a 5 on the LESS, suggesting the two groups may not be different in terms of landing error performance according to the LESS. Having a more diversified sample of subjects, as well as having a sample size of at least 20 ($n \geq 20$), would shed more light onto whether or not there is a relationship between poor landing technique and FCT deformation in healthy females.

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