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Position and Time: Examination of LESS Scores for Division 1 Basketball Players

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for Division 1 Basketball Players

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Table of Contents

Tables and Figures

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ABSTRACT

Background: The anterior cruciate ligament (ACL) is responsible for stabilizing the knee by limiting the movement of the tibia anteriorly. The injuring of this ligament is one of the most prevalent sports related knee injuries to occur in athletics, specifically female athletes between the ages of 14 and 18.

Purpose: The purpose of this research was to examine differences in LESS scores between frontcourt, backcourt, male, and female NCAA Division 1 basketball players and to measure any changes in LESS scores between the beginning and end of the season.

Methods: Participants were 24 Division 1 basketball athletes (10 female, 14 male). They completed a LESS screen three times and scores were analyzed using a computer system (Dartfish). These screens were scored by the researcher and then analyzed in SPSS to test for statistical significance.

Results: Results showed no statistically significant difference in LESS scores between position (0.65) or gender (0.904), but did show a significant decrease in LESS scores from preseason to postseason testing.

Conclusion: Overall, Longwood's basketball athletes do not seem to differ based on gender or position which would conclude that the athletes training regiments are similar to each other and not specified to limitation or positions. The significant decrease in preseason LESS scores to postseason LESS scores could be attributed to the similar training regimens as well.

INTRODUCTION

The anterior cruciate ligament (ACL) is located within the knee joint and is responsible for stabilizing the knee by limiting the movement of the tibia anteriorly. The injuring of this ligament is one of the most prevalent sports related knee injuries to occur in athletics (Padua, et al., 2009). Athletes who have the highest risk of an ACL tear are female athletes between the ages of fourteen and eighteen who engage in sports that involve sharp turns, quick accelerations, and pivoting movements (Padua, et al., 2009). Examples of these high-risk movement sports includes: soccer, basketball, skiing, volleyball, and tennis. The athletes who participate in high-risk sports complete movements necessary for deceleration and, if the athlete is unable to control their deceleration, they may be at a higher risk for non-contact ACL injuries (Wesley, Aronson, & Docherty, 2015). After an ACL tear, surgery and/or lengthy rehabilitation may allow an athlete to return to competition, but there still can be other significant long-term health impacts. One of these long-term health impacts is knee osteoarthritis (OA), with over 50% of individuals with an ACL tear developing knee OA within 12 years (Chaudhari, Briant, Bevill, Koo, & Andriacchi, 2008). Although ACL tears are typically repaired via surgery, the injury can be managed in some individuals non-surgically with the use of physical therapy. ACL reconstruction surgery often results in a significant financial burden with the average cost per surgery to be $17,000 in the U.S. (Houston, Greenfield, & Wojtys, 2000). This older figure does not account for the increase in health care costs or the necessary months of post operation physical therapy.

A common misconception with the public is that after surgery from a torn ACL, an athlete can return to normal competition within a short period of time. While many athletes do return to competition, approximately 25% or more are physically unable to return to their previous levels of activity (Padua, et al., 2015). Of those athletes that are able to return to their previous level of activity, a significant number of them, 20%, experience a second ACL injury in their lifetime (Gokeler, et al., 2014). Paterno, Rauh, Schmitt, Ford and Hewitt (2014) determined that athletes who have previously torn their ACL are also six times more likely to re-injure their repaired ACL than an athlete who has never suffered an ACL injury. They also concluded that female athletes who had suffered an ACL injury were twice as likely to tear the ACL in their contralateral knee than those without a previous ACL injury (Paterno, 2014). Non-contact ACL injuries tend to stem from poor mechanics. In a study done by David Bell et al (2014), athletes who previously tore their ACL demonstrated poor landing mechanics with the injured leg and received Landing Error Scoring System (LESS) scores indicating a higher risk of injury than prior to their injury. This, along with Paterno's study (2014), confirms that athletes who tear their ACL tend to demonstrate high risk landing mechanics and are at a significantly higher risk than their uninjured counterparts for an ACL injury (retear or contralateral). Initial injuries caused by poor mechanics may continue to affect the athlete after repair if the underlying biomechanical issues are not addressed.

Knee OA is a lifelong injury that affects activities of daily living making simple tasks more difficult for impacted individuals. Individuals with knee OA experience an increase in pain the longer he/she has knee OA as the cartilage continues to wear away and bone-to-bone contact is increased. Athletes who experience an ACL tear are much more likely to develop OA in their injured knee later on in life, with over 50% of athletes who experience an ACL injury developing knee OA within a twelve-year range after their initial ACL injury occurred. In comparison, athletes who did not injury their ACL, only had a 7% chance of developing knee OA. This increase in risk of developing knee OA can possibly be linked to a shift in knee joint mechanics in an individual after an ACL injury. It is believed that due to compensation for the repaired ligament, the knee adapts by altering the loading pattern within the knee, thus increasing forces applied to cartilaginous areas not usually responsible for load bearing (Chaudhari, Briant, Bevill, Koo, & Andriacchi, 2008). This altered loading pattern on the articular cartilage may then contribute to the development of knee OA in this injured group of individuals.

Women in collegiate sports are 6-8 times more likely to suffer a knee injury while participating, specifically an ACL injury, than their male counterparts (Arendt, Agel, & Dick, 1999). Females who participate in sports requiring quick movements and changes of direction are at the highest risk of an ACL injury (Padua, et al., 2009). Although not specific to all females, significant research has suggested that this increased risk could be linked to hormonal, anatomical, or biomechanical/ neuromuscular factors (Shultz, et al., 2015). Anatomically, females have a smaller ACL in length, volume, and cross-sectional area than males, even after adjusting for body size (Chandrashekar, Slauterbeck, & Hashemi, 2005). Additionally, female ACL's have been shown to have lower collagen density than their male peers (Hashemi, Chandrashekar, Mansouri, Slauterbeck, & Hardy, 2008). Collagen is responsible for allowing flexibility in the ACL and thus, a decreased level of collagen may result in a decrease of flexibility in the ACL. Most females also have greater tibial slopes (Hashemi, Chandrashekar, Bill, et al., 2008) and smaller femoral widths than males which are both related to smaller ACL sizes (Chandrashekar, Slauterbeck, & Hashemi, 2005). These anatomical differences between genders may lead to greater joint issues, such as ACL tears, at the onset of exercise (Shultz, et al., 2015).

Hormonal differences between males and females, specifically pertaining to estrogen levels, may also be linked to gender differences in ACL injury incidences (Shultz, et al., 2015).

The changes in hormone levels during the menstrual cycle, specifically the preovulatory phase, in females has been linked to an increase in the incidence of ACL injuries (Shultz, et al., 2015). The ACL is home to sex-related hormone receptors, such as estrogen receptors, and may affect collagen metabolism allowing the hormone to directly affect the ACL (Faryniarz, Bhargava, Lajam, Attia, & Hannafin, 2006). Females during their menstrual cycle demonstrate more knee laxity than females who are not in their menstrual cycle, which is already higher than their male counterparts (Deie, Sakamaki, Sumen, Urabe, & Ikuta, 2002). Besides estrogen, the hormone relaxin, which was found in elevated levels in many females with a torn ACL (Dragoo, et al., 2011), may cause a break down in collagen structure which could lead to an increase in ACL laxity and injury (Dragoo, Lee, Benhaim, Finerman, & Hame, 2003).

Biomechanically, females tested in a functional exercise protocol demonstrated landing mechanics that were not as “by the book” as compared to their male counterparts (Wesley, Aronson, & Docherty, 2015). Most noncontact ACL injuries are sustained during a sudden deceleration or change in motion suggesting that landing mechanics are directly linked to these injuries (Shimokochi & Shultz, 2008). ACL injuries tend to be associated with an upright landing with little to no hip and trunk displacement during loading, causing a higher vertical ground reaction force (Blackburn & Padua, 2009), which then must be absorbed by the knee. Cognitive function may also have a correlation with ACL injuries as athletes who had a slower processing speed and worse spatial awareness were more likely to sustain an ACL injury (Herman & Barth, 2015). Therefore, athletes with decreased cognitive function may have an increased risk of ACL injury because their control of body parts, such as trunk placement during landings, may be decreased (Herman & Barth, 2015).

Many non-contact ACL injuries occur in the second-half of an athlete's season and/or game (Moller & Lamb, 1997). Because these injuries occur in the later half of the season, changes to landing techniques may decrease amount of injuries. Timing of injury late in a game or season may be linked to the athlete's fatigue. After an athlete completes strenuous activities, the muscles surrounding the fatigued area often display decreased coordination (Nyland, Shapiro, Stine, Horn, & Ireland, 1994). The decreased coordination and fatigued muscles attempting to compensate may result in changes in an athlete's landing mechanics (Nyland, Shapiro, Stine, Horn, & Ireland, 1994). If an athlete is continuously completing jump/landing movements, the quadriceps and hamstrings will start to experience fatigue which could result in increased anterior tibial translation (Wojtys, Wylie, & Houston, 1996). Since the ACL is responsible for limiting the movement of the tibia anteriorly, this suggests that fatigue may cause an increased amount of stress placed on the ACL, thus increasing the injury risk (Wojtys, Wylie, & Houston, 1996). Anatomical and hormonal gender differences cannot be easily or ethically changed to reduce the incidence of an ACL injury, but biomechanical differences can be adjusted by implementing prevention programs that directly affect the landing issues.

In examining sport specific risk, Krosshaug, et al. (2007) examined the likelihood of suffering an ACL injury for frontcourt versus backcourt basketball athletes. The researchers utilized videos of 39 participants injuring their ACL's. They categorized the movement associated with the injury as: one leg, two legs, or crossovers. In the video analysis, 29 of the 39 athletes were injured doing something called "attacking," which was defined as when the backcourt athlete drove towards the basket. This supports the idea that the "attacking" mode with planting and cutting motions used by back court athletes may be associated with an increased risk of knee injuries. Although non-contact ACL injuries are the most common, Krosshaug, et al., (2007) did notice that prior to the injury for many of the female athletes, there was physical contact with another player right before the injury. This contact could have caused the athlete to become unbalanced during the subsequent motion and resulted in a poor landing which would increase the risk of an ACL injury. Even though contact could have led to a decrease in coordination, these injuries are still classified as non-contact due to the injury not being the result of blunt force trauma. Most of the injuries occurred while the athlete was in possession of the ball and occurred during a landing maneuver (Krosshaug, et al., 2007). Frontcourt athletes differ from backcourt athletes in their common sports movements. Frontcourt players, playing closer to the basket, can be jostled more when shooting or going for a rebound, but do not demonstrate significant planting and cutting motion. This contact from other individuals while shooting or rebounding, could account for the injury mechanism for frontcourt players.

The most effective way to combat ACL injury rates and the acute and long-term health impacts is the implementation of a prevention program (i.e. FIFA 11+). A variety of ACL prevention programs have been utilized effectively to decrease the risk of an ACL injury (Prodromos, Han, Rogowski, Joyce, & Shi, 2007). While there are no standards for these prevention programs, they tend to include activities such as plyometric training, balance training, and strengthening exercises (Shultz et al, 2015). It has been suggested that benefits can be seen from these types of activities when they are performed two to three times a week (Shultz et al, 2015). Much of the focus is on strengthening the hamstring muscles and increasing lower extremity neuromuscular control during landing (McCall, Carling, Nedelec, et al., 2014). Strengthening the hamstrings is a main focus because a hypertrophied quadricep without mechanical balance from the hamstrings could result in an athlete being predisposed for an ACL injury (Moul, 1998). The hamstrings are responsible for aiding the ACL by reducing anterior movement of the tibia during landing maneuvers and thus an imbalanced hamstring muscle could result in injurious landing mechanics (Moul, 1998).

An increased number of ACL injuries occur during preseason training and a modified practice regimen may also assist with preventing ACL injuries (Hootman, Dick, & Agel, 2007). This could include multiple shorter practices throughout the day instead of one longer practice, increasing recovery time, or not exercising in an environment that could be detrimental, such as running on wet concrete (Hootman, Dick, & Agel, 2007). These changes in practice schedule could decrease injury risk without the implementation of prevention programs, however, a prevention program would still be beneficial for at risk athletes. Limited knowledge on the effectiveness of prevention programs may be linked to compliance issues. The reactions of coaches to prevention programs strongly influence program adherence (Ekstrand, 2013), mostly because a coach who does not agree with the program will not encourage the athletes to participate. Athletes and coaches are both more likely to adhere to a change in program if the program leads to increased performance and decreased injury rates (Keats, Emory, & Finch, 2012). It may be beneficial to improve athlete compliance by educating athletes about their risk of injury, which can be completed with a clinical screen of landing mechanics.

A clinical tool that helps assess a specific athlete's landing mechanics for an increased risk of ACL injury is the Landing Error Scoring System (LESS). The LESS is a screening tool commonly used to assess likelihood of lower extremity injuries based upon an individual's landing performance. This system was developed by Padua, et al. (2009) and implemented in his JUMP ACL (Joint Undertaking to Monitor and Prevent ACL injuries) study with military academy subjects. The JUMP ACL study collected data from 2691 subjects and utilized that information to determine the components of the LESS. Padua, et al. (2009) completed this study to test the reliability of the LESS screen in identifying risk as compared to that of an in-depth 3D motion analysis. After completing this study, the researchers concluded that the LESS was a clinically relevant tool that was a reliable and less expensive way to assess an individual's risk of suffering an ACL injury.

The LESS is designed to allow a clinician to examine the landing of an individual to identify high risks errors in landing technique that may lead to an ACL injury. Clinicians utilize a scoring sheet that identifies where on the subject to examine in the sagittal plane and frontal plane during their landing. As part of the evaluation, the clinician examines the torso, feet, knees, and hips in the frontal and sagittal plane utilizing a video and assigns the athlete a score based on the landing performance. The lower the number of "errors" (points), the lower the risk of an ACL injury. It has been determined through an extensive examination that athletes who scored above five points were at a higher risk for an ACL injury than those who scored below five (Padua, et al., 2009). Even though using LESS screening assigns an athlete the likelihood of injury, it does not conclude that athletes who scored above five will absolutely suffer an injury, nor does it suggest that athletes who scored below five are immune from an ACL injury.

The purpose of this research study was to examine differences in LESS scores between frontcourt, backcourt, male, and female NCAA Division 1 basketball players and to measure any changes in LESS scores between the beginning and end of the season.

METHODS

Participants

Participants in this study were 24 Division I men and women's basketball players (14 males, 10 females). Each participant completed a health questionnaire about any previous lower extremity injuries and certified their clearance to participate fully in all practice activities.

Athletes who had suffered an injury and were unable to practice or play were excluded from participation in the study. Prior to participating, participants were informed of possible risks and completed consent forms approved by the Longwood University IRB. Participation for the initial LESS screen prior to the season was 24 participants, however, only 15 completed the postseason LESS screen (12 males, 3 females). These losses in participants were due to team departures, injuries, and NCAA restrictions on team activities post season.

Participant Testing

Each athlete was tested in an athletics strength and conditioning facility during a team strength and conditioning session. A warm-up designed by the specific strength coach for each team was completed by all participants before testing. Typical strength and conditioning apparel (shorts and t-shirts) and shoes were worn by the participants. After completing the three landing trials, the participant finished their strength and conditioning routine.

LESS Set-up

Participants completed the LESS activity as outlined by Padua (2015). Each participant was verbally informed of the LESS protocol and asked to stand on a 30-centimeter plyometric box with their toes near the edge. The participant was then informed to complete a horizontal broad jump out until his or her heels went past a piece of tape on the ground that was

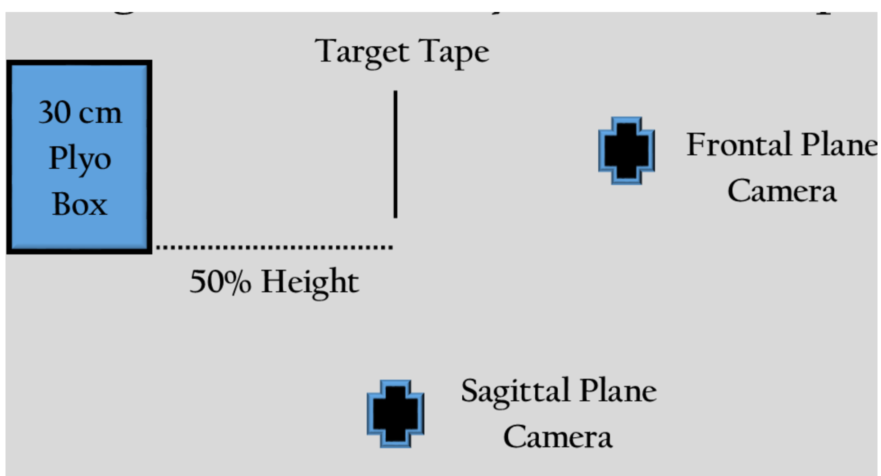


Figure 1: Accurate depiction of LESS set-up

at a distance from the box that was 50% of the participant's height. After completing the landing from the box, the participant was informed to immediately complete a maximal vertical jump. While specific instructions were given, the jump and landing activity was not demonstrated for participants so as to not bias their performance. Additionally, athletes did not receive feedback on their landings during testing. When running the test, we allowed each athlete to complete practice runs until he or she felt comfortable with the maneuver. Cameras (GoPro, Inc., San Mateo, CA) facing the frontal and sagittal plane recorded the landing for later analysis. The physical camera set-up utilized in this study is depicted in Figure 1.

Scoring of Performance

The videos of participant performances were evaluated using Dartfish 6.0 (Dartfish USA, Alpharetta, GA). The landing performances were analyzed using the LESS scoring sheet by the main researcher of the study. She was trained by her supervisor by scoring multiple LESS screens completed by other athletes and her scores were compared to that of her supervisors. Each trial was scored and the average of the three trials was used in the statistical analysis. Appendix 1 includes the scoring sheet utilized for the LESS screen. LESS scores greater than 5 are considered high and the individuals are "at risk" for an ACL injury.

Statistical Analysis

A univariate 2x2 ANOVA design was utilized via SPSS to analyze the preseason LESS scores for differences in gender and position. When examining changes in LESS scores over the season by gender and position, a second 2x2 repeated measures ANOVA was completed using SPSS. Statistical results were considered significant if they had a P value $\leq .05$.

RESULTS

Average LESS scores for men and women preseason were very similar to each other. P values for men versus female showed no significance at 0.904 and frontcourt versus backcourt at 0.65. Because these P values are over .05, the statistical analysis showed no significance. Postseason LESS scores for men averaged 5.47 ± 1.09 and women averaged 6.44 ± 0.84, which showed more of a difference than preseason data. These scores and their significance are depicted in Tables 1 and 2. There was a significant decrease in preseason LESS scores versus postseason LESS scores with a significance of $P \leq 0.001$. The univariate 2x2 ANOVA on the preseason LESS scores showed no statistical differences for gender and position. The t-test comparing preseason LESS scores to postseason scores showed a decrease in LESS scores over season.

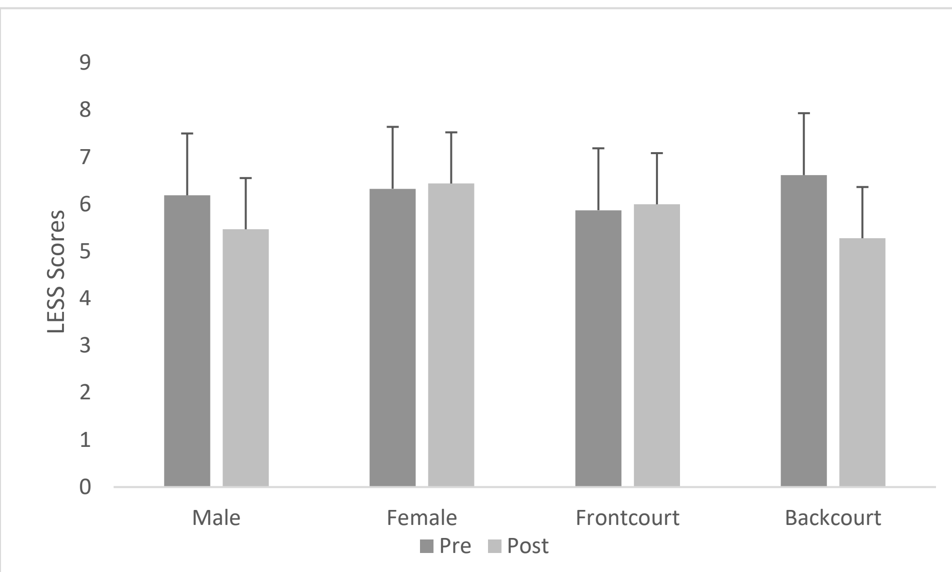
	Number	**Less**	**P**
Males	14	6.38	0.904
Females	10	6.3	
Frontcourt	12	6.25	0.65
Backcourt	12	6.44	

Table 1: This table depicts Preseason LESS scores compared by position and gender to test for significance.

	Number	Pre	Post	Difference	P
Males	12	6.19	5.47	0.72	0.001 *Pre-Post Comparison
Females	3	6.33	6.44	0.11	
Frontcourt	8	5.88	5.99	0.12	
Backcourt	7	6.62	5.28	1.33	

Table 2: This table depicts average preseason and postseason LESS scores for both genders and positions to test for a difference in pre to post scores.

Figure 2: This graph depicts LESS score results between males and females, frontcourt and backcourt for pre and postseason



DISCUSSION

Female vs Male

There was no statistical difference in the LESS scores between female and male basketball athletes in this study. This means at Longwood University, men and women's basketball athletes do not differ significantly in their LESS determined ACL risk. Landing technique did differ slightly as women tended to err more in patella placement while men err more in knee angle by not reaching the full 90° at maximal flexion. These results could be explained by examining the strength and conditioning programs utilized by both teams. Studies show (Moul, 1998; Shultz, et al., 2015) that prevention programs can decrease risk of ACL injuries. Since both programs are utilizing information gained from studies, and the Strength and Conditioning staff are all CSCS certified, the training regiments would be similar allowing the athletes to receive training similar to a prevention program. This suggests that the biomechanical landing differences between genders could be decreased, allowing for similar LESS scores

Frontcourt vs Backcourt

There was no statistical difference in the LESS scores between frontcourt and backcourt basketball athletes in this study. As stated earlier, it is believed that the "attacking" movements of backcourt athletes should increase the likelihood of ACL injury (Krosshaug, et al., 2007). However, this was not confirmed by the LESS results from this study. This could be caused by the athletes at Longwood possibly being trained the same instead of trained based on the physical demands of the position. Future research could look at the possibilities of using video analysis to examine whether or not a LESS screen is capable of assigning risk to both frontcourt and backcourt athletes since the movements required differ so greatly.

Preseason vs Postseason

There was a significant difference in LESS scores between preseason and postseason basketball athletes ($P = 0.001$). The average LESS scores decreased from preseason testing to postseason testing. This may be due to the smaller amount of athletes that participated in postseason testing or due to the increased variations in scores. When looking at postseason data in comparison to preseason data, some participants scores decreased while others increased.

Because of the smaller sample size, these variations effected the results more than the small fluctuations in scores.

The continued use of the strength and conditioning facilities throughout the season may have also trained the athletes to strengthen imbalanced muscles. The continued training regiment could have acted like a prevention program and that would account for the decrease in LESS scores. Fatigued muscles would be unable to perform at the same capability during a game unless the muscles have been trained to last longer during a performance. The training regiment that these athletes use may decrease the affects of fatigue simply by increasing the endurance of the muscles. While this study examined group changes, future studies could examine individual changes in LESS scores to determine impacts on individual performance.

Limitations

Since only Longwood Basketball athletes were included, the sample size for this specific study was small. In future research, to rectify this limitation, a study could be completed that included either all of Longwood's athletes, or basketball athletes at multiple universities. Basketball was chosen for this specific study because of the increased risk of the sport as well as the different physical demands based on position, which seemed like an important area to research. The sample size was lessened again for post season data by a variety of factors: NCAA practice regulations, team departures, and injuries, which caused the sample size to drop from 24 participants to 15. Most of these losses in participants were female due to team's scheduling conflicts.

Another limitation is the environment in which each participant was tested. A strength and conditioning session was utilized for the testing environment based on the tight schedules of the athletes. However, because the athletes were pulled aside during different segments of the training session, each athlete could have a different level of fatigue already in place. For example, if during the training session, an athlete completed multiple repetitions of a heavy back squat, he or she would already have fatigued quadricep muscles prior to testing. This could also account for the postseason scores not being much different than the preseason scores.

Lastly, although the LESS analyzer was taught how to score a LESS screen and practiced before grading the actual research, she is still considered a novice in the field based on few years of experience. Although this could be an issue, she scored each screen which would lessen the impact of being a novice in the field. That along with prior training makes this less of a limitation.

CONCLUSION

The purpose of this research was to examine differences in LESS scores between frontcourt and backcourt NCAA Division 1 basketball players and to measure any changes in LESS scores between the beginning and end of the season. In conclusion, the preseason test showed no significant difference in LESS scores between gender or between position. The postseason results showed a statistically significant decrease in LESS scores from preseason to postseason. This would conclude that fatigue over season did not affect LESS scores for this group of participants and that the strength and conditioning programs may be structured in a way to reduce athlete's risk of injury. Overall, this study showed that Longwood's men and women's basketball programs did not have a significant difference in LESS scores when gender or position was taken into consideration. Future research could look at LESS scores preseason and postseason for a specific program but compare the athletes' scores that remain in the program to those who depart the program, searching for a survivor bias. The survivor bias may have affected the results by having the athletes who became injured during the season removed from the study.

This research would solve the statistical issues with the limited amount of postseason scores available. Overall, Longwood University's basketball athletes are at an increased risk for ACL injury based on their LESS scores assigned during this study, but do not seem to differ based on gender or position in this specific study which would conclude that the athletes training regiments are similar to each other and not specified for limitations or positions.

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Landing Error Scoring System(LESS)* Scoring Tool

Athlete Number: Reviewer:

Testing Date: Review Date:

** as adapted from Padua et al. (2015)*

Measure	Description	Camera View	Score		Score
Knee flexion: Initial contact	The knee is flexed less than 30 degrees at initial contact.	Sagittal	0= Absent	1= Present	
Hip flexion: Initial contact	The thigh is in line with the trunk at initial contact (sagittal plane).	Sagittal	0= Absent	1= Present	
Trunk flexion: Initial contact	The trunk is vertical or extended on the hips at initial contact (straight back)	Sagittal	0= Absent	1= Present	
Ankle-plantar flexion: Initial contact	The foot lands heel to toe or with a flat foot at initial contact (0= toe to heel)	Sagittal	0= Absent	1= Present	
Medial knee position: Initial contact	The center of the patella is medial to he midfoot at initial contact	Frontal	0= Absent	1= Present	
Lateral-trunk flexion: Initial contact	The midline of the trunk is flexed to the left or the right side of the body at initial contact	Frontal	0= Absent	1= Present	
Stance width: Wide	The feet are positioned greater than a shoulder width apart (acromion processes) at contact	Frontal	0= Absent	1= Present	
Stance width: Narrow	The feet are positioned less than a shoulder width apart (acromion processes) at contact	Frontal	0= Absent	1= Present	
Foot position: External rotation	The foot is externally rotated more than 30 degrees between initial contact and maximum knee flexion	Frontal	0= Absent	1= Present	
Foot postion: Internal rotation	The foot is internally rotated more than 30 degrees between initial contact and maximum knee flexion	Frontal	0= Absent	1= Present	
Symmetric initial foot contact	1 foot lands before the other foot or 1 foot lands heel-toe & the other foot lands toe-heel	Frontal	0= Absent	1= Present	
Knee-flexion displacement	The knee flexes less than 45 degrees between initial contact and maximum knee flexion	Sagittal	0= Absent	1= Present	
Hip-flexion displacement	The thigh does not flex more on the trunk between initial contact and maximum knee flexion	Sagittal	0= Absent	1= Present	
Trunk -flexion displacement	The trunk does not flex more between initial contact and maximum knee flexion	Sagittal	0= Absent	1= Present	
Medial knee displacement	At the point of maximum medial knee position, the center of the patella is medial to the midfoot.	Frontal	0= Absent	1= Present	
Joint displacement	Soft: the participant demonstrates a large amount of trunk, hip, and knee displacement. AVG: the participant has some, but not a large amount of trunk, hip, and knee displacement. Stiff: the participant goes through very little, if any, trunk, hip and knee displacement.	Sagittal	0 = Soft 1= Avg	2= Stiff	
Overall impression	Excellent: the participant displays a soft landing with no frontal- plane or transverse-plane motion. Poor: the participant displays large frontal plane or transverse plane motion or the participant displays a stiff landing with some frontal plane or transverse plane motion. AVG: all others	Frontal	0=Excellent 1= Avg	2= Poor	
	Total Score				

Notes:

Created by Tim Coffey, 2019