Biomechanical differences in landing techniques in focused, static distraction, and moving distraction

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Introduction

Injuries can take athletes away from their sports for extended periods of time. Understanding the risk factors of injury during sport is the first step in reducing the incidence of injury. The focus of this paper will be on knee injury in basketball players. Three quarters of ACL injuries are non-contact (Boden, Sheehan, Torg, & Hewett, 2010). These non-contact injuries happen during movements such as landing and cutting. During a landing task the body must absorb ground reaction forces efficiently, and with proper technique to avoid injury. The main predictor for ACL injury risk is the evidence of knee valgus upon landing. When landing with knee valgus the ACL becomes taut before any assistance from the MCL is given. This position is compromising the ACL's ability to absorb GRFs and greatly increases the risk of injury (Chaudhari, Hearn, & Andriacchi, 2005). For example, a reduction of 2 degrees in knee valgus reduces the compressive load threshold by the equivalent of one body weight (Boden et al., 2010). Reduction of compressive load takes stress off an individual's joints and lowers the risk of injury. Currently plyometric training is the main training method used to prevent injury.

Plyometric training has been shown to reduce risk of injury and even improve jumping performance (Hewett, Stroupe, Nance, & Noyes, 1996). Use of augmented feedback during training has also been shown to further improve technique and should be used in conjunction with plyometric training for maximum benefit (Myer et al., 2013). The use of 2D motion capture is a cheap and realistic resource that can be used during jump training and has been shown to improve technique. Conventional training follows the principle of specificity.

The principle of specificity states that sports training should be relevant to the desired task you wish to improve. Conventional plyometric training takes this into account by repetitively having participants jump to practice landing technique. However, jumping in a controlled setting is different from jumping during a game. During a game there are other athletes around and your focus is on the ball not your technique. Distraction during a game is a possible reason for technique improvements through training not transferring to a game situation. Currently no training protocols incorporate distraction. By adding distraction to training technique improvements could transfer better into game situations.

Distraction has been shown to increase peak GRFs, and further increases of GRFs are seen when an athlete is fatigued (Dempsey, P. C., Handcock, & Rehrer, 2014). Overhead catching has been shown to change landing kinematics, with the highest risk of injury resulting from a ball being thrown towards the stance leg of the individual while in the air (Dempsey, A. R., Elliott, Munro, Steele, & Lloyd, 2011). The combination of increased GRFs and technique breakdowns caused by distraction amplify an individual's risk of injury (Dempsey et al., 2014). Adding a distraction element during training could improve technique transfer into game situations, and possibly further reduce an athlete's injury risk.

Hypothesis

We hypothesize that after distracted training, athletes will land with similar increased knee flexion and decreased ground reaction forces during distracted and focused landing tasks.

Purpose

The purpose of this study was to identify the impact of a distracted jump training protocol on landing techniques in both a distracted and focused jump landing task for recreationally active individuals ages 18-25.

Review of Literature

The purpose of this study is to identify the impact of a distracted jump training protocol on landing techniques in both a distracted and focused jump landing task. This literature review covers proper landing technique/injury risk, distraction’s effect on landing, intervention strategies, and feedback during training.

Proper Landing Technique/Injury Risk

Non-contact injuries are responsible for three quarters of ACL injuries (Boden et al., 2010). These non-contact injuries can occur through multiple mechanisms, but the focus of this study will be during landing. During landing the lower limbs must absorb ground reaction forces to avoid injury. Through proper technique the lower limbs act to reduce the speed at which the force goes through the body. Basketball players are at an especially higher risk due to frequent and repetitive jumping performed during their sport. Female athletes are at a two to eight times higher risk of acquiring ACL injuries than their male counterparts, specifically noncontact injuries (Boden et al., 2010).

Slight changes in landing technique such as increased knee valgus, increased knee extension, and landing flat footed place individuals at a higher risk of injury (Boden et al., 2010). Simply reducing the valgus moment by 2 degrees reduces the compressive load threshold by the equivalent of 1 body weight (Boden et al., 2010). During a bilateral drop landing task, female basketball players showed asymmetry in knee valgus during landing. Herrington proposed this asymmetry might be due to a dominate leg having varying mechanics (Herrington, 2011). Bilateral jumping and landing are common during movements such as the jump shot and rebounding in basketball. Repetitive exposure during sport to poor landing technique only increases an athlete’s risk of injury. Other sport specific variables also play a role in an athlete’s landing technique.

Fatigue can change the way the body absorbs loads (Coventry, O’Connor, Hart, Earl, & Ebersole, 2006). Basketball is a physically demanding sport that requires athletes to perform quick sprints with continuous movement throughout a game. With this exertion, fatigue is a factor that can affect athletes late in a game. The body starts to rely more on larger muscular such as the hip extensors. This shift leads to increased hip flexion and decreased plantarflexion upon initial contact (Coventry et al., 2006). Decreased plantarflexion is associated with a higher risk of injury (Boden et al., 2010).

Even when fatigue is not present varying patterns of muscle activation still play a role in injury risk. High quadricep to hamstring activation ratio (Q:H) leads to increased knee extension and higher risk of injury (Walsh, Boling, McGrath, Blackburn, & Padua, 2012). Females naturally have lower hamstring activation than their male counterparts. In a study done by Hewett et al. even after 6 weeks of training females only reached equal levels of hamstring to quadricep activation ratios as the males, and their pre-training value was at 51%. Well below the hypothesized 60% threshold for putting athletes at risk of serious knee injury (Hewett et al., 1996). In addition to fatigue changing muscle activation patterns, game specific factors also increase the risk of injury in basketball players. These game specific factors distract individuals leading to break down in landing technique.

Distraction’s Effect on Landing

During a game of basketball an athlete’s focus is on the game situation and not on their technique. Ideally during practice, when time can be spent practicing correct technique, the movements of the game become ingrained and the body always uses correct technique. Unfortunately, perfect technique is not always transferred into games. One factor believed to play a role in this break down in technique is distraction caused by game situations. In a study done by D. Zahradink three landing conditions were analyzed for volleyball players during a block at the net. The conditions were set to simulate game specific situations of either a successful or failed block. A stick landing and step back landing were used to simulate a successful block, because the athlete would not have to make another play on the ball after a successful block. A run back landing simulated a failed block because the athlete needed to get into position to return the ball again. The run back landing condition showed greater peak knee valgus when compared to a stick landing (Zahradnik, Uchytil, Farana, & Jandacka, 2014). The continued attention to a task during a landing could be a possible reason for this increase in knee valgus.

When the knee is in a position of knee valgus the ACL becomes taut before the MCL provides any additional support. This puts the ACL in a compromised position to absorb GRF's. In comparison when the knee is in a varus position the LCL absorbs 70% of the load even when no muscle activation is present (Chaudhari et al., 2005). Knee valgus caused by sport specific tasks are not limited to landing actions. When performing cutting movements while holding various sporting equipment an increase in knee valgus was seen when the plant leg arm was closer to the midline of the body (Chaudhari et al., 2005). The holding of equipment such as a football or lacrosse stick causes the arm to be closer to the midline preventing the plant leg arm from going to its natural position away from the midline during a cut. This study done by Chaudhari et al. is not the only to analyze the effect of upper body movement on lower extremity mechanics.

Upper body movement is inevitable during sport, especially basketball where the arms are used to grab the ball and bring it down during a rebound. In a study done by Dempsey et al. overhead catching in Australian football was analyzed. The purpose of this study was to identify changes in lower body kinematics in relation to position of an overhead catch and to identify joint postures that were associated to high injury risks such as knee valgus (Dempsey et al., 2011). Participants underwent multiple conditions with varying overhead position of the ball in reference to their preferred support leg. The ball being thrown at the preferred support leg had significantly higher knee valgus moment than when the ball was thrown away from the support leg (Dempsey et al., 2011). Overhead catching showed kinematic changes in the hip and trunks movement in the sagittal plane during single leg landing. Increased torso rotation and lateral flexion away from stance leg have been linked to higher knee internal rotation and valgus moments respectively (Dempsey et al., 2011). Other kinematics changes include the knee being externally rotated relative to the direction of travel. This was associated with both high valgus and high internal rotation moments at the knee. Additionally, external foot rotation was correlated with peak valgus moment (Dempsey et al., 2011). Distraction's role in landing is not limited to increased knee valgus. Landing with distraction causes higher peak ground reaction forces and these GRF's are further increased with fatigue and external load (Dempsey et al., 2014). Cognitive distraction, such as serial 7s, has also been linked to decreases in balance and changes in approach to a task (Ketcham et al., 2019). This is consistent with the idea that the level of attention along with perceived risk of a task will change the movement strategy used (Dempsey et al., 2014). These changes in movement strategy lead to technique breakdown.

Increases in GRF's coupled with technique breakdown leads to substantial increases in an athlete's risk of injury. So, what is the best way to prevent these breakdowns? Many have tried to answer the question of the best way to prevent injury through training. However, none address the idea of training with a distraction element to better translate technique improvements into game situations.

Intervention Strategies

Intervention strategies to reduce knee injury during landing often have multiple components, such as strength, flexibility, and neurological adaptations, all coming together to reduce risk. In a review of 242 articles that analyze the effects of plyometric jump training 47.1% involved the combination of other methods of training along with jump training. The most frequently paired training methods involved resistance, speed, or agility in conjunction to jump training (Ramirez-Campillo et al., 2018). Some of the less explored methods of training involve balance, coordination, or stretching (Ramirez-Campillo et al., 2018). Of the 242 articles none paired plyometric training with distraction. As outlined below the current forms of training have been shown to reduce injury risk but could be improved further with the introduction of distraction into training.

With plyometric training, 10 of 11 female athletes reduced their landing forces on average by 456 N (103 lbs) (Hewett et al., 1996). In this study by Hewett et al. knee abduction and adduction were the sole predictor in reduction of landing forces. Benefits were also seen in hamstring to quadricep muscle activation ratios. As previously mentioned, females tend to have a hamstring to quad activation ratio of 51% compared to an untrained male whose activation ratio is on average 65%. After this training program the female's activation ratio was closer to that of the untrained male (Hewett et al., 1996). This intervention even improved mean jump height by 1.5 inches over just 6 weeks. One limitation of this study was the amount of time required to comply with the study. Over 6 weeks participants had 3 trainings per week lasting around 2 hours (Hewett et al., 1996). Large time commitment is a massive downside when applying this study in a practical setting, because no coach or team is going to delegate large amounts of practice time to perform this protocol. However, it showed many favorable benefits such as reduction in landing force, and increased jump height.

Similar benefits to the study done by Hewett et al. were shown in a program that only lasted 4 weeks. There was a reduction in knee valgus of 36% over the 4 weeks for a jump shot condition. In this condition female basketball players were asked to dribble to the free throw line and to take a jump shot (Herrington, 2010). This simulates more effectively real game improvements in technique. The major benefit of this program was the reduction in time of training sessions from upwards of 2 hours to only 15 minutes (Herrington, 2010). With a reduction in time this 4-week program had to be very effective in the type of training used. Herrington isolated jump training and saw benefits during jump-landing tasks, but does this mean that jump training is the best way to train these athletes?

In another study done by Herrington et al. the effects of strength training and jump-training were compared. The findings showed that both strength and jump training had benefits but only to tasks specific to those trainings (Herrington, Munro, & Comfort, 2015). Strength training showed significant improvements in frontal plane knee angle (FPKA) in a single leg squat, where jump training improved FPKA during a drop landing task (Herrington et al., 2015). Due to lack of crossover of benefits from these trainings the conclusion can be drawn that you should train using the method most specific to your goals. In theory a combination of both training methods offers the most benefit because you will increase stability around the knee through strengthening exercises and improve on landing technique through jump training.

Access to strength training equipment can be a limitation, therefore a successful plyometric training program is better suited for adoption by teams. In a study done by Aerts et al. a three month jump landing technique program was evaluated. Jump landing scores for males were significantly improved, and female's scores showed a significant difference between the controlled and intervention groups. One limitation of this study was the high dropout rate, but for individuals who completed the program variables such as knee valgus and lower-extremity flexion were influenced (Aerts et al., 2015). With all training programs a model of feedback is important in teaching new techniques and improving upon them.

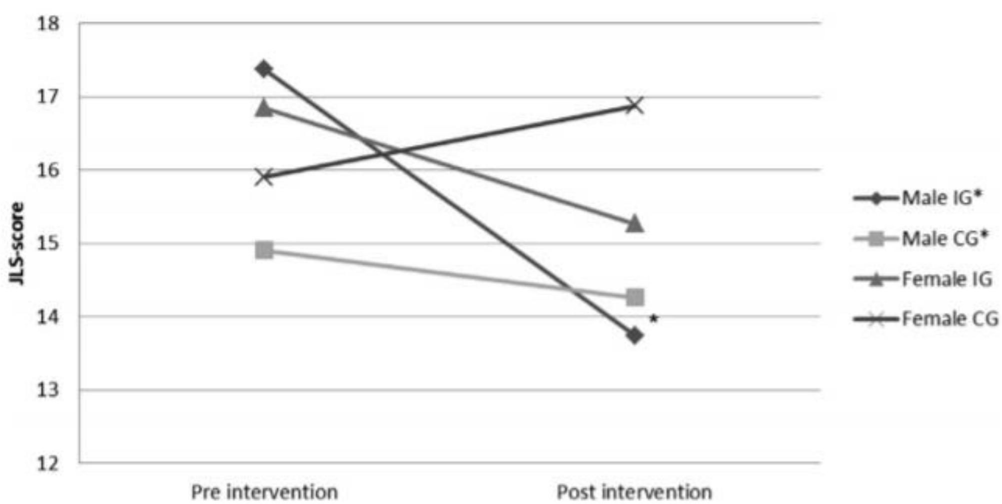

Figure 2 — The mean jump-landing-scoring (JLS) system score of the intervention group (IG) and control group (CG) at preintervention and postintervention. *Significant difference between IG and CG at *P* < .05.

Fig 1. Jump Landing Score Pre- and Post-intervention (Aerts et al., 2015)

Feedback

The biggest challenge facing feedback during training programs is practicality. In a study done by Nyman & Armstrong real-time feedback was used to aid technique during a drop landing. Participants would perform the drop landing with a real-time video feed of themselves on a screen in front of them. This kinetic-based biofeedback would analyze participants knee flexion and knee separation. On the screen these values would be displayed in green if they were within a safe range or red if they were not within a safe range (Nyman & Armstrong, 2015). The kinetic-based biofeedback group showed an increase in knee flexion of 46% and an increase in knee separation of 21% (Nyman & Armstrong, 2015). The main limitation to this form of feedback is the practicality. The equipment used in this study is not readily available to coaches and teams across the country, so forms of feedback that can readily be used are important to consider when designing an intervention.

Augmented feedback through 2D motion capture is that solution. 2D motion capture is available to anyone with a camera, which most coaches and teams have. In a study done by Myer et al. augmented feedback using 2D motion capture was shown to cause significant improvements in peak FPKA when used to analyze a tuck jump (Myer et al., 2013). In this study the only difference between the control and feedback group was the augmented feedback of the tuck jump. Both groups underwent the same training protocol. The augmented feedback also showed transfer of skill into a drop vertical jump (Myer et al., 2013). This is important because one noted limitation of augmented feedback is task specific improvement. By showing a transfer of skill there is hope that augmented feedback could also show improvements in game situations.

For this study the three-month program proposed by Aerts et al is used. A distraction element during training is the next step in addition to jump-training and augmented feedback to improve technique transfer to sport. Use of distraction or multi-tasking has been shown to improve automaticity of a skill or movement and not affect the amount of time required to learn said skill when compared to a control (Poolton et al., 2016). Further research needs to be done in regard to the affect distraction during jump-training has on improvements in technique during game situations.

Summary

During landing an athlete's technique is important in reducing their risk of injury. When landing properly your body absorbs GRF's in a chain reaction that involves the entire body working together. Slight changes in technique especially in areas such as the knee and hip can increase an athlete's risk of injury. These technique breakdowns can come from a lack of training, but even with training they are still seen. One possible reason for this is distraction.

Distraction during a sporting event is a possible cause of technique breakdown. During a game specific task an athlete must divide their attention between the task and landing. This lack of focus during landing could cause technique breakdowns that result in a higher risk of injury. Coaches and trainers use training to help reduce injury risk.

One of the main forms of training used is plyometric training. Plyometric training has been shown to improve technique during a controlled setting, but it is still unknown how skill transfers to a game. Because a game situation involves distraction it could be beneficial to practice landing with a distraction element present. This could help improve transfer of technique into game situations.

Methods

Design

The purpose of this study was to identify the impact of a distracted jump training protocol on landing mechanics in both a distracted and a focused jump landing task for recreationally active individuals ages 18-25. Pre and post-test measures were recorded for three conditions focused, static distraction, and walking jump.

Subjects

Criteria for participation required that participants were recreationally active ages 18-25 with no current lower extremity injuries. This study was approved by the university IRB and all participants provided informed consent before participation. A copy of the IRB can be found in the appendix.

Instrumentation

We used an 8-camera infrared motion capture system (Oqus 300, Qualisys, Gothenburg, Sweden) with 2 AMTI force plates (Advanced Mechanical Technology, Inc., Watertown, MA) set at a gain of 2K. All trials in all conditions were captured at a camera frequency of 240 Hertz and force plate frequency of 960 Hertz for 6 seconds. Each condition had three successful trials captured. For a trial to be considered successful the participant landed with one foot on each force plate and arms extended overhead.

Procedure

After completion of the IRB participants height and weight were record and participants were prepped with reflective markers for motion capture. The marker set used includes the trunk and both legs.

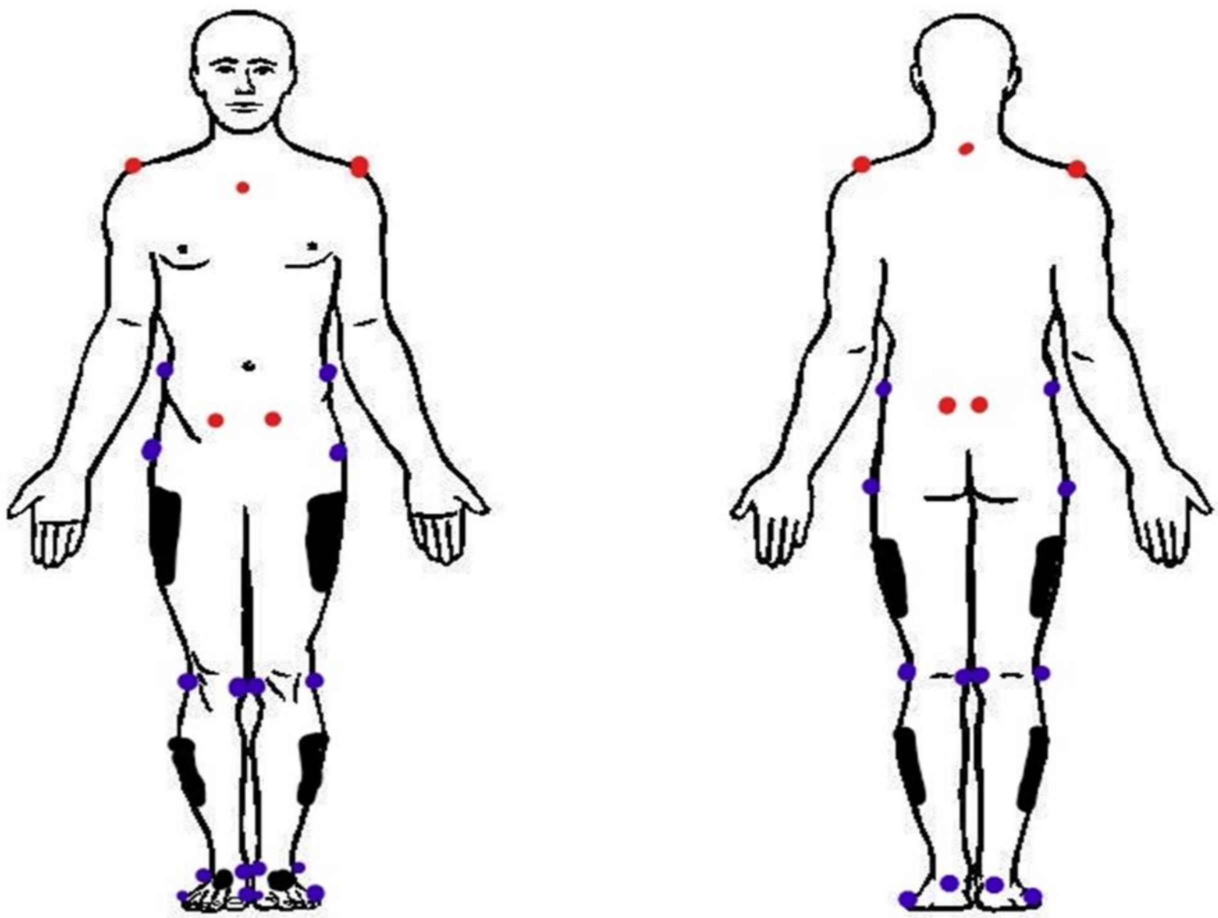

Fig 2. Marker placement on anatomical model

- Left & Right 1st and 5th Metatarsals
- Left & Right Lateral and Medial Ankle
- Left & Right Heel
- Left & Right Lateral and Medial Knee
- Left & Right Greater Trochanter
- Left & Right ASIS
- Left & Right Superior Iliac Crest
- Left & Right PSIS
- Jugular Notch
- C7
- Left & Right Acromion
- Left & Right Thigh plate (4 markers)
- Left & Right Shank plate (4 markers)
- Left & Right Foot plate (3 markers)

Before collection of trials the participants maximum standing reach was recorded and was used to set the ball height for the static distraction condition. The ball height is set at 20% of the participants max standing reach plus their height (equation 1).

$$Max\ Reach\ Height(m)\ x\ 0.20 + Participant\ Height(m) = Static\ Distraction\ Ball\ Height(m)$$

<u>Condition 1 – Focused Jump</u>

For the focused jump condition, participants began by standing 0.305 m away from the force plates and were instructed to jump onto the force plates and focus on their landing technique. A researcher also demonstrated the protocol by themselves jumping onto the force plate and focusing on their landing with arms extended overhead. Three successful trials were then recorded.

<u>Condition 2 – Static Distraction</u>

The static distraction condition used a ball suspended at static distraction ball height. The participant began 0.305 m away from the force plates and was instructed to jump and tap the suspended ball with both hands. At no point during instruction for this condition was the participant told to focus on their landing. A researcher also demonstrated the protocol by themselves completing the task and tapping the ball with both hands and landing. Three successful trials were then recorded.

<u>Condition 3 – Walking Jump</u>

Condition 3 is dynamic distraction utilizing a walking jump in which participants performed a double leg jump 0.305 m away from the force plate after a one step approach. During the jump participants were instructed to tap the suspended ball with both hands. A researcher also demonstrated the protocol by themselves completing the task and tapping the ball with both hands and landing. Three successful trials were then recorded.

Training

The training program proposed by Aerts et al was used for training between pre and post-test. Participants were required to attend 90% of trainings and were given a one-week break during the universities spring break.

Week	Technique, month 1	Fundamentals, month 2	Performance, month 3
1	Cocontractions, 10 L + R	Lying position, 15	X-hops, 6 cycles L + R
	Wall squat, 10 L + R	Pelvic bridge, 10 s	Hop-hop-hold, 8 L + R
	Lateral jump and hold, 8 L + R	Repeated tuck jumps, 10 L + R	Mattress jumps, 30 s
	Front lunges, 10	Squat jump, 10	Single-leg 90°,[a] 8 L + R
	Step-hold, 8	Jump single-leg hold, 8	Max squat jumps-hold, 10 L + R
2	Cocontractions, 10 L + R	Pelvic-bridge single-leg, 10	Crossover-hop-hop-hold, 8 L + R
	Squat, 10 L + R	Prone-bridge hip–shoulder flexion, 10 L + R	Single-leg 4-way hop-hold,[a] 3 Cycles L + R
	Step-hold, 8 L + R	Side-to-side tuck jump, 10 s	Single-leg 90° ball,[a] 8 L + R
	Walking lunges, 10	Lateral hop and hold, 8 L + R	Step, jump up, down, vertical jump, 5 L + R
	Lateral jump and hold, 8	Hop and hold, 8	Max squat jumps-hold, 10
3	Squat, 10	Single-leg pelvic bridge,[a] 10 L + R	Single-leg 4-way hop-hold ball,[a] 4 Cycles L + R
	Lateral jump and hold, 8 L + R	Prone-bridge hip extension, 10 L + R	Single-leg 180°, 10 L + R
	Single tuck jump with soft landing, 10 L + R	Side-to-side tuck jumps, 10 L + R	Jump, jump, jump, vertical jump, 10 s
	Lunge jumps, 10 s	Lateral hops, 10 s	Mattress jumps, 40 L + R
	Lateral jumps, 10	Double-leg 90°, 8 L + R	Running, jump down 1-legged, jump, 8
4	Squat jumps, 10	Single-leg pelvic-bridge ball, 10 L + R	Single-leg 180°, 10 L + R
	Lateral jumps, 10 s	Prone-bridge hip-opposed shoulder flex-ion, 10 L + R	Jump, jump, jump, vertical jump, 15 L + R
	Double tuck jump, 8 L + R	Lateral hops with ball, 10 s	Running, jump down 1-legged, jump, 10
	Broad jump, 10	Single-leg lateral hop-hold, 5 L + R	Layup,[b] 10
	Scissor jumps, 8	Single-leg 90°, 8 L + R	Height jump,[b] 10

Note: Training sessions were held twice a week, with 10-min sets, 1-min rest between exercises. Abbreviations: L, left; R, right.

[a] Exercise on the mattress. [b] Sport-specific jumps for basketball, can be adjusted depending on the sport.

Fig 3. Jump Training Program (Aerts et al., 2015)

Data Analysis

Variables of interest are peak ground reaction force, knee flexion at contact, and knee valgus at contact. Both legs were averaged together and compared between pre- and post-testing. A Student's t-test was used to determine significance set at $p < 0.05$. Motion capture and force data was analyzed through Qualisys Track Manager and Visual 3D. In QTM, motion capture data was gap filled and converted into .c3d files for Visual 3D. Pipelines in Visual 3D were used to determine initial contact by finding the first frame where force data was present. This marked an event in which all variables of interests were measured. Vertical ground reaction forces and knee angle in the frontal and sagittal plane were measured.

Results

Due to COVID-19 data collection was not completed, because of this we can only speak on what was expected from the few pre-training data collections that were collected. Pre-training values showed increased GRF's and decreased knee flexion at contact during the static distraction conditions (Figure 4). Decreased knee flexion and increased GRF's resulted in a less efficient absorption of force by an individual and may increase the risk of injury during landing. Based on the literature we expect that jump training will improve both peak GRF and knee angle at contact (Aerts et al., 2015) & (Hewett et al., 1996). With a distraction element introduced during training we expect to see the difference between peak GRF's and knee angle at contact in the focused and distracted conditions decrease.

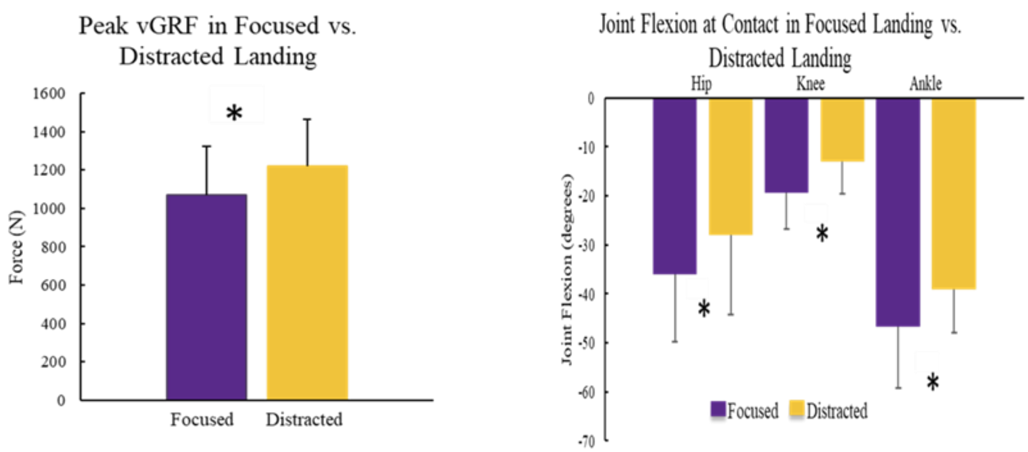

Fig 4. Peak vGRF in Focused vs. Distracted Landing & Joint Flexion at Contact in Focused Landing vs. Distracted Landing

Discussion

The study had some limitations within the testing and training. Limitations of testing are the lack of a standardized moving target and individuals unique jumping styles making the static distraction condition not feel natural for some participants. While a static distraction works as a target to take focus away from landing, a moving target would more directly simulate a rebound during a game. A moving target similar to the one used in a study done by Dempsy et al. to see the effects of an overhead catch on landing would help make a direct comparison to a game situation (Dempsey et al., 2011). With a standardized static distraction location some participants felt unnatural when landing, to combat this we would move the target forward or backwards slightly, so participants landed naturally. Training also had limitations.

Dropout and differing activity levels among participants were both limitations of training. With a longer training program and no incentive for participants, dropout was expected in some capacity. If participants were to dropout their data could no longer be used for the study. As seen in the literature dropout is a limitation of many training programs (Aerts et al., 2015). With the design of our training program we assume that all participants could complete all exercises. If a participant is new to exercise, they might not be able to complete the program in its entirety, and this could change the effectiveness of the program. Therefore, differing activity levels is a limitation, because the training does not directly translate to all activity levels. Activity levels outside of our training program could also affect results. Participants who train on their own could improve ahead of those who do not train outside of our programed sessions.

If training were to have been implemented and been successful in reducing the difference between focused and static distraction conditions, jump training protocols would begin to regularly incorporate distraction. Coaches, trainers, and physical therapist could benefit from adding distraction into their injury reduction protocols. The next step in this study is to see the effects of a distracted training protocol on a basketball team's injury rates over the course of a season. This will allow researchers to evaluate the effectiveness of distracted jump training in a game setting.

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<u>Appendix</u>

Figure 1.

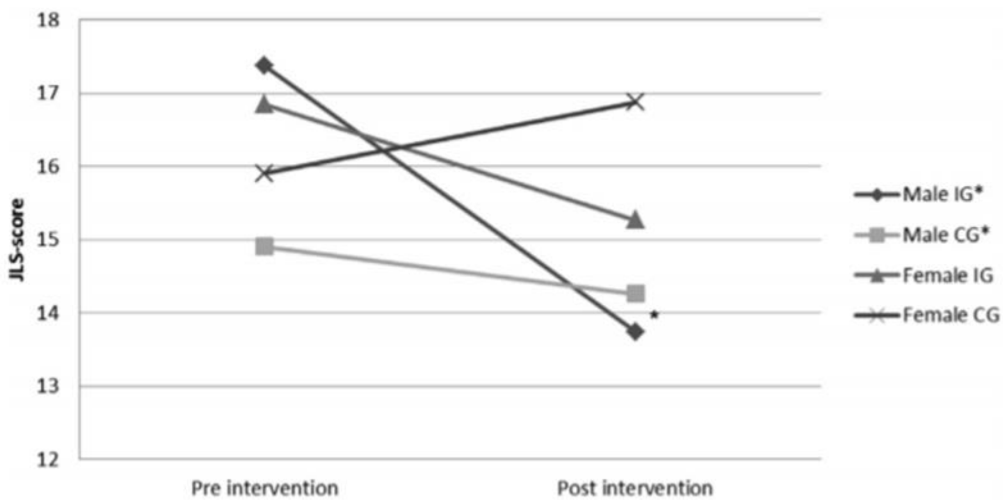


Figure 2 — The mean jump-landing-scoring (JLS) system score of the intervention group (IG) and control group (CG) at preintervention and postintervention. *Significant difference between IG and CG at $P < .05$.

Figure 2.

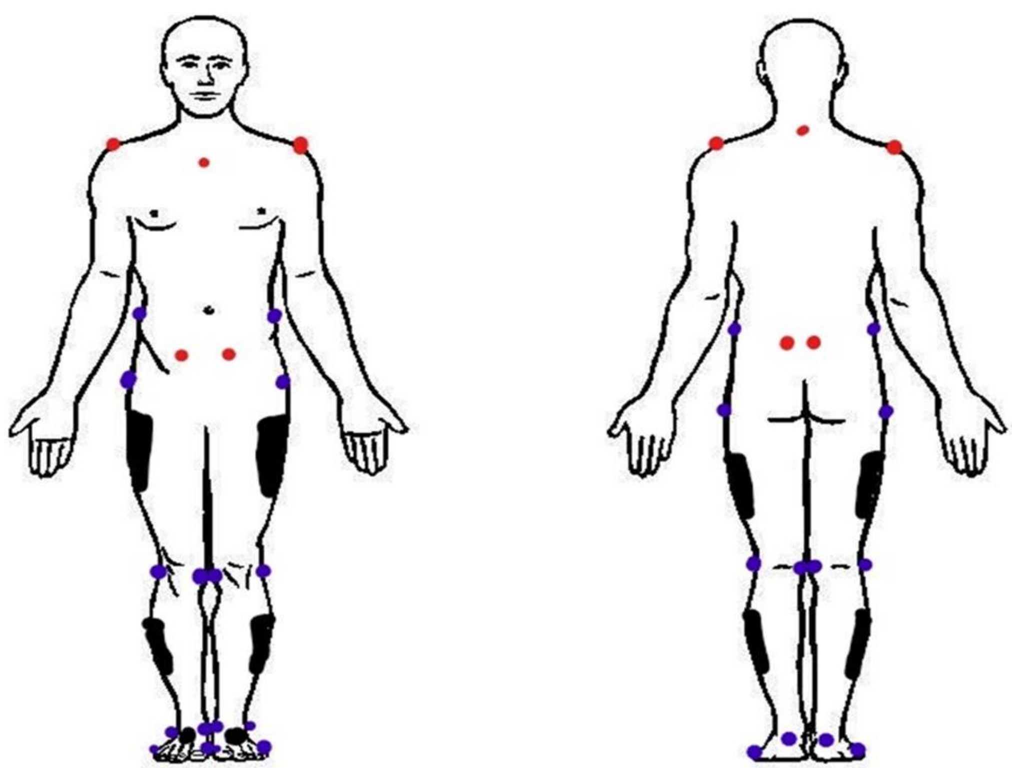


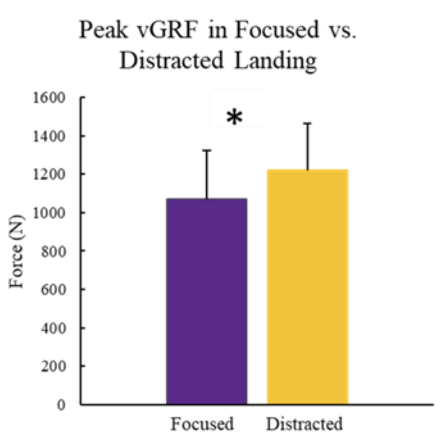
Figure 3.

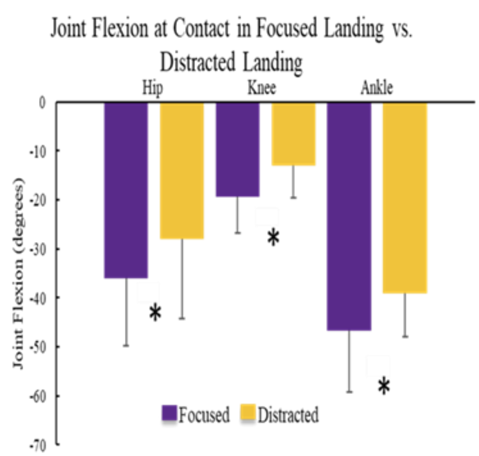
Week	Technique, month 1	Fundamentals, month 2	Performance, month 3
1	Cocontractions, 10 L + R	Lying position, 15	X-hops, 6 cycles L + R
	Wall squat, 10 L + R	Pelvic bridge, 10 s	Hop-hop-hold, 8 L + R
	Lateral jump and hold, 8 L + R	Repeated tuck jumps, 10 L + R	Mattress jumps, 30 s
	Front lunges, 10	Squat jump, 10	Single-leg 90°,[a] 8 L + R
	Step-hold, 8	Jump single-leg hold, 8	Max squat jumps-hold, 10 L + R
2	Cocontractions, 10 L + R	Pelvic-bridge single-leg, 10	Crossover-hop-hop-hold, 8 L + R
	Squat, 10 L + R	Prone-bridge hip–shoulder flexion, 10 L + R	Single-leg 4-way hop-hold,[a] 3 Cycles L + R
	Step-hold, 8 L + R	Side-to-side tuck jump, 10 s	Single-leg 90° ball,[a] 8 L + R
	Walking lunges, 10	Lateral hop and hold, 8 L + R	Step, jump up, down, vertical jump, 5 L + R
	Lateral jump and hold, 8	Hop and hold, 8	Max squat jumps-hold, 10
3	Squat, 10	Single-leg pelvic bridge,[a] 10 L + R	Single-leg 4-way hop-hold ball,[a] 4 Cycles L + R
	Lateral jump and hold, 8 L + R	Prone-bridge hip extension, 10 L + R	Single-leg 180°, 10 L + R
	Single tuck jump with soft landing, 10 L + R	Side-to-side tuck jumps, 10 L + R	Jump, jump, jump, vertical jump, 10 s
	Lunge jumps, 10 s	Lateral hops, 10 s	Mattress jumps, 40 L + R
	Lateral jumps, 10	Double-leg 90°, 8 L + R	Running, jump down 1-legged, jump, 8
4	Squat jumps, 10	Single-leg pelvic-bridge ball, 10 L + R	Single-leg 180°, 10 L + R
	Lateral jumps, 10 s	Prone-bridge hip-opposed shoulder flexion, 10 L + R	Jump, jump, jump, vertical jump, 15 L + R
	Double tuck jump, 8 L + R	Lateral hops with ball, 10 s	Running, jump down 1-legged, jump, 10
	Broad jump, 10	Single-leg lateral hop-hold, 5 L + R	Layup,[b] 10
	Scissor jumps, 8	Single-leg 90°, 8 L + R	Height jump,[b] 10

Note: Training sessions were held twice a week, with 10-min sets, 1-min rest between exercises. Abbreviations: L, left; R, right.

[a] Exercise on the mattress. [b] Sport-specific jumps for basketball, can be adjusted depending on the sport.

Figure 4.





IRB

Study ID:UMCIRB 19-003268 Date Approved: 1/21/2020 Does Not Expire.

***Title of Study**: Influence of jump-landing training on lower-extremity biomechanics*

Informed Consent to Participate in Research

Information to consider before taking part in research that has no more than minimal risk.

Title of Research Study: Influence of jump-landing training on lower-extremity biomechanics

Principal Investigator: Nicholas Murray (Person in Charge of this Study)
Institution, Department or Division: Department of Kinesiology
Address: 166 Minges Coliseum, Greenville, NC 27858
Telephone #: (252) 737-2977

Researchers at East Carolina University (ECU) study issues related to society, health problems, environmental problems, behavior problems and the human condition. To do this, we need the help of volunteers who are willing to take part in research.

Why am I being invited to take part in this research?
The purpose of this study is to evaluate the effect that an eight-week jump-landing training program has on lower-extremity biomechanics in distracted landing-tasks. You are being invited to take part in this research because you are a healthy adult between 18-25 years of age, have no current lower-extremity injuries, do not wear a brace that prohibits full range of motion, and participate in a team sport at least 3 days/week and/or 6 hours/week. The decision to take part in this research is yours to make. By doing this research, we hope to learn how jump-landing training can influence biomechanics during distracted landing.

If you volunteer to take part in this research, you will be one of about 40 people to do so.

Are there reasons I should not take part in this research?
There are minimal risks associated with this study, however, you should not participate if you are currently experiencing or recovering from a lower-extremity injury that prohibits full range of motion in a joint or your ability to complete a series of jump-landing tasks. You can choose not to participate at any time prior to or during the study.

What other choices do I have if I do not take part in this research?
You can choose not to participate.

Where is the research going to take place and how long will it last?
The research will be conducted at East Carolina University in Greenville, North Carolina. You will need to come to the Human Movement Analysis Lab located on the first floor of the Laupus Library building located on the ECU Health Science Campus two times during the study. The pre and post testing sessions will last approximately 1-1.5 hours each. For the training sessions, you will be asked to arrive at the ECU Student Recreation Center on main campus or the ECU Health Science Recreation Center. Training sessions will occur 3 days/week for eight weeks and are expected to last 30 minutes.

Page 1of 3

Consent Version # or Date:____________

***Title of Study**: Influence of jump-landing training on lower-extremity biomechanics*

What will I be asked to do?

You will be asked to do the following: complete a maximum jump height task and four jump-landing conditions for pre and post training data collections. For the maximum jump height trial, you will step onto the force plate and jump as high as you can.

The four jump conditions include:

- Focused jump: no distraction present, jump up and focus on landing.
- Distracted jump: you will jump up on the force plate and grab a suspended ball.
- Moving target jump: you will step onto the force plate and jump to catch a ball released from a ball-release apparatus.
- Walking jump: you will start off the force plate, take a step onto the force plate, and jump up as you take that one step.

During the pre and post training sessions, a non-invasive EEG cap will be used to record brain activity. Once the cap is in place and properly aligned, the scalp under each electrode will be prepared by first gently abrading the skin using the wooden end of a standard cotton swab with pumice and Vitamin E to reduce impedance to the electrode, and then inserting a conductive gel with a 16-gauge blunt needle. Eye movements will be recorded with electrodes placed above and below the left eye to capture electrooculographic (EOG) activity. Non-invasive Electromyography (EMG) electrodes will be placed over the motor points of the gastrocnemius lateralis and tibialis anterior to monitor ankle flexion and extension, and rectus femoris and biceps femoris.

For the training program, you will be asked to train individually or with a partner. Prior to training, you will complete a survey containing questions about individual and paired training. Every participant will complete the same routine of agility, balance, and plyometric exercises. Certain plyometric exercises will contain distraction tasks. You will receive verbal or video bandwidth feedback throughout the training program based on your recruitment period (spring/summer 2020 or fall 2020). Verbal feedback are the traditional verbal cues that coaches and/or experts provide to athletes to help improve or alter a movement. Video bandwidth feedback provides a computer generated model of correct movement patterns and allows you to see how closely your movements align with the model, thus, reducing the need for verbal feedback from the study staff.

What might I experience if I take part in the research?

There is a minimal risk of injurt with an athletic movement. Any risks that may occur with this research are no more than what you would experience in your normal team sport activities or typical training session. We don't know if you will benefit from taking part in this study. There may not be any personal benefit to you but the information gained by doing this research may help others in the future.

Will I be paid for taking part in this research?

We will not be able to pay you for the time you volunteer while being in this study.

Will it cost me to take part in this research?

It will not cost you any money to be part of the research.

How will you keep the information you collect about me secure? How long will you keep it?

Your data will be stored on a secured server. You will be assigned an ID number and that will be used to identify any of your data files. The data will not contain any information that can be used to identify you. Data will be kept for a minimum of 3 years following the completion of this study.

***Consent Version # or Date:*______________**

Title of Study: *Influence of jump-landing training on lower-extremity biomechanics*

What if I decide I don't want to continue in this research?
You can stop at any time after it has already started. There will be no consequences if you stop and you will not be criticized. You will not lose any benefits that you normally receive.

Who should I contact if I have questions?
The people conducting this study will be able to answer any questions concerning this research, now or in the future. You may contact the Principal Investigator at (252) 737-2977 (Monday-Friday, between 9:00-5:00)

If you have questions about your rights as someone taking part in research, you may call the Office of Research Integrity & Compliance (ORIC) at phone number 252-744-2914 (days, 8:00 am-5:00 pm). If you would like to report a complaint or concern about this research study, you may call the Director of the ORIC, at 252-744-1971.

Is there anything else I should know?
Identifiers might be removed from the identifiable private information or identifiable biospecimens and, after such removal, the information or biospecimens could be used for future research studies or distributed to another investigator for future research studies without additional informed consent from you or your Legally Authorized Representative (LAR). However, there still may be a chance that someone could figure out the information is about you.

I have decided I want to take part in this research. What should I do now?
The person obtaining informed consent will ask you to read the following and if you agree, you should sign this form:

- I have read (or had read to me) all of the above information.
- I have had an opportunity to ask questions about things in this research I did not understand and have received satisfactory answers.
- I know that I can stop taking part in this study at any time.
- By signing this informed consent form, I am not giving up any of my rights.
- I have been given a copy of this consent document, and it is mine to keep.

____

Participant's Name (PRINT) **Signature** **Date**

Person Obtaining Informed Consent: I have conducted the initial informed consent process. I have orally reviewed the contents of the consent document with the person who has signed above, and answered all of the person's questions about the research.

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Person Obtaining Consent (PRINT) **Signature** **Date**

Consent Version # or Date:____________