A Thesis

entitled

Effects of Dual Tasking on Anticipated and Unanticipated Cutting Maneuvers on Knee Biomechanics in Collegiate Male Athletes

by

Taylor Frendt

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Exercise Science

Grant Norte, PhD, AT, ATC, CSCS, Committee Chair

Charles Armstrong, PhD, Committee Member

Thomas McLoughlin, PhD, Committee Member

Luke Donovan, PhD, AT, ATC, Committee Member

Amanda Bryant-Friedrich, PhD, Dean
College of Graduate Studies

The University of Toledo

May 2017
An Abstract of

Effects of Dual Tasking on Anticipated and Unanticipated Cutting Maneuvers on Knee Biomechanics in Collegiate Male Athletes

by

Taylor Frendt

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Science Degree in Exercise Science

The University of Toledo
May 2017

An athlete is required to adapt to different situations throughout participation such as not knowing which direction they will be running, judging the actions of their opponents, catching or throwing a ball, and listening to the people around them. We investigated the effects of anticipation and dual tasking on trunk and lower extremity kinematics during a side step cutting maneuver in 32 healthy active males. Participants were directed with a green light to cut to the right or left either before they started running, anticipated cut, or right before they made the cut, unanticipated cut. While making the cut the participant also had to focus on possibly catching a ball meaning the ball was either faked or thrown to the participant. Our results did not indicate there was a significant effect of anticipation on a task. However, when the ball was either faked or thrown regardless of anticipation there was a decrease in lateral trunk flexion towards the stance leg at peak knee flexion and toe off. There was also an increase in trunk rotation at initial contact, peak knee flexion, and toe off when the ball was thrown. Overall, anticipation or dual tasking did not affect lower extremity kinematics.
Acknowledgements

I would like to take this opportunity to thank all those who helped me throughout this entire process. Amanda Murray, PhD, PT, DPT for making our large amount of data accessible. My two advisors, Grant Norte, PhD, AT, ATC, CSCS and Luke Donovan, PhD, AT, ATC, for helping me to discover a research question, figure out how to test it, and makes sense of our findings. Charles Armstrong, PhD for showing me how to use and trouble shoot problems with all of the lab equipment that was needed. My undergraduate assistants, Elizabeth Sares, Lindsay Elliot, Francisco Jimenez, and Tyler Straub, for without whom my study could not run. Nichole Henderson for spending countless hours in the lab in the lab with me and reminding me we are one step closer to being done. Finally to my mother Donna and boyfriend Lucas for listening to my never ending frustration and excitement around my entire research experience.
# Table of Contents

Abstract iii  
Acknowledgments iv  
Table of Contents v  
List of Tables vii  
List of Figures viii  
I. Manuscript 1  
  A. Introduction 1  
  B. Methods 3  
  a. Study Design 3  
  b. Participants 3  
  c. Procedures 4  
  d. Data Reduction 7  
  e. Statistical Analysis 7  
C. Results 8  
D. Discussion 10  
E. Conclusion 13  
References 19  
Appendices  
A. The Problem 23  
B. Literature Review 28  
C. Additional Methods 49  
D. Additional Results 84
E. Back Matter

F. Bibliography

vi
List of Tables

Table 1  Participant Demographics. .................................................................14
Table 2  Trunk angle (°) (mean ± SD). .............................................................15
Table 3  Hip angle (°) (mean ± SD). .................................................................16
Table 4  Knee angle (°) (mean ± SD). ...............................................................17
Table 5  Ankle angle (°) (mean ± SD). ............................................................18
List of Figures

MANUSCRIPT

Figure 1 Laboratory Set-up. .................................................................14

APPENDIX D

Figure D1 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw and unanticipated no ball throw. ..........84

Figure D2 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated ball fake and unanticipated ball fake. ..................84

Figure D3 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated ball throw and unanticipated ball throw. .......................85

Figure D4 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw, anticipated ball fake, anticipated ball throw. .................................................................85

Figure D5 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between unanticipated no ball throw, unanticipated ball fake, unanticipated ball throw. ...........................................................................86

Figure D6 Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw, unanticipated ball fake, unanticipated ball throw. ...........................................................................86

Figure D7 Percent of Dominant Leg Failed Trials.................................87

Figure D8 Percent of Non-Dominant Leg Failed Trials. ...........................87

Figure D9 Percent of Failed Trials Over 5 Rounds.................................88

Figure D10 Average Speed Per Cutting Condition...............................88
Chapter One

Manuscript

Introduction.

The incidence rate of anterior cruciate ligament (ACL) injuries continues to rise for male and female athletes, yet the prevalence remains higher within the male college aged athletic population.\textsuperscript{1,2,3,4} Epidemiological studies have found that there are over 80,000 ACL tears in the United States each year, with a total cost of $1 billion.\textsuperscript{5} The male incidence rate is highest in handball (0.24), wrestling (0.19), rugby (0.18), and lacrosse (0.17) followed by soccer (0.12), football (0.08), and basketball (0.08).\textsuperscript{1} When comparing incidence rate across age, collegiate athletes (0.150) have the highest incidence rate followed by high school athletes (0.061).\textsuperscript{4} In an effort to reduce ACL injuries, there is a need to study the associated risk factors. These risk factors include environmental, such as playing surface or weather, hormonal, such as menstruation, anatomical, such as hip and knee angle or ligament laxity, and biomechanical, such as skill level, body movement, or neuromuscular control.\textsuperscript{5,6} Out of all the risk factors, the biomechanical risk factors, especially body movement, can be modified.\textsuperscript{5}

30\% of ACL injuries results from a contact mechanism whereas 70\% of ACL injuries occur from a noncontact mechanism.\textsuperscript{5} Past studies on causes of noncontact ACL tears have found a majority of ACL injuries occur during a sharp deceleration combined with a plant and cut maneuver or during a landing maneuver.\textsuperscript{6,7} The side-step cut has been studied as an athletic maneuver used to mimic the risk of sustaining a noncontact ACL injury in a controlled environment.\textsuperscript{8,6,5} Previous authors have defined the side-step cut as a task that begins with “planting the foot opposite to the direction one wishes to go,
then using the other leg for the first step in the new direction.” High-speed 3D motion capture, 2D video, and athlete recall of the injury suggest that trunk and lower extremity joint angles, moments, and ground reaction force are critical biomechanical factors used to assess and understand the risk of ACL injury. Under normal cutting mechanics when the athlete is at sub maximal speed with nothing else to focus on, joint angles and moments do not create stress on the ACL that can lead to injury. However, changes of increased trunk lateral flexion, hip abduction, and knee valgus while cutting can have a significant impact on the stress placed on the ACL.

During game situations most maneuvers are unanticipated, meaning the athlete is unsure of the direction they will be cutting as the cutting direction is often influenced by the changing environment. When compared to anticipated cuts, meaning they know which way they are cutting ahead of time, these unanticipated cuts produce changes in lower extremity joint kinematics and kinetics within the sagittal, frontal, and transverse planes that could cause increased strain on the ACL. The second aspect of game situations is the reaction to the external events. Dual tasking can be defined as completing a known cognitive task while completing a functional task. For example, focusing on an external event (catching a ball) while running or cutting is a dual task. Prior studies have found increases in hip abduction and knee flexion and decreases in trunk lateral sway when a person is walking or ascending/descending stairs while focusing on carrying an object, leading researchers to believe the knee in placed in a position that further increases the risk for ACL injury.

If there is an additive effective between anticipation and dual tasking, lower extremity biomechanics during games may be much different than lower extremity
biomechanics measured in a laboratory setting using traditional cutting tasks. If this is the case, prevention programs designed to alter biomechanical risk factors should also include a dual-tasking component to better represent game scenarios. Studies have been done comparing anticipation and dual tasking separately however to our knowledge no studies have examined the combined effect. A study has not yet been completed comparing trunk and lower extremity kinematics during anticipated and unanticipated side-step cuts with an external event, such as a ball being thrown, present. Therefore, the purpose of this study is to assess trunk and lower extremity kinematics during an anticipated and unanticipated cutting task while dual tasking.

Methods.

Study Design. A descriptive laboratory study with crossover design was used to compare trunk, hip, knee, and ankle kinematics in the sagittal frontal and transverse planes during anticipation (anticipated cut, unanticipated cut), dual tasking (no ball throw, ball fake, ball throw), and the combination of anticipation and dual tasking.

Participants. A sample of convenience was recruited from our University. Thirty-two healthy males, 18-30 years of age were recruited. To be eligible for participation, participants must have reported being physically active (Tegner 6) and regularly participating in a cutting sport at least one time per week (football, soccer, basketball, rugby, lacrosse, and ultimate Frisbee). Participants were excluded if they reported any of the following: (1) history of lower extremity surgery; (2) lower extremity injury within past 6 weeks that still results in pain or dysfunction; (3) any vestibular,
balance, or connective tissue disorders. All procedures were approved by the Biomedical
Institutional Review Board, and all participants provided written informed consent.

**Procedures.**

**Screening.** All participants attended one testing session. Upon arrival, all
participants’ demographic (age, height, weight, dominant limb, physical activity/week,
injury/illness history) information was collected. Limb dominance was determined by
asking which leg the participant would kick a ball with. Subjective knee function was
recorded using the Knee Injury and Osteoarthritis Outcome Score (KOOS).

**Participant Set-Up.** Once all forms were completed the researcher explained and
demonstrated the testing procedure. Then the participant performed a minimum of three
practice trials in each direction until they felt comfortable. After they were familiarized,
38 retroreflective markers were placed on the acromioclavicular joint, sternal notch, C7
spinous process, right inferior angle of the scapula, Iliac crest, PSIS, sacrum, greater
trochanter, lateral condyle, lateral malleolus, calcaneus, 5th metatarsal, and 2nd metatarsal
head using double-sided tape. A cluster of four markers was secured bilaterally to the
lateral thigh and shank using elastic tape. All participants wore standardized shoes
(ASICS Men’s Gel-Contend 3 Running Shoe, Irvine, CA) and the same researcher
applied the markers for all participants.

**Instrumentation.** Three-dimensional joint kinematics of the ankle, knee, hip, and
trunk were measured using a 12 camera, digital Eagle motion analysis 3-D system (Eagle,
Motion Analysis Corporation, Santa Rosa, CA) sampled at 200 Hz. A custom timing gate
program was used to indicate the direction of the cut for the anticipation condition.
Laboratory Set-Up. A 2ft by 2ft square region containing an AMTI in ground force plate (OR5-6, Advanced Mechanical Technologies Inc., Phoenix, AZ), used to indicate where the participants needed to cut, was set up 6 meters from the starting position with a timing gate placed 2 m from the starting position towards the square region. (Figure 1).

The approach speed for all cuts was 3.5-5.5 m/s, which was tracked between the first and second timing gates. All trials slower than 3.5 m/s or faster than 5.5 m/s were considered a failed trial, and were redone at the end of the original 60 trials. Once the participants hit the force plate, they made a cut at 45° in the specified direction (right or left) for either an anticipated or unanticipated cut. A white tape line was placed on the lab floor at a 45° angle to ensure the participant completed the appropriate cutting angle. Joint motions were collected during all trials and reduced to assess joint biomechanics.

Cutting Conditions. The order of the cutting conditions were randomized via concealed envelope by a third party prior to the start of the study. These side-step cutting conditions included:

1. Anticipated cut to the right, no ball throw
2. Anticipated cut to the left, no ball throw
3. Unanticipated cut to the right, no ball throw
4. Unanticipated cut to the left, no ball throw
5. Anticipated cut to the right, ball fake
6. Anticipated cut to the left, ball fake
7. Unanticipated cut to the right, ball fake
8. Unanticipated cut to the left, ball fake
9. Anticipated cut to the right, ball throw
10. Anticipated cut to the left, ball throw
11. Unanticipated cut to the right, ball throw
12. Unanticipated cut to the left, ball throw

For the anticipated cut, a light to indicate which direction they will cut will be on before the start of the trial. For the unanticipated cut, the light will turn on after the participant runs through the first timing gate (0.9144m from the starting point). For the anticipated and unanticipated cuts with the unanticipated ball toss, a ball may or may not be passed to the participant as they approach the force plate. Each cutting condition will have five successful trials, resulting in 60 total trials, which consist of the participant meeting the correct approach speed, foot coming in full contact with the force plate, and staying within the correct cutting pathway. If the participant fails to stay within the correct approach speed, place their foot on the force plate, or perform the correct cut type (side-step vs crossover) that trial will be redone after all 60 original trials have been completed. In order to reduce the risk of fatigue, participants will get a ten minute break after 20 trials and then again after 40 trials. Every 15 trials the subject will be asked about their level of fatigue using a Rated Perceived Exertion Scale. Once the participants have completed five successful trials of each cut they have completed the study.

Data Reduction. Since all participants identified as right leg dominant, trunk, hip, knee, and ankle kinematics from the 30 trials of side-step cuts to the left were processed using Cortex 5.5.0 Software. All data were filtered with a low-pass Butterworth filter at a cutoff frequency of 12 Hz (Erickson, Thomas et al. 2015). Visual 3D software was used to smooth data to 100 frames so that each frame represented one
percent of the cut cycle during the stance phase. One complete cut cycle was the time between one heel-strike until toe-off of the same foot. All dependent variables were analyzed at initial contact, peak knee flexion, and toe off.

**Statistical Analysis.** All dependent variables were calculated across all 100 points of the cut cycle with 95% confidence intervals (CIs). A time series CI analysis was performed across the entire cut cycle to determine any increments where the CIs did not overlap. If CIs did not overlap for at least 3 consecutive time increments, those increments in the cut cycle were considered statistically significant. Paired t-tests were used to assess the influence of anticipation on each dependent variable. One-way analyses of variance were used to assess the influence of dual tasking on each dependent variable for the anticipated and unanticipated cutting conditions separately, and for the additive effect. Bonferroni post hoc comparisons were used in the event of significant differences. Cohen’s d effect sizes were calculated to determine the magnitude of difference in kinematics between all comparisons. The level of statistical significance was set a priori at $P \leq .05$. All statistical analyses were performed using SPSS (version 20.0, IBM, Chicago, IL).

**Results.**

All cutting conditions were completed between 3.9m/s-5.6m/s. There were no significant differences between the speeds within the anticipated conditions and the speeds within the unanticipated conditions. The anticipated conditions ran significantly slower than the unanticipated conditions respectively (no ball throw, ball fake, ball throw; $p \leq .05$). Participant demographics can be seen in table 1. Trunk, hip, knee, and ankle
kinematics are presented for each condition (anticipation, dual tasking, and additive effect) in tables 2-5.

**Influence of Anticipation (A v U: No Ball Throw, Ball Fake, Ball Throw).** There were no differences in trunk, hip, knee, or ankle kinematics between the anticipated and unanticipated cutting conditions during the no ball throw, ball fake, and ball throw conditions (all $p > 0.05$).

**Influence of Dual Tasking (Anticipated: No Ball Throw, Ball Fake, Ball Throw).** Compared to no ball throw, the ball fake condition resulted in a decrease in trunk lateral flexion towards the stance limb was noticed at peak knee flexion ($5.29 \pm 0.2^\circ$, $d = -0.95 \ [-1.47, -0.44]$, $p = <0.001$) and toe off ($4.42 \pm 1.87^\circ$, $d = -0.83 \ [-1.34, -0.32]$, $p = 0.004$).

Compared to no ball throw, the ball throw condition resulted in a decrease of trunk lateral flexion towards the stance limb was noticed at peak knee flexion ($6.04 \pm 1.58^\circ$, $d = -0.96 \ [-1.48, -0.45]$, $p = <0.001$) and toe off ($4.58 \pm 2.82^\circ$, $d = -0.77 \ [-1.34, -0.32]$, $p = 0.004$). There was also an increase in trunk extension at peak knee flexion ($4.14 \pm 0.27^\circ$, $d = -0.88 \ [-1.39, -0.36]$, $p = 0.006$).

When comparing ball fake to ball throw within anticipated cuts, no differences were found.

**Influence of Dual Tasking (Unanticipated: No Ball Throw, Ball Fake, Ball Throw).** Compared to no ball throw, the ball fake condition resulted in a decrease in trunk lateral flexion towards the stance limb was noticed at peak knee flexion ($4.57 \pm 0.2^\circ$, $d = -0.78 \ [-1.29, -0.27]$, $p = 0.001$) and toe off ($3.45 \pm 0.86^\circ$, $d = -0.56 \ [-1.06, -0.06]$, $p = 0.031$).
Compared to no ball throw, the ball throw condition resulted in a decrease in trunk lateral flexion towards the stance limb at peak knee flexion (5.75 ± 0.74°, $d = -0.91$ [-1.42, -0.32], $p = 0.001$) and toe off (3.96 ± 1.3°, $d = -0.62$ [-1.12, -0.12], $p = 0.031$). There was also an increase in trunk rotation towards the stance limb at initial contact (6.2 ± 1.08°, $d = -0.53$ [-1.02, -0.03], $p = 0.016$) and at toe off (9.78 ± 6.9°, $d = -0.64$ [-1.15, -0.14], $p = 0.027$). An increase in knee flexion was observed at toe off (4.49 ± 1.59°, $d = 0.57$ [0.07, 1.07], $p = 0.044$) and an increase in eversion was observed at peak knee flexion (2.69 ± 0.18°, $d = -0.62$ [-1.12, -0.12], $p = 0.034$) when comparing the no ball throw to the ball throw condition.

When comparing ball fake to ball throw within unanticipated cuts, there were no statistically significant differences found.

**Influence of the Additive Effect (Anticipated No Ball Throw, Unanticipated Ball Fake, Unanticipated Ball Throw).** Compared to anticipated no ball throw, the unanticipated ball fake condition resulted in a decrease in trunk lateral flexion towards the stance limb at peak knee flexion (4.87 ± 0.33°, $d = -0.87$ [-1.38, -0.36], $p < 0.001$) and at toe off (3.54 ± 2.21°, $d = -0.64$ [-1.14, -0.14], $p = 0.017$)

Compared to anticipated no ball throw, the unanticipated ball fake condition resulted in a decrease in trunk lateral flexion towards the stance limb at peak knee flexion (6.05 ± 1.27°, $d = -0.99$ [-1.51, -0.47], $p < 0.001$) and at toe off (4.05 ± 2.65°, $d = -0.70$ [-1.20, -0.19], $p = 0.017$). There was also an increase of trunk extension at peak knee flexion (4.22 ± 1.43°, $d = -0.79$ [-1.30, -0.28], $p = 0.007$) as well as an increase in ankle eversion during peak knee flexion (2.51 ± 0.42°, $d = -0.62$ [-1.13, -0.12], $p = 0.036$).
Discussion.

The findings of this study refuted our hypothesis that the combination of anticipation and dual tasking (which better mimics game-like scenarios) influences trunk and lower extremity kinematics during cutting. The primary findings of this study showed a decrease in trunk lateral flexion towards the stance limb when comparing a ball fake or ball throw condition to a no ball throw condition, as well as an increase in trunk rotation towards the stance limb when comparing a ball throw condition to ball fake condition. To our knowledge, this was the first to combine anticipation and dual tasking during a side step cut in a controlled laboratory setting.

While prior studies that have found differences while dual tasking, those differences were still only 5-8º of difference at one joint, in the sagittal or frontal planes, at different time points.\textsuperscript{19,20} Those differences were also noted when comparing male and female cutting patterns. When examining within gender no differences were observed.\textsuperscript{19,20} Historically, differences in gender have been viewed as important factors when it comes to ACL injury. Several studies show significant differences in biomechanics in females when compared to males.\textsuperscript{12,2,5,19} We chose to only look at males since a study like this has not been done before.

While trunk motion is believed to influence lower extremity kinematics, there did not appear to be an effect in this study.\textsuperscript{10,21} The differences were likely observed due to the physical aspect of catching the ball rather than the physiological or cognitive response related to dual tasking since there were no differences between the ball fake and ball throw conditions.
Interestingly, there were no clinically meaningful differences in hip, knee, or ankle kinematics. A possible explanation for the lack of differences observed may be related to the Dynamical Systems Theory. It is likely that a finite number of ways to complete any task successfully exists, and that as the complexity of the task increases, the number of ways to complete the task decreases. When we quantified the percentage of times the participants failed the different trials we noticed that as the task got more complex the number of times they failed to correctly complete it increased (see figure 7) thus supporting this idea. To help put it in perspective the participants only failed the anticipated no ball throw condition around 12% of the time but they failed the unanticipated ball fake and unanticipated ball throw 26% and 31% of the time respectively. Although they failed the more complex tasks more often, as the testing process continued they began to complete the trials more successfully. In the first round of trials they failed 25% of the trials they tried to complete however by the last round of trials they only failed 15% of the trials they tried to complete. This may indicate a learning effect meaning the more times they were given to complete the task the better they got at successfully completing the task.. When a person successfully completes the cutting task, the biomechanics look similar regardless of complexity.

**Clinical Implications.** The findings of this study suggest that as the task becomes more complicated, or game-like, an athlete is more likely to fail at completing it. During these failed trial scenarios could be where somebody is at a greater risk of sustaining an injury. However, the more times they are given to practice the task within a controlled environment, the more likely the individual is to complete the task successfully. These ideas may have implications for injury prevention programs. Much of
the focus of existing ACL prevention programs is placed on neuromuscular control and landing technique.\textsuperscript{24} However, currently there is little evidence to support the inclusion of dual tasking during these prevention programs. Another aspect where dual tasking should be involved is towards the end stages of rehabilitation programs. Again allowing the athlete to get used to dual tasking while controlling their movements will better prepare them for the high risk situations they are about to return to.

**Limitations.** The goal of the study was not to necessarily place individuals in a more susceptible position for injury, but rather to evaluate whether changing the focus of the mind from the task to an external event would play a larger role in biomechanical changes similar to those in real-life scenarios. Overall, increasing the complexity of the task may be a more accurate representation of a real-life scenario. However, as the complexity of any task increases, so do the confounding variables that may influence the outcome of the task. The conclusions drawn from these results should be viewed with respect to certain study limitations. For example, there could be variability in timing and location of the ball throw between trials and subjects. The ball thrower was instructed to throw the ball one step before the participant hit the force plate so that they had to catch it while landing on the force plate to make the cut. To help increase the consistency we allowed for plenty of warm-up trials between the ball thrower and the participant so they could determine the correct timing. Although the ball throw was somewhat controlled there is a lot more variability during athletic events. Another limitation is that is study was completed using healthy male athletes with no history of lower extremity injury. More studies should be done to determine if gender, skill level, age, or injury history would be factors in this task.
While doing comparisons between trials we did not analyze the failed trials. Failed trials occurred when the participant did not hit the force plate fully, went the wrong direction, or collapsed during the cut because they could not adjust fast enough. Those trials simulate failed motions during game play and could show changes in biomechanics that lead to injury. We also only analyzed the cuts made using their dominant leg not their non-dominant leg. Those trials could open them up to injury as they were uncomfortable completing them. Finally, fatigue was not a factor of this study due to the amount of rest between each trial the participant had. Most injuries occur towards the end of events when the athlete is fatigued.

Conclusion.

Anticipation during side step cutting maneuvers appears to have no effect on trunk and lower extremity kinematics. However, dual tasking effects trunk rotation and lateral flexion towards the stance leg when the athlete has to attend to a ball. These results are one step closer to looking at lower extremity biomechanics during simulated athletic activities in sports with potential for upper extremity use during participation.
Table 1. Participant demographics, mean (SD)

<table>
<thead>
<tr>
<th></th>
<th>Healthy Males (n=32)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>23.12 (3.62)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>81.29 (17.26)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.02 (6.97)</td>
</tr>
<tr>
<td>Tegner</td>
<td>6.75 (1.04)</td>
</tr>
<tr>
<td>KOOS</td>
<td>98.14 (2.71)</td>
</tr>
<tr>
<td>Average Cut Speed (m/s)</td>
<td>4.78 (0.27)</td>
</tr>
</tbody>
</table>

Figure 1. Laboratory Set-up

![Diagram showing laboratory set-up with gates and start location](image)
<table>
<thead>
<tr>
<th>Condition</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>No Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated</td>
<td>-2.65 ± 5.45</td>
<td>12.38 ± 6.02</td>
<td>-98.20 ± 8.41</td>
</tr>
<tr>
<td>*P value</td>
<td>.010</td>
<td>.336</td>
<td><strong>.052</strong></td>
</tr>
<tr>
<td>Ball Fake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>-3.28 ± 5.38</td>
<td>7.50 ± 5.60</td>
<td>-101.17 ± 7.88</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>-3.27 ± 5.39</td>
<td>7.64 ± 5.25</td>
<td>-102.20 ± 7.74</td>
</tr>
<tr>
<td>*P value</td>
<td>.976</td>
<td>.165</td>
<td>.156</td>
</tr>
<tr>
<td>Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>-4.20 ± 5.06</td>
<td>7.15 ± 5.56</td>
<td>-102.18 ± 7.98</td>
</tr>
<tr>
<td>*P value</td>
<td>.285</td>
<td>.564</td>
<td>.047</td>
</tr>
<tr>
<td>Anticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>-1.17 ± 5.85</td>
<td>11.97 ± 5.33</td>
<td>-99.98 ± 9.84</td>
</tr>
<tr>
<td>Ball Fake</td>
<td>-3.28 ± 5.38</td>
<td>7.50 ± 5.60</td>
<td>-101.17 ± 7.88</td>
</tr>
<tr>
<td>Ball Throw</td>
<td>-4.20 ± 5.06</td>
<td>7.15 ± 5.56</td>
<td>-102.18 ± 7.98</td>
</tr>
<tr>
<td>*P value</td>
<td>.078</td>
<td>.001</td>
<td>.094</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NBT &gt; BF/BT</td>
<td>NA</td>
</tr>
<tr>
<td>Additive Effect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>-2.65 ± 5.45</td>
<td>12.38 ± 6.02</td>
<td>-98.20 ± 8.41</td>
</tr>
<tr>
<td>Ball Fake</td>
<td>-3.27 ± 5.39</td>
<td>7.64 ± 5.25</td>
<td>-102.20 ± 7.74</td>
</tr>
<tr>
<td>*P value</td>
<td>.318</td>
<td>&lt;.001</td>
<td>.016</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NBT &gt; BF/BT</td>
<td>NBT &gt; BT</td>
</tr>
</tbody>
</table>

Abbreviations: A, anticipated; U, unanticipated; BT, ball throw; BF, ball fake
Positive values: hip flexion, hip adduction, hip internal rotation, knee flexion, knee varus, knee internal rotation, ankle dorsiflexion, ankle inversion, forefoot abduction
Negative values: hip extension, hip abduction, hip external rotation, knee extension, knee valgus, knee external rotation, ankle plantarflexion, ankle eversion, forefoot abduction
* Significant at P ≤ 0.05
† Significant at P ≤ 0.01
‡ Significant at P ≤ 0.001
<table>
<thead>
<tr>
<th>Condition</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>No Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>41.72 ± 12.26</td>
<td>-5.03 ± 6.79</td>
<td>8.22 ± 9.59</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>40.98 ± 12.57</td>
<td>-4.01 ± 6.96</td>
<td>6.31 ± 9.64</td>
</tr>
<tr>
<td>P value</td>
<td>.025</td>
<td>.121</td>
<td>.001</td>
</tr>
<tr>
<td>Ball Fake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated</td>
<td>39.32 ± 12.33</td>
<td>-1.67 ± 6.89</td>
<td>6.19 ± 9.95</td>
</tr>
<tr>
<td>P value</td>
<td>.031</td>
<td>.080</td>
<td>.055</td>
</tr>
<tr>
<td>Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>37.71 ± 11.08</td>
<td>-2.71 ± 6.69</td>
<td>7.11 ± 10.09</td>
</tr>
<tr>
<td>P value</td>
<td>.179</td>
<td>.128</td>
<td>.136</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Condition</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>Unanticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>40.98 ± 12.57</td>
<td>-4.01 ± 6.96</td>
<td>6.31 ± 9.64</td>
</tr>
<tr>
<td>Ball Fake</td>
<td>39.32 ± 12.33</td>
<td>-1.67 ± 6.89</td>
<td>6.19 ± 9.95</td>
</tr>
<tr>
<td>P value</td>
<td>.707</td>
<td>.319</td>
<td>.968</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Additive Effect</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>Anticipated No Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated Ball Fake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P value</td>
<td>.540</td>
<td>.090</td>
<td>.697</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: A, anticipated; U, unanticipated; BT, ball throw; BF, ball fake
Positive values: hip flexion, hip adduction, hip internal rotation, knee flexion, knee valgus, knee internal rotation, ankle dorsiflexion, ankle inversion, forefoot adduction
Negative values: hip extension, hip abduction, hip external rotation, knee extension, knee varus, knee external rotation, ankle plantarflexion, ankle eversion, forefoot abduction

* Significant at P ≤ 0.05
<table>
<thead>
<tr>
<th>Condition</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>No Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>28.53 ± 7.49</td>
<td>-3.40 ± 5.52</td>
<td>-4.49 ± 5.81</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>30.78 ± 7.94</td>
<td>-3.25 ± 5.37</td>
<td>-3.84 ± 5.75</td>
</tr>
<tr>
<td>*</td>
<td>.003</td>
<td>.541</td>
<td>.147</td>
</tr>
<tr>
<td>Ball Fake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>25.56 ± 7.27</td>
<td>-3.70 ± 5.49</td>
<td>-5.00 ± 6.12</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>29.35 ± 8.71</td>
<td>-3.50 ± 5.69</td>
<td>-3.85 ± 6.09</td>
</tr>
<tr>
<td>*</td>
<td>.001</td>
<td>.507</td>
<td>.008</td>
</tr>
<tr>
<td>Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>26.05 ± 6.42</td>
<td>-4.39 ± 5.48</td>
<td>-3.96 ± 6.46</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>27.82 ± 6.73</td>
<td>-4.10 ± 5.24</td>
<td>-3.71 ± 6.20</td>
</tr>
<tr>
<td>*</td>
<td>.031</td>
<td>.214</td>
<td>.950</td>
</tr>
<tr>
<td>Anticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>28.53 ± 7.49</td>
<td>-3.40 ± 5.52</td>
<td>-4.49 ± 5.81</td>
</tr>
<tr>
<td>Ball Fake</td>
<td>25.56 ± 7.27</td>
<td>-3.70 ± 5.49</td>
<td>-5.00 ± 6.12</td>
</tr>
<tr>
<td>Ball Throw</td>
<td>26.05 ± 6.42</td>
<td>-4.39 ± 5.48</td>
<td>-3.96 ± 6.46</td>
</tr>
<tr>
<td>*</td>
<td>.203</td>
<td>.762</td>
<td>.798</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Unanticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>30.78 ± 7.94</td>
<td>-3.25 ± 5.37</td>
<td>-3.84 ± 5.75</td>
</tr>
<tr>
<td>Ball Fake</td>
<td>29.35 ± 8.71</td>
<td>-3.50 ± 5.69</td>
<td>-3.85 ± 6.09</td>
</tr>
<tr>
<td>Ball Throw</td>
<td>27.82 ± 6.73</td>
<td>-4.10 ± 5.24</td>
<td>-3.71 ± 6.20</td>
</tr>
<tr>
<td>*</td>
<td>.324</td>
<td>.812</td>
<td>.955</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Additive Effect**

Anticipated No Ball Throw  
Unanticipated Ball Fake  
Unanticipated Ball Throw  

<table>
<thead>
<tr>
<th>P value</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

**Abbreviations:** A, anticipated; U, unanticipated; BT, ball throw; BF, ball fake

| Positive values: hip flexion, hip abduction, hip internal rotation, knee flexion, knee varus, knee internal rotation, ankle dorsiflexion, ankle inversion, forefoot adduction  |
| Negative values: hip extension, hip abduction, hip external rotation, knee extension, knee valgus, knee external rotation, ankle plantarflexion, ankle eversion, forefoot abduction  |

* Significant at P < 0.05
<table>
<thead>
<tr>
<th>Condition</th>
<th>Initial Contact</th>
<th>Peak Knee Flexion</th>
<th>Toe-Off</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sagittal</td>
<td>Frontal</td>
<td>Transverse</td>
</tr>
<tr>
<td>No Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated</td>
<td>-0.69 ± 9.19</td>
<td>11.97 ± 5.06</td>
<td>-7.87 ± 6.45</td>
</tr>
<tr>
<td>Unanticipated</td>
<td>-0.20 ± 8.41</td>
<td>12.52 ± 4.73</td>
<td>-7.51 ± 6.87</td>
</tr>
<tr>
<td>P value</td>
<td>.621</td>
<td>.130</td>
<td>.309</td>
</tr>
<tr>
<td>Ball Fake</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Unanticipated</td>
<td>0.02 ± 8.53</td>
<td>12.38 ± 4.73</td>
<td>-6.43 ± 6.45</td>
</tr>
<tr>
<td>P value</td>
<td>.662</td>
<td>.172</td>
<td>.428</td>
</tr>
<tr>
<td>Ball Throw</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P value</td>
<td>.780</td>
<td>.425</td>
<td>.427</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>.999</td>
<td>NA</td>
</tr>
<tr>
<td>Unanticipated Cut</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No Ball Throw</td>
<td>-0.69 ± 9.19</td>
<td>11.97 ± 5.06</td>
<td>-7.87 ± 6.45</td>
</tr>
<tr>
<td>Ball Throw</td>
<td>-2.16 ± 10.73</td>
<td>11.95 ± 5.70</td>
<td>-6.10 ± 6.64</td>
</tr>
<tr>
<td>P value</td>
<td>.758</td>
<td>.999</td>
<td>.535</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Additive Effect</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anticipated No Ball Throw</td>
<td>-0.69 ± 9.19</td>
<td>11.97 ± 5.06</td>
<td>-7.87 ± 6.45</td>
</tr>
<tr>
<td>Unanticipated Ball Fake</td>
<td>0.02 ± 8.53</td>
<td>12.38 ± 4.73</td>
<td>-6.43 ± 6.45</td>
</tr>
<tr>
<td>Anticipated Ball Throw</td>
<td>-1.93 ± 10.02</td>
<td>12.35 ± 4.91</td>
<td>-5.88 ± 6.79</td>
</tr>
<tr>
<td>P value</td>
<td>.697</td>
<td>.934</td>
<td>.460</td>
</tr>
<tr>
<td>Post hoc</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

Abbreviations: A, anticipated; U, unanticipated; BT, ball throw; BF, ball fake
Positive values: hip flexion, hip abduction, hip internal rotation, knee flexion, knee varus, knee internal rotation, ankle dorsiflexion, ankle inversion, foot abduction
Negative values: hip extension, hip abduction, hip external rotation, knee extension, knee valgus, knee external rotation, ankle plantarflexion, ankle eversion, foot abduction
*
†
‡
Significant at $P \leq 0.05$
References


Appendix A

The Problem

A.1 Statement of the Problem

Epidemiological studies have found that there are over 80,000 ACL tears in the United States each year, with a total cost of $1 billion. The side-step cut has been suggested to be an athletic maneuver that may put the athlete into greater risk of sustaining a noncontact ACL injury. Under normal cutting mechanics joint angles and moments do not create stress on the ACL that can lead to injury. However, changes in cutting mechanics at the trunk, hip, or knee can have a significant impact on the on the moments around the knee thus increasing the stress placed on the ACL. During game situations most maneuvers are unanticipated, usually occurring as a reaction to an external event such as avoiding another player or following a ball. These unanticipated cuts produce changes in lower extremity joint angles and moments within the sagittal, frontal, and transverse planes that can cause increased strain on the ACL. The second aspect of game situations is the reaction to the external event. This external event can be cognitive, such as seeing where a defender is and changing direction accordingly, or manual, such as catching, carrying, or throwing a ball. When these external events have been combined with another task such as running, cutting, or jumping changes in kinematics and kinetics have been observed to place the knee into a position that further increases the risk for ACL injury. If there is an additive effect of unanticipated side-step cutting and an external event, kinematics and kinetics around the knee during actual game play may be greater than those measured in an experimental laboratory study. The purpose of this study is to examine and compare changes in the knee kinematics and
kinetics during an anticipated and unanticipated cut when a collegiate male athlete is focused on catching a ball.

A.2 Research Questions

1. Do unanticipated cuts cause a change in knee and hip kinematics and kinetics that places the knee closer to a point of failure when compared to an anticipated cut?

2. Do unanticipated and anticipated cuts cause a change in knee and hip kinematics and kinetics that places the knee closer to a point of failure when the subject is focused on a ball as compared to when they aren’t?

A.3 Experimental Hypothesis

1. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion in the unanticipated cut as compared to the anticipated cut.

2. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated and anticipated cut when the subject has to focus on catching a ball afterwards.

A.4 Assumptions

The following assumptions will apply to this study:

1. Subjects have a similar sports history/experience and they accurately report their activity level using the Tegner Activity Level scale

2. Subjects will give their maximal effort during each cut.
3. Subjects will perform the cut correctly.

A.5  Delimitations

1. The study is limited to males.
2. The study focuses on college club sport athletes age 18 to 30.
3. The athletes will have no previous injury to the lower extremity (knee and hip) in the past six months.
4. Each subject will complete the anticipated and unanticipated cutting task.
5. The markers will be placed by the same clinician.
6. The ball will be thrown by the same clinician.

A.6  Limitations

1. Timing, location, and speed of ball throw to participants.
2. Ability of motion capture system to collect lower extremity motion during high speed movements.
3. Markers came detached resulting in reapplication.
4. Fatigue was not experienced.
5. Failed trials were not analyzed.

A.7  Operational Definitions

1. **Athlete** – Individual between the age or 18 and 22 who participate in club sports at their university.
2. **Risk Factor** – A condition or behavior that increases the risk of injury.
3. **Non-contact injury** – No force is applied directly to the knee joint, i.e. no direct blow from an opponent, object, or the ground.

4. **Kinetics** – The study of forces acting on the knee such as vertical and lateral ground reaction forces.

5. **Kinematics** – The branch of mechanics concerned with the motion of objects without reference to the forces that cause the motion.

6. **Cutting maneuver** – The subject will run straight then sidestep cut to the left or crossover cut to the right at a 45° angle.

7. **Anticipated** – Knowing the direction the subject will cut before they begin the task.

8. **Unanticipated** – Not knowing the direction the subject will cut before they begin the task. They will know during the step before their foot contacts the force plate.

9. **Dual tasking** - The combination of doing more than one task at a time such as doing a cognitive task (speaking or solving problems) or manual task (holding or catching an object) while trying to complete another task (walking, running, cutting, or using stairs)

10. **Heel strike** – The moment in the cutting gait cycle where the subject’s heel of the cutting leg comes into contact with the ground; signals beginning of task analyzation

11. **Toe off** – The moment in the cutting cycle where the subject’s toe of the cutting leg leaves the ground; signals end of task analyzation

**A.8 Significance of Study**

If the data were to support the above hypotheses it would be recommended to add dual-tasking into daily training exercises. Allowing athletes to complete warm-up activities while focusing on ball handling or something else will allow them to train their
body to handle those situations at game speed. Dual tasking will help with muscle memory conditioning so that the body reacts as it should regardless of the distractions due to the dual-taking implemented into their training.
Appendix B

Literature Review

B.1 Anatomy

B.1.1 Joints & Bones

The knee joint complex is made up of three different joints: tibiofemoral, patellofemoral, and tibiofibular. The tibiofemoral joint lies between the medial and lateral condyles of the femur and the plateau of the tibia. This joint is classified as a diarthrotic joint as it allows for flexion and extension, as well as medial and lateral rotation.\(^1\) The patellofemoral joint lies between the posterior aspect of the patella and the intercondylar groove of the distal femur. This joint allows for non-axial movements such as superior and inferior gliding of the patella along the femur.\(^1\) The major purpose of the patella acts as a fulcrum between the quadriceps tendon and the patellar tendon in order to improve the force produced during knee extension.\(^1\) The tibiofibular joint is located between the head of the fibula and the lateral condyle of the tibia. It is not located within the capsule of the knee joint and therefore is not very functionally related to the knee.\(^1\)

B.1.2 Ligaments & Cartilage

Within the tibiofemoral joint there are four major ligaments: medial collateral ligament (MCL), lateral collateral ligament (LCL), anterior cruciate ligament (ACL), and the posterior cruciate ligament (PCL). The MCL attaches from the medial epicondyle of the femur to the medial condyle of the tibia with the purpose of limiting abduction of the joint within the frontal plane. The LCL attaches from the lateral epicondyle of the femur to the head of the fibula with the purpose of limiting adduction of the joint within the frontal plane.
The ACL attaches from the anterior intercondylar region of the tibia to the medial aspect of the lateral condyle of the femur with the purpose of limiting anterior translation of the leg when the thigh is fixed, posterior translation of the thigh when the leg is fixed, and medial rotation within the joint. The ACL is comprised of an anteromedial bundle and a posterolateral bundle. The anteromedial bundle is taunt when the knee is flexed and the posterolateral bundle is taunt when the knee is fully extended. The PCL attaches from the posterior intercondylar region of the tibia to the lateral aspect of the medial condyle of the femur, with the purpose of limiting posterior translation of the leg when the thigh is fixed, and anterior translation of the thigh when the leg is fixed.

Along with the ligaments, the tibiofemoral joint has two menisci: a medial meniscus and a lateral meniscus. The medial meniscus is shaped like the letter “C” and the lateral meniscus is shaped similar the letter “O”. These menisci are meant to help increase congruency between the tibia and femur, create stability, and aid is cushioning or shock absorption.

B.1.3 Musculature

The anterior compartment of the thigh contains the quadriceps femoris group consisting of the rectus femoris, vastus lateralis, vastus medialis, and vastus intermedius. These muscles insert onto the tibial tuberosity via the patellar tendon and assist in extension of the knee. The posterior compartment of the thigh contains the hamstring group consisting of the biceps femoris, semitendinosus, and semimembranosus. The biceps femoris inserts on the head of the fibula, the semimembranosus inserts on the medical condyle of the tibia, and the semitendinosus inserts medially on the pes anserine tendon. As a group these muscles flex the knee.
The pes anserine muscle group is made up of the gracilis, sartorius, and semitendinosus, all of which attach to the anterior medial tibia. This group assists in knee flexion and internally rotates the tibia when the foot is not planted on the ground. When the foot is planted these muscles externally rotate the femur on the fixed tibia. The iliotibial band (IT band), which is an extension of the tensor fasciae latae muscle, crosses the knee joint laterally and attaches at Gerdy’s tubercle on the anterolateral aspect of the tibia. Although the IT band does not make a significant contribution in motion of the knee, it plays a key role in knee stability by acting as an anterolateral knee ligament because of its deep fibers attaching to the lateral joint capsule.

B.2 Prevalence of Injury

B.2.1 Overall ACL Incidence

The most commonly used method of ACL tear incidence measurement is “tears per 1,000 exposures,” with an exposure being one athlete’s participation in one practice or competition. An injury is defined by three criteria: 1) occurring during participation in an organized practice or competition; 2) requiring medical attention by athletic trainer or physician; and 3) resulting in restriction of activity for one or more days.

Differences in ACL tear incidence rates can be identified by comparing sports. The amounts of athletic exposures ranked from most to least are basketball, soccer, lacrosse, football, handball, rugby, and wrestling. However, the ACL incidence rates were reversed with handball, wrestling, rugby, and lacrosse having the highest ACL incidence rates (0.24, 0.19, 0.18, 0.17; respectively), followed by soccer, football, and
basketball (0.12, 0.08, 0.08; respectively). 1 A study comparing injury rates across 15 sports over a 16 year period (1988-2004) found similar results expect for football had the highest ACL incidence rate (Spring = 0.33, Fall = 0.18) when compared to other sports. 21 According to Arendt and Dick, the male soccer ACL incidence rate was 0.13 and the male basketball ACL incidence rate was 0.07. 2 Mihata et al found the ACL injury rate in men’s lacrosse (0.17) to be higher than those in basketball (0.08) and soccer (0.12). 3

Another way differences in ACL tear incidence rates can be identified is by comparing age. The high school (ages 16-19 years) and collegiate level (ages 14-20 years) athletes are the ages in which most ACL injuries occur (4.2% of all injuries, and 5.5% of all injuries; respectively). 4 This is due to the athletes being highly active and involved in athletic activities that would put them at risk, therefore creating a higher incidence rate. A study done by Beynnon et al., shows that the injury rate for first time noncontact ACL injuries in the high school level of play is 0.061, whereas in the college level it is 0.150. 22 Within these age groups football accounted for 63.9% of all injuries and 60% of all knee injuries. 4 Within those football injuries, knee injuries made up 36.9% with specific ACL injuries making up 2.8%. 4 ACL injuries made up 3.9% of all male injuries, and 9.6% of all male knee injuries. 4

B.3 Etiology

B.3.1 Mechanism of ACL Rupture

In a study performed by Boden et al, 89 athletes (72 male knees and 28 female knees) between the ages of 14-48 years were interviewed about the events surrounding their ACL injury. 6 Through questionnaires and video analysis they discovered that a
noncontact mechanism was reported in 72% of cases and that a contact injury was reported in 28% of ACL injuries. Kobayashi et al also gathered injury information from 1,661 athletes using video analysis (806 males and 852 females). He found that 1,010 of the injuries would be classified as having a noncontact mechanism, which further broken down is 51.5% of male injuries and 70% of female injuries.

Through video analysis two main mechanisms have been found to occur most frequently. The first is a sharp deceleration, also known as a plant-and-cut movement, with a forceful valgus and external or internal rotation with the knee close to full extension. With this mechanism Boden et al analyzed hip and trunk movement and found that the uninjured side hip was in a neutral position and the trunk was leaning backwards. The second was during a landing maneuver, typically on one leg also with a forceful valgus and external or internal rotation with the knee close to full extension. Boden et al found that there was a slightly higher incidence of injuries occurring with external tibial rotation, when the body is moving internally while the lower leg stays in place. One theory around ACL injury occurring through sharp deceleration is that they require eccentric force generation by the quadriceps during slight knee flexion angles, which cause maximum anterior shear force, which provides even more force to strain the ACL.

Interviews and video analyses are not the only ways stress on the ACL has been investigated. Meyer and Haut used cadaver anterior cruciate ligaments to examine the torsional forces and compressive forces the ACL could withstand. They found that when torsional forces are applied, internal rotation of the tibia and valgus rotation of the femur occurred during and after injury. When compressive forces are applied, the
femur displaces posteriorly relative to the tibia until and after ACL failure. During compressive forces the direction of tibia rotation changed from internal rotation in pre failure tests to external rotation after failure of the ACL.

B.4 Biomechanics

B.4.1 Kinematics of Anticipated Side-step Cut

The sidestep cut is performed “by planting the foot opposite to the direction one wishes to go, using the other leg for the first step in the new direction.” For example, if the athlete wanted to cut to the left they would plant and push off with their right foot while their left foot would make the first step to the left. High speed motion capture, video, and athlete recall of the injury have shown that body positioning/joint angles are critical in assessing and understanding the risk of injury. Therefore further research on the kinematics around these events is needed.

B.4.1.1 Trunk

Prior to the cut the athlete must slow down, or decelerate, in order to be able to change direction. During this movement the torso stays erect until the tibia on the plant leg becomes vertical. The dorsiflexion in the foot causes greater knee flexion so that the torso, or center of mass, stays posterior to the planted foot. When the center of mass passes over the athlete’s foot the torso and pelvis are then internally rotated on the femur. As the athlete starts to take off out of the cut the torso then externally rotates on the femur to allow for the change in direction.

As with all other joint positions, trunk orientation is important during a side-step cut and it contributes to the athlete’s overall center of balance. A person’s base of support
is defined as a point bisecting the line of contact between the shoe and the floor at initial contact. In order to avoid falling, the athlete’s center of mass must fall within their base of support. If the center of mass leaves the base of support the athlete has a chance at recovery but if it moves too far outside the base of support it results in the athletes falling over. Sipprell et al found that athletes who land with their center of mass greater than two foot lengths posterior to their base of support are at an increased risk of ACL injury.

B.4.1.2 Hip

As the body decelerates and the heel comes in contact with the ground, the hip is flexed and the pelvis is rotated internally on the femur. This hip flexion is caused by the forward and downward force of the torso as it moves. As the center of mass shifts over the pivot leg the hip moves into its maximum flexion. The torso or pelvis then externally rotates away from the pivot leg in the new direction and moves into extension during take-off. Jorrakate et al studied the joint angles present at initial contact and at peak knee valgus moment during a side-step cut in male athletes. They found that at initial contact the hip was in 60° flexion, 8° adduction, and 8° internal rotation; and at peak knee valgus moment the hip was at 53° flexion, 7° abduction, and 10° internal rotation.

Flexion of the hip joint during deceleration allows for increased knee flexion and a decreased ground reaction force that is produced. McClean found that sagittal plane loading alone cannot cause injury to the ACL. Increased hip external rotation was found to cause greater knee valgus which leads to a predisposition in ACL injury. Also
an increase in hip abduction contributes to an increase in knee valgus which placed strain on the ACL.  

B.4.1.3 Knee

Throughout the cutting maneuver the knee goes through a variation of range of motion. At initial contact the knee is in full extension and full external tibial rotation. The point of maximal external tibial rotation is during deceleration and take-off when the knee is in its most extended position. The knee begins to flex to a maximum of 60° while the tibia internal rotates on the femur as the athlete’s center of mass shifts over the plant foot. Internal tibial rotation is associated with the amount of knee flexion throughout the cut. Once the athlete begins to take off in the new direction the knee moves back into extension. Jorrakate et al found during a normal anticipated side-step cut the knee was in 33° flexion, 4° varus, and 3° internal rotation at initial contact; and was at 35° flexion, 4° varus, and 1° internal rotation at the peak knee valgus moment.

A study done by Cross et al found that athletes go through roughly 20° of total tibial rotation throughout a side step cut. Peak tibial rotation was found around 35% of the stance phase which is when the torso is over top of the knee. Peak tibial internal rotation found during the side-step cutting maneuver is not the maximal tibial internal rotation possible therefore; the researchers concluded that since the ACL only becomes taunt with maximal internal tibial rotation, under normal circumstances the ACL would not be susceptible to rupture.

The job of the ACL is to prevent forward translation of the tibia relative to the femur. Cadaver studies have shown that at 30° of knee flexion the ACL represents 85% of the total capsular and ligamentous resistance. During 15°-30° of knee flexion, a
quadriceps contraction increases the strain placed on the ACL by causing anterior shear forces on the tibia.\textsuperscript{7}\textsuperscript{22} A combination of internal tibial rotation, a quadriceps contraction, and knee valgus past normal circumstances would place extra strain on the ACL or even cause impingement which would make it more susceptible to injury.\textsuperscript{7}\textsuperscript{27} If an athlete has poor neuromuscular control the knee can fall into a valgus position which can place the ACL under increased strain leading to injury.\textsuperscript{11}\textsuperscript{27} 6\textsuperscript{10}

**B.4.1.4 Ankle**

As the heel strikes during deceleration, the ankle is dorsiflexed but it immediately plantar flexes as to allow the entire foot to come in contact with the ground.\textsuperscript{8} The foot then dorsiflexes due to the forward momentum of the torso however increased knee flexion keeps the center of mass behind the posterior to the ankle.\textsuperscript{8} As the torso passes over the ankle, the ankle is externally rotated toward the direction the athlete will head after the cut is complete.\textsuperscript{28} In order to take off in the new direction the ankle plantar flexes fully to propel the body forward.\textsuperscript{8}

Jorrakate et al found that at initial contact the ankle was in $2^\circ$ plantar flexion, $1^\circ$ inversion, and $7^\circ$ external rotation; and at peak knee valgus moment the ankle was at $0.3^\circ$ plantar flexion, $1^\circ$ inversion, and $8^\circ$ external rotation.\textsuperscript{28} The ankle external rotation combined with hip internal rotation could cause a twisting about the knee joint which results in excessive torsional force to the knee.\textsuperscript{28}

**B.4.1.5 Summary**

The joint angles during the stance phase of a side-step cut can cause injury to the ACL. Normal cutting mechanics require the trunk to stay erect to keep the center of mass behind the plant leg.\textsuperscript{8} 10 The hip is to stay in flexion and adduction until take-off as an
increased abduction contributes to increased knee valgus. Increased knee valgus, internal rotation, and anterior shear increases susceptibility of ACL injury. Ankle external rotation contributes torsional forces to the knee increasing the strain already placed on the ACL.

**B.4.2 Kinetics Anticipated Side-step Cut**

Not only can joint angles cause strain on the ACL, but also the internal forces being produced from the trunk to the ground can cause an additional strain on the ACL. The side-step cut increases moments at the hip, knee, and ankle joints.

**B.4.2.1 Trunk**

During a jump landing task, landing upright increases the peak knee extensor moments and the overall vertical ground reaction force while at the same time decreasing the knee flexion angle which produces a decreased hip flexor moment. Leaning slightly forward causes the opposite to occur, the overall vertical ground reaction force and peak knee extensor moments will decrease while the knee flexion angle and hip extensor moments increase. The forward lean during landing also allows the lower extremity muscles to absorb more of the landing forces which reduces the strain placed on the capsuloligamentous and skeletal structures. These studies indicate that landing with the torso leaned forward places less strain on the ACL.

During the deceleration, external femoral rotators are used to produce the required internal pelvic and trunk rotation. This internal pelvic rotation creates external rotatory torque on the femur which in turn increases the deceleration forces distributed to the medial side of the knee causing stress to the medial ligaments. Weak hip abductors may
cause an ipsilateral trunk lean in order to move the center of mass closer to the stance limb.\textsuperscript{23,7} This lean will cause the ground reaction force vector to move laterally which creates a greater lever arm relative to the knee joint center.\textsuperscript{23} Due to the torso holding over half of the body’s overall mass, lateral motion increases ground reaction forces and knee abduction loads.\textsuperscript{23,25}

**B.4.2.2 Hip**

Pollard et al found the average hip moments for male athletes during anticipated side-step cuts; the peak hip extensor moment was 6.6 Nm/kg, peak hip adductor moment was 0.87 Nm/kg, and peak hip external rotator moment was 0.025 Nm/kg.\textsuperscript{29} This adductor moment may be the result of the trunk lean over the stance limb which shifts the center of mass laterally.\textsuperscript{29} During a jump landing task, Brown et al found the peak hip flexion moment to be -0.91 Nm/kg, the peak hip abduction moment to be 0.29 Nm/kg, and the peak hip internal rotation moment to be -0.31 Nm/kg.\textsuperscript{12} Houck et al found the hip moment at initial contact to be 0.02 Nm/kg in adduction, and the hip moment at 30% of the stance phase to be 1.6 Nm/kg in abduction.\textsuperscript{13} This change could be due to the torso beginning to rotate and the momentum moving towards the new direction.

**B.4.2.3 Knee**

Withrow et al used 10 cadaveric knees to compare compressive loads during a jump landing task with and without valgus loading.\textsuperscript{31} They found that there was a 30% greater strain on the ACL during the compressive loading in valgus and flexion when compared to the compressive loading in only flexion.\textsuperscript{31} Meyer and Haut found that compressive forces cause anterior displacement of the tibia on the femur which pushes
the ACL to failure. They also found that compressive forces caused the tibia to internally rotate prior to injury but externally rotate once the ACL failed.

Boden et al concluded that poor neuromuscular control during a side-step cut should be viewed as a risk factor of ACL injury. McLean et al performed neuromuscular perturbations on athletes to produce significant increases in knee anterior force, valgus, and internal rotation moments. They found that peak anterior drawer forces never exceeded 2000 N which is the pre-determined injury threshold for the ACL. However valgus loads reached values high enough to cause injury to the ACL. Those who have excessive knee valgus movement during a side-step cut experience a three times greater ground reaction force than those who have normal knee frontal plane movements. Jorrakate et al found that the average peak knee valgus moment during a side-step cut in male athletes is 0.6 Nm/kg, which appeared to increase as the hip, knee, and ankle joint angles increased. Overall their research suggested that hip flexion, knee flexion, and ankle inversion and external rotation are related to peak knee valgus moment during side-step cutting.

### B.4.2.4 Ground Reaction Force

One prevention factor for knee injuries, and more specifically ACL injuries, would be reducing the peak ground reaction forces created during a side-step cut. Those who have excessive knee valgus movement during a side-step cut experience a three times greater ground reaction force than those who have normal knee frontal plane movements. After adding in the forces and moments acting at the foot, a laterally directed ground reaction force would create a lateral force at the distal tibia which creates a larger lever arm which would increase the knee valgus moment. McLean found that a
greater degree of peak knee valgus would increase the ground reaction force which would increase the likelihood of valgus buckling. An increase in hip abduction combined with excessive knee valgus also causes an increase in vertical ground reaction force due to moving the center of mass laterally which creates a larger moment arm.

B.4.2.5 Summary

Overall slight changes in kinetics at the trunk, hip, knee, or ankle can have a significant impact on the moments around the knee. Decreasing ground reaction force is an important factor in preventing knee injuries. Increasing neuromuscular control during a side-step cut will also assist in preventing knee injuries.

B.4.3 Kinematics Unanticipated Side-step Cut

During game situations most maneuvers are unanticipated usually occurring as a reaction to an external event such as avoiding another player or following a ball. There are many differences in joint angles and moments between anticipated and unanticipated side-step cuts. Several studies have used unanticipated cutting maneuvers to recreate realistic, or game-like, scenarios.

B.4.3.1 Trunk

In a study done by Houck et al, an increase in lateral trunk orientation was found during unanticipated cutting tasks. This change resulted in further lower extremity joint moment changes, such as a decreased hip joint angle, which increase the potential for ACL injury. They believe that the alterations in trunk kinematics suggest the mechanical demands of the unanticipated task constrained the subject’s ability to implement a new motor plan. Houck et al and Besier et al also found a decrease in
stride width during unanticipated tasks which, if not compensated by the torso position, can alter knee moments to increase the strain placed on ACL.  

B.4.3.2 Hip

Throughout the stance phase of a side-step cut there are differences in hip kinematics during an unanticipated task. Houck et al found that the decreased hip abduction angle suggests a failure of the lower extremity to medially rotate around the subtalar joint during the unanticipated side-step cut. Brown et al used an unanticipated jump task to look at hip and knee moments. During the unanticipated landing tasks hip flexion, hip abduction, and hip internal rotation all increased when compared to the anticipated jump landing. Pollard found that at peak hip flexion, males performing unanticipated cut had an average of 9° of hip adduction and 3.5° of hip internal rotation.

B.4.3.3 Knee

Knee joint angles have been shown to alter during unanticipated side-step cutting tasks. Beiser et al found that at peak push off knee flexion increased by 4° during the unanticipated 60° side-step cut and by 5.4° during the unanticipated 30° side-step cut when compared to their respective anticipated side-step cuts. Brown et al found that during the unanticipated landing tasks knee flexion, knee abduction, and knee internal rotation all increased when compared to the anticipated jump landing. Pollard found that at peak knee flexion, males performing unanticipated cut had an average of 1.5° of knee abduction, or varus, and 6° of knee internal rotation. Weinhandl et al found that sagittal plane loading contributed to 62% and transverse plane contributed to 12% of total ACL loading during an unanticipated task. All of these findings suggest that cutting
maneuvers without adequate planning may increase the risk of non-contact knee ligament injuries.¹¹

**B.4.3.4 Summary**

Trunk, hip, knee, and ankle joint angles are altered during unanticipated cutting tasks which cause an increased strain on the ACL. Those changes combined with a lack of neuromuscular control increase the risk of ACL injury.⁶

**B.4.4 Kinetics Unanticipated Side-step Cut**

The differences in joint angles during unanticipated cutting tasks have shown an increase in the moments and ground reaction forces produced which further increase the strain placed on the ACL.

**B.4.4.1 Trunk**

As found by Shimokochi et al and Blackburn et al, performing a jump landing with the torso leaned forward places less strain on the ACL.¹⁰ ³⁰ Houck et al discovered that during an unanticipated side-step cut the trunk will increase in lateral orientation and the individual’s torso will remain more erect than they would during an anticipated cut and thus have an increased strain on the ACL.¹³ This change could be due to the body not having enough time to change its motion pattern. Due to the torso holding over half of the body’s overall mass, lateral motion increases ground reaction forces and knee abduction loads.²³ ²⁵

**B.4.4.2 Hip**

Pollard et al found that at the peak hip flexion moment, males performing unanticipated cut had an average hip abduction moment of 0.96 Nm/kg and hip external
rotation moment of 0.47 Nm/kg. Houck et al found that at initial contact the hip moment was 0.06 Nm/kg of adduction during the unanticipated cut whereas the hip moment during the anticipated cut was 0.02 Nm/kg of adduction. Then at 30% of the stance phase the hip moment was 1.39 Nm/kg of abduction during the unanticipated cut whereas the hip moment during the anticipated cut was 1.62 Nm/kg of abduction. These changes in moments cause changes in knee moments that can place a greater strain on the ACL.

B.4.4.3 Knee

A study done by Besier et al, compared flexion/extension, varus/valgus, and internal/external rotation moments at the knee during anticipated and unanticipated side-step cutting maneuvers. The researchers found that the unanticipated cut at 60° had a 19% less flexion moment, and the 30° cut had a 6% increase in flexion moment when compared to the anticipated cut at peak push off. In regards to varus/valgus moments the researchers found that subjects fell into two distinct groups; the valgus group and the varus group. During peak push off those in the valgus group experienced 55% larger valgus moments during unanticipated side-step cuts than during the anticipated, and those in the varus group experienced a 34% reduction in varus moment during the unanticipated cut when compared to the anticipated cut. The unanticipated cut at 30° and the unanticipated cut at 60° had a greater internal rotation moment during deceleration when compared with their respective anticipated cuts (49% and 129% respectively). The researchers concluded that potential for knee ligament injury during unanticipated cutting tasks may increase if muscle activation strategies do not
proportionally with the large flexion, varus/valgus, and internal/external rotation moments.\textsuperscript{11}

Pollard found that at the peak knee flexion moment, males performing unanticipated cut had an average knee adduction moment of 0.31 Nm/kg and knee external rotation moment of 0.09 Nm/kg.\textsuperscript{33} Houck et al found that in the frontal plane at the beginning of the stance phase the knee moment was toward abduction but as the stance phase progressed the knee adduction moment quickly increased.\textsuperscript{13} They believe this response is due to the immediate redirecting of the center of mass away from the stance leg in the new direction.\textsuperscript{13}

**B.4.4.4 Ground Reaction Force**

Brown et al found an increase in ground reaction force during an unanticipated jump landing and cutting than in an anticipated jump landing and cutting task.\textsuperscript{12} An increase in vertical ground reaction force increases the moments around the joint which can lead to an increase in ACL injury risk. A reduction in ground reaction force is an important factor in knee injury prevention.\textsuperscript{5}

**B.4.4.5 Summary**

During unanticipated side-step cutting maneuvers, differences in kinematics, kinetics, and ground reaction forces have been revealed in male athletes when compared to an anticipated side-step cut.

**B.4.5 Dual-tasking Kinematics**

There are several studies that have looked at doing a cognitive, such as speaking or solving problems, or manual task, such as holding or catching an object, while trying
to complete another task, such as walking, running, cutting, or using stairs. The combination of doing more than one task at a time is defined as dual-tasking. Dual-tasking is used to recreate realistic, or game-like, scenarios.

B.4.5.1 Trunk

Asai et al had 117 healthy older subjects walk on a treadmill while dual-tasking. They had a cognitive task where the subjects counted backwards from 100 while walking, and they had a manual task where the subjects had to balance a ball on a tray while walking. After completing the tests they discovered that subjects had a slower gait and greater stride length variability while performing either the cognitive or manual task. The manual task significantly decreased trunk accelerations in the mediolateral and anteroposterior directions. The cognitive task significantly increased trunk accelerations in both the mediolateral and anteroposterior directions. These differences could be due to the subjects feeling the need to keep their arms tight to their body and restrict trunk movement for stability to balance the ball.

Another study done by Cowling et al had subjects perform a jump landing task while catching a ball. They examined the differences between a jump landing when catching the ball and a jump landing without catching a ball, both of which were anticipated tasks. They found that there was a significant increase in trunk angle relative to the right-hand horizontal at initial contact and peak ground reaction force when subjects had to catch a ball.

B.4.5.2 Hip

Fedie et al had subjects run and perform an anticipated side-step cut to the left. During these trial they has three conditions: 1) Cut, subject ran forward and cut at a 45°
angle, 2) Pass, subject ran forward and after completing the cut a ball was passed to them by a researchers, and 3) Fake, subject ran forward and after completing the cut a ball was fake passed to them, i.e. the research did not throw the ball. Throughout their study they found a significant increase in hip abduction at initial contact when the athletes had to attend to a ball when compared to a normal side-step cut. They also found a significant increased average peak hip abduction when the athletes had to attend to a ball. Cowling et al found an increase in hip flexion angle at initial contact and peak ground reaction force when the subjects had to catch a ball during a jump landing task.

B.4.5.3 Knee

Fedie et al found an increase of 4° in peak knee flexion at initial contact when athletes had to attend to a ball when compared to a normal side-step cut without the ball. Cowling et al found no difference in knee joint angle when comparing jump landing tasks. A study done by Miyatsu et al compared subjects throwing a ball while performing a jump landing task to a normal jump landing task. They found that while throwing a ball subjects landed with less knee flexion which suggests a link between upper-limb motion and an increased potential for knee injury.

B.4.5.4 Summary

Dual-tasking changes trunk, hip, and knee kinematics throughout different activities such as walking, running, cutting, and jumping. These changes in kinematics can place the knee into a position that increases the risk for ACL injury.

B.4.6 Dual-tasking Kinetics
Dual-tasking changes trunk, hip, and knee moments and the overall ground reaction force produced throughout different activities such as walking, running, cutting, and jumping. These situations create realistic or game-like scenarios within the lab setting.

B.4.6.1 Hip

A study done by Vallabhanosula et al examined the ground reaction force produced while ascending stairs and doing either a cognitive task, counting backwards from 100, or manual task, carrying a box. They found that the peak hip extensor moment decreased while subjects performed a cognitive task and increased when subject performed a manual task. They also found a decrease in peak hip flexor moment during a cognitive task but no change during the manual task. These changes in hip moment can cause further moment changes around the knee which can place further strain on the ACL.

B.4.6.2 Knee

A study done by Chaudhari et al looked at anticipated side-step cuts while the subject had different sport-dependent arm positions: 1) run and cut with nothing in arms (baseline), 2) run and cut with football in opposite arm of plant foot (cut-side football), 3) run and cut with football in same arm as plant foot (plant-side football), and 4) run and cut while holding a lacrosse stick vertically in front of their body (lacrosse). They found a 60% increase in knee valgus moment during the lacrosse cut and a 29% increase in knee valgus moment during the plant-side football cut. Add to those results that Fedie et al found an increase of 23.5% in internal knee adduction peak joint moment when athletes had to attend to a ball when compared to a normal side-step cut.
suggest this occurs because there is a smaller medial component of the ground reaction force the orients the ground reaction force vector further from the knee joint when subjects are attending to a ball. These results added together indicate that sport-dependent arm position or attending to a ball can have a substantial influence on the types of loads that can cause a noncontact ACL injury.

**B.4.6.3 Ground Reaction Force**

Vallabhajosula et al found that peak vertical ground reaction force was decreased when the subjects had to perform the cognitive task but it was increased when subjects had to perform a manual task. They also found that this trend continued to increase or decrease the further subjects got up the stairs. This change could be due to them slowing down or getting fatigued as they continued. An increase in vertical ground reaction force increases the moments around the joint which can lead to an increase in ACL injury risk. A reduction in ground reaction force is an important factor in knee injury prevention.

**B.4.6.4 Summary**

Dual-tasking changes trunk, hip, and knee moments and the overall ground reaction force produced throughout different activities such as walking, running, cutting, and jumping. These changes in moments and ground reaction force can place the knee into a position that increases the risk for ACL injury.
Appendix C

Additional Methods

Executive Summary

University of Toledo

Project Title: Effects of Dual Tasking on Anticipated and Unanticipated Cutting Maneuvers on Knee Biomechanics in Collegiate Male Athletes

Project Supervisor: Charles Armstrong PhD

Research Team: Taylor Frendt, AT, ATC (Study Coordinator), Grant Norte, PhD, ATC, CSCS (Sub-Investigator), Thomas McLoughlin, PhD (Sub-Investigator), Luke Donovan, PhD, AT, ATC (Sub-Investigator)

Purpose

If there is an additive effect of unanticipated side-step cutting and an external event, kinematics and kinetics around the knee during actual game play may be greater than those measured in an experimental laboratory study. If this is the case biomechanical and neuromuscular factors can be modified for the athlete to be better prepared for these high demands on the knee and thus prevent ACL injury. Studies have been done comparing anticipated cuts and unanticipated cuts, and anticipated cuts or jump landings while catching a ball or not. A study has not yet been completed comparing joint angles, moments, and ground reaction force during anticipated and unanticipated side-step cuts with an external event, such as a ball being thrown, present. The purpose of this study is to examine and compare changes in the knee kinematics and kinetics during an
anticipated and unanticipated cut when a collegiate male athlete is focused on catching a ball.

**Subjects**

Healthy Males between ages of 18-30

Physically Active (Tegner scale at least 6)

**Inclusion Criteria**

- All Participants
  - 18-30 years old
  - Male
  - Tegner activity level of 6 or greater

**Exclusion Criteria**

- All Participants
  - History of lower extremity joint surgery
  - Lower extremity injury within past 6 weeks that still results in pain or dysfunction
  - Vestibular, balance, or connective tissue disorders

**Study Design**

Descriptive crossover laboratory study

**Independent Variables**

- Conditions
  1. Anticipated cut
  2. Unanticipated cut
  3. Ball throw
a. No ball throw
b. Ball throw
c. Fake ball throw

**Dependent Variables**

Kinematics (Degrees)

1. Trunk frontal plane kinematics
2. Trunk sagittal plane kinematics
3. Hip frontal plane kinematics
4. Hip sagittal plane kinematics
5. Knee frontal plane kinematics
6. Knee sagittal plane kinematics

Kinetics (Nm/kg)

1. Hip frontal plane moments
2. Hip sagittal plane moments
3. Knee frontal plane moments
4. Knee sagittal plane moments

Ground Reaction Force (N/kg)

1. Lateral
2. Vertical

1. Discrete variable analysis at a specific time point:
   a. Heel Strike
   b. Toe off

2. Curve analysis from heel strike to toe off (normalized to 100 frames)
**Procedures**

1. Obtained informed consent

2. Screening

3. Self-Reported Function Questionnaires
   a. Knee Injury and Osteoarthritis Outcome Score
   b. Tegner Activity Scale
   c. General Health History

4. Determination of cut type preference
   a. Side-Step Cut vs Crossover Cut

5. Practice cutting trials until participant feels comfortable with testing procedure.

6. Participant set-up
   a. Put on standardized shoes
   b. Place reflective markers

7. Static, Marching, and Walking Trials (2 of each)

8. 60 Successful Cutting Trials (5 of each condition)
   a. Successful trial: participant meeting the correct approach speed, foot coming in full contact with the force plate, and staying within the correct cutting pathway
   b. Failed trial: If the participant fails to stay within the correct approach speed, place their foot on the force plate, or perform the correct cut type (side-step vs crossover) that trial will be redone after all 60 original trials have been completed

**IRB Protocol**
Statistical Analysis

For the dependent variables trunk, hip, and knee frontal and sagittal kinematics and kinetics 90% confidence intervals (CIs) were calculated across all 100 points of the cut cycle. A time series CI analysis was performed across the entire cut cycle to determine any increments where the CIs did not overlap between the six groups (AL, UL, ALBN, ALBY, ULBN, ULBY). If CIs did not overlap for at least 3 consecutive time increments, those increments in the cut cycle were considered statistically significant.

Separate 1x3 ANOVAs will be used to identify differences in sagittal, transverse, and frontal plane kinematics and kinetics for the following comparisons:

1. Anticipated cut: no ball throw vs. ball throw vs. fake ball throw
2. Unanticipated cut: no ball throw vs. ball throw vs. fake ball throw

Separate Dependent t-tests will be used to identify differences in sagittal, transverse, and frontal plane kinematics and kinetics for the following comparisons:

3. Anticipated cut (no ball throw) vs. Unanticipated cut (no ball throw)
4. Anticipated cut (ball throw) vs. Unanticipated cut (ball throw)
5. Anticipated cut (fake ball throw) vs. Unanticipated cut (fake ball throw)
6. Anticipated cut (no ball throw) vs. Unanticipated cut (ball throw)
7. Anticipated cut (no ball throw) vs. Unanticipated cut (fake ball throw)

Research Hypothesis
1. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion in the ball throw and ball fake conditions when compared to the no ball throw conditions within the anticipated cut.

2. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion in the ball throw and ball fake conditions when compared to the no ball throw conditions within the unanticipated cut.

3. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated cut when compared to the anticipated cut during the no ball throw condition.

4. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated cut when compared to the anticipated cut during the ball throw condition.

5. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated cut when compared to the anticipated cut during the fake ball throw condition.

6. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated cut ball throw condition when compared to the anticipated cut during the no ball throw condition.

7. There will be an increase in peak knee valgus, internal rotation, lateral ground reaction forces, and a decrease in peak hip flexion during the unanticipated cut fake ball throw condition when compared to the anticipated cut during the no ball throw condition.
LOWER EXTREMITY BIOMECHANICS IN COLLEGIATE MALE ATHLETES

Principal Investigator: Charles Armstrong, PhD
Other Staff (identified by role): Taylor Frendt, ATC (student-investigator)
Contact Phone number(s): (419) 530-5369

What you should know about this research study:

- We give you this consent/authorization form so that you may read about the purpose, risks, and benefits of this research study. All information in this form will be communicated to you verbally by the research staff as well.

- Routine clinical care is based upon the best-known treatment and is provided with the main goal of helping the individual patient. The main goal of research studies is to gain knowledge that may help future patients.

- We cannot promise that this research will benefit you. Just like routine care, this research can have side effects that can be serious or minor.

- You have the right to refuse to take part in this research, or agree to take part now and change your mind later.

- If you decide to take part in this research or not, or if you decide to take part now but change your mind later, your decision will not affect your routine care.

- Please review this form carefully. Ask any questions before you make a decision about whether or not you want to take part in this research. If you decide to take part in this research, you may ask any additional questions at any time.

- Your participation in this research is voluntary.

PURPOSE (WHY THIS RESEARCH IS BEING DONE)

You are being asked to take part in a research study of examining how your legs move during the common athletic task of running forward and changing directions to either your right or left, this is known as cutting, and then catching a ball. The purpose of the study is to examine the difference in how your legs move during a cut in which you know which way you are going to cut before you start running, known as an anticipated cut, to a cut in which you do not know which way you will cut until after you start running, known as an unanticipated cut, while focusing on catching a ball.
You were selected as someone who may want to take part in this study because you are a physically active college male participating in a cutting sport at least one time per week (football, soccer, basketball, rugby, lacrosse, etc.). This research study will be conducted in the Musculoskeletal Health and Movement Sciences Laboratory at the University of Toledo Main Campus. We will be enrolling 40 subjects between the ages of 18-30 years.

**DESCRIPTION OF THE RESEARCH PROCEDURES AND DURATION OF YOUR INVOLVEMENT**

If you decide to take part in this study, you will be asked to report to the Musculoskeletal Health and Movement Sciences Laboratory at the University of Toledo on a single occasion. You will perform a side-step cutting task, similar to what you would do if you were playing basketball. We will record your leg movement while you perform these tasks both in an anticipated and unanticipated manner. This entire testing session will take approximately 2 hours.

**Eligibility Screening**

Before you can officially enroll in this study, you will be asked a series of questions to determine your eligibility. These questions are similar to ones you would be asked in a health history screening at your doctor’s office. You will also have your height and weight measured as you would at your doctor’s office.

**Subject Set-Up**

Once all forms are completed, the researcher will explain and demonstrate the testing procedure. Then you will familiarize yourself with the cutting procedure by doing at least three practice trials in each direction until you feel comfortable. After you are familiarized, reflective markers will be placed on your legs, hips, and shoulders using elastic tape. You will be given tennis shoes to wear.

**Warm-Up**

You will be allowed up to 10 minutes to warm up your muscles by walking on a treadmill.

**Cutting Task**

For the side-step cutting task, you will take approximately a four-step approach, strike a target on the floor with the appropriate limb, cut at a 45° angle, and potentially catch a ball. You will be asked to perform up to 5 trials of this task for each limb and in two conditions, anticipated and unanticipated. For unanticipated, the direction of your cut will be presented to you one step prior to your foot striking the target on the floor. For the anticipated task, the direction of your cut will be presented before your four-step approach. You will be offered as much rest as you need between trials. This task will take approximately 90 minutes to perform. The order of these running conditions will be randomized via concealed envelope. These running conditions are:

1. Anticipated cut to the right
2. Anticipated cut to the left
3. Unanticipated cut to the right
4. Unanticipated cut to the left
5. Anticipated cut to the right with unanticipated ball toss (ball not tossed)
6. Anticipated cut to the left with unanticipated ball toss (ball not tossed)
7. Unanticipated cut to the right with unanticipated ball toss (ball not tossed)
8. Unanticipated cut to the left with unanticipated ball toss (ball not tossed)
9. Anticipated cut to the right with unanticipated ball toss (ball tossed)
10. Anticipated cut to the left with unanticipated ball toss (ball tossed)
11. Unanticipated cut to the right with unanticipated ball toss (ball tossed)
12. Unanticipated cut to the left with unanticipated ball toss (ball tossed)

SURVEYS
You will be asked to complete three brief surveys to provide the researchers with information regarding your general health history, how well your knee is functioning, and in what types of activities you are currently able to participate. These will take approximately 10 minutes to complete.

RISKS AND DISCOMFORTS YOU MAY EXPERIENCE IF YOU TAKE PART IN THIS RESEARCH

Likely Risks
• Muscle soreness or knee discomfort. You will be given adequate warm-up and offered ice bags after participation to reduce the risk of soreness and discomfort.

Unlikely Risks
• Injury to your knee. This risk is unlikely if you have been cleared for full activity.
• Skin irritation due to athletic tape coming in direct contact with the skin.
• Breach in confidentiality. This risk is unlikely as the following safeguards have been put in place.
  All study-related forms will be kept in a locked filing cabinet in the Musculoskeletal Health and Movement Sciences (MHMS) laboratory. Only members of the investigative staff will have access to the filing cabinet. Within the data files, there will be nothing to identify the subject to the information. All forms will be coded by assigning each subject an ID number.

There are no known risks to unborn children at this point. There may be risks that the researchers are unaware of at this time.

POSSIBLE BENEFIT TO YOU IF YOU DECIDE TO TAKE PART IN THIS RESEARCH
There are no direct benefits to you for participating in this research study. This study is designed for the investigators to learn more about biomechanics in an adolescent population during anticipated and unanticipated sport specific tasks.

COST TO YOU FOR TAKING PART IN THIS STUDY
You will be asked to pay for all costs associated with travel to and from the University of Toledo’s main campus as a result of participating in this study.

PAYMENT OR OTHER COMPENSATION TO YOU FOR TAKING PART IN THIS RESEARCH
If you decide to take part in this research you will not receive any financial compensation for participating.

ALTERNATIVE(S) TO TAKING PART IN THIS RESEARCH
The only alternative to taking part in this research is not to participate. Your care through the University of Toledo Medical Center will not be affected should you decline participation.

CONFIDENTIALITY – (USE AND DISCLOSURE OF YOUR PROTECTED HEALTH INFORMATION)
By agreeing to take part in this research study, you give to The University of Toledo (UT), the Principal Investigator and all personnel associated with this research study your permission to use or disclose health information that can be identified with you that we obtain in connection with this study. We will use this information for the purpose of conducting the research study as described in the research consent/authorization form.

Under some circumstances, the Institutional Review Board, or the Research and Sponsored Programs of the University of Toledo may review your information for compliance audits. If you receive any payments for taking part in this study, your personal information and limited information about this study will be
given to The University of Toledo’s accounts payable department as necessary to process payment to you. We may also disclose your protected health information when required by law, such as in response to judicial orders.

The University of Toledo is required by law to protect the privacy of your health information, and to use or disclose the information we obtain about you in connection with this research study only as authorized by you in this form. There is a possibility that the information we disclose may be re-disclosed by the persons we give it to, and no longer protected. However, we will encourage any person who receives your information from us to continue to protect and not re-disclose the information.

Your permission for us to use or disclose your protected health information as described in this section is voluntary. However, you will not be allowed to participate in the research study unless you give us your permission to use or disclose your protected health information by signing this document.

You have the right to revoke (cancel) the permission you have given to us to use or disclose your protected health information at any time by giving written notice to:

Charles Armstrong, PhD at 419-530-5369

However, a cancellation will not apply if we have acted with your permission, for example, information that already has been used or disclosed prior to the cancellation. Also, a cancellation will not prevent us from continuing to use and disclose information that was obtained prior to the cancellation as necessary to maintain the integrity of the research study.

Except as noted in the above paragraph, your permission for us to use and disclose your protected health information will stop at the end of the research study.

A more complete statement of University of Toledo’s Privacy Practices is set forth in its Joint Notice of Privacy Practices. If you have not already received this Notice, a member of the research team will provide this to you. If you have any further questions concerning privacy, you may contact the University of Toledo’s Privacy Officer at 419-383-6933.

IN THE EVENT OF A RESEARCH-RELATED INJURY
In the event of injury resulting from your taking part in this study, treatment can be obtained at a health care facility of your choice. You should understand that the costs of such treatment will be your responsibility. Financial compensation is not available through The University of Toledo or The University of Toledo Medical Center. By signing this form you are not giving up any of your legal rights as a research subject. In the event of an injury, contact:

Charles Armstrong, PhD at 419-530-5369

VOLUNTARY PARTICIPATION
Taking part in this study is voluntary. You may refuse to participate or discontinue participation at any time without penalty or a loss of benefits to which you are otherwise entitled. If you decide not to participate or to discontinue participation, your decision will not affect your future relations with the University of Toledo or The University of Toledo Medical Center.

NEW FINDINGS
You will be notified of new information that might change your decision to be in this study if any becomes available.
OFFER TO ANSWER QUESTIONS
Before you sign this form, please ask any questions on any aspect of this study that is unclear to you. You may take as much time as necessary to think it over. If you have questions regarding the research at any time before, during or after the study, you may contact:

Charles Armstrong, PhD at 419-530-5369

If you have questions beyond those answered by the research team or your rights as a research subject or research-related injuries, please feel free to contact the Chairperson of the University of Toledo Biomedical Institutional Review Board at 419-383-6796.

SIGNATURE SECTION (Please read carefully)

YOU ARE MAKING A DECISION WHETHER OR NOT TO PARTICIPATE IN THIS RESEARCH STUDY. YOUR SIGNATURE INDICATES THAT YOU HAVE READ THE INFORMATION PROVIDED ABOVE, YOU HAVE HAD ALL YOUR QUESTIONS ANSWERED, AND YOU HAVE DECIDED TO TAKE PART IN THIS RESEARCH.

BY SIGNING THIS DOCUMENT YOU AUTHORIZE US TO USE OR DISCLOSE YOUR PROTECTED HEALTH INFORMATION AS DESCRIBED IN THIS FORM.

The date you sign this document to enroll in this study, that is, today’s date, MUST fall between the dates indicated on the approval stamp affixed to the bottom of each page. These dates indicate that this form is valid when you enroll in the study but do not reflect how long you may participate in the study. Each page of this Consent/Authorization Form is stamped to indicate the form’s validity as approved by the UT Biomedical Institutional Review Board (IRB).

<table>
<thead>
<tr>
<th>Name of Subject (please print)</th>
<th>Signature of Subject or Person Authorized to Consent</th>
<th>Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Relationship to the Subject (Healthcare Power of Attorney authority or Legal Guardian)</td>
<td></td>
<td>a.m.</td>
</tr>
<tr>
<td>Time</td>
<td>p.m.</td>
<td></td>
</tr>
<tr>
<td>Name of Person Obtaining Consent (please print)</td>
<td>Signature of Person Obtaining Consent</td>
<td>Date</td>
</tr>
<tr>
<td>Name of Witness to Consent Process (when required by ICH Guidelines) (please print)</td>
<td>Signature of Witness to Consent Process (when required by ICH Guidelines)</td>
<td>Date</td>
</tr>
</tbody>
</table>

YOU WILL BE GIVEN A SIGNED COPY OF THIS FORM TO KEEP.
KOOS KNEE SURVEY

Today's date: _____/_____/_____. Date of birth: _____/_____/_____.

Name: ________________________________________________

INSTRUCTIONS: This survey asks for your view about your knee. This information will help us keep track of how you feel about your knee and how well you are able to perform your usual activities. Answer every question by ticking the appropriate box, only one box for each question. If you are unsure about how to answer a question, please give the best answer you can.

Symptoms
These questions should be answered thinking of your knee symptoms during the last week.

S1. Do you have swelling in your knee?
   □ Never  □ Rarely  □ Sometimes  □ Often  □ Always

S2. Do you feel grinding, hear clicking or any other type of noise when your knee moves?
   □ Never  □ Rarely  □ Sometimes  □ Often  □ Always

S3. Does your knee catch or hang up when moving?
   □ Always  □ Often  □ Sometimes  □ Rarely  □ Never

S4. Can you straighten your knee fully?
   □ Always  □ Often  □ Sometimes  □ Rarely  □ Never

S5. Can you bend your knee fully?
   □ Always  □ Often  □ Sometimes  □ Rarely  □ Never

Stiffness
The following questions concern the amount of joint stiffness you have experienced during the last week in your knee. Stiffness is a sensation of restriction or slowness in the ease with which you move your knee joint.

S6. How severe is your knee joint stiffness after first wakening in the morning?
   □ None  □ Mild  □ Moderate  □ Severe  □ Extreme

S7. How severe is your knee stiffness after sitting, lying or resting later in the day?
   □ None  □ Mild  □ Moderate  □ Severe  □ Extreme
Pain
P1. How often do you experience knee pain?

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Monthly</th>
<th>Weekly</th>
<th>Daily</th>
<th>Always</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What amount of knee pain have you experienced the last week during the following activities?

P2. Twisting/pivoting on your knee

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P3. Straightening knee fully

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P4. Bending knee fully

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P5. Walking on flat surface

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P6. Going up or down stairs

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P7. At night while in bed

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P8. Sitting or lying

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

P9. Standing upright

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Function, daily living**

The following questions concern your physical function. By this we mean your ability to move around and to look after yourself. For each of the following activities please indicate the degree of difficulty you have experienced in the last week due to your knee.

A1. Descending stairs

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A2. Ascending stairs

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For each of the following activities please indicate the degree of difficulty you have experienced in the last week due to your knee.

<table>
<thead>
<tr>
<th>Activity</th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td>A3. Rising from sitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A4. Standing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A5. Bending to floor/pick up an object</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A6. Walking on flat surface</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A7. Getting in/out of car</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A8. Going shopping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A9. Putting on socks/stockings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A10. Rising from bed</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A11. Taking off socks/stockings</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A12. Lying in bed (turning over, maintaining knee position)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A13. Getting in/out of bath</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A14. Sitting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A15. Getting on/off toilet</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
For each of the following activities please indicate the degree of difficulty you have experienced in the last week due to your knee.

A16. Heavy domestic duties (moving heavy boxes, scrubbing floors, etc)

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A17. Light domestic duties (cooking, dusting, etc)

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Function, sports and recreational activities**
The following questions concern your physical function when being active on a higher level. The questions should be answered thinking of what degree of difficulty you have experienced during the last week due to your knee.

SP1. Squatting

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SP2. Running

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SP3. Jumping

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SP4. Twisting/pivoting on your injured knee

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

SP5. Kneeling

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Quality of Life**

Q1. How often are you aware of your knee problem?

<table>
<thead>
<tr>
<th></th>
<th>Never</th>
<th>Monthly</th>
<th>Weekly</th>
<th>Daily</th>
<th>Constantly</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q2. Have you modified your lifestyle to avoid potentially damaging activities to your knee?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
<th>Totally</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q3. How much are you troubled with lack of confidence in your knee?

<table>
<thead>
<tr>
<th></th>
<th>Not at all</th>
<th>Mildly</th>
<th>Moderately</th>
<th>Severely</th>
<th>Extremely</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Q4. In general, how much difficulty do you have with your knee?

<table>
<thead>
<tr>
<th></th>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
<th>Extreme</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Thank you very much for completing all the questions in this questionnaire.*
**TEGNER ACTIVITY LEVEL SCALE**

Please indicate in the spaces below the HIGHEST level of activity that you participated in BEFORE YOUR INJURY and the highest level you are able to participate in CURRENTLY.

<table>
<thead>
<tr>
<th>Level</th>
<th>Activity Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 10</td>
<td>Competitive sports- soccer, football, rugby (national elite)</td>
</tr>
<tr>
<td>Level 9</td>
<td>Competitive sports- soccer, football, rugby (lower divisions), ice hockey,</td>
</tr>
<tr>
<td></td>
<td>wrestling, gymnastics, basketball</td>
</tr>
<tr>
<td>Level 8</td>
<td>Competitive sports- racquetball or bandy, squash or badminton, track and field</td>
</tr>
<tr>
<td></td>
<td>athletics (jumping, etc.), down-hill skiing</td>
</tr>
<tr>
<td>Level 7</td>
<td>Competitive sports- tennis, running, motorcars speedway, handball</td>
</tr>
<tr>
<td></td>
<td>Recreational sports- soccer, football, rugby, bandy, ice hockey, basketball,</td>
</tr>
<tr>
<td></td>
<td>squash, racquetball, running</td>
</tr>
<tr>
<td>Level 6</td>
<td>Recreational sports- tennis and badminton, handball, racquetball, down-hill</td>
</tr>
<tr>
<td></td>
<td>skiing, jogging at least 5 times per week</td>
</tr>
<tr>
<td>Level 5</td>
<td>Work- heavy labor (construction, etc.)</td>
</tr>
<tr>
<td></td>
<td>Competitive sports- cycling, cross-country skiing</td>
</tr>
<tr>
<td></td>
<td>Recreational sports- jogging on uneven ground at least twice weekly</td>
</tr>
<tr>
<td>Level 4</td>
<td>Work- moderately heavy labor (e.g. truck driving, etc.)</td>
</tr>
<tr>
<td>Level 3</td>
<td>Work- light labor (nursing, etc.)</td>
</tr>
<tr>
<td>Level 2</td>
<td>Work- light labor</td>
</tr>
<tr>
<td></td>
<td>Walking on uneven ground possible, but impossible to back pack or hike</td>
</tr>
<tr>
<td>Level 1</td>
<td>Work- sedentary (secretarial, etc.)</td>
</tr>
<tr>
<td>Level 0</td>
<td>Sick leave or disability pension because of knee problems</td>
</tr>
</tbody>
</table>


**SURGICAL HISTORY**

Have you had any additional surgeries to your knee other than those performed by Dr. Stone?

Yes / No

If Yes:

What procedure(s) were performed?

When was the surgery performed?

Who performed the surgery?
<table>
<thead>
<tr>
<th>Height</th>
<th>Weight</th>
<th>Sex</th>
<th>Age</th>
<th>Date of Birth</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Please check below if you have had any of the following and explain checked items on line.

**General Medical**
- □ Allergies/Sensitivities (latex, cold, medications, etc.)
- □ Asthma
- □ Cancer
- □ Biomedical devices (implants, pacemaker, etc.)
- □ Diabetes
- □ Pregnant or nursing
- □ Recent illness (cold, flu, infection, etc.)
- □ Surgery
- □ Other: 

  Please Explain:

**Neurological**
- □ Epilepsy/Seizures
- □ Anxiety disorder
- □ ADHD
- □ Diabetic neuropathy
- □ Multiple Sclerosis
- □ Parkinson disease
- □ Cerebral Palsy
- □ Vertigo
- □ Balance disorder
- □ Concussion or Traumatic brain injury
- □ Other: 

  Please Explain:

**Cardiovascular**
- □ High blood pressure
- □ Shortness of breath
- □ Heart attack
- □ Heart disease
- □ Stroke
- □ Heart murmur
- □ Thrombosis or Embolism
- □ Marfan’s Syndrome
- □ Sickle cell trait
- □ Cardiac Arrhythmia (irregular heart beat)
- □ Other: 

  Please Explain:

**General Orthopaedic**
- □ Surgery
- □ Previous fracture
- □ Sprains or Strains (ligament/muscle/tendon)
- □ Osteoarthritis
- □ Rheumatoid arthritis
- □ Assistive devices (crutches, braces, etc.)
- □ Gout
- □ Osteoporosis/Osteopenia
- □ Other: 

  Please Explain:

**Other**
- ✤ Have you taken any prescription or over-the-counter medications within the last 24-hours?
  - □ YES □ NO  **If yes, please list:** 

    ____________________________________________

- ✤ Have you consumed any of the following stimulants or depressants in the last 12-hours?
  - □ Caffeine □ Alcohol □ Tobacco

    **If yes, please explain:** 

    ____________________________________________

- ✤ Do you exercise regularly? □ YES □ NO

    **If yes, what type and for how long?** 

    ____________________________________________

- ✤ Are you currently experiencing physical pain? □ YES □ NO

    **If yes, please indicate location, severity, and currently treatments for you pain:** 

    ____________________________________________
The University of Toledo Kinesiology Department
Study: The Effect of Dual Tasking on Anticipated and Unanticipated Cutting Maneuvers on Knee Biomechanics in College Male Athletes

Subject General History Form

Subject ID Number: ________
Age: ________
Gender: Male  Female
Height: ________ (inches)
Weight: ________ (lbs)
Dominant Leg (limb you kick a ball):  Right  Left

Previous Injuries/illnesses and description:


Current Physical Activity per week description:


INCLUSION CRITERIA

Yes  No
☐ ☐  Age of 18 – 30 years
☐ ☐  Male
☐ ☐  Physically active in cutting sport at least 1 time per week (Tegner score of 6)

EXCLUSION CRITERIA

Yes  No
☐ ☐  Lower extremity joint injury within past 6 weeks that still results in pain or dysfunction
☐ ☐  Lower extremity joint surgery
☐ ☐  Vestibular, balance, or connective tissue disorders.

Cut Type Preference: ________________________________

Assigned Version Date: 08/15/2016

APPROVED BY UNIVERSITY OF TOLEDO IRB
<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Cut Type</th>
<th>Speed</th>
<th>Force Plate</th>
<th>Cut Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>LABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>LUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>LU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>RUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>RUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>RABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>LUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>LABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>RU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>RABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>LABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>LUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>LU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>RUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>RUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>RABN</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check Marker Set:

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Cut Type</th>
<th>Speed</th>
<th>Force Plate</th>
<th>Cut Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>LUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>LABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>23</td>
<td>RU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>24</td>
<td>RABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>25</td>
<td>RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>26</td>
<td>LABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>27</td>
<td>LUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td>LU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>29</td>
<td>RUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td>RUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Check Fatigue:

Check Marker Set:

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Cut Type</th>
<th>Speed</th>
<th>Force Plate</th>
<th>Cut Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>32</td>
<td>RABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>LUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>LABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>35</td>
<td>RU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>36</td>
<td>RABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>37</td>
<td>RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>38</td>
<td>LABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>39</td>
<td>LUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>----</td>
<td>-----</td>
<td>--------------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>LU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>41</td>
<td>RUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>RUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>RABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>45</td>
<td>LUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>46</td>
<td>LABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>47</td>
<td>RU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>RABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>RA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>LABY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>51</td>
<td>LUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>52</td>
<td>LU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>53</td>
<td>RUBN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>54</td>
<td>RUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>55</td>
<td>LA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>RABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>57</td>
<td>LUBY</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>58</td>
<td>LABN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>59</td>
<td>RU</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>60</td>
<td>RABY</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Check Marker Set:**

**Check Fatigue:**

**Check Trial Order:**

REDO?
Specific Testing Protocol

**Cortex Hardware and Software Set-up**

1. Turn on cameras (located to the right of the computer)

2. Open Cortex 5.5.1
   a. Open File “IRB #201477” and “Set as working folder”

3. All lights on force plate should be off (use calibration square for calibration)
   a. To change collection sample rate- Change Multiple of Frame Rate
      i. Cameras collect 200 Frames/sec
   b. Save calibration
   c. Click “All on” and “Connect to cameras”

4. Calibration of the cameras
a. Do “Update calibration”  
   i. Every once in a while do “Floor calibration”  
   ii. At the beginning of every day of data collection click calibrate for cameras  
   iii. Click “ok to overwrite” and collect for 2 minutes with calibration wand  
   iv. Check volume  
   v. When calibrating go through all cameras and mask any reflections  

b. Click center wheel and drag. Then right click to delete.  
   i. 3D Residual: Average approximately 0.5 and deviation approximately one half of average  

5. Calibration of force plate  
   a. Calibration square goes around force plate 1 (back corner – closest to door and computer  

Floor Set-Up  

1. Measure 6m from the center of the force plate (towards the entrance door to the lab)  
   a. Mark the 6m mark with tape so the participants know where to start
2. Mark two 45° angles from the corners of the force plate with tape so the participants know the angle to cut during the trials

3. The first gate will be placed approximately 1 stride length from the force plate toward the start line to trigger the light for unanticipated cutting task

   a. For anticipated task, light will be on before the start of the trial

4. The other two gates will be placed approximately 1.5m from the corners of the force plate at a 45° angle, where the subjects will be able to run through the gate in the given direction

   a. Tape will be used to mark the legs of the tripod as to repeat the exact position for the next data collection day
5. Tilt the television on the wall to the direction the participants will start
   a. A countdown clock will be visible so the participant knows when to begin each trial
6. Trial order will be randomized by a third party
7. The speed to be maintained is 3.5-5.5m/s

**Cortex Data Collection Procedures (General Set-up)**

1. Marker Placement
   a. Double sided tape was pre-applied to the markers prior to participant arrival
   b. All areas were shaved if needed
   c. 42 reflective markers placed on participant:
      1. Right acromioclavicular joint
      2. Left acromioclavicular joint
      3. Sternal notch
      4. C7 vertebrae
      5. Inferior angle of right scapula
      6. Right PSIS
      7. Left PSIS
      8. Sacrum
      9. Right iliac crest
     10. Left iliac crest
     11. Right greater trochanter
     12. Left greater trochanter
     13. Right lateral quad cluster (4 markers)
     14. Left lateral quad cluster (4 markers)
     15. Right lateral femoral condyle
     16. Left lateral femoral condyle
     17. Right medial femoral condyle (Only for static trial, removed for rest of trials)
18. Left medial femoral condyle (Only for static trial, removed for rest of trials)
19. Right lateral shin cluster (4 markers)
20. Left lateral shin cluster (4 markers)
21. Right lateral malleolus
22. Left lateral malleolus
23. Right medial malleolus (Only for static trial, removed for rest of trials)
24. Left medial malleolus (Only for static trial, removed for rest of trials)
25. Right calcaneus
26. Left calcaneus
27. Right base of 5th metatarsal
28. Left base of 5th metatarsal
29. Right 2nd metatarsal head
30. Left 2nd metatarsal head

2. To bring up saved marker sets click on Marker Sets “Add/remove”
   a. Check the box next to “Frendt Static” and “Frendt Dynamic”
   b. Markers will then be on the right of the screen
3. Static & Dynamic trials completed to build marker templates
a. Two static trials: They hold still with arms crossed on the force plate with all 42 reflective markers on for 5 seconds.

b. Two marching trials: Medial femoral condyle and medial malleoli markers will then be removed. They will cross their arms across their chest and the trial will begin to record for 5 seconds, at the three second mark they march in place.

c. Two walking trials: Participant will walk with arms down at their side so that one foot steps onto the force plate. They will complete two steps before and after stepping on the force plate.

4. Switch to “Post Process” mode and select a marching trial. Use Quick ID to identify each marker to their landmarks.

a. Once completed turn markers on by clicking top of column, then click “Rectify”, “Linear join”, “Smooth”, and “Delete unnamed”
b. Check marker visibility by clicking “Tools” then “Timelines”

c. Once timeline looks good click “Create Template” and save it - This template will allow the marker set to be recognized during future trials with that participant.

d. Go to File and click “Save Marker Set Frendt Dynamic” before beginning

**Timing Gate Set-up**
1. Log on to laptop and connect to “Linksys 2504” internet
2. Open “timing Program 1”
3. Change the distance to gate 1 from start to 0.9144m, and the distance between gate 1 and gate 2 to 6.99m.

a. The researcher can input the randomized order of the trials before each participant begins

- Right & Left
- Light on at start of countdown = anticipated
- Light on after first gate = unanticipated

b. The participant will complete a total of 60 trials

- 5 Anticipated cut to the right
- 5 Anticipated cut to the left
- 5 Unanticipated cut to the right
- 5 Unanticipated cut to the left
- 5 Anticipated cut to the right, ball fake
- 5 Anticipated cut to the left, ball fake
- 5 Unanticipated cut to the right, ball fake
- 5 Unanticipated cut to the left, ball fake
- 5 Anticipated cut to the right, ball throw
- 5 Anticipated cut to the left, ball throw
- 5 Unanticipated cut to the right, ball throw
- 5 Unanticipated cut to the left, ball throw

c. Participants will be asked for their cut type preference during an athletic activity as this will be the type of cut they have to perform throughout the duration of testing.
- Side-Step: When going to the left their right foot will be on the force plate and when going to the right their left foot will be on the force plate.

- Crossover: When going to the left their left foot will be on the force plate and when going to the right their right foot will be on the force plate

**Anticipated Cutting Procedure**
1. The participants will have as many practice trials as needed
2. The participants will begin at the start marked 6m from the force plate
3. Once the countdown begins a light on either gate will turn green to indicate which way the participant is to cut.
4. Once the countdown hits 0 the participant will run through the first gate, step on the force plate, and cut through the indicated second gate.
5. After completion of the trial the clock will count down 30 seconds before the start of the next trial

**Unanticipated Cutting Procedure**
1. The participants will begin at the start marked 6m from the force plate
2. Once the countdown hits 0 and the participant runs through the first gate, a light on either gate will turn green to indicate which way the participant is to cut.

3. The participant will step on the force plate, and cut through the indicated second gate.
4. After completion of the trial the clock will count down 30 seconds before the start of the next trial

**Ball Toss Procedure**

1. The researcher will be standing behind and between the middle tripods holding the ball in front of them.

   a. This shows the participant that the ball may or may not be thrown to them during that trial
2. Participants will perform the designated anticipated or unanticipated cut and as they are about to come in contact with the force plate the ball may or may not be passed to their chest.

   a. Even if the researcher is not going to throw the ball they will still step forward as if they are going to throw the ball.

3. If there is no ball throw or fake ball throw the researcher will hold the ball behind their back so that the participant knows they do not have to pay attention to the ball.

**Data Reduction Procedures**

1. Open the folder you wish to work out of and click “Set as Working Folder”
2. Click on “Post Process” in upper left corner, and select the capture you wish to edit in the upper right corner

3. Advance capture so that all markers are present, turn markers on and “MakeUnnamed”
4. Quick ID, Rectify, Linear Join, Smooth, Delete Unnamed, Check Timeline

5. Select frames along bottom where you wish to cut them, check the timeline, if all looks good click “Cut Outside” at top of screen

6. Right click on the marker set that is not being used by that trial and remove it
7. File, Save Capture, name and hit save
8. File, Export, C3D file
Data Analysis Procedures

1. Open Visual 3D v6 x64
2. Open workspace: File, Open/Add, Frendt_PROCESSED.cmo
3. Open participant static trial: Model, Create (Add Static Calibration File), Hybrid Model from C3DFile, Select participant static trial
4. First participant files: must build model and save model template using following parameters:

<table>
<thead>
<tr>
<th>Thorax/Ab</th>
<th>Proximal</th>
<th>RPSIS</th>
<th>LPSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distal</td>
<td>RAC</td>
<td>LAC</td>
</tr>
<tr>
<td></td>
<td>Depth</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Extra Markers</td>
<td></td>
<td>C7, LAC, RAC, LPSIS, RPSIS</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Pelvis</th>
<th>Proximal</th>
<th>RPSIS</th>
<th>LPSIS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distal</td>
<td>RGT</td>
<td>LGT</td>
</tr>
<tr>
<td></td>
<td>Depth</td>
<td>0.014</td>
<td></td>
</tr>
<tr>
<td>Extra Markers</td>
<td></td>
<td>LASIS, LGT, RGT, RASIS, Sacrum</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left Thigh</th>
<th>Proximal</th>
<th>LLFC</th>
<th>LMFC</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distal</td>
<td>LLM</td>
<td>LMM</td>
</tr>
<tr>
<td>Extra Markers</td>
<td></td>
<td>LTC1, LTC2, LTC3, LTC4</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Left Shank</th>
<th>Proximal</th>
<th>LLM</th>
<th>LMM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extra Markers</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Distal     L5M     L2RAY
Extra Markers: LCAL, L2RAY, L5M

Right Thigh
Proximal    RGT
Distal      RLFC    RMFC
Radius      .089
Extra Markers: RTC1, RTC2, RTC3, RTC4

Right Shank
Proximal    RLFC    RMFC
Distal      RLM     RMM
Extra Markers: RSC1, RSC2, RSC3, RSC4

Right Foot
Proximal    RLM     RMM
Distal      R5M     R2RAY
Extra Markers: RCAL, R5M, R2RAY

5. All following participant files: Model, Apply Model Template, FrendtModel.mdh
   a. Change participant mass and height on Subject Data Metrics tab, build model
6. Return to workspace: File, Open/add, Insert New Files into your currently open workspace, select the participant files you wish to add into your workspace
7. Model, Assign Model to Motion Files, Select Model, Select trials for model to be assigned to
8. Label participant trials into appropriate file tags (LA, LABN, LABY, LU, LUBN, LUBY).
Appendix D

Additional Results

Figure 1. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw and unanticipated no ball throw.

Figure 2. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated ball fake and unanticipated ball fake.
Figure 3. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated ball throw and unanticipated ball throw

Figure 4. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw, anticipated ball fake, anticipated ball throw
Figure 5. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between unanticipated no ball throw, unanticipated ball fake, unanticipated ball throw

Figure 6. Tri-planar kinematic comparisons across the ankle, knee, hip, and trunk between anticipated no ball throw, unanticipated ball fake, unanticipated ball throw
Figure 7. Percent of Dominant Leg Failed Trials

Figure 8. Percent of Non-Dominant Leg Failed Trials
Figure 9. Percent of Failed Trials Over 5 Rounds

![Bar chart showing the percent of failed trials over 5 rounds.]

Figure 10. Average Speed Per Cutting Condition

![Bar chart showing average speed per cutting condition.]

- Anticipated Mean: 4.63 m/s
- Unanticipated Mean: 4.94 m/s

Range: 3.9 – 5.6 m/s
Appendix E

Back Matter

Recommendations for Future Research:

1. Look at the failed trials that occur during testing
2. Look at the effect fatigue has on anticipation, dual-tasking, and the combination of anticipation and dual tasking
3. Look at the incorporation of dual-tasking into current injury prevention programs

NATA Conference Abstract:

Effects of Dual Tasking on Anticipated and Unanticipated Cutting Manuevers on Knee Biomechanics in Collegiate Male Athletes
Frendt TR, Norte G: University of Toledo

Context: An athlete is required to adapt to different situations throughout participation such as not knowing which direction they will be running, judging the actions of their opponents, catching or throwing a ball, and listening to the people around them. Prior research has shown that anticipation (knowing which way to go) and dual tasking (catching a ball or avoiding a defender) cause changes in biomechanics that could open the athlete up to injury. If the athlete has to focus on both anticipation and dual tasking, known as the additive effect, will those changes when become greater. **Objective:** We investigated the effects of anticipation and dual tasking on trunk and lower extremity kinematics during a side step cutting maneuver **Design:** Descriptive crossover laboratory study **Participants:** 32 healthy males between the ages of 18-30 (23.12 ± 3.62 yo) scoring at least a 6 on the Tegner activity scale (6.75 ± 1.04) with no history of lower extremity injury or surgery. Average weight: 81.29 ± 17.26 kg; Average height: 180.02 ±6.97 cm. **Interventions:** Our independent variables were the two conditions of anticipation (anticipated/unanticipated side step cut) and dual tasking (no ball throw, ball fake, ball throw). Ankle, knee, hip, and trunk kinematics were collected using Motion capture software and 12 eagle cameras. During an anticipated cut a light would be on before the participant ran to show them which direction to go. During an unanticipated cut a light would turn on one step before they made the cut to show them which direction they would go. During the no ball throw condition the ball thrower will hold the ball behind their back showing the participant they do not need to focus on the ball. During the ball fake or ball throw conditions the ball thrower holds the ball in front of them showing the participant that they need to pay attention to the ball. The ball was either faked or thrown to the participant one step before making the cut. Comparisons were done at initial contact, peak knee flexion, and toe off within
anticipation (anticipated vs unanticipated) using a paired t-test and within dual tasking (no ball throw, ball fake, ball throw) using a one way ANOVA with a Bonferroni post hoc. Results were deemed significant if they had a p-value <0.05 and a moderate or large Cohen’s d effect size. Kinematics were also analyzed using a curve analysis with 95% confidence intervals across the stance phase. Results were deemed significant if the confidence intervals did not overlap for 3 consecutive points. **Main Outcome Measures:** No changes in kinematics at the ankle, knee, and hip at all time points. At peak knee flexion and toe off there was a decrease in trunk lateral flexion when the ball was involved as compared to when it was not. **Results:** Our results did not indicate there was a significant effect of anticipation on a task. However, when the ball was either faked or thrown regardless of anticipation there was a decrease in lateral trunk flexion towards the stance leg at peak knee flexion and toe off. There was also an increase in trunk rotation at initial contact, peak knee flexion, and toe off when the ball was thrown. **Conclusions:** Overall, anticipation or dual tasking did not affect lower extremity kinematics. Having the involvement of the ball (fake or throw) caused an decrease in trunk lateral flexion towards the stance leg and when the ball was thrown there was an increase in trunk rotation towards the stance leg.

Word Count: 586 (Needs to be at 450)
Appendix F

Bibliography


