THE RELATIONSHIP BETWEEN PERSONALITY, KNEE BRACES, AND STIFFNESS REGULATION AFTER ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION

by

Kelly E. McGuire

A thesis submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Master of Science in Exercise Science

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by

Kelly E. McGuire

Approved: ____________________________________________
Charles B. Swanik, Ph.D.
Professor in charge of thesis on behalf of the Advisory Committee

Approved: ____________________________________________
William B. Farquhar, Ph.D.
Chair of the Department of Kinesiology and Applied Physiology

Approved: ____________________________________________
Kathleen S. Matt, Ph.D.
Dean of the College of Health Sciences

Approved: ____________________________________________
James G. Richards, Ph.D.
Vice Provost for Graduate and Professional Education
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ABSTRACT

Context: After anterior cruciate ligament (ACL) reconstruction, the outcomes may vary widely with some returning to full function and participation while others cannot regardless of the existing mechanical stability. Certain personality constructs like sensation seeking, mental toughness, and kinesiophobia, may interact with joint stiffness regulation and the use of knee braces to affect one’s rehabilitation, functional outcome and timely return to unrestricted physical activities. Objective: The purpose of this study is to determine if personality influences stiffness and investigate how braces may affect stability in ACL reconstructed patients compared to healthy controls, as well as determine if a relationship exists between personality, knee stiffness, and the knee brace. Method: 15 ACL reconstructed (ACLR) subjects with clearance to return to full participation and 14 healthy controls participated in the study. Subjects completed several psychometric surveys to analyze levels of sensation seeking, mental toughness, kinesiophobia and knee function. Participants completed a single legged hopping test with and without a functional knee brace (DonJoy Full Force, DJO Global). Reactive knee stiffness regulation was measured with a customized device in both the braced and non-braced conditions. Statistical Analysis: A 3 way analysis of variance (ANOVA) was used to compare knee stiffness between groups with both startle and brace conditions. Individual t-tests were
used to detect personality differences between groups. A 2 way ANOVA was used to compare global rating of knee function scores between groups with and without a knee brace. A 2 way ANOVA was used to compare functional hop scores between groups with and without a knee brace. Pearson correlation coefficients were used to assess relationships between personality, function and stiffness. **Results:** The brace caused significantly greater knee stiffness than the non-braced conditions. There was significantly less knee stiffness when a subject was startled than when they were not startled. There were no significant differences in stiffness values between groups. There were no significant differences between groups with the hop test. The brace significantly increased time on the hop test. The ACLR group had significantly greater kinesiophobia. Correlations were found with both sensation seeking and mental toughness with knee stiffness. **Conclusion:** ACLR individuals are able to stiffen their knee like healthy controls and knee braces can increase passive reactive knee stiffness. Personality traits such as sensation seeking and mental toughness may influence knee stiffness regulation strategies.
Chapter 1

INTRODUCTION

Anterior cruciate ligament (ACL) injuries are increasingly present in athletic populations, \(^1,2\) with an average of 200,000 ACL injuries annually. \(^2\) Surgical reconstruction is often recommended to restore mechanical laxity, but optimal muscle stiffness regulation must be achieved during a lengthy rehabilitation if functional joint stability is to be restored. \(^3\) During the final stages of rehabilitation and return to participation, many patients are fitted with a knee brace to increase stability; however, functional outcomes vary widely, as do patient preferences for braces. These differences may be explained by personality traits and/or distinct stiffness regulation strategies. \(^4-6\)

Previous evidence suggests that braces increase functional stability, primarily through enhanced proprioceptive feedback and the regulation of joint stiffness. \(^4-6\) However, patient outcomes, even after reconstructive surgery still vary, with some individuals displaying persistent functional limitations upon return to their pre-injury activities or sports. \(^7\) One area with limited research includes the potential role of several personality constructs such as sensation seeking, mental toughness, and kinesiophobia. These constructs may influence patients’ neuromuscular control strategies during recovery, rehabilitation and brace application, affecting the person’s potential return to activity. \(^8-12\) At present, there is inadequate data investigating the effects of personality on knee stiffness while braced and not braced, and potential benefits for improved outcomes and functional performance after surgical reconstruction.

Personality in sport and rehabilitation from injury has been a growing topic in research because individuals can be more vulnerable to injury based on certain
psychosocial factors. Sensation seeking addresses how an individual reacts and responds to life stress, and is measured with respect to each persons “optimal level of stimulation”. Low sensation seekers have a lower threshold for life stresses without experiencing negative consequences. For example, the increased arousal during activities perceived as risky, can decrease coordination due to heightened muscle tension (stiffness). These neuromuscular events may predispose certain individuals to injury especially, in low sensation seeking populations. Conversely, one may not achieve their full functional outcome after injury without accepting some risks during recovery, rehabilitation and return to activity.

The capacity to accept these life stressors may also be related to another personality construct of interest, mental toughness. This characteristic is often compared to hardness, acting as a stress buffer. One method of defining mental toughness is considered the “4 C’s;” and includes control, commitment, challenge, and confidence. The second method of discussing mental toughness is coping appraisals and threat appraisals. Coping appraisals are an individual’s way of measuring self-efficacy and treatment efficacy, whereas threat appraisals assess the perceived susceptibility for injury or the severity of an injury. The end goal of defining mental toughness after injury is to understand how an individual perceives his or her own susceptibility and injury severity. Those with high mental toughness tend to consider their injuries less severe and believe they are less susceptible to future injury. This mental toughness therefore, can be a dynamic factor pertaining to rehabilitation compliance and return to full activity.

The final personality construct of interest is kinesiophobia. It is defined as a fear of injury or re-injury, and can be debilitating when shaping a person’s return to play decisions. Kvist et al found that 24 percent of ACL reconstructed individuals did not return to their previous level of activity due to a fear of re-injury. However, these individuals should present with a mechanically stable knee after reconstructive
surgery, therefore the underlying neuromuscular barriers limiting return to full physical activity must be explored.

These three personality constructs can influence a person’s return to activity and potential risk of injury because each one impacts how a person may manage stress or fear, while they are attempting to execute physical activities with complex joint stiffness regulation strategies that are needed to maintain stability. 8-10

In many patients, the ability to return to pre-injury activity levels has not correlated well with joint laxity or other biomechanical factors. 7 Functional stability requires a synergy between both static and dynamic stabilizers within a joint. The ligaments and joint capsule provide static stability, whereas muscles and tendons surrounding the joint primarily provide dynamic stability. 3 An injury to the anterior cruciate ligament disrupts knee stability, and ordinarily reconstructive surgery is needed to repair the mechanical (static) instability. 3 After the static stability is returned, it is suspected that proprioceptive feedback and neuromuscular control is restored to regulate joint stiffness.

Knee stiffness testing is one measurement of joint stability and primarily examines dynamic stability. Valle et al defined knee stiffness as an “intrinsic property of the tissue to resist deformation”. 14 The ability to reactively stiffen the knee can be altered after injury due to deafferentation of mechanoreceptors in the ACL that are disrupted or damaged with trauma. 3,14-17 It is proposed that the loss of proprioceptive information may not be fully restored with surgical reconstruction. 15-17 However, the ACL braces originally designed to mechanically protect the knee, by limiting anterior tibial translation, may have other beneficial neuromuscular effects that alter stiffness and stability after surgical reconstruction. 4-6

Knee braces are marketed to protect capsuloligamentous static restraints during rehabilitation and prevent subsequent re-injury. The underlying mechanism, in which knee braces aid in restoring function, is not always known. Based on the design of the brace, some appear to primarily enhance proprioceptive information, where as others increase stability due to their mechanical rigidity. 4-6 It was found that both knee
sleeves and rigid shell braces can decrease knee laxity compared to no brace conditions, and that sleeves alone may increase balance and peak rate of force development. Two different studies investigated aspects of knee stiffness and found that the DonJoy brace was the most effective in resisting anterior tibial displacement. Moreover, subjects with athletic physiques exhibited less displacement while wearing a brace than those with more sedentary body composition, suggesting greater benefits through dynamic restraint of stiffness regulation.

Braces appear to be an effective way to maximize functional outcomes in some patients, however it is not understood why some patients prefer knee braces while others do not want to wear them, and feel that they are hindering their performance. We propose that certain personality constructs may interact with the application of knee braces and joint stiffness regulation strategies, which ultimately influences functional outcomes of patients after an ACL surgery. We expect to see an increase in stiffness with the application of the knee brace.

The purpose of this study is to determine if personality influences stiffness and investigate how braces may affect stability in ACL reconstructed patients compared to healthy controls, as well as determine if a relationship exists between personality, knee stiffness, and the knee brace.
Participants:

Twenty-nine male and female participants between the ages of 18 and 35 years were recruited for participation in this experiment. The average time since reconstruction for the ACLR group was 3.3 years, the range was 9 months to 7 years. The demographics for the subjects can be found in Table 1. All subjects completed the same testing protocol regardless of group. The experimental group was composed of participants who sustained an ACL injury and had reconstructive surgery on the injured knee. Subjects with ACLR were eligible for the study once they were cleared for full participation by their surgeon. The control group was composed of healthy participants who were physically active at least three days per week. They had no history of ACL injury or other knee injury in the past six months that limited activity. Members of the control group must not have undergone any surgery on their knee. Participants with a symptomatic lower extremity injury, at the time of testing, were excluded from participating in either group. Subjects participated in one testing session lasting approximately one hour.

Table 1  Demographic Statistics

<table>
<thead>
<tr>
<th></th>
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</tr>
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<tbody>
<tr>
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<td>11</td>
</tr>
<tr>
<td>Males</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Age (yrs.)</td>
<td>20.9 ± 3.0</td>
<td>20.9 ± 1.9</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>170.4 ± 8.6</td>
<td>173.1 ± 12.9</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>67.7 ± 16.8</td>
<td>74.3 ± 19.2</td>
</tr>
</tbody>
</table>

Mean ± SD
Surveys:

Participants completed a variety of surveys and scales prior to testing. These surveys asked questions about the participant’s knee pain and function, the knee braces, and individual personality traits the participants possess.

Knee Outcome Survey- Activities of Daily Living (KOS-ADL):

The KOS-ADL is a 14-item self-report instrument designed to measure symptoms and functional limitations experienced during activities of daily living in participants with a variety of knee injuries. Six of the items ask about symptoms the subject is experiencing and the other eight focus on functional abilities/limitations due to their knee injury. The survey is self-explanatory, patient completed, and requires no additional training to score. It has the ability to detect change when it is administered throughout the rehabilitation process and has been validated for use with ligamentous injuries in the knee. It is scored as a percentage of the patient’s score of the total possible score. The higher scores demonstrate no symptoms or functional limitations.\(^{20}\)

International Knee Documentation Committee Survey (IKDC):

The IKDC is an 18 item self-reported measure of knee function pertaining to symptoms, sports/daily activities, and current knee function compared to knee function prior to injury. It is a compiled of yes and no questions, likert scales, and numerical rating scales. This survey is patient completed and requires no additional training on the part of the researcher. Similar to the scoring of the KOS-ADL the IKDC is score as a percentage with 100 percent being the optimal score. This scale in particular can detect change following surgical intervention in the knee and it is validated for use with ligamentous injuries.\(^{20}\)

Global Rating of Knee Function:

The Global Rating of Knee Function allows participants to report their level of knee function compared to their ability prior to injury using their pre-injury activity
level as 100 percent. The global rating of knee function was measured using a 10-centimeter long visual analog scale in which the extremes are labeled zero and 100. The subject marked a vertical line on the horizontal line to express their perceived level of function with and without the brace.21

**Mental Toughness Questionnaire (MT18):**

The MT18 is an eighteen item scale that includes a 5-point Likert scale ranging from 1= *strongly agree* to 5 = *strongly disagree*. Previous research provides evidence for the validity and reliability of the MT18.8 This questionnaire has not previously been used on knee patients. Lower scores on the MT18 indicate increased mental toughness.

**Sensation Seeking Scale (SSS-V):**

The SSS-V is a 40 item self-report questionnaire and is composed of four subscales: Thrill and Adventure Seeking, Disinhibition, Experience Seeking, and Boredom Susceptibility.13 There are two choices for each question and the subject must choose the one that describes them more. The scale has been validated in previous research.10,13 The higher scores on this scale indicate increased sensation seeking. The maximum score is a 40.

**Tampa Scale of Kinesiophobia:**

The TSK is a 17 item patient completed scale that evaluates a person’s fear of movement. It is a reliable tool that utilizes 4-point likert scales.9,23 In order to score the scale, you add the score for each question, however on questions 4, 8, 12, and 16 you invert the numbers so a “4” would actually be scored a “1”. The higher scores reported on the scale, indicate higher levels of kinesiophobia.
**Functional Testing:**

Functional ability was assessed using a timed six-meter single leg hop test. In order to assess hop distance, a measuring tape was secured to the floor with marks indicating the start and finish line. Subjects were instructed by verbal cues throughout testing on when to begin each trial. Participants completed three measured practice trials and three test trials of the hopping test for each the braced and un-braced condition. The braces used were DonJoy Full Force (DJO Global, Vista, CA). The order of these conditions (braced vs. non-braced) was randomized for each subject. The participants safely hopped as fast as possible for the length of the measuring tape to the finish line, while the researcher gathered the times with a manual stop watch.\(^7,21,24\)

**Stiffness and Proprioception Assessment Device (SPAD):**

A custom-built Stiffness and Proprioception Assessment Device (SPAD) was used to evaluate long-range and short-range stiffness values. This is a servomotor that is fit into a gearbox, mounted on a pedestal (approximately 4ft above the floor), and connected to a motor driver hardware and operated with a desktop computer with customized LABVIEW software.\(^25,26\) It is located next to an adjustable chair, where each subject was seated. The subject’s leg rested on the adaptor arm, which moved through a pre-programmed range of motion and a torque reaction sensor quantified resistance in order to calculate joint stiffness. There are customized safety features of the SPAD including three emergency stop switches, proximity sensors that evaluate the adaptor arm movement range, and mechanical motion blocks. Also, preset speeds cannot be overridden by internal motor settings. In order to continue testing when the motor is shut off, the investigator must restart the motor driver power supply.

**Procedures:**

All subjects attended one testing session lasting approximately one hour. Subjects completed the informed consent document and demographic information.
Next, the subjects completed the KOS-ADL, IKDC, MT18, SSS-V, and TSK. After all surveys were completed, subjects were fitted with a non-custom hinged knee brace.

Subjects warmed up on a standard stationary exercise bicycle for five minutes followed by a group of stretching exercises. Subjects were then asked to participate in the functional hopping test. Performance of this task was completely optional. The participant was asked, “If I gave you a knee brace right now and asked you to hop on your injured leg consecutive times, do you think you could successfully do that?” If the participant responded “yes,” the hop task was completed. If the participant responded “no,” the hop task was not performed. All subjects chose to participate in the hopping tests. The subject completed the Global Rating of Knee function after each condition.

After the functional hopping tests all participants completed the knee stiffness testing on the SPAD. All knee stiffness trials were performed both braced and unbraced, for all participants. The order of testing was randomized. Subjects were seated on the device with the trunk and thigh secured, the back supported, and the hip in 90 degrees of flexion. The device connector arm was aligned with the knee being tested. A pad on the adaptor arm applied pressure over the distal lower limb to stabilize the leg, while another pad on the chair stabilized the upper limb, applying pressure to the thigh. A vacuum splint was placed over the lower leg and ankle to enhance mechanical contact and limit vibration. The weight of the limb was recorded and used to correct measures for gravity.

Quick perturbations were applied to the knee for stiffness tests. Movements of the knee occurred at 1000° per second² acceleration to a velocity of 100° per second through a 40° flexion arc of motion. Passive reactive stiffness was calculated. Patients were asked to remain completely relaxed and then attempt to extend their knee in reaction to a randomly timed flexion perturbation of their knee during all trials. These trials assessed reflexive abilities and neuromuscular function. A minimum of thirty seconds rest was provided between each of the trials and conditions to avoid fatigue.
After visual inspection, the three most satisfactory of the five trials per condition were used in analysis. A custom LABVIEW program was used to collect and analyze data. An acoustic startle stressor was applied to address possible response to sudden unanticipated events and arousal level. This served as an additional trial completed in a randomized order during the trials both during the braced and unbraced conditions. There was one acoustic startle per condition. The randomization ensured that any differences found during the startle trial were not the result of habituation and an order effect. Subjects were given headphones that supply white noise as background sound to eliminate for external cues. ASR trials require noise >100dB sound pressure level (SPL) for a 10ms period, which occurred just 150ms prior to the movement perturbation.

**Statistical Analysis:**

All statistical analyses were performed using SPSS and the significance level was set at *a priori* (*p* < .05). Descriptive analysis was used to identify any outliers or irregularities in the distribution. Two, 3x2 (group x condition x startle), independent analysis of variances (ANOVA) were used for both the short and long range stiffness values to compare passive reactive knee stiffness between groups. A 2x2 (group x condition) independent analysis of variance (ANOVA) was used to assess self reported knee function with and without the brace. A 2x2 (group x condition) independent analysis of variance (ANOVA) was used to assess functional ability in the hopping test. Independent samples t-tests were used to determine differences in subjective knee function and the personality constructs between ACLR and health controls. Pearson correlation coefficients were used to assess relationships between personality, subjective knee function, and stiffness.
Chapter 3

RESULTS

There were significant differences in subjective knee function, measured by the International Knee Documentation Committee and Knee Outcome Survey – Activities of Daily Living between groups. The ACLR subjects had significantly lower scores in the IKDC ($p = .002$) and KOS-ADL ($p = .001$) (Table 2). There was a significant difference in the global rating of knee function (GRKF) between brace conditions ($p = .025$). The interaction between groups for the GRKF is trending towards significance ($p = .059$). Figure 1 compares GRKF scores for ACLR and healthy subjects in both the braced and non-braced conditions.

Hopping Tests

There were no significant differences between groups in the functional hopping tests ($p = .747$). Time to complete the 6 meter timed hop test was significantly greater with the brace than without ($p = .030$). Figure 2 compares functional hopping test scores for ACLR and health subjects with and without the brace.

Knee Stiffness

Means and standard deviations for all stiffness values are provided in Table 3. Also listed in Table 3 are the $p$-values and effect sizes for the main effects found in the 3-way ANOVAs analyzing the stiffness values. In the 3-way ANOVA there were no significant differences in short-range stiffness values. Braced conditions had
significantly greater long-range stiffness than non-braced conditions ($p = .013$). Bracing increased long-range stiffness in all subjects, but did not affect long-range stiffness differently between the two groups.

The startle condition significantly decreased long-range stiffness ($p = .033$), but there was no interaction effect between groups. The startle condition caused a much greater increase in variance for the ACLR group but not for the control group. Although it is not significant, the ACLR subjects overall had decreased short and long range stiffness values than healthy controls. Figures 2 and 3 compares long-range stiffness values between groups for both brace conditions with and without a startle.

Personality Constructs:

Means and standard deviations for the three personality surveys are provided in Table 4. There were no significant differences between groups for sensation seeking or mental toughness between groups. ACLR subjects displayed significantly greater kinesiophobia on the TSK ($p = .029$) than healthy controls.

Correlations:

There was a significant relationship between the short stiffness conditions both with ($p = .029$) and without ($p = .003$) the brace on while being startled. There was also a significant relationship between the short stiffness brace conditions without the startle ($p = .001$). There was no significance during the startle condition with and without the brace. Table 5 provides the significance values and Pearson correlation coefficients for the correlations of the short stiffness values. All subjects were assessed together for the correlations; no distinctions between groups were made.
Significant relationships between stiffness and personality were also found. Long-range stiffness (braced and w/out a startle has a significant negative relationship with mental toughness (p= .049). Lower scores on the MT-18 actually equate to an increased level of mental toughness; therefore, participants with increased mental toughness had increased stiffness while wearing a brace if they were not startled. A significant positive relationship was found between sensation seeking and long-range stiffness with a startle without the brace (p= 0.26). Higher sensation seekers had increased stiffness when they were startled and not wearing the knee brace. Table 6 provides the significance values and Pearson correlation coefficients for the personality surveys and stiffness values. Figures 4 and 5 show graphs of the correlation between stiffness, sensation seeking, and mental toughness.

Negative relationships were found between the TSK and the IKDC (p= .011) and KOS-ADL (p= .004). Higher (better) scores on the functional knee surveys equated to lower levels of kinesiophobia, but those with less function and possibly more pain were more kinesiophobic.
Table 2  Statistics for IKDC and KOS-ADL

<table>
<thead>
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<th>Healthy</th>
<th>ACLR</th>
<th>p-value</th>
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<tr>
<td>IKDC</td>
<td>99.59 ± 1.54</td>
<td>93.02 ± 7.11</td>
<td>0.002*</td>
</tr>
<tr>
<td>KOS-ADL</td>
<td>99.89 ± 0.4</td>
<td>94.31 ± 6.25</td>
<td>0.001*</td>
</tr>
</tbody>
</table>

*Significant at the p-value < .05. Mean±SD. IKDC: International Knee Documentation Committee, KOS-ADL: Knee Outcome Survey –Activities of Daily Living.

Knee Functional Measures

Figure 1  Mean GRKF Scores for healthy and ACLR subjects
Figure 2  Functional Hopping Times with and without a Brace
Table 3  Means and Standard Deviations of Stiffness Values

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<th>Stiffness Condition</th>
<th>Healthy</th>
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<td>Long Range Startle Brace</td>
<td>.0537 ± .0109</td>
<td>.0487 ± .0191</td>
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<td>Long Range Non-Startle Brace</td>
<td>.0535 ± .0095</td>
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<td>.0450 ± .0159</td>
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<td>.0518 ± .0119</td>
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<td>.0709 ± .0149</td>
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</table>

*Significant at p < .05; Stiffness values reported in Nm/deg/kg
*Significance set at \( p < .05 \); significance is between conditions

**Figure 3**  Effect of Brace conditions in ACLR and Control Subjects

*Significant at \( p < .05 \); significance is between conditions

**Figure 4**  Effect of Brace conditions without a startle in ACLR and Control Subjects
Table 4  Statistics for Personality Surveys

<table>
<thead>
<tr>
<th></th>
<th>Healthy</th>
<th>ACLR</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensation Seeking (SSS-V)</td>
<td>19.14 ± 6.28</td>
<td>19.33 ± 5.69</td>
<td>0.944</td>
</tr>
<tr>
<td>Mental Toughness (MT-18)</td>
<td>40.86 ± 5.31</td>
<td>37.93 ± 4.93</td>
<td>0.946</td>
</tr>
<tr>
<td>Kinesiophobia (TSK)</td>
<td>28.0 ± 3.64</td>
<td>35.6 ± 8.11</td>
<td>0.029*</td>
</tr>
</tbody>
</table>

*Significant at the p-value < .05

Table 5  Short Stiffness Correlations

<table>
<thead>
<tr>
<th></th>
<th>Short S B</th>
<th>Short N-S B</th>
<th>Short S N-B</th>
<th>Short N-S N-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.029*</td>
<td>0.738</td>
<td>0.326</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Short S B</th>
<th>Short S N-B</th>
<th>Short N-S B</th>
<th>Short N-S N-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.738</td>
<td>0.065</td>
<td>0.003*</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Short S B</th>
<th>Short S N-B</th>
<th>Short N-S B</th>
<th>Short N-S N-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.065</td>
<td>0.348</td>
<td>0.527</td>
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</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Short S B</th>
<th>Short S N-B</th>
<th>Short N-S B</th>
<th>Short N-S N-B</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>p-value</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.326</td>
<td>0.001**</td>
<td>0.003*</td>
<td></td>
</tr>
</tbody>
</table>

* Significant at the p-value <.05. ** Significant at the p-value < .001. Short S B: Short-range startled stiffness with brace; Short N-S B: Short-range non-startled stiffness with brace; Short S N-B: Short-range startled stiffness with non-brace; Short N-S N-B: Short-range non-startled stiffness with non-brace
Table 6  Stiffness and Personality Correlations

<table>
<thead>
<tr>
<th></th>
<th>SSS-V</th>
<th>MT-18</th>
<th>TSK</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Startle Brace stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.177</td>
<td>0.464</td>
<td>0.264</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-0.258</td>
<td>0.142</td>
<td>-0.215</td>
</tr>
<tr>
<td>Short No-Startle Brace stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.566</td>
<td>0.948</td>
<td>0.181</td>
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<tr>
<td>Pearson Correlation</td>
<td>0.111</td>
<td>0.013</td>
<td>0.255</td>
</tr>
<tr>
<td>Short Startle No-Brace stiffness</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.733</td>
<td>0.755</td>
<td>0.189</td>
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<tr>
<td>Pearson Correlation</td>
<td>0.066</td>
<td>0.06</td>
<td>0.251</td>
</tr>
<tr>
<td>Short No-Startle No-Brace stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.651</td>
<td>0.59</td>
<td>0.087</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>-0.088</td>
<td>-0.104</td>
<td>0.324</td>
</tr>
<tr>
<td>Long Startle Brace stiffness</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.278</td>
<td>0.993</td>
<td>0.733</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.208</td>
<td>0.002</td>
<td>-0.066</td>
</tr>
<tr>
<td>Long No-Startle Brace stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.203</td>
<td>.049*</td>
<td>0.241</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.243</td>
<td>-.370</td>
<td>0.225</td>
</tr>
<tr>
<td>Long Startle No-brace stiffness</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.026*</td>
<td>0.963</td>
<td>0.559</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.412</td>
<td>-0.009</td>
<td>0.113</td>
</tr>
<tr>
<td>Long No-Startle No-Brace stiffness</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>( p )-value</td>
<td>0.161</td>
<td>0.161</td>
<td>0.67</td>
</tr>
<tr>
<td>Pearson Correlation</td>
<td>0.267</td>
<td>-0.267</td>
<td>-0.083</td>
</tr>
</tbody>
</table>

*Significant at the \( p \)-value < .05. SSS-V: Sensation Seeking Scale; MT-18: Mental toughness 18 item questionnaire; TSK: Tampa Scale of Kinesiophobia
Figure 5  Correlation between Long Range Stiffness with a Brace and Mental Toughness

Figure 6  Correlation between Long Range Stiffness with a Startle
Chapter 4
DISCUSSION

Overall the ACLR subjects had knee stiffness equal to healthy controls and both groups responded similarly to the brace and startle conditions. Applying the braces significantly increased all subjects’ ability to reactively stiffen their knees, whereas the startle decreased all subjects’ knee stiffness. ACLR subjects demonstrated significantly higher levels of kinesiophobia than their healthy counterparts. Several correlations were found linking personality constructs, knee stiffness, and bracing suggesting that further research is needed to determine any influence they may have on patient outcomes.

Overall, our ACLR subjects can stiffen their knees, through dynamic restraint, the same as healthy individuals; however a tendency was seen in ACLR individuals having overall lower stiffness value in our study. Miranda et. al\textsuperscript{27} determined that ACLR subjects had decreased anterior-posterior tibial excursion than subjects that had an intact ACL. This study also showed increased ground reaction force during a jump-cut maneuver in their ACLR group, which the author states can predispose, an individual to ACL injury.\textsuperscript{27} This variability and decrease in knee stiffness seen in our study may be associated with occasional episodes of instability if the ACLR individual cannot consistently regulate knee stiffness to accommodate functional demands.

Our results may suggest a small deficit, which could be statistically significant across a large population of ACLR subjects. Our testing technique occurs in a laboratory setting, is the most direct measure of knee stiffness, and likely provides an assessment of stability under optimal conditions for all subjects. Extraneous variables
that may influence neuromuscular coordination are controlled, which one may suggest limits the generalizability of these results to knee stability under high intensity physical activities. However, the ACLR group also stiffened similarly under a braced condition and during unanticipated startling responses. Both bracing and the startle created main effects, which may supersede small stiffness differences in ACLR subjects. Our subjects also had completed rehabilitation and were cleared by a physician for full activity. The data are promising, in that those patients who undergo reconstructive surgery may regain the capacity to stiffen their knees similar to healthy subjects.

Among ACLR patients and clinicians, there is disagreement over the use of braces to enhance knee stability.4-6 Our brace application caused a significant increase in reactive knee stiffness, which was true for all subjects, not just ACLR. Liggins6 et al conducted a study that assessed many different types of knee braces, and their resistance to anterior tibial translation. The results from the study showed that the hinged knee braces were most effective.6 It was concluded that mechanical characteristics of the brace, the brace design, and brace fit were the three most important factors in determining brace efficacy.6 Lui5 et al investigated the impact that body composition has on brace efficacy as well as the most effective brace with the tissue compliance. The researchers simulated three different body compositions by manufacturing artificial limbs with similar tissue compliance and attaching the braces to the artificial limbs for testing.5 They found that individuals with an athletic composition, rather than sedentary people, were more resistant to anterior tibial translation and that greater force could be resisted by the brace with this composition.5 One major difference between these two studies and the present study is that the
previous studies assessed mechanical stability/stiffness on artificial limbs while ours was reactive knee stiffness on human subjects. Ramsey et. al\(^4\) believed that it was an increase in proprioceptive information that caused a decrease in anterior tibial translation than non-braced conditions. We believe that the active stiffness in our study facilitated a greater neuromuscular response to a knee flexion perturbation with the brace than without. The passive friction/stiffness of the brace alone is too low to account for the magnitude of stiffness difference we observed.

Because there is a high rate of non-contact injury mechanisms and increased risk for ACLR subjects to re-injury their knees, current research suggests that unanticipated events likely disrupt important neuropsychological processes needed to maintain joint stability. The startle response is frequently used for research purposes in evaluating the magnitude of subjects’ neuromuscular reaction when confronted with sudden unanticipated sensory stimuli.\(^{28,29}\) Our startle trials significantly decreased the reactive ability of subjects to stiffen their knees compared to the non-startle trials. Previous work in our laboratory found identical results in healthy males and females, but this is the first study to assess ACLR patients. During the startle trials, there was a large variance seen in the ACLR subjects, which suggests difficulty in predicting who may be adversely affected by anticipated events. The large variance in responses to the startle by the ACLR subjects may be a predisposing neuropsychological factor or a consequence of neuroplastic changes after injury that have recently been identified within this population.\(^{16,17,30,31}\) However, because the startle response also significantly decreased stiffness in healthy subjects, continued research is needed to establish its clinical relevance and potential to heighten ones’ risk for coordination failures that impair stiffness regulation and joint protection. The startle response has
also been linked to several personality characteristics including fear and arousal levels, which may also play a role in the variance we observed.\textsuperscript{28,29}

Sensation seeking (SS) is “the optimal level of arousal” and a “stress resiliency factor”.\textsuperscript{10,13} High SS individuals have an increased threshold for life stress and thrive in those situations.\textsuperscript{10,13} These qualities are closely linked to coping skills because without great coping skills higher sensation seekers may not flourish in stressful situations. Conversely, in order for a low sensation seeker to survive in stressful situations they need to apply their coping mechanisms and use them to their fullest extent.\textsuperscript{10} Low sensation seekers appear to be at a greater risk of injury during, or immediately after stress, due to their decreased coping mechanisms.\textsuperscript{10} Our results demonstrated that individuals with higher levels of SS, displayed greater reactive knee stiffness when they were startled than lower sensation seekers. This was the first study to correlate stiffness regulation when startled and SS. There are two opposing theories that may explain why high sensation seekers have high stiffness values during a startle.\textsuperscript{10} The first hypothesis is that it takes more sensory stimuli to arouse the high SS person because they have more coping resources to potentially stressful situations. The second hypothesis suggests that high sensation seekers may actually seek sensory experiences for the purpose of achieving higher arousal levels. It appears that when high sensation seekers are startled, the stimulus may have a facilitatory effect that helps optimally arouse the nervous system. The result is a reactive response to knee perturbation that produces greater stiffness, which may help with joint protection.\textsuperscript{13,32}

Another personality construct related to risk taking in physically active people is kinesiophobia. This is a fear of injury or re-injury\textsuperscript{33} and previous studies have shown that kinesiophobia is one of the primary reasons that individuals do not return
to their previous level of activity after an ACL tear and subsequent reconstruction.\textsuperscript{9} Self reported knee function has also shown to have a correlation to kinesiophobia in previous research.\textsuperscript{23} Kvist et al\textsuperscript{9} stated that kinesiophobia may occur due to a lack of confidence in the patient’s own knee even after surgery. Our ACLR subjects demonstrated significantly higher levels of kinesiophobia than healthy individuals and our results support previous work suggesting that past experiences of injury may result in increased fear of re-injury during a functional activity.

Similar to the argument of fear, is the notion that mental toughness may aid in recovery after injury. Mental toughness is very similar to hardiness and determines how an individual is able to cope with stress.\textsuperscript{34} It is a buffer to stress. There are many aspects of mental toughness that are commonly discussed such as commitment, self-motivation, resilience, and perseverance.\textsuperscript{12} One other component to mental toughness that is very important relates to how influential or in control a person feels of their situation, instead of relying on destiny.\textsuperscript{34} We found a negative relationship between mental toughness and knee stiffness in a braced condition. Therefore those with higher mental toughness produced greater stiffness when they were wearing this brace. The most obvious conclusion would suggest that individuals feel like the have more control while wearing the brace. This confidence may minimize inhibitory influences from the motor cortex on muscle recruitment and stiffness regulation that would otherwise exist as a barrier to the dynamic restraint mechanism.

One major limitation of this study is the sample size. An increased and more diverse sample would provide a better indication of what may be occurring to the general public after ACL reconstruction. Future research should further investigate the relationship between ACL reconstructed patients and kinesiophobia and determine if
anything can be done to lessen this fear of re-injury. Future studies should also examine the startle reaction and what occurs in ACL reconstructed subjects during this reaction to determine if there are ways to predict the reaction from these individuals to prevent subsequent injury due to startle.

**Conclusion**

ACLR patients can stiffen their knee as well as healthy controls in a controlled laboratory setting, however clinicians and researchers can expect greater variance in these stiffness measures by the ACLR patients. Functional knee braces caused an increase in knee stiffness measures, whereas the startle caused a decrease in knee stiffness. Both sensation seeking and mental toughness have an impact of knee stiffness, which may be influenced by the startle or brace. ACLR individuals continue to present with increased levels of kinesiophobia, which may require intervention strategies to maximize patient outcomes.
Chapter 5

LITERATURE REVIEW

Anterior Cruciate Ligament (ACL) injuries can happen in any sport at all levels of competition. ACL injuries have gained a lot of notoriety in the media and society in general due to the length of time an athlete usually misses after injury, and continue to be a topic of research due to some long-term sequelae from the injury. Researchers have investigated the differences between those individuals that return to play and those who do not but there is still much research to be done due to the inconclusive results.

Epidemiology

Over 200,000 ACL occur annually in the United States, and the rate of injury continues to grow with each subsequent analysis of ACL tears.\textsuperscript{1,2} An epidemiological study of NCAA athletes between 1989 and 2004 found that the rate of injury has increased by 1.3 percent per year, despite the increased awareness and implementation of prevention programs.\textsuperscript{1} In the sampling of 15 percent of the collegiate population there were an average of 313 injuries per year over the course of 16 years, which translates to about 2000 injuries in that timeframe for all of intercollegiate athletics.\textsuperscript{1} Interestingly, that same study showed that ACL injuries only accounted for approximately 3 percent of all injuries, but are significant because an athlete normally missed more than one week of activity.\textsuperscript{1}

ACL injuries tend to be of greater concern for females more than males. Other than football the highest rate of ACL injury was seen in women’s soccer, women’s lacrosse, and women’s gymnastics in the NCAA.\textsuperscript{1} Men’s football had the greatest number of injuries, but women’s sports possessed the highest rates.\textsuperscript{1} This could be
due to the fact that there are normally more men participating in the sports with high risk of injury than women. Out of all of the NCAA sports examined, the only male sport above .1 ACL injury per 1000 athlete exposure was football, but there were four women’s sports above this rate. Female soccer and basketball players had a greater incidence of ACL injuries than their male counterparts in both injury numbers and rates.  

Alarmingly, individuals who suffer one ACL injury are at an increased risk for a second or even third injury. Salmon et al found that 12 percent of those who have ACL reconstructive surgery will sustain a second tear. Many people may think that this is just on the previously injured knee, but in actuality the increased rate is for both knees (6 percent for both the ipsilateral and contralateral limb). Another study has shown that females are four times more likely to suffer a contralateral injury than males. All of the data on ACL re-injury leads us to believe that there is some reason that these individuals are more at risk for ACL injury and re-injury than others.

**Personality**

Athletic injuries normally have some psychological consequences in conjunction with the obvious physical effects. Psychological factors can lead a person to be more vulnerable to injury and can also impact a person’s rehabilitation in terms of compliance and return to play. There are three personality constructs that may be of concern before and after injury: sensation seeking, mental toughness, and kinesiophobia. There are other personality constructs that can also contribute, but these are the three are of interest for this study due to the results from previous work in our lab.

Sensation seeking refers to the “optimal level of arousal” that a person can withstand. Smith et al defined sensation seeking as a “stress resiliency factor”, meaning low sensation seekers have a lower threshold for life stress than higher sensation seekers. Those who are termed high sensation seekers may actually go in search of stressful situations and thrive in those scenarios.
be linked to injury in both high and low sensation seekers. High sensation seekers may search out adventure and get injured as a consequence, whereas low sensation seekers have a harder time dealing with stress and can be mentally preoccupied during activity, thus getting injured due to a loss of neuromuscular coordination. It has been shown that an increase in arousal or stress can cause an increase in muscle tension resulting in injury susceptibility.¹⁰

Smith et al¹⁰ conducted research on the level of sensation seeking and time lost from injury during a single athletic season. The athletes in the study completed the Sensation Seeking Scale V, questions about recent life events and their coping skills. They also counted the number of days the subjects did not participate in their sport due to injury. Time lost was cumulative for all injuries that an athlete may have sustained, whether it was one or multiple separate injuries. The results of the study showed that lower sensation seekers had a greater risk of injury after higher levels of stress in their sport. It also found higher sensation seekers possess better coping mechanisms, which included peaking under pressure, concentration, freedom from worry, and stress management.¹⁰ This study is important in the realm of sensation seeking and injury because it shows that lower sensation seekers are at an increased risk for injury when they are stressed, so teaching coping mechanisms could theoretically decrease this risk. Because the risk of re-injury is greater in ACL reconstructed individuals than their healthy counter parts, identifying levels of sensation seeking may help to identify injury prone patients and prevent some re-tears of the ACL.

Zuckerman is one of the leaders in sensation seeking research and is responsible for the Sensation Seeking Scale.¹³ This study will utilize the fifth version of this survey. The scale underwent four different revisions to provide the best tool to determine sensation seeking. The tool was tested across genders and cultures to determine any differences that may affect the reliability.¹³ The fifth version of the scale eliminated the general scale and instead focuses on the four factors that Zuckerman described as significant to determine sensation seeking. These factors are thrill and adventure seeking, experience seeking, disinhibition, and boredom
susceptibility. All of these components were reliable between males and females as well as across cultures in American and English subjects, except the boredom susceptibility, which was not clearly seen in females. However, boredom susceptibility was similar within cultures so it remained a part of the scale. One interesting fact that Zuckerman found while comparing genders and cultures is men have higher levels of sensation seeking than females, indicating a higher level of optimal stimulation. The study also found that as individuals age, their level of sensation decreases as expected. The sensation seeking scale is an important, useful, and reliable tool when determining the optimal level of arousal for individual subjects.

The next personality construct of interest is mental toughness. Mental toughness has become a popular topic in sport psychology because of its link to performance. Mental toughness is essentially how individuals cope with stress and has been compared to hardiness, however there are many different ways of defining mental toughness. The first approach describes mental toughness through coping and threat appraisals. Coping appraisals refer to self-efficacy and the efficacy of the treatment, whereas threat appraisals describe the perceived susceptibility and perceived severity of a situation (or injury) a person feels. A second system of defining mental toughness is termed the 4 C’s: Control, Commitment, Challenge, and Confidence. Each of these factors involves belief in oneself and thinking you are able to do something about your fate, instead of destiny being decided for you. In addition to the theories previously listed, others define mental toughness based on characteristics possessed by mentally tough individuals or even the outcomes from mental toughness such as the ability to cope with stress.

Research on mental toughness has shown that individuals with increased mental toughness do not feel that their injury is as severe, and do not believe that they are at risk of future or worse injury, whereas those with less mental toughness feel the opposite. The same study also demonstrated that those with higher mental toughness are able to deal with higher levels of pain during rehabilitation, thought to be a result of their coping strategies. Crust et al investigated the coping strategies of mentally
tough individuals and found that increased mental toughness showed greater coping mechanisms. These subjects utilized the strategies during practice and games. It is also important to note that this study did not find any significant differences between levels of mental toughness across genders. Mental toughness has not been thoroughly researched in rehabilitation from injury; however it may be possible that those with increased mental toughness cope with the pain effectively, thus benefitting from rehabilitation for a quicker return to play than counterparts who possess less mental toughness. However, this may also mean that these individuals do not recognize when their pain is severe enough to modify behaviors. On the other hand, low levels of mental toughness may not allow a person to cope with their fear of re-injury and make them fearful of returning to physical activity, which can lead to kinesiophobia.

Kinesiophobia is the final personality construct that will be investigated in this paper. There has been an increase in research on the fear of re-injury and movement after ACL injury. Kori et al defined kinesiophobia as “an excessive, irrational and debilitating fear of physical movement and activity resulting from a feeling of vulnerability to painful injury or re-injury”. This fear may cause those with kinesiophobia to avoid activity and not return to their previous level of participation. One study found that the 47 percent of individuals that did not return to their previous level of activity had a greater fear of re-injury and 24 percent of them claimed that it was main reason that they did not return to their previous activity level. Another study examined the relationship between self-reported levels of function and fear of movement during rehabilitation after ACL reconstruction. They found that kinesiophobia is higher in the beginning of the rehabilitation process but it trends lower as pain decreases and as function increases. Most of the studies looking at fear of movement and injury use the Tampa Scale of Kinesiophobia to quantify the subject’s amount of kinesiophobia. All of these personality constructs can contribute to the confidence and/or fears a person experiences after surgery and the choices that they make including when and if they return to play and their reliance on a knee brace.
The Knee

Both static and dynamic stabilizers provide joint stability. The functional stability of a joint relies on both factors to have proper movement. Muscles and tendons are the primary dynamic stabilizers of the knee, which use muscle activation and tension to achieve stability via stiffness regulation. Ligaments, cartilage, bone and the joint capsule provide static stability and guide the movements within the joint. The anterior cruciate ligament is primarily responsible for preventing excessive anterior translation of tibia. An injury to this ligament can decrease both static and dynamic stability because of mechanoreceptors located in the ACL. The mechanoreceptors are responsible for sensing the joint position, joint motion, and force. With the disruption of these mechanoreceptors the muscles may not be able to fully stabilize the knee, which can lead to many of the symptoms experienced after an ACL tear.

Knee Stiffness is just one measure of knee stability. Stiffness is defined as the ability of a tissue, whether it is muscle, ligament, bone, or tendon, to resist deformation. The individual stiffness of each structure combines to stabilize the knee dynamically and statically. Knee stiffness can be measured in a few different ways. One way to measure knee stiffness is through an oscillation test, which is essentially dropping the leg and allowing it to swing like a pendulum. The time until the leg stops moving as well as the distance it travels is measured and then used to calculate stiffness values. Another method of measuring stiffness is to directly quantify the change in joint position and load with a customized instrument, known in our lab as the Stiffness and Proprioceptive Device (SPAD). Please refer to the methods section for more information about the SPAD. Finally stiffness can be measured subjectively with a visual analog stiffness scale based on each individual’s perception of his or her joint stiffness/stable. It is important to understand the structures of the knee and how they contribute to stability in order to better comprehend what occurs after an ACL injury.
**ACL Injury**

Non-contact mechanisms of injury are most common with the ACL and account for approximately 72 percent of all ACL tears.\(^{37}\) Two common actions when individuals injure the ligament are landing on a single leg or a planting/cutting maneuver.\(^{38-45}\) These mechanisms of injury are associated with some or many of the following mechanisms that are primarily seen with an ACL tear: valgus collapse of the knee, quadriceps contraction (eccentric), low angle of knee flexion, hip or trunk motion, a fixed planted foot, and tibial rotation.\(^{38,39,41,42,44-49}\) Injury to the ACL leads to dysfunction because of the lack of proprioceptive information and mechanical stability. Decreases in proprioception, balance, strength, and functional performance as well as biomechanical adaptations are typically seen after injury.\(^{30}\) Individuals respond differently to injury and no two cases are the same. The amount of pain and dysfunction cannot always be predicted and may have an effect on the outcome.

**Copers and Non-Copers**

After injury to the ACL, individual are often classified as a coper or a non-coper. Copers are able to return to their pre-injury level of activity and have no limitations; consequently, non-copers are unable to return to their pre-injury level of activity and sport due to lasting dysfunction and episodes of “giving way.”\(^{7}\) The classification is able to be made pre and post reconstruction. In a study of ACL deficient individuals it was found that 63 percent were considered potential non-copers while the other 37 percent were potential copers.\(^{21}\) Mechanical laxity does not correlate to a person’s functional capacity and an increase in laxity does not automatically cause someone to be a non-coper. Eastlack et al\(^{7}\) found that there were no significant differences in laxity testing or the International Knee Documentation Committee (IKDC) survey between the copers and non-copers, but there were significant differences in functional performance. Results similar to this led to the creation of a classification scheme to differentiate between copers and non-copers.
The classification criteria between copers and non-copers include a functional test, subjective episodes of giving way, the Knee outcomes survey- activities of daily living (KOS-ADL), and the global rating of knee function. The KOS-ADL assesses subjective functional status of the knee and is both valid and reliable. The global rating of knee function is a visual analog scale that allows the subjects to rate their perceived knee function with 100 percent equating to their pre-injury level. The functional hopping test is a timed single leg six-meter hop. True copers had significantly less laxity, fewer episodes of giving way, higher levels of activity, and improvements in the KOS-ADL as compared to non-copers. It has been shown however, that the hopping test is not required to determine copers from non-copers. Eastlack et al found significant differences between the copers and the non-copers on the hopping test but over 60 percent of the non-copers did not complete the task due to fear of greater injury. It has also been shown that during a one-year follow-up of copers and non-copers there were no differences in the performance on the hopping test between copers and non-copers. Whether a person is a coper or a non-coper should not influence whether a brace is prescribed for the patient.

**Knee Braces**

When addressing return to play after anterior cruciate ligament injuries, the use of functional knee braces is frequently debated. Many individuals returning to athletic participation are fitted and receive a functional knee brace to wear for the beginning stages of return to play, but then decide against its continued use. Questions arise as to whether or not the braces are effective for increasing joint stability and which brace is the best option.

There are many variations of stiffness studies on knee braces. Most of these are mechanical in nature and investigate many different brace styles and brands within each style. In a study by Liggins et al various braces were studied for their overall mechanical stiffness. The researchers investigated many brands of four main types of braces utilized after ACL reconstruction: knee sleeves, sprung sleeves, hinged sleeves,
and frame braces. A load was applied to an artificial limb to cause anterior translation of the “tibia.” The study found that hinged knee braces provided the most stiffness out of all types tested, and the Donjoy ACL brace was most effective within this category. The primary conclusions drawn from this study were that three factors lead to the efficacy of a brace: the mechanical characteristics of the materials that make the brace, the brace design, and the brace fit. A study by Liu et al examined the effect of soft tissue composition on brace efficacy. The study used an artificial limb but each limb had a different soft tissue compliance representing an athletic individual, a recreational athlete, and a sedentary person. The study found all braces were more effective on those with a soft tissue compliance similar to a competitive athlete. The authors also investigated which brace was best with this compliance and found that the Donjoy Custom brace had the least amount of anterior tibial displacement under the greatest amount of force. This study again addressed mechanical stability of the knee brace and not dynamic stability.

Other studies on functional knee braces utilize electromyography (EMG) to examine the muscle activity while the braces are being worn. Ramsey et al hypothesized that knee braces are effective due to the proprioceptive feedback they provide to stabilize the joint rather than the brace actually “stabilizing the joint.” It can be interpreted that the proprioceptive feedback increases the dynamic stability and not just mechanical stability. It is important to note that this study was completed on anterior cruciate ligament deficient knees, not those that have been reconstructed. EMG of the rectus femoris, semitendinosus, biceps femoris and lateral gastrocnemius were measured as well as kinematic measurements of anterior tibial displacement. The study found that there was a decrease in hamstring activity just prior and during foot strike but an increase in rectus femoris activity just after foot strike during a hopping task. The authors stated the most anterior tibial translation occurs during the time of foot strike. All of these changes were based on the brace condition compared to the unbraced condition in the same subject on the same limb. It could be expected that hamstring activity would be greater when the greatest amount of tibial translation
occurs because it is responsible for assisting in the prevention of this motion. The authors concluded that there was no reduction in anterior displacement between braced and non-braced conditions. Secondly, the authors stated that they believe based on their findings that the braces work due to proprioceptive feedback rather than mechanical stability. The previously discussed articles express the controversy that exists over the function of knee braces and how they are able to assist in stability after anterior cruciate ligament injury during the return to play phase of rehabilitation.

This study is significant because it addresses a few different factors that are important in anterior cruciate ligament research. This study will be combining personality, knee stiffness, functional measures, and knee braces to determine if personality influences the efficacy of knee braces in stiffness measures. Another unique feature of this study is that it is investigating a single knee brace, which has been proven to be the most effective in previous research on a variety of tasks instead of multiple braces on only one task. The goal of this research is to provide further insight on the influence of personality on knee stiffness and if differing personalities benefit from knee braces more than others. This study can benefit clinicians because if a personality construct is proven to function better or worse with the brace than they can measure a level of the construct in patients and see if a brace may be beneficial.
REFERENCES


Appendix A

INFORMED CONSENT DOCUMENT
Informed Consent Form

Title of Project: The Relationship between Personality, Knee Braces and Knee Stiffness after Anterior Cruciate Ligament Reconstruction

Principal Investigator (s): Kelly McGuire
Other Investigators: Dr. C. “Buz” Swanik, Advisor
Yong Woo, MS, ATC

You are being asked to participate in a research study. This form tells you about the study including its purpose, what you will do if you decide to participate, and any risks and benefits of being in the study. Please read the information below and ask the research team questions about anything you do not understand before you decide whether to participate. Your participation is voluntary and you can refuse to participate or withdraw at anytime without penalty or loss of benefits to which you are otherwise entitled. If you decide to participate, you will be asked to sign this form and a copy will be given to you to keep for your reference.

WHAT IS THE PURPOSE OF THIS STUDY?

The purpose of this study is to obtain information regarding functional knee braces used after anterior cruciate ligament (ACL) surgery. We hope to gain information about why some people like the knee braces and others do not. This study is being completed for a master’s thesis.

You are being asked to take part in this study because you had anterior cruciate ligament reconstructive surgery within the past one to five years and have returned to full physical activity or are being tested as a healthy control for comparison. We expect to have 30 subjects in this study. You will be excluded from this study if you injured your posterior cruciate ligament along with your ACL, have swelling, or have not returned to the same level of activity that you were participating at before your...
knee injury. You will also be excluded if you have had any other injury to you foot, ankle, knee, hip or leg in the past six months that limits moderate physical activity. Lastly, all participants with a history of cardiovascular, neurological, or hearing impairments will be excluded.

WHAT WILL YOU BE ASKED TO DO?

If you chose to participate in this study you will be asked to come to the Human Performance Laboratory in the Fred Rust Arena on the University of Delaware’s south campus for one testing session that will last about sixty to ninety minutes. You will begin by completing this informed consent document and a health history questionnaire. Then you will complete additional surveys that include personal questions about risky behaviors such as drug use or sex, which we ask you to answer as honestly as possible. We promise to provide complete confidentiality with all answers and you do not need to answer any questions that you do not wish to or feel uncomfortable answering.

After completing the questionnaires you will be asked to warm up on a stationary bicycle for 5 minutes. You will then be fitted for a knee brace that you will wear during different tasks. The knee brace is commercially available for purchase from DonJoy. All participants that have had ACL surgery will wear the brace on their injured leg while all other participants will be randomly asked to wear it on their left or right leg. Next, you will be asked to perform a single leg 6 meter timed hopping test. This is voluntary and you can decline participation in this part of the study if you do not feel comfortable hopping on your injured knee. You will get 3 practice trials and then 3 timed trials. You will do this with the brace on and then again without the brace. You will be given time to rest between each trial. Figure 1a shows the hopping trials.

After you are finished with the hopping test we will test the stiffness of your knee on a machine. In order to determine muscle activity, we will tape small sensors over the muscles in the front and back of your thigh with hypoallergenic tape or non-
tape methods of attaching the equipment will be available if you are allergic to adhesive skin tape. In order for the tape to be secure, the area will be shaven, abraded, and cleansed with an alcohol swab before application of the sensors. Cables from the sensors will be attached to a small box near you during the tests. The box sends information about your muscles to a computer. We will also apply a sensor over a muscle near your eye to monitor your eye reaction to the acoustic sound. It will detect your eye movement when you blink. You will sit in the customized machine and be secured in the chair. If you feel uncomfortable at any time investigators will be present to help you out of the chair immediately. Figure 1b shows the machine for testing your knee stiffness. You will then have your strength tested to determine the amount of force used during the testing. When the testing begins you will be asked to stay as relaxed as possible for all trials. You will be given rest in between trials. This will be completed both with the knee brace on and off.

WHAT ARE THE POSSIBLE RISKS AND DISCOMFORTS?
You may experience muscle or joint soreness following the testing. This soreness is similar to that experienced after weight lifting. There is a small risk of muscle or joint injury (pulled muscle, joint sprain, broken bone) because of participating in this study. There is a risk of joints giving way during the hopping portion of the study. In order to reduce this risk you will be provided a knee brace to protect and support your knee.
There is also a risk of cuts from the razor while shaving the leg for the application of the sensors. Proper warm-up and rest periods will be used in order to reduce the risk of injury due to hopping and testing devices have several safety features to limit risk. Similar studies in this lab and other labs have used these tests with no serious injuries.

WHAT ARE THE POTENTIAL BENEFITS?
You will not benefit directly from taking part in this research. However the knowledge gained from this study may contribute to our understanding of why knee braces are beneficial to individuals who have had ACL surgery. We hope that this study will lead to further research on knee braces and the effect that they have on the people wearing them.

HOW WILL CONFIDENTIALITY BE MAINTAINED?
All data collected will be kept confidential and used for research purposes only. Data may be used for research in the indefinite future. Confidentiality will be maintained using a code number. The code number will be used for the remainder of the study. Only investigators involved with the study will have access to this list. When the study is completed and the data analyzed, the list and data will be stored in a locked cabinet for three years and then be archived. Your name will not be used in any report. When publishing results, no personally identifiable information will be used. The University of Delaware Institutional Review Board may view your research records, but the confidentiality of your records will be protected to the extent permitted by law.

WILL THERE BE ANY COSTS RELATED TO THE RESEARCH?
There will be no cost to participate in this study.

WILL THERE BE ANY COMPENSATION FOR PARTICIPATION?
There will no compensation for participating in this study.
WHAT IF YOU ARE INJURED BECAUSE OF THE STUDY?
If you are injured during research procedures, you will be offered first aid at no cost. If you require additional medical treatment, you or your third-party payer (for example your health insurance) will be responsible for the cost. By signing this document you are not waiving any rights that you may have if injury was the result of negligence of the University or its investigators.

DO YOU HAVE TO TAKE PART IN THIS STUDY?
Taking part in this research study is entirely voluntary. You do not have to participate in this research. If you choose to take part, you have the right to stop at any time. If you decide not to participate or if you decide to stop taking part in the research at a later date, there will be no penalty or loss of benefits to which you are otherwise entitled. Your refusal will not influence current or future relationships with the University of Delaware. As a student, if you decide not to take part in this research, your choice will have no effect on your academic status or your grade in the class.

WHO SHOULD YOU CALL IF YOU HAVE QUESTIONS OR CONCERNS?
If you have any questions about this study, please contact the Principal Investigator, Kelly McGuire at kmcguire@udel.edu or 973-534-5455 or Dr. Buz Swanik at cswanik@udel.edu or (302)-831-2306.
If you have any questions or concerns about your rights as a research participant, you may contact the University of Delaware Institutional Review Board at 302-831-2137.
I am interested in participating and also certify that I have agreed to receive further information for a future follow-up research project associated with this project and will participate in the follow-up testing. Please contact me.

CONTACT INFORMATION:

Your signature below indicates that you are agreeing to take part in this research study. You have been informed about the study’s purpose, procedures, possible risks and benefits. You have been given the opportunity to ask questions about the research and those questions have been answered. You will be given a copy of this consent form to keep.

By signing this consent form, you indicate that you voluntarily agree to participate in this study.

__________________________________________  __________
Signature of Participant                               Date

__________________________________________
Printed Name of Participant
Appendix B

RECRUITMENT FLIER
PARTICIPANTS WANTED:

People who have had ACL surgery and have been cleared to return to full activity

People willing to serve as healthy controls (MUST NOT HAVE HAD ANY PREVIOUS KNEE SURGERY)

You are not eligible for testing if you currently experience:
Swelling, Decreased Range of Motion

Any other hip, knee, or ankle injury

Testing will last 60-90 minutes

Location:
Room 160 of the Human Performance lab. The Entrance is the right/rear corner of the Fred Rust Ice Arena, located on the South Campus of the University of Delaware. PARKING IS FREE OF CHARGE
549 South College Avenue
Newark, DE 19716

ACL STUDY

To Schedule an appointment please contact:

Kelly McGuire, ATC
Graduate Assistant Athletic Trainer
Phone: (973)-534-5455
Email: kmcguire@udel.edu

Subject’s Assurances:
Participation in this research project is voluntary. You may choose to discontinue participating in this research project at any time without consequence.

Please bring or wear active shorts and a tshirt
Appendix C

DEMONOGRAPHIC QUESTIONNAIRE
**Demographic Questionnaire**

PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR ABILITY.

1. Gender: Male Female


5. Dominant leg: Left Right

6. Injured Knee: Left Right Neither

7. How many times have you sprained your knee? ________

8. When was your most recent knee sprain? ________

How did you sprain your knee?
____________________________________________

9. Have you ever had surgery on your knee?

Yes No

If Yes, explain _______________________________________________________

10. Are you currently experiencing any pain or soreness in your hip, knee, or ankle?

Yes No

If Yes, explain _______________________________________________________

11. Have you suffered any injuries to your hip or ankle in the past 6 months?

Yes No

If Yes, explain _______________________________________________________
Appendix D

PHYSICAL ACTIVITY READINESS QUESTIONNAIRE (PAR-Q)
Physical Activity Readiness Questionnaire (PAR-Q)

Common sense is your best guide in answering these few questions. Please read the carefully and check YES or NO opposite the question if it applies to you. If yes, please explain.

<table>
<thead>
<tr>
<th>YES</th>
<th>NO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>1.</td>
<td>Has your doctor ever said you have heart trouble?</td>
</tr>
<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Do you frequently have pains in your heart and chest?</td>
</tr>
<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>Do you often feel faint or have spells of severe dizziness?</td>
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<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
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<tr>
<td>4.</td>
<td>Has a doctor ever said your blood pressure was too high?</td>
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<tr>
<td></td>
<td>Yes,</td>
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<tr>
<td></td>
<td></td>
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<tr>
<td>5.</td>
<td>Has your doctor ever told you that you have a bone or joint problem(s), such as arthritis that has been aggravated by exercise, or might be made worse with exercise?</td>
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<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>6.</td>
<td>Is there a good physical reason, not mentioned here, why you should not follow an activity program even if you wanted to?</td>
</tr>
<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>7.</td>
<td>Are you over age 60 and not accustomed to vigorous exercise?</td>
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<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>8.</td>
<td>Do you suffer from any problems of the lower back, i.e., chronic pain, or numbness?</td>
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<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>9.</td>
<td>Are you currently taking any medications? If YES, please specify.</td>
</tr>
<tr>
<td></td>
<td>Yes,</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>10.</td>
<td>Do you currently have a disability or a communicable disease? If YES, please specify.</td>
</tr>
<tr>
<td></td>
<td>Yes,</td>
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<tr>
<td></td>
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</tbody>
</table>

Print Name ____________________________ Signature ____________________________ Date ___________
Appendix E

SUBJECTIVE KNEE SURVEYS
Knee Outcome Survey Activities of Daily Living Scale (KOS-ADL)

The following questionnaire is designed to determine the symptoms and limitations that you experience because of your knee while you perform your usual daily activities. Please answer each question by checking the one statement that best describes you over the last 1 to 2 days. For a given question, more than one statement may describe you, but please mark only the statement which best describes you during your usual daily activities.

Symptoms

To what degree do each of the following symptoms affect your level of daily activity? Check one answer for each symptom.

<table>
<thead>
<tr>
<th>Symptom</th>
<th>I do not have the symptom</th>
<th>I have the symptom but it does not affect my activity</th>
<th>The symptom affects my activity slightly</th>
<th>The symptom affects my activity moderately</th>
<th>The symptom affects my activity severely</th>
<th>The symptom prevents me from all daily activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pain</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stiffness</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swelling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Giving way, buckling, or shifting of the knee</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Weakness</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Limping</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Functional Limitations with Activities of Daily Living

How does your knee affect your ability to perform each of the following tasks? Check one answer per task.

<table>
<thead>
<tr>
<th>Activity</th>
<th>Activity is not difficult</th>
<th>Activity is minimally difficult</th>
<th>Activity is somewhat difficult</th>
<th>Activity is fairly difficult</th>
<th>Activity is very difficult</th>
<th>I am unable to do the activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Walk</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Go up stairs</td>
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<td></td>
</tr>
<tr>
<td>Go down stairs</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stand</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Kneel on the front of your knee</td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Squat</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sit with your knee bent</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rise from a chair</td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
International Knee Documentation Committee (IKDC)

SYMPTOMS*:

Grade symptoms at the highest activity level at which you think you could function without significant symptoms, even if you are not actually performing activities at this level

1. What is the highest level of Activity that you can perform without significant knee pain?
   1 Very strenuous activities like jumping or pivoting as in basketball or soccer
   2 Strenuous activities like heavy physical work, skiing or tennis
   3 Moderate activities like moderate physical work, running or jogging
   4 Light activities like walking, housework or yard work
   5 Unable to perform any of the above activities due to knee pain

2. During the past 4 weeks, or since your injury, how often have you had pain?

   Never 1 2 3 4 5 6 7 8 9 10 Constant

3. If you have pain, how severe is it?

   No pain 1 2 3 4 5 6 7 8 9 10 Worst pain

4. During the past 4 weeks, or since your injury, how stiff or swollen was your knee?

   1 Not at all 2 Mildly 3 Moderately 4 Very 5 Extremely
5. What is the highest level of activity you can perform without significant swelling in your knee?

1. Very strenuous activities like jumping or pivoting as in basketball or soccer
2. Strenuous activities like heavy physical work, skiing or tennis
3. Moderate activities like moderate physical work, running or jogging
4. Light activities like walking, housework, or yard work
5. Unable to perform any of the above activities due to knee swelling

6. During the past 4 weeks, or since your injury, did your knee lock or catch?

   Yes  No

7. What is the highest level of activity you can perform without significant giving way in your knee?

   1. Very strenuous activities like jumping or pivoting as in basketball or soccer
2. Strenuous activities like heavy physical work, skiing or tennis
3. Moderate activities like moderate physical work, running or jogging
4. Light activities like walking, housework or yard work
5. Unable to perform any of the above activities due to giving way of the knee

SPORTS ACTIVITIES:

8. What is the highest level of activity you can participate in on a regular basis?

1. Very strenuous activities like jumping or pivoting as in basketball or soccer
2. Strenuous activities like heavy physical work, skiing or tennis
3. Moderate activities like moderate physical work, running or jogging
4. Light activities like walking, housework or yard work
5. Unable to perform any of the above activities due to knee swelling
9. How does your knee affect your ability to:

<table>
<thead>
<tr>
<th>Action</th>
<th>Not Difficult at all</th>
<th>Minimally Difficult</th>
<th>Moderately Difficult</th>
<th>Extremely Difficult</th>
<th>Unable to do</th>
</tr>
</thead>
<tbody>
<tr>
<td>Go Up stairs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go Down Stairs</td>
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<tr>
<td>Kneel on the front of your knee</td>
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<tr>
<td>Squat</td>
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<tr>
<td>Sit with your knee bent</td>
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<tr>
<td>Rise from a chair</td>
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<tr>
<td>Run straight ahead</td>
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<tr>
<td>Jump and land on your involved leg</td>
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<tr>
<td>Stop and start quickly</td>
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</tbody>
</table>
FUNCTION:

10. How would you rate the function of your knee on a scale of 0 to 10 with 10 being normal, excellent function and 0 being the inability to perform any of your usual daily activities which may include sports?

FUNCTION PRIOR TO YOUR KNEE INJURY:

<table>
<thead>
<tr>
<th>Couldn’t Perform</th>
<th>No limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily activity</td>
<td>1 2 3 4 5 6 7 8 9 10 in daily activity</td>
</tr>
</tbody>
</table>

CURRENT FUNCTION OF YOUR KNEE:

<table>
<thead>
<tr>
<th>Can’t Perform</th>
<th>No limitation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily activity</td>
<td>1 2 3 4 5 6 7 8 9 10 in daily activity</td>
</tr>
</tbody>
</table>
Global Rating of Knee Function

Please complete the following scale based on the functional test you just completed with the brace.

How would you rate the current function of your knee during your usual daily activities on a scale from 0 to 100 with 100 being your level of function prior to your injury and 0 being the inability to perform any of your usual activities?

0 50 100

Please mark on the scale above and write the number here ______________

Stiffness Scale

Please complete the following scale for your knee stiffness based on the functional test you just completed with the brace.

How would you rate your knee stiffness during the hopping test on a scale from 0 to 100 with 100 being very stiff and 0 being not stiff at all?

0 50 100

Please mark on the scale above and write the number here ______________

Global Rating of Knee Function
Please complete the following scale based on the functional test you just completed without the brace.

How would you rate the current function of your knee during your usual daily activities on a scale from 0 to 100 with 100 being your level of function prior to your injury and 0 being the inability to perform any of your usual activities?

0  50  100

Please mark on the scale above and write the number here ______________

Stiffness Scale

Please complete the following scale for your knee stiffness based on the functional test you just completed without the brace.

How would you rate your knee stiffness during the hopping test on a scale from 0 to 100 with 100 being very stiff and 0 being not stiff at all?

0  50  100

Please mark on the scale above and write the number here ______________
Appendix F

PERSONALITY QUESTIONNAIRES
Mental Toughness 18 Item Questionnaire (MT-18)

DIRECTIONS: Read each of the following statements and indicate your response to each statement based on the five-point scale below. Simply circle the number that corresponds best to your response to each statement as it relates to you and the sport you are currently involved in. Try to respond as honestly and openly as you can to each statement as it pertains to your participation in sport right now.

1. I get distracted and lose focus in competition.
   Strongly Agree  Agree  Neutral /Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

2. I feel positive about my abilities in competition.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

3. I feel in control of my performance.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

4. I really enjoy the thrill of competition.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

5. My mind wanders during competition.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

6. If I compete up to my potential, I believe that I will be successful.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

7. Making mistakes does not get me down.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

8. I am completely concentrated on the task at hand.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

9. I always fight to win every minute of competition.
   Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
   1  2  3  4  5

10. I feel as though I can handle criticism well and use it to my advantage.
    Strongly Agree  Agree  Neutral/Undecided  Disagree  Strongly Disagree
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<td>11. I bounce back from setbacks and do not get too discouraged.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>12. Once I lose my cool in competition, it is hard for me to get it back quickly.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>13. I have a strong desire to compete, perform well, and win.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>14. I feel as though my skills as an athlete will allow for success at the collegiate level.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>15. As I perform, I am able to block out my own worries and fears.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>16. Even if I start out with some mistakes, I normally finish strong in the end.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>17. I block out the crowd and all other distractions in competition.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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<td>18. I always give my best effort in competition.</td>
<td>Strongly Agree</td>
<td>Agree</td>
<td>Neutral/Undecided</td>
<td>Disagree</td>
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Tampa Scale of Kinesiophobia

Please indicate your response to the following items by circling one of the numbers, which have the following meaning:
1 = strongly disagree; 2 = disagree; 3 = agree; 4 = strongly agree

Please answer these items carefully, thinking about how you are generally.

Do not spend too much time on any one item.

1. I’m afraid that I might injure myself if I exercise

   1   2   3   4

2. If I were to try to overcome it, my pain would increase

   1   2   3   4

3. My body is telling me I have something dangerously wrong

   1   2   3   4

4. My pain would probably be relieved if I were to exercise

   1   2   3   4

5. People aren’t taking my medical condition seriously enough

   1   2   3   4

6. My accident has put my body at risk for the rest of my life

   1   2   3   4

7. Pain always means I have injured my body

   1   2   3   4
8. Just because something aggravates my pain does not mean it is dangerous
   1 2 3 4

9. I’m afraid I might injure myself accidentally
   1 2 3 4

10. Simply being careful that I do not make any unnecessary movements is the safest thing I can do to prevent my pain from worsening
   1 2 3 4

11. I wouldn’t have this much pain if there weren’t something potentially dangerous going on in my body
   1 2 3 4

12. Although my condition is painful, I would be better off if I were physically active
   1 2 3 4

13. Pain lets me know when to stop exercising so I don’t injure myself
   1 2 3 4

14. It’s really not safe for a person with a condition like mine to be physically active
   1 2 3 4

15. I can’t do all the things normal people do because it’s too easy for me to get injured
   1 2 3 4

16. Even though something is causing me lots of pain, I don’t think its actually dangerous
   1 2 3 4

17. No one should have to exercise when he/she is in pain
   1 2 3
Sensation Seeking Scale

Directions: Each of the items below contains two choices, A and B. Please circle the letter of the choice which most describes your likes or the way you feel. In some cases you may find items in which both choices describe your likes or feelings. Please choose the one which better describes your likes or feelings. In some cases you may find items in which you do not like either choice. In these cases mark the choice you dislike least. Do not leave any items blank.

It is important you respond to all items with only one choice, A or B. We are interested only in your likes or feelings, not in how others feel about these things or how one is supposed to feel. There are not right or wrong answers as in other kinds of tests. Be frank and give your honest appraisal of yourself. All answers will be kept confidential and your name will not be associated with your responses. You do not need to answer any question you feel uncomfortable answering.

1. A I like "wild" uninhibited parties.  
   B I prefer quiet parties with good conversation.

2. A There are some movies I enjoy seeing a second or even a third time.  
   B I can't stand watching a movie I've seen before.

3. A I often wish I could be a mountain climber.  
   B I can't understand people who risk their necks climbing mountains.

4. A I dislike all body odors.  
   B I like some of the earthy body smells.

5. A I get bored seeing the same old faces.  
   B I like the comfortable familiarity of everyday friends.

6. A I like to explore a strange city or section of town by myself, even if it means getting lost.  
   B I prefer a guide when I am in a place I don't know well.

7. A I dislike people who do or say things just to shock or upset other people.  
   B When you can predict almost everything a person will do and say he or she must be a bore.

8. A I usually don't enjoy a movie or a play where I can predict what will happen in advance.  
   B I don't mind watching a movie or play where I can predict what will happen in advance.

9. A I have tried marijuana or would like to.  
   B I would never smoke marijuana.
10. A I would not like to try any drug which might produce strange and dangerous effects on me.
B I would like to try some of the new drugs that produce hallucinations.

11. A A sensible person avoids activities that are dangerous.
B I sometimes like to do things that are a little frightening.

12. A I dislike “swingers” (people who are uninhibited and free about sex).
B I enjoy the company of real “swingers.”

13. A I find that stimulants make me uncomfortable.
B I often like to get high (drinking liquor or smoking marijuana).

14. A I order the dishes with which I am familiar, so as to avoid disappointment and unpleasantness.
B I like to try new foods that I have never tasted before.

15. A Looking at someone’s home movies, travel slides, or home videos bores me tremendously.
B I enjoy looking at home movies, travel slides, or home videos.

16. A I would not like to take up water-skiing.
B I would like to take up the sport of water-skiing.

17. A I would not like to try surf-board riding.
B I would like to try surf-board riding.

18. A When I go on a trip I like to plan my route and timetable fairly carefully.
B I would like to take off on a trip with no pre-planned or definite routes, or timetable.

19. A I prefer the “down-to-earth” kinds of people as friends.
B I would like to make friends in some of the “far-out” groups like artists or “Punks.”

20. A I would not like to learn to fly an airplane.
B I would like to learn to fly an airplane.

21. A I prefer the surface of the water to the depths.
B I would like to go scuba diving.

22. A I stay away from anyone I suspect of being “gay” or “lesbian.”
B I would like to meet some persons who are homosexual (men or women).

23. A I would never want to try jumping out of a plane with or without a parachute.
B I would like to try parachute jumping.
24. A I prefer friends who are excitingly unpredictable.
    B I prefer friends who are reliable and predictable.

25. A I am not interested in experience for its own sake.
    B I like to have new and exciting experiences and sensations even if they are a little frightening, unconventional, or illegal.

26. A The essence of good art is in its clarity, symmetry of form and harmony of colors.
    B I often find beauty in the “clashing” colors and irregular forms of modern paintings.

27. A I enjoy spending time in the familiar surroundings of home.
    B I get very restless if I have to stay around home for any length of time.

28. A I like to dive off the high board.
    B I don’t like the feeling I get standing on the high board (or I don’t go near it at all).

29. A I like to date members of the opposite sex who are physically exciting.
    B I like to date members of the opposite sex who share my values.

30. A Heavy drinking usually ruins a party because some people get loud and boisterous.
    B Keeping the drinks full is the key to a good party.

31. A The worst social sin is to be rude.
    B The worst social sin is to be a bore.

32. A A person should have considerable sexual experience before marriage.
    B It’s better if two married persons begin their sexual experience with each other.

33. A Even if I had the money I would not care to associate with flighty rich persons in the “jet set.”
    B I could conceive of myself seeking pleasures around the world with the “jet set.”

34. A I like people who are sharp and witty even if they do sometimes insult others.
    B I dislike people who have their fun at the expense of hurting the feelings of others.

35. A There is altogether too much portrayal of sex in movies.
    B I enjoy watching many of the “sexy” scenes in the movies.

36. A I feel best after taking a couple of drinks.
    B Something is wrong with people who need liquor to feel good.
37. A People should dress according to some standards of taste, neatness, and style.
   B People should dress in individual ways even if the effects are sometimes strange.

38. A Sailing long distances in small sailing crafts is foolhardy.
   B I would like to sail a long distance in a small but seaworthy sailing craft.

39. A I have no patience with dull or boring persons.
   B I find something interesting in almost every person I talk with.

40. A Skiing fast down a high mountain slope is a good way to end up on crutches.
   B I think I would enjoy the sensations of skiing very fast down a high mountain slope.
Appendix G

FUNCTIONAL HOP TEST REPORTING FORM
**Functional Hopping Test**

Limb Tested:  Right    Left  
Is this the dominant or non- dominant limb:  Non-dominant    Dominant

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Appendix H

IRB LETTER
DATE: February 24, 2014

TO: Kelly McGuire

FROM: University of Delaware IRB

STUDY TITLE: [523585-2] The Relationship between Personality, Knee Braces and Knee Stiffness after Anterior Cruciate Ligament Reconstruction

SUBMISSION TYPE: Amendment/Modification

ACTION: APPROVED

APPROVAL DATE: February 24, 2014

EXPIRATION DATE: November 25, 2014

REVIEW TYPE: Expedited Review

Thank you for your submission of Amendment/Modification materials for this research study. The University of Delaware IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a study design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the study and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the study via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this office prior to initiation. Please use the appropriate revision forms for this procedure.

All SERIOUS and UNEXPECTED adverse events must be reported to this office. Please use the appropriate adverse event forms for this procedure. All sponsor reporting requirements should also be followed.

Please report all NON-COMPLIANCE issues or COMPLAINTS regarding this study to this office.

Please note that all research records must be retained for a minimum of three years.

Based on the risks, this project requires Continuing Review by this office on an annual basis. Please use the appropriate renewal forms for this procedure.
If you have any questions, please contact Nicole Farnese-McFarlane at (302) 831-1119 or nicolefm@udel.edu. Please include your study title and reference number in all correspondence with this office.