THE RELATIONSHIP BETWEEN PERSONALITY AND FUNCTIONAL ABILITY FOLLOWING ANTERIOR CRUCIATE LIGAMENT INJURY

by

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ABSTRACT

Anterior cruciate ligament (ACL) injury occurs often, and nearly 70 percent of the time from a non-contact mechanism. Certain neuropsychological characteristics and changes in cerebral cortex activation have been linked to this mechanism. Personality may contribute to risk of non-contact injury and restoration of function. This emerging area of research may disclose new results that compliment current rehabilitation given the central nervous system's ability to undergo plastic changes. The purpose of this study was to evaluate the constructs locus of control (LOC), grit, mental toughness, sensation seeking, and kinesiophobia in ACL deficient (ACLD) and healthy subjects. Twenty-one healthy controls and seven individuals who suffered non-contact ACL injury participated in this study. Injuries were sustained during physical activity approximately 42 days prior to participation. Each subject completed the Multidimensional Health Locus of Control (MHLC), Grit Scale, Mental Toughness 18-Item Questionnaire (MT18), Sensation Seeking Scale-V (SSS-V), and Tampa Scale of Kinesiophobia (TSK). The ACLD subjects additionally reported the number of incidences of "giving way" and completed the Knee Outcome Survey-Activities of Daily Living (KOS-ADL) and the global rating of knee function to be classified as potential copers or non-copers. Independent samples t-tests were used to determine construct differences between the ACLD and healthy subjects. There was significantly greater sensation seeking in the ACLD group ($p = .017$).

Although not significant, the ACLD subjects displayed more internal LOC than the healthy subjects (30.17±3.06, 26.95±4.47, respectively, $p = .113$) and less external LOC attributed to powerful others (14.00±4.82, 17.76±4.58, respectively, $p = .091$). The expression of more sensation seeking and internal LOC may permit choices whereby more risk is deemed acceptable and this may create more chances for injurious events. On the contrary, externalists are more responsive to stress which may predispose them to injury because heightened arousal can alter motor output. Fear was related to the number of episodes of "giving way" ($r = .67$). Moments of instability may contribute to being more fearful, which may impede rehabilitation. This research suggests psychological constructs such as sensation seeking, LOC, and fear may contribute to the dynamic restraint mechanism and functional outcome of ACLD patients.

Chapter 1

INTRODUCTION

Forty-seven percent of knee ligament sprains involve the anterior cruciate ligament (ACL), and a majority result from a non-contact mechanism of injury.[1, 2] Between 72 and 95 percent of ACL injuries are attributed to a non-contact mechanism in which there is no player-to-player contact.[1, 3] Neuropsychological deficits have been identified in athletes prior to non-contact ACL injuries, and changes in cortical activation are present in the ACL deficient (ACLD) and ACL reconstructed populations.[1, 4-6] This suggests that the central nervous system (CNS) has an important role in controlling dynamic restraint in those who sustain a non-contact ACL injury. Some patients are able to cope with this injury using CNS strategies that promote dynamic restraint, yet others have difficulty returning to their previous level of functional activity.[2] Return to play rates reported in the literature range from 14% to 57.5% in the ACLD population, which indicates that more than 43% do not resume their pre-injury activity level.[2] Pre-injury, or previous level of activity, refers to resuming the same sport and the same level of competition that the individual participated in prior to injuring the ACL.[7] There is limited data exploring behavior via cognitive function and personality that may help determine predisposition to non-contact injury and this area of research may reveal promising new

results that compliment current rehabilitation efforts given the CNS's ability to undergo plastic changes.

During pre-season testing, Swanik et al.[1] found that intercollegiate athletes, playing a variety of sports, who went on to suffer non-contact ACL injury had displayed decreased performance on neuropsychological tests evaluating cognitive functioning and impairments. Neuropsychological characteristics, including memory, processing speed, and reaction time, play an important role in coordination, suggesting that when these are diminished some athletes may be predisposed to non-contact injury.[1] Decreased reaction times commonly occur when memory and fine motor tasks occur in conjunction with walking or auditory stimuli.[1, 8] Distracted driving is a common example of decreased reaction time and poor performance.[1] Similarly, executing complex athletic motor programs in a changing environment can decrease reaction time and processing speed.[1] Musculoskeletal performance can be impaired by exposure to an acute stressor leading to activation of the arousal response.[9, 10] Heightened physiological arousal and moments of uncertainty or hesitation reduce muscle activity and alter dynamic restraint capabilities which increases vulnerability to musculoskeletal injury.[1, 9] Decreased visual and verbal memory is also related to faulty coordination.[1] Athletes with decreased visual attention may struggle to sort and identify important incoming visual stimuli and redirect attention.[1] Known as decreased visual spatial awareness, this disorientation interrupts execution of motor programs leading to uncoordinated movement.[1]

CNS changes in cerebral cortex activity have also been found to accompany ACL injury.[4-6] ACL sprains result in deafferentation of ligamentous and capsular

mechanoreceptors, which disturbs the sensorimotor system and results in modified behavior.[4, 6, 11, 12] Mechanoreceptors are the first component of the sensorimotor system and convey afferent information to the CNS, which responds with an appropriate efferent signal.[4] Altered afferent information due to mechanoreceptor damage sustained at the time of injury leads to changes in cortical processing and efferent signaling as a result.[4, 12] The lack of afferent information from the periphery compromises CNS organization and requires compensatory strategies to carry out behaviors.[12] As a result, additional focused attention and neuropsychological involvement are necessary to successfully execute tasks.[4, 5] Research has found cortical activation increases in the areas responsible for movement preparation, recognition of movement, and detection of painful stimuli after ACL injury.[6] Following ACL reconstruction, increased frontal lobe activity is present during joint reposition and force reproduction tasks because the tasks appear more complex.[4, 5] These altered neural characteristics may influence functional ability without the ACL. Functionally coping with ACL rupture refers to the development of altered dynamic restraint strategies that allow athletes to return to pre-injury activity without experiencing instability or re-injury. This differs from psychological coping, or conscious cognitive and behavioral efforts used to manage injury as a stressful situation.[13]

Personality is one subset of the neuropsychology field that has received little research in regard to non-contact injuries. Neuropsychology explores the relationship between brain functioning and behavior, including motor behaviors needed to dynamically stabilize joints during physical activity. Complex psychological concepts such as motivation, personality, anxiety, or intelligence are referred to as constructs.

Other researchers have begun to consider the psychological effects of ACL reconstruction on returning to sport and have collected data using the Psychovitality Questionnaire and the ACL Return to Sport Index, for example.[14-19] Research has yet to explore constructs, including kinesiophobia, locus of control (LOC), grit, mental toughness, and sensation seeking in the ACLD population. Further exploration of these constructs may indicate a predisposition for non-contact injury and may allow for optimal mental preparation to facilitate return to play with concurrent re-injury risk reduction.[14-18]

The importance of researching constructs is evident when athletes appear to perform well on objective laboratory measures of function, but remain physically incapable of performing sport specific activities.[20] Physicians, athletic trainers, and physical therapists describe anecdotal evidence of patients with little confidence for returning to competition, despite restored objective and subjective stability in the affected knee joint.[14] This suggests that factors other than knee function affect return to pre-injury levels of physical activity.[7] Psychological constructs may contribute to the discrepancy between objective and subjective performance.[18] Posttraumatic reactions, including intrusive thoughts and avoidance behaviors, are known to occur following injury, and these emotions may be prolonged despite physically recovering, or may be triggered upon return to activity.[21, 22] For instance, ACLD individuals who perceive many functional limitations may have lower tolerance for stressors associated with the rehabilitation and return to play experience.[23, 24] Interpretations of these experiences can contribute to increased fear, catastrophizing, or any other less than ideal psychological response to injury.[19] Addressing these experiences during rehabilitation, or with a sport

psychologist, may facilitate successful return of physically and mentally prepared individuals. Resuming functional activity is not only important to team competition, but also for healthy growth and development that decreases susceptibility to illness and optimizes recuperation and quality of life.

Previous research concerning constructs and function following ACL injury has been limited to kinesiophobia in the ACL reconstructed population. Kinesiophobia is the fear of physical movement due to vulnerable feelings toward pain and/or re-injury which results in avoiding functional activities perceived as threatening and underestimating physical abilities.[14-18] Fear of re-injury is the most common reason for reducing or ceasing activity post-reconstruction, and ACL reconstructed individuals who do not resume pre-injury activity express more kinesiophobia on the Tampa Scale of Kinesiophobia (TSK) than those who return to pre-injury function.[7, 14, 18] Investigation of kinesiophobia in the ACLD population is warranted because fear may contribute to the re-occurrence of secondary non-contact injuries or inhibit ACLD individuals from returning to full activity.[7] Feeling vulnerable may result in hesitations during activity, which modifies muscle activity and alters the normal dynamic restraint mechanism necessary for preserving joint stability.[1] The influence of this construct on physical capabilities supports the hypothesis that others may contribute to modified behavior as well. What is not known is how locus of control (LOC) contributes to physical ability.

LOC is the extent to which results of behavior are perceived as under personal control, under the control of powerful others, or due to chance.[23, 25] The perception of personally being in control of outcomes is referred to as internal LOC, while perceiving

outcomes in the hands of powerful others or due to chance is known as external LOC.[23, 25] Perceived personal control is important to physical and psychological health.[26] ACLD patients with an internal LOC who are preparing for ACL reconstruction have fewer perceived functional limitations and report significantly better surgical outcomes compared to externalists.[23, 27] LOC may similarly influence function in the ACLD population. Perseverance may also play a role in performance and so the personality construct known as grit should be researched in this population.

Grit is a relatively new construct that measures dedication to and passion for a goal that is pursued over a long period of time, despite adversity. Previous research indicates that grit is a predictor of success in competitive environments.[28] Grit has primarily been researched in relation to education and military accomplishments. However, it may be important to managing adversity and hardiness that are characteristic of physical activity. Physical activity is a long term commitment that requires perseverance and expression of grit may be influential to level of competition or resiliency to be able to overcome injury and remain active. This study expands the grit literature base by investigating the construct in a physically active environment in the face of psychological distress. Mental toughness is another construct that may allow athletes to overcome psychological distress and maintain a high level of competition.

Mental toughness can be defined by the four C's – control, commitment, challenge, and confidence.[29] Control is defined by feeling and acting influential.[29] Commitment refers to the tendency to engage in the surrounding environment, as opposed to becoming alienated, and challenge refers to the belief that life is changeable

and that change is an opportunity, not a threat.[29] Confidence is a high sense of self belief.[29] These personal beliefs influence approach, response, and appraisal of adversity, or unexpected and challenging situations, in order to perform exceptionally.[30] The theory associating mental toughness, risk taking, and rehabilitation adherence has already been proposed in research. It suggests that mentally tough individuals may take unnecessary risks and experience non-contact injury, but have the psychological resources necessary to recover from such injury. Similarly, sensation seekers may have the resources to successfully perform.

Sensation seeking is also related to risk taking and is an individualized level of optimal arousal.[31] The risk-taking hypothesis purports that high sensation seekers engage in risky behavior for the purpose of experiencing arousal, which may concurrently expose their bodies to undue risk possibly resulting in injury.[31] The competing hypothesis, known as the stress buffering hypothesis, contends that high sensation seekers can tolerate greater amounts of arousal because they are equipped with more resources to effectively manage this feeling.[31] This hypothesis suggests that high sensation seekers are capable of navigating the complex athletic environment without sustaining non-contact injury.[31]

The purpose of this study was to evaluate the five constructs in ACLD and healthy individuals. A functional assessment tool was used to identify ACLD potential copers and non-copers, and based on this tool the researchers hypothesized that (1) potential copers would report fewer incidences of "giving way" and perform better on the Knee Outcome Survey-Activities of Daily Living (KOS-ADL) and global rating of knee

function compared to non-copers. This research was designed to test the hypotheses that (2a) non-copers express more external LOC and (2b) more kinesiophobia than potential copers and control subjects, that (2c) potential copers are grittier and (2d) have more mental toughness than non-copers and control subjects, and that (2e) non-copers have fewer sensation seeking behaviors than potential copers and control subjects. The researchers long term aim is to develop a regression analysis capable of predicting functional ability in the ACLD population and hypothesize that (3) an internal LOC, a low expression of kinesiophobia, and a high expression of grit, mental toughness, and sensation seeking indicate the ability to resume activity prior to surgical intervention.

Chapter 2

METHODS

2.1 Participants

Twenty-eight male (N = 15) and female (N = 13) volunteers within the range of 18-45 years of age (M = 22.14, SD = 5.67) were recruited from the University of Delaware population and surrounding orthopedic offices. The control group (N = 21) was composed of healthy participants who had no history of knee injury and who were physically active at least three days per week. Twenty of the healthy subjects were right leg dominant and one was left leg dominant. Subjects who had sustained an ACL injury in the previous 6 months comprised the experimental group (N = 6). Subjects with concomitant, asymptomatic knee injury were included if they were able to function without pain or effusion. This is similar to other research concerning the ACLD population.[32] One injured subject was excluded from the experimental group because the ACL in the injured knee had previously been reconstructed. These subjects were informed of the research by their orthopedic surgeon along with an informational brochure and completed a permission to contact form if they were willing to participate (Appendix A). The subject was eligible for participation when edema resolved, range of motion was restored, and the subject was able to hop on the involved limb.[32, 33] The injured subjects were physically active at least three days per week pre-injury so that the

goal of returning to physical activity was consistent across groups. All of the ACLD subjects were right leg dominant. Four subjects had injured their right leg and two had injured their left leg. All injuries were the result of a non-contact mechanism and occurred during physical activity (soccer, football, skiing, conditioning). One ACLD subject was classified as a potential coper and the others were classified as non-copers based on a functional assessment tool. All subjects completed the informed consent process (UDIRB# 319746-4) (Appendix B) approved by the University of Delaware Institutional Review Board. Participants were asked to complete the Physical Activity Readiness Questionnaire (PAR-Q) (Appendix C).

2.2 Inventories (Appendix D)

2.2.1 Multidimensional Health Locus of Control (MHLC)[34]

The MHLC measures control over health status.[34] The MHLC is an 18-item self-assessment that contains three subscales: internal, powerful others, and chance. Ratings are made on a 6-point Likert scale, with responses ranging from *1 = strongly disagree* to *6 = strongly agree*. A higher score on any of the three subscales indicates a stronger perception of health outcomes being controlled by the self, powerful others, or chance, respectively. The psychometric properties of the MHLC have been supported in previous research.[34] The three subscales are independent of one another.[35] Test-retest reliability coefficients demonstrate respectable stability, with values ranging from .66 to .73 for the three subscales. Internal consistency has also been established with Cronbach alpha values ranging from .66 to .73 for the internal subscale, .56 to .75 for the powerful others subscale, and .55 to .83 for the chance subscale.[36]

2.2.2 Grit Scale[28, 37, 38]

The Grit Scale is a 17-item self-report questionnaire that measures grit. Ratings are made on a 5-point Likert scale and responses range from *"Very much like me"* to *"Not like me at all."* Grit is measured by assigning numerical values to the Likert scale responses and calculating the average score for specified items. A higher score indicates the expression of more grit. The Grit Scale is comprised of five subscales that have been shown to be reliable: Grit (α = .81), Consistency of Interest (α = .81), Perseverance of Effort (α = .70), Brief Grit (α = .78), and Ambition (α = .69).[28] Previous research regarding the Grit Scale has established evidence of psychometric soundness, face validity for adolescents and adults with pursuits in various domains, low likelihood of ceiling effects in high-achieving populations, and precise fit with the construct of grit.[28]

2.2.3 Mental Toughness 18-Item Questionnaire (MT18)[39]

The MT18 is a measure of mental toughness based on the 4 C's approach.[38] Ratings on the MT18 are made on a 5-point Likert scale ranging from *1 = strongly disagree* to *5 = strongly agree* and the score is calculated by adding the values for each item. A higher score indicates expression of more mental toughness. Previous research provides evidence for the validity and reliability of the MT18.[29]

2.2.4 Sensation Seeking Scale-V (SSS-V)[40]

The SSS-V is a 40 item forced-response questionnaire used to measure sensation seeking. The assessment tool is composed of four subscales: Thrill and Adventure Seeking, Disinhibition, Experience Seeking, and Boredom Susceptibility. Scale scores are calculated by summing the respective questionnaire items and the sum of the four

scale scores results in the total score. A higher score indicates more sensation seeking tendencies. The SSS-V has shown good psychometric properties and moderate reliability, $\alpha = .75$.[41]

2.2.5 Tampa Scale of Kinesiophobia (TSK)[42]

The TSK consists of 17 statements that are rated on a 4-point Likert scale ranging from *1 = strongly disagree* to *4 = strongly agree*. A higher score on the TSK indicates more fear. Previous research suggests that the TSK is reliable (Cronbach's alpha .77 to .81) and valid in populations with acute and chronic musculoskeletal pain.[14]

2.3 Functional Assessment Tool (Appendix E)

Each ACLD subject was classified as a potential coper or non-coper based on a functional assessment tool that has been used in previous research.[32, 33, 43-45] This consisted of a self-report of the number of incidences of "giving way" experienced since the initial injury, the Knee Outcome Survey-Activities of Daily Living (KOS-ADL), and the global rating of knee function measured via visual analog scale.[33] Significant differences have been found between copers and non-copers on the KOS-ADL and on the global rating of knee function.[2] This suggests that the combination of reported incidences of "giving way", the KOS-ADL, and the global rating of knee function should distinguish copers from non-copers.[2] These variables, in addition to the six-meter timed hop task, best correlate with group assignment, accounting for 72% of the variance (R^2=0.72).[33]

The six-meter timed hop task was optional in this study because research disagrees if this task can effectively categorize ACLD individuals.[2, 32] Herrington and Fowler[2] completed a systematic review to identify the best measurement tool to

distinguish copers and non-copers and found that 60 percent of participants in one study refused to execute a single hop, primarily reporting fear as the reason for not hopping. Another study found no significant difference between ACLD groups on any single-leg hop test, suggesting that it is not an effective means of identifying copers and non-copers.[32] In fact, researchers do not even consider hop performance a reliable criterion for safe return to sport because both true copers and non-copers have been shown to perform better than 90 percent on single-leg hop tests.[32]

Subjects meeting the following criteria were classified as potential copers: no more than one episode of "giving way" since injury, KOS-ADL score of 80 percent or greater, and global rating of knee function score of 60 percent or greater.[32, 33] Subjects who failed to meet these guidelines were classified as non-copers.

2.3.1 Six-meter Timed Hop Test

If the subject elected to perform the timed hop test, this test was performed first so that the subject could realistically self-evaluate his/her function during a physically demanding task on the subsequent self-report measures.[33] A cloth tape measure was securely adhered to the floor to measure hop distance, and a start and a finish line were marked on the floor six meters apart. The subject began with their toes behind the start line and was instructed to hop as fast as he/she felt safe. Each trial began with a verbal cue and ended when the subject crossed the finish line, six meters away. Time was kept with a manual stopwatch. The hop test was performed bilaterally and the subject had to demonstrate a controlled landing for the trial to be considered successful and the score recorded. The average of the two recorded trial scores was used for analysis. The score

was calculated by dividing the time for the uninjured extremity by that of the injured extremity.[32]

2.3.2 Incidences of "Giving way"

Subjects were asked to report the number of incidences of "giving way" they have experienced since the initial "giving way" at the time of injury. An episode of "giving way" was explained to the subject as a perceived subluxation event of the knee when the knee felt unstable or loose or the subject experienced pain or effusion.[32]

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

The KOS-ADL is a14-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.[45] The score on the KOS-ADL was calculated by adding the values for each question and dividing by 70, the total possible number of points, and multiplying by 100 in order to express the score as a percentage.[32]

2.3.4 Global Rating of Knee Function

The global rating of knee function allows subjects 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 were labeled zero and 100. The subject marked a vertical line on the horizontal line to express their perceived level of function.[32]

2.4 Procedure

Subjects were asked to report to the Human Performance Lab for one testing session lasting approximately 30 minutes. Upon arrival, subjects completed the informed

consent document and the PAR-Q as previously described. Each subject also completed a demographic questionnaire (Appendix F). The subject was then asked to complete the five self-response inventories, MHLC, Grit Scale, MT18, SSS-V, and TSK, as described earlier. Subjects were encouraged to complete each inventory to the best of their ability in order to most accurately reflect their feelings.

The ACLD subject was then 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 response was "yes," then the subject rode a stationary bicycle for five minutes and put on the supplied off-the-shelf DonJoy knee brace (OA FullForce Knee Brace, Vista, CA) to perform the six-meter timed hop test. The subject first performed a single-leg hop on the injured leg at a self-selected level of effort, and then at maximum ability to become acquainted with hopping. This was followed by two practice trials of the six-meter timed hop test, and then two recorded trials of the timed hop task. Practice and recorded trials were performed on the uninjured leg first, then on the injured leg. If the subject responded "no," to the question, then he/she did not ride the stationary bicycle or perform the hop task. The injured subject lastly reported the number of incidences of "giving way" he/she has experienced since injury and completed the KOS-ADL in addition to the global rating of knee function.

After completing the inventories, the control subjects rode a stationary bicycle for five minutes and afterward put an off-the-shelf DonJoy knee brace (OA FullForce Knee Brace, Vista, CA) on their non-dominant leg. This was done so that the healthy subjects experienced the same external sensory stimuli provided by the knee brace as the injured

subjects who were required to wear the brace for safety. Applying the knee brace to the healthy non-dominant limb was the best equivalent to applying the brace to an ACLD limb. None of the ACLD or control subjects had previous experience wearing a knee brace. The healthy subjects were instructed to perform the six-meter timed hop test in the same manner as those without an ACL. The subject performed a single-leg hop on the non-dominant leg at a self-selected level of effort, and then at maximum ability. This was followed by two practice trials of the six-meter timed hop test, and then two recorded trials of the timed hop task. Practice and recorded trials were performed on the dominant leg first, then on the non-dominant leg.

2.5 Statistical Analysis

For all statistical analyses, significance was set at $p < .05$. A large amount of information was calculated and transferred from standardized inventories to an electronic database so the accuracy of the data was verified. Accuracy of the demographic variables was reviewed for each subject weeks after being entered into the database. Item responses from the standardized inventories were calculated two different times by the primary investigator to verify correctness. All statistical analyses were performed using SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp). Independent samples t-tests were used to determine differences in demographics between groups and as the primary statistical analysis to determine differences in the five constructs between the ACLD and healthy samples. Pearson's correlation coefficient was conducted to explore the relationship between fear and physical ability in the ACLD sample.

Chapter 3

RESULTS

Statistics for demographics are provided in Table 3.1. Ages of healthy and injured subjects ranged from 18 to 42 years old and there was a statistically significant difference in age between the two groups ($p = .014$). There was no significant difference between the number of healthy and ACLD males and females ($p = .553$). The groups did not significantly differ in height ($p = .246$) or weight ($p = .205$).

Table 3.1. Demographic Statistics

	Healthy (N = 21)	ACLD (N = 6)	*p*-value
Males	11	4	
Females	10	2	
Age (yrs)	20.8±2.6	27.2±10.4	.014*
Height (in)	67.2±3.3	69.2±4.5	.246
Weight (lbs)	154.1±23.1	169.2±31.2	.205

*Significant at the *p*-value < .05. Mean ± SD.

Means and standard deviations for the five personality inventories are provided in Table 3.2. The ACLD subjects expressed significantly greater sensation seeking qualities (p = .017) and this represented a large effect size d = .96. Figure 3.1 compares mean scores on the Sensation Seeking Scale-V between groups. Although not significant, the ACLD subjects displayed more internal locus of control (LOC) than the healthy subjects (p = .113) and scored lower on the Multidimensional Health Locus of Control (MHLC) powerful others subscale (p = .091). Figure 3.2 compares mean scores on the MHLC internal and powerful others subscales between groups.

Table 3.2. Personality Inventory Statistics

	Healthy (N = 21)	ACLD (N = 6)	p-value	Power (1- β err prob)	Total sample size to achieve $p < .05$
MHLC-I	27.0±4.5	30.2±3.1	.113	.42	76
MHLC-C	17.2±3.7	18.0±3.8	.644	.07	1,124
MHLC-PO	17.8±4.6	14.0±4.8	.091	.38	84
Grit Scale	3.8±0.2	3.8±0.4	.844	.06	4,422
MT 18	59.3±3.9	60.0±2.2	.693	.07	1,152
TSK	32.7±6.2	32.4±7.3	.926	.05	26,564
SSS -V	17.0±3.8	22.5±7.2	.017*	.52	

*Significant at the p-value < .05. Mean ± SD. MHLC-I: Multidimensional Health Locus of Control internal subscale, MHLC-C: Multidimensional Health Locus of Control chance subscale, MHLC-PO: Multidimensional Health Locus of Control powerful others subscale, MT18: Mental Toughness 18-Item Questionnaire, TSK: Tampa Scale of Kinesiophobia, SSS-V: Sensation Seeking Scale-V.

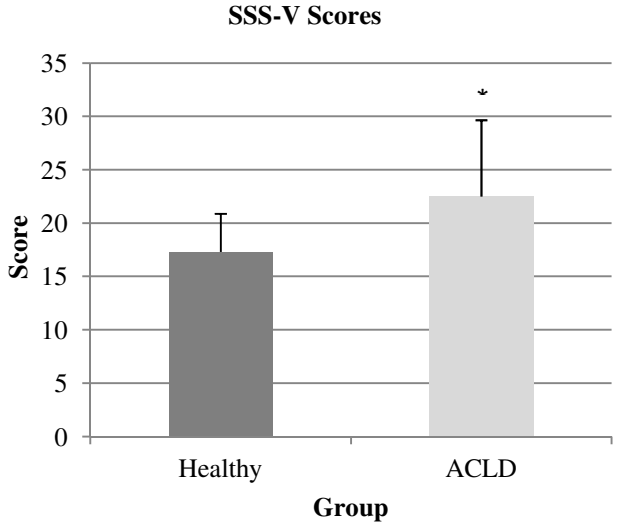

Figure 3.1. Mean Sensation Seeking Scale-V (SSS-V) scores for healthy and ACLD subjects. * indicates significance at $p < .05$. Error bars represent standard deviation.

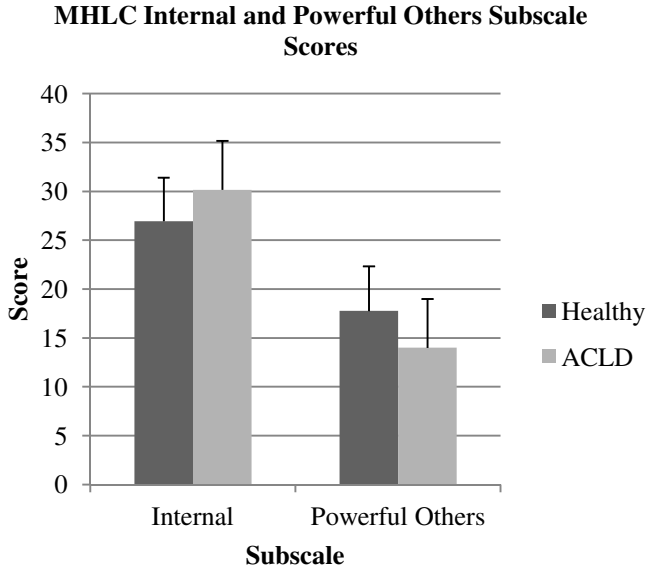

Figure 3.2. Mean Multidimensional Health Locus of Control (MHLC) internal and powerful others subscale scores for healthy and ACLD subjects. Error bars represent standard deviation.

The mean scores for locus of control (LOC), grit, and sensation seeking displayed by the control subjects were similar to the normative values for adults reported in the literature. The mean scores on the Multidimensional Health Locus of Control (MHLC), Grit Scale, and Sensation Seeking Scale-V (SSS-V) from this sample and the published norms are provided in Table 3.3. The fact that the scores reported by control subjects reflect those collected in other studies indicates that the methodology used in this study was appropriate and valid.[28, 46, 47] This finding is important to continue the current line of research and indicates that the data is suitable for comparison to those scores recorded by the ACLD sample.

Table 3.3. Control Subject Mean Scores Compared to Published Norms

	Literature		Sample	
	N	Mean ± SD	N	Mean ± SD
MHLC-I	1,287	25.6[46]	21	27.0±4.5
MHLC-C	1,287	16.2[46]	21	17.2±3.7
MHLC-PO	1,287	19.6[46]	21	17.8±4.6
Grit Scale	1,545	3.7±0.7[28]	21	3.8±0.3
SSS-V	25	22.6±5.5[47]	21	17.0±3.8

Mean ± SD. MHLC-I: Multidimensional Health Locus of Control internal subscale, MHLC-C: Multidimensional Health Locus of Control chance subscale, MHLC-PO: Multidimensional Health Locus of Control powerful others subscale, SSS-V: Sensation Seeking Scale-V.

Five of the ACLD subjects were considered non-copers. These subjects scored between 59 and 94 on the Knee Outcome Survey-Activities of Daily Living (KOS-ADL). On the global rating of knee function, the non-copers rated their perceived function as 25 to 85 percent compared to their pre-injury ability. These subjects reported between two and 10 episodes of "giving way," an average of 4.17 episodes since that at the time of injury. The average number of days from injury to participation in this study was 42.83 days. Fear was related to the number of episodes of "giving way," and the most fearful ACLD subjects reported experiencing the most moments of instability ($r = .67$). Figure 3.3 depicts the relationship between reported number of incidences of "giving way" and expression of fear on the TSK. None of the non-copers performed the timed six-meter hop test. Three of the five non-copers believed that they would be able to single-leg hop six meters; however they did not consent to physically perform the test. Two non-copers did not believe that they could successfully perform consecutive single-leg hops. One of the ACLD subjects was considered a coper. This subject scored an 87 on the KOS-ADL, rated his/her perceived function as 60 percent compared to his/her ability prior to injury on the global rating of knee function, and reported no episodes of "giving way" since that experienced at the time of injury. The coper in this sample believed that he/she would be able to single-leg hop six meters but did not consent to physically perform the test. Statistics for the functional assessment of all six ACLD subjects are provided in Table 3.4.

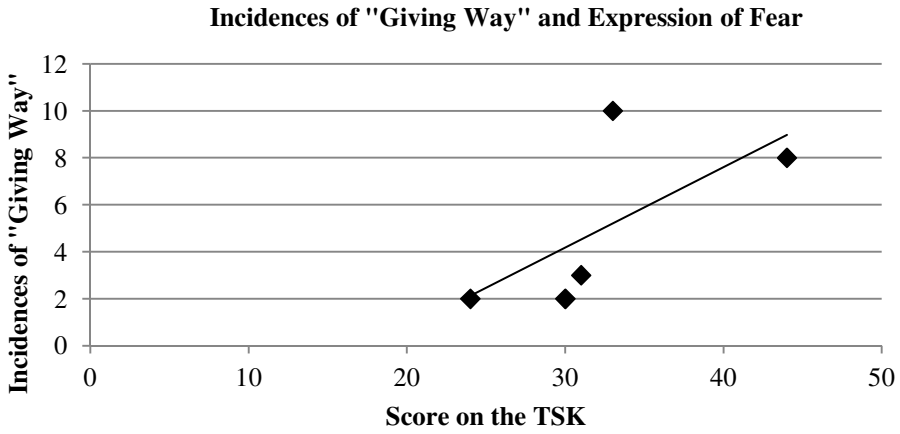

Figure 3.3. The relationship between the number of incidences of "giving way" since injury and expression of fear on the TSK in the ACLD sample (r = .67).

Table 3.4. ACLD Functional Assessment Statistics

	Mean	SD
KOS-ADL	81.2	13.7
Global rating of knee function	60.0	22.1
Episodes of "giving way"	4.2	3.9

KOS-ADL: Knee Outcome Survey-Activities of Daily Living.

Chapter 4

DISCUSSION

The ACLD subjects in this study expressed significantly more sensation seeking than the healthy control subjects. Additionally the ACLD subjects displayed more internal LOC than the healthy subjects and less external LOC attributed to powerful others, although these differences were not statistically significant. Fear was related to the number of incidences of "giving way" experienced since injury. The athletic environment contains numerous risk factors that can increase stress and interrupt neuromuscular control necessary for proper dynamic restraint capabilities and joint stability.

Intrinsic and extrinsic factors can contribute to injury predisposition. Psychological characteristics, such as stress, inattention, distraction, and fatigue, are some intrinsic factors.[48] Extrinsic factors worth consideration are playing surface, weather, equipment, and aggression of opposing players, in addition to others.[49] Injuries are multifactorial and physiological distress imposed by any combination of these factors or others may disturb musculoskeletal function.[1, 9, 10] Increased stimulation or stress from the surrounding environment heightens arousal which can alter motor output.[9, 10] Personality constructs and perceptions of the surrounding environment influence decision making to possibly engage in risky situations and alter neuromuscular control.

Environments with many external risk factors for injury naturally create a predisposition for bodily harm.[49] The fact that the ACLD sample in this study expressed more sensation seeking suggests that these individuals believe that they can successfully navigate this complex environment. According to the stress-buffering hypothesis, high sensation seekers are able to tolerate more arousal because they possess the psychological resources to effectively manage these feelings.[31] For example, sensation seeking is related to lower levels of anxiety reactivity.[50] This means that situations involving danger cause minimal anxiety in high sensation seekers.[50] Research speculates that psychological coping resources may help high sensation seekers appropriately manage feelings of arousal in these situations.[31]

The stress-buffering hypothesis likely lies upon a continuum with the risk-taking hypothesis. On the latter end of the continuum, high sensation seekers may enter threatening environments because they want to engage in stimulating experiences.[31] For example, research has found that regular paragliders and opioid dependent users desire kinesthetic and autonomic sensation more than control subjects.[51] Injury can occur in either situation if the motor control strategies needed for dynamic joint stability are compromised.[1]

The potential coper in this sample expressed greater sensation seeking tendencies than the control subjects (18, $M = 17$, respectively) and this lends the most support to the stress buffering hypothesis. It is unlikely that high sensation seekers would be seeking intense levels of arousal soon after injury. On the contrary, potential copers' expression of sensation seeking may indicate that this population is equipped with more robust

psychological resources needed to cope with injury. Their sensation seeking tendencies continue to suggest that they are willing to engage in risky environments, but this may bode well for their outlook on rehabilitation and willingness to attempt returning to full activity.

The expression of more sensation seeking and a stronger belief that health is under personal control in the ACLD sample may permit choices whereby more risk is deemed acceptable. Over time this may create, on average, more chances for injurious events. The higher internal LOC mean score for the ACLD subjects implies that they view health as under their own personal control. Internalists may inadvertently expose themselves to threatening environments because their perception of health may inhibit them from perceiving danger. It may be that LOC internalists think they can accept any challenge because they perceive themselves as being in control of health outcomes. This perception may decrease the risks internalists perceive and result in them engaging in higher risk or threatening environments more frequently. Over time this behavior could jeopardize their ability to always maintain neuromuscular control and dynamic joint stability, ultimately predisposing them to injury.

The expression of more internal LOC by the ACLD subjects may contribute to their likelihood to play without restraint. Previous research showed that people respond to traumatic hand injuries differently based on how they perceive the event would impact their life, and it seems likely that this perception applies to any injury.[52] The literature suggests that individuals react to injuries in either adaptive, negative, or mixed manners.[22] Research concerning spinal cord injuries has found that those who are

adaptive to spinal cord injury have less external LOC than those who are less adaptive.[53] Individuals with this adaptive belief have also been shown to recover more quickly after knee surgery, possibly because they have fewer perceived functional limitations during rehabilitation.[23, 24] This finding extends beyond knee injuries, as other studies with different subject populations have also found that those with an internal LOC are more likely to display improved function and lower disability levels.[23]

The potential coper in this sample scored approximately two points less on the MHLC internal LOC subscale than the average score of the control subjects (25, M = 26.95, respectively). No baseline values were collected on the ACLD subjects so the researchers do not know the subjects' internal LOC prior to their injury. It is possible that having a high perception of being in control of health outcomes leads to ACLD individuals attempting to maintain activities of daily living consistent with their lifestyle pre-injury. Internal LOC has been associated with higher needs for achievement.[23] However, trying to maintain a pre-injury lifestyle may predispose injured individuals to experiencing more incidences of "giving way" and allow them to realistically appraise the degree to which they are functionally impaired, and this may lead to their classification as non-copers. There may be an ideal range of internal LOC that is represented by the control subjects, the normative values, and the potential coper. Research suggests that bi-locals, individuals with a combination of internal and external LOC, most efficiently handle stress and cope with disease.[54]

The ACLD subjects expressed less external control attributed to powerful others than those who were healthy, but they expressed more external control attributed to

chance factors, such as luck or fate. ACLD externalists may require rehabilitation program modifications, for example a slowed progression of activity, and/or may benefit from interacting with a sport psychologist to ensure functional improvement.[23] Predominant external LOC is not ideal because it indicates that health is not perceived as personally controllable.[27] External LOC attributed to chance factors is regarded as the least adaptive form of LOC and that attributed to powerful others is considered slightly more adaptive because at least the individual believes health is controlled by people.[27] The potential coper in the sample expressed more external LOC attributed to chance factors than the control subjects (21, $M = 17.19$, respectively). This may be because individuals who believe outcomes are predominately determined by luck or fate participate in physical activity without restraint. Externalists may believe that if they are meant to get hurt then they will become injured independent of their inherent athletic ability or physical actions. In addition, externalists are more vulnerable to external stimuli and therefore more responsive to stress.[55] This may predispose externalists to injury because heightened arousal can alter motor output.[1, 9, 10] The qualities of mental toughness have also been studied and may serve as a buffer to stress.

The 4 C's approach to mental toughness purports that mentally tough individuals display control, commitment, confidence, and challenge.[29] Challenge is representative of the belief that change is an opportunity and not a threat.[29] These aspects relate to hardiness and recent findings suggest that hardiness acts as a buffer to stress and may be related to improved performance.[29] Clough and colleagues have summarized the four qualities by saying that mentally tough individuals have "a high sense of self-belief and

an unshakable faith that they can control their own destiny."[13] This concept of control is similar to that characteristic of internal health LOC. The fact that the ACLD subjects expressed high internal LOC in regard to health suggests that they have adequate self-belief to become engaged in situations as opposed to feeling threatened by change or other external factors. This belief may extend beyond health outcomes and this may be why the ACLD and control subjects scored equally well on the Mental Toughness 18-Item Questionnaire (MT18).

Few studies to date have used the MT18 to quantify mental toughness. Most studies have interviewed subjects to better understand the development and maintenance of this construct, and those that have quantified mental toughness most commonly use the original, long version of this instrument, the Mental Toughness 48-Item Questionnaire.[30] Levy et al[29] did use the MT18 to quantify mental toughness in patients diagnosed with tendinitis and completing rehabilitation. Levy's study reported a large amount of variance (M = 50.44, SD = 13.32), possibly because some of the patients were competitive athletes while others were recreational athletes, and because the patients represented a large age range. The fact that Levy's sample was injured may explain why the control subjects in our study scored, on average, approximately 10 points higher (M = 59.33, SD = 3.88). There was less variance in the current sample and the scores were within one standard deviation of previous research. Individuals who have been in rehabilitation for a long duration may not maintain a high level of competitive spirit and this may contribute to a decline in mental toughness. The current sample had yet to experience the rigor of physical therapy or to be impaired for an extended amount of time. The potential coper in

this sample scored among the highest (61, control subjects $M = 59.33$) which suggests that mental toughness may be a factor following injury. A mentally tough ACLD patient may have the confidence and commitment to sustain rehabilitation and return to activity. Grit has been researched in academic and military settings; however it may be noteworthy during rehabilitation because it does intend to quantify commitment to a goal over time.

Grit is characterized by goal setting and the construct is long-term in nature. The true value of the Grit Scale may not have been achieved in this study because grit pertains to periods of time much greater than 42.83 days, the average number of days post-injury in this ACLD sample. The researchers expect grit to distinguish ACLD potential copers and non-copers, as opposed to differentiating healthy and injured people. However, this sample only included one potential coper and this did not provide the opportunity to explore a difference in grit between the two ACLD groups. As a result, all of the ACLD subjects expressed similar amounts of grit compared to the controls. Grit may become a more important factor to consider during rehabilitation, a long-term commitment that relies heavily on achieving goals.[28] Grit has not been thoroughly examined in an athletically inclined population and so future research should explore the construct in this injury and return to participation context. A repeated measures design conducted over the course of rehabilitation may indicate fluctuations in the expression of grit as patients face and overcome adversity. One reason that patients may not complete the rehabilitation process is fear of re-injury.

Participating in this study so soon after injury may also explain the expression of kinesiophobia. To date, this construct has been investigated post-reconstruction of the ACL. Medium- and long-term follow-up studies have found that kinesiophobia influences return to pre-injury activity level in some ACL reconstructed people.[14, 15, 17, 18] However, most subjects returning from reconstruction fear injury provoking situations, re-injury during competition, and environmental conditions the most.[7] Subjects in this study were instructed to complete the TSK based on their current feelings and so it is possible that when the subjects were completing the survey, approximately 42 days post-injury, they were not considering these circumstances because they are more pertinent during the return to play phase of rehabilitation, which may occur later. The ACLD subjects in this sample were far from returning to pre-injury activity. If the subject was not entertaining the thought of playing or the risks involved, then they may not have felt threatened or expressed fear. This is supported by research that has found that fear only significantly contributed to a regression model 181 to 372 days post-reconstruction, as opposed to earlier time periods.[16] Less fear, in the prior study, was associated with higher scores of perceived function on the International Knee Documentation Committee (IKDC).[16] This is supported by the fact that injured people who successfully return to activity express less fear than those who do not resume activity.[7, 14, 18] Interestingly, the ACLD subjects in this sample that expressed the most fear reported the most episodes of "giving way", and research has found that those who wait more than three months post-injury to undergo reconstructive surgery express more fear, possibly due to the instability and "giving way" experienced during this time.[7] Therefore, it is possible that the

numerous instances of "giving way" experienced by subjects in the current sample resulted in more fear. This may have contributed to the ACLD patient's unanimous unwillingness to perform the six-meter timed hop test. Fear of movement or re-injury can impede rehabilitation, and if proper function of the body's dynamic restraints is not properly restored there is an increased risk of subsequent injury.

One strength of this study was the use of a homogeneous sample. The sample was composed of adults and those in the ACLD group all experienced non-contact ACL injury. In addition, the study examined multiple psychosocial factors simultaneously. Previous research has indicated that the questionnaires that were used are valid and reliable.[14, 28, 29, 36, 41] There were several limiting factors in this study that need to be addressed in future research. This study was limited by a very small sample size. The sample size in addition to some insignificant results prevented development of a regression analysis capable of predicting physical ability. Data collection of this nature will continue in order to develop this innovative area of research. ACLD patients who chose not to participate in this research were not tracked so we do not know how they differ from those ACLD subjects who did participate. As a result, this sample could be considered one of convenience. All of the participants were at least recreationally active and all of the ACLD subjects suffered a non-contact injury while performing physical activity. Therefore, the generalizability of these findings to patients with differing amounts of athletic participation or exposure is limited and these findings cannot be generalized to patients who suffered a contact injury.

Neuropsychological data is lacking in sports medicine and orthopedic settings compared to inpatient care facilities.[23] Continuing research in this area is important to increase understanding of neuropsychological factors that may predispose the athletic population to non-contact injury. These factors may also play a role in explaining why some individuals can return to physical activity and why others cannot. The ACLD subjects in this study expressed significantly greater sensation seeking tendencies than the healthy subjects and large differences in mean scores and variances on other construct inventories further suggest that the two groups differ. These results provide a basis for further exploration into these personality constructs and other neuropsychological factors that may help explain non-contact injury and the subsequent return to activity.

Chapter 5

LITERATURE REVIEW

Unintentional injury is the leading cause of death among individuals younger than 44 years old and unintentional falls is the leading cause of nonfatal injuries treated in emergency departments, according to the National Center for Health Statistics.[56, 57] One type of unintentional injury results from a non-contact mechanism, which frequently occurs in sport and vigorous physical activities. The National Collegiate Athletic Association Injury Surveillance System collected injury and exposure data for 15 sports from 1988 to 2004.[58] Approximately 5,000 ACL injuries were reported across sports during this time and occurred most frequently in men's football and women's gymnastics, basketball, and soccer.[58] In the United States alone, approximately 250,000 ACL injuries occur annually.[59] More than seventy percent of ACL injuries result from a non-contact mechanism of injury.[1, 60] For example, 95 percent of 93 ACL injuries observed during two Norwegian team handball seasons and 71 percent of 100 ACL injuries sustained during American sport competition resulted from a non-contact mechanism.[61, 62]

Non-contact ACL injury commonly occurs during landing or cutting, soon after foot strike, when inadequate regulation of knee stiffness via muscular contractions exposes ligaments to excessive loads.[1, 3, 63] The knee is often near full extension at the

time of injury, and the predominant force is an anteriorly directed shear force on the tibia, according to cadaveric and biomechanical research.[3, 63] The ACL is the primary restraint to this anterior displacement of the tibia relative to the femur and is important to rotational stability of the knee.[64] The posterolateral bundle of the ACL is believed to be more important to stability because the in situ force absorbed by this bundle is greatest near full knee extension, when ACL injury commonly occurs.[3, 63, 65] The anteromedial bundle also carries the most load when the knee is past 30 degrees of flexion.[65] Excessive contraction of the quadriceps as the knee nears extension may contribute to non-contact ACL injury when the agonist hamstring muscles do not resist the load.[59, 60, 63] Contraction of the quadriceps generates tension in the patellar tendon, which results in anterior shear force on the proximal tibia.[63] Valgus force is commonly observed in conjunction with the anterior shear force; however this torque only stresses the ACL if the medial collateral ligament (MCL) is significantly injured.[63] For instance, in the case of a non-contact basketball injury, the knee valgus angle increased from 4 to 15 degrees in 30 milliseconds.[63] Neuromuscular control is the ability to produce controlled movements via coordinated muscle activation and is important for accurately anticipating and reacting to the physical demands of a rapidly changing environment without injury.[12, 65]

Ground reaction forces during maneuvers like deceleration, pivoting, or landing can exceed five times a person's body weight and responding to these excessive loads requires neuromuscular control strategies for dynamic joint stabilization.[1] This requires transformation of sensory information into muscle activation.[11] Mechanoreceptors are the beginning of the sensorimotor system and innervate cutaneous, capsuloligamentous, and

tenomuscular tissue.[6, 11] Ruffini endings, Pacini corpuscles, and Golgi-tendon organs, in conjunction with vestibular and visual receptors, provide the CNS with sensory information via afferent pathways.[6] The sensory information provided by mechanoreceptors concerning joint position is referred to as proprioception, or the ability to perceive movement, force, and joint position.[4] Joint position sense (JPS) is a component of proprioception that assesses the ability to reproduce joint angles.[4] Injury to the ACL leads to decreased proprioception due to a lack of mechanoreceptors.[12] ACLD individuals display a significantly higher mean threshold to detection of passive change in position in the injured knee than the healthy knee, unlike healthy controls with nearly identical threshold values compared bilaterally.[66] Proprioception in ACLD knees is more sensitive as the knee extends and at the end range of knee extension.[67] Specifically, the threshold to detect passive motion in the ACLD knee is significantly more sensitive moving into extension than flexion, and the threshold is significantly more sensitive moving into extension from a starting angle of 15 degrees compared to 45 degrees.[67] Motor programs in the CNS respond to afferent signals by producing a motor response, propagated along efferent pathways.[11] While laboratory tests suggest proprioception tests are sensory in nature, further examination suggests more extensive CNS processes are involved in the performance of these measures.

Feed-forward, feedback, and dynamic systems, a combination of the two previous mechanisms, are all theoretical models of how one interprets afferent information and produces efferent responses.[11] The cerebral cortex relies on feed-forward processing to initiate a learned motor program based on experience, current environmental cues and the

desired movements, then the feedback mechanism would regulate reflexive motor responses to any unanticipated external stimuli.[1] These preparatory and reactive motor strategies control muscle contractions and stiffness characteristics of the tenomuscular unit.[1] Muscle stiffness is the ability to resist changes in muscle length and neural regulation of muscle stiffness is important to movement strategies and dynamic restraint.[11] Muscle stiffness, flexibility, force, and preparatory and reactive muscle activation all influence dynamic restraint strategies.[2, 11] Proper regulation of these factors may contribute to avoiding non-contact injury or to the resumption of activity if injury should occur.[2, 11] ACLD individuals who can return to physical activity can adequately stabilize the knee joint via muscle activation in the absence of the ACL, the primary static restraint.[11]

Some research suggests the ACLD population is largely composed of two subgroups, potential copers and non-copers. Potential copers delay or decide against operative management and try to return to pre-injury levels of sport activity via dynamic restraint strategies.[2] For example, feed-forward quadriceps inhibition as the foot approaches heel strike decreases anterior shear force on the tibia when the foot contacts the ground.[11] This inhibition coupled with hamstring activation is a preparatory mechanism allowing potential copers to anticipate joint loading.[11] On the contrary, non-copers are unable to return to previous levels of activity due to repeated episodes of "giving way" and commonly elect to undergo reconstructive surgery.[2] An episode of "giving way" is a perceived subluxation event of the knee with associated pain and effusion.[32] "Giving way" may be the result of altered kinematics displayed by non-

copers.[11] For instance, research indicates some non-copers have delayed onset to peak activity in the lateral hamstring and medial gastrocnemius, which is a less effective strategy to stabilizing the knee against anterior forces.[11] Less than 14 percent of the ACLD population is composed of true copers.[68]

A large percentage of ACLD individuals classified as potential copers and who choose conservative management successfully delay surgery without experiencing "giving way."[43] In one study, 22 of 28 (79%) potential copers who selected conservative management resumed pre-injury activity levels without experiencing knee instability.[33] Twelve of these individuals continued to perform at this level without undergoing reconstructive surgery, while 9 elected to have surgery at the end of their sport season.[33] In another study, a 6- to 11- year follow-up revealed 18 of 22 (82%) competitive handball players with ACL injury returned to pre-injury activity without surgical management and only 58% of those who underwent surgery returned to this activity level .[43] A different piece of literature stated only 14% of conservatively treated patients resumed unlimited physical activity, while 36% of those who underwent reconstruction achieved this same level.[2] Kaplan[43] reported that conservatively managed individuals had good knee function (87/100 on the Lysholm Knee Scale) at a 12- to 66-month follow-up and displayed a normal hop for distance, but experienced a 21.3% reduction in activity level from pre-injury to follow-up, according to the Tegner Scale. Physical activity is closely associated with the overall concept of health which is not static, suggesting that a decline in physical activity may affect daily performance, disease susceptibility, and other dimensions of health including emotional, social, and intellectual behaviors.[69] The variety in success

rates of conservatively and surgically managed ACLD individuals reported here suggests identification of potential copers and non-copers remains difficult and success rates of each management approach remain variable. This may be because research has yet to identify what characteristics allow an ACLD individual to cope. Expanding the breadth of research in this area to include neuropsychological factors may help distinguish ACLD individuals best able to return to activity and model intervention programs to maximize these beneficial constructs.

Research is just beginning to explore the role of neuromuscular control and brain function in non-contact knee injuries. The cerebral cortex is responsible for motor programming via feed-forward and feedback processes.[1] Neuropsychological testing is one way to indirectly measure performance of the cerebral cortex executive functions.[11] Neuropsychological tests evaluate cognitive functioning and are most often used in sport to assess cerebral and cortical changes associated with concussion.[1, 70] Since the cerebral cortex is influential to motor control, deficits in cognitive function, including reaction time, processing speed, and memory, are indicative of diminished capacity for neuromuscular control.[1] Poor neuromuscular control is a predisposition to non-contact injury and individuals who suffered a non-contact ACL injury in one study had slower reaction times, processing speeds, and visual and verbal memory scores on a pre-season neuropsychological assessment than healthy, matched controls.[1]

This suggests that neuropsychological deficits can influence the risk of non-contact injury because they may predispose individuals to errors in coordination or poor judgment.[1] Athletic competition is a complex, changing environment and interpreting

multiple stimuli can decrease reaction times, leading to hesitation that modifies muscle activity and compromises dynamic restraint strategies.[1, 8, 71] Heightened arousal can alter motor output.[10] Furthermore, a narrow visual field due to increased arousal levels may make it difficult to interpret competing incoming stimuli from the environment.[1] Disorientation can also alter execution of motor programs or muscle activity, therefore compromising dynamic restraint strategies.[1] Disruption of the sensorimotor system may alter cortical activity and contribute to changes in neuromuscular control following ACL injury.[4, 6]

Functional magnetic resonance imaging (fMRI) has shown reorganization of several sensorimotor cortical areas in the ACLD population that ultimately validates the CNS role in compensating for musculoskeletal injuries, such as the ACL tear.[6] fMRI measures blood flow and metabolic changes that occur in response to neural firing during functional movement .[6] Individuals with ACL rupture display decreased activity in many cortical areas during a knee flexion and extension task compared to healthy individuals.[6] This may be attributed to differentiation of the ascending afferent pathways.[6] ACL injury disrupts mechanoreceptors, which modifies afferent proprioceptive information transmitted to the CNS.[6] These changes result in an inability to use the peripheral information to carry out actions, such as organizing behavior and function.[12] The injured individuals display significantly greater fMRI signal change in three cortical areas.[6] First, the contralateral presupplementary motor area influences movement preparation, and higher activation of this part of the cortex may result from increased planning that is necessary for the injured population to execute a motor task.[6] Second, the contralateral

posterior secondary somatosensory area receives sensory stimuli, most often that associated with pain, such that higher activation of this area in injured individuals may be indicative of pain or instability during movement.[6] Third, the ipsilateral posterior inferior temporal gyrus is located in the visual cortex and is associated with the recognition of movement.[6] Increased activation of this area in the ACLD population may indicate an increased need for motion visualization and feedback during movement of the injured joint due to the lack of proprioceptive information.[6] Changes in cortical activity may continue to be present following ACL reconstructive surgery.

Electroencephalography (EEG) has shown altered cortical activity in the ACL reconstructed population, likely because deafferentation of ligamentous and capsular mechanoreceptors has disrupted the sensorimotor system, thus changing motor behavior.[4, 6, 11, 12] ACL reconstructed individuals display significantly more cortical activity in the frontal lobe while performing a JPS task with either lower extremity than that displayed by healthy individuals.[4] Frontal Theta power is generated in the anterior cingulated cortex and is an indicator of focused attention and task complexity.[4] Increased activity in those with a reconstructed ACL suggests that JPS tasks appear more complex to this population and so more focused attention is required to complete the task.[4] ACL reconstructed individuals also display significantly less Alpha-2 power in the parietal region than healthy individuals.[4] Alpha-2 power represents task-specific demands and the amplitude is inversely related to the amount of neuronal activation during cognitive and motor processes.[4] Therefore, the significantly lower power in the ACL reconstructed group is indicative of higher cortical activation.[4] This is likely because the reconstructed

individuals are required to integrate multiple new sources of information.[4] These include the JPS task, altered afferent information from the knee joint, and the execution of an unfamiliar motor program.[4] The synchronization of this information requires additional neuronal resources recruited from the parietal cortex to complete the task.[4] Cortical activity has also been measured during force reproduction tasks in the ACL reconstructed population.

Cortical activity is altered during a force reproduction task in individuals who have undergone ACL reconstruction.[5] ACL reconstructed individuals reproduce target forces with the same error in accuracy and neuromuscular control strategies as healthy individuals.[5] However, like the JPS task, frontal Theta power significantly differs between reconstructed and healthy individuals.[5] This can be explained by increased focused attention necessary for the reconstructed population to successfully execute the task.[5] The frontal lobe is an active component of working memory, and reconstructed individuals may require more neuropsychological resources related to working memory to reproduce force because the altered afferent information does not match the anticipated information from long-term memory.[5] A neuropsychological approach to rehabilitation following ACL reconstruction has been shown to progressively decrease asymmetry of load during stance, result in a more stable walk, decrease swelling and flexion force impairment, and improve physical activity when compared to a traditional post-reconstruction rehabilitation.[12] This rehabilitation approach relies on exercises focused on proprioceptive and motor problems that need to be resolved by engaging executive functions such as attention, awareness, memory, and language.[12] Modifications in

neuropsychological function and cortical activity appear to be an important component of ACL injury. Studying cortical activity of the brain is one approach to exploring behavior in the branch of neuropsychology. Personality is another important factor in sports injuries.[72]

This area of neuropsychology has received little attention in the literature, but appears to influence patterns of response in the presence of stressful stimuli.[14-18] Kinesiophobia is the fear of physical movement due to feelings of vulnerability to pain or re-injury, resulting in avoidance behavior and underestimating physical capabilities.[14, 15] A few medium- to long-term follow up studies indicate that kinesiophobia influences the ability for some ACL reconstructed individuals to return to pre-injury activity levels.[14-18] The Tampa Scale of Kinesiophobia (TSK) is a self-report questionnaire used to measure pain-related fear of movement or re-injury in patients with or at high risk for chronic musculoskeletal pain.[16] Higher TSK scores indicate elevated levels of pain-related fear, and this is associated with a decreased likelihood that individuals will resume physical activity.[15, 16] ACL reconstructed individuals who did not return to their pre-injury activity level expressed greater fear of re-injury than ACL reconstructed individuals who did resume pre-injury activities.[7, 14, 18] Research has shown that those who wait more than three months from the time of injury to undergo ACL reconstruction express more fear, possibly due to the instability and episodes of "giving way" experienced during the long period of time before surgery.[7] Athletes expressed the most fear of re-injury on a written survey in response to questions regarding injury provoking situations, re-injuring the knee during competition, and environmental conditions, such as playing surface.[7] Injured

athletes are concerned about exposing their bodies to the same environment that caused injury and are concerned that their fear of re-injury will hinder them from playing assertively.[17] These behavioral manifestations include holding back, playing at less than maximum effort, being wary of injury provoking situations, and taping or bracing the knee for protection.[7] These moments of hesitation and uncertainty modify muscle activity, thereby compromising dynamic restraint strategies which contribute to the risk of re-injury.[1, 8, 71] Fear of re-injury may play an important role in the injured individual's confidence in their knee joint and post-injury functional activity.[15] Other psychosocial constructs may similarly contribute to non-contact injury and the impending recovery.

LOC is one construct that influences rehabilitation adherence and recovery.[23, 73] LOC is representative of the extent to which individuals perceive the results of behavior as under their control and it is two dimensional.[25] Internal LOC is the belief that an outcome is directly related to the preceding behavior, while external LOC is the belief that outcome is controlled by powerful others or chance.[23] Internal health LOC and powerful others health LOC are the most adaptive forms because both represent the belief that health is controllable, either by self or others, as opposed to health being the result of chance.[25] The perception of personal control is important to physical and psychological health.[26] Healthy individuals who are aware of the healthful benefits of exercise and who express an internal LOC adhere more to exercise and voluntarily exercise more often than externalists.[72] Injury rehabilitation demands adherence to exercise protocol and so LOC influences recovery success.[72]

Internal LOC is beneficial to recovery from illness and orthopedic injury.[27] For example, patients recovering from a cardiac event with an external LOC remained under intensive care, and required longer hospital stays following intensive care, than cardiac patients with an internal LOC.[25] Internal LOC among these patients also indicated a more likely ability to return to work.[74] Stroke patients with an internal LOC demonstrated more progress in rehabilitation, measured by movement restrictions, compared to externalists recovering from a stroke.[25] Similarly, internalists more quickly regained functional wrist movement following wrist fracture relative to the rehabilitation progress of externalists.[25] LOC is also predictive of home exercise completion among patients undergoing upper extremity rehabilitation.[23] Overall, injured patients perceived by rehabilitation clinicians as recovering rapidly more frequently attributed their success to internal and controllable factors than those recovering more slowly, which is consistent with findings in the ACLD population.[23]

Control style is a significant predictor of adherence in athletes recovering from knee injury and is significant to those anticipating reconstructive surgery.[25] Patients preparing for ACL reconstruction who perceive fewer functional limitations expressed a more internal LOC than those who perceive many functional limitations.[23] Likewise, ACLD patients who convey an internal LOC one week prior to reconstruction reported significantly better outcomes relative to those experienced by externalists.[27] There have been significant findings about LOC in regard to ACL reconstruction, but the literature has yet to investigate the construct in the ACL population forgoing reconstructive surgery and it is unknown how this construct may contribute to non-contact injury predisposition.

The role of LOC on rehabilitation progress among injured populations suggests it will be similarly influential in the ACLD population. There are, however, more constructs that are similar to LOC that may also contribute to injury risk and rehabilitation.

Grit is a personality trait that encompasses perseverance and passion for long-term goals.[28] A gritty person is dedicated to a goal for an extensive period of time despite the adversity that is encountered.[28] Grit is considered to be a non-cognitive skill, a group of skills and traits that contribute to human development and success.[28] The Personal Qualities Project examined the effect of over 100 preadmission variables on success in college, and one of those variables was follow-through which is comparable to grit.[28] Follow-through is defined as purposeful, continuous commitment to certain types of activities versus sporadic efforts in diverse areas and was identified as the single best predictor of significant accomplishment in many domains, including sport.[28] Grit is a helpful trait during challenging experiences, for example it is a predictor of West Point cadets' completion of the Beast Barracks and is a predictor of advancement to higher rounds in the Scripps National Spelling Bee, as grittier spellers perform better than less gritty competitors.[75] Grit is an innovative non-cognitive skill that first emerged in research conducted by Duckworth et al. in 2007.[28] The trait continues to be investigated in a variety of contexts, and these should include different environmental conditions and psychological upset. Research has yet to explore grit in the context of physical activity, although a lifetime of physical activity requires passion and commitment. This is important because physical activity is often attributed to successful aging.[26] This study also expands grit research by investigating the construct in the presence of injury which is

important because the injury experience often results in posttraumatic reactions. The presence of certain constructs, such as grit, may allow some to be more successful than others in defeating these reactions. Rehabilitation and physical activity are long-term commitments that include performance challenges and plateaus, such that grit may influence the ACLD population.

Mental toughness is another construct that involves optimally managing events and outcomes.[10, 27, 52] Mental toughness can be defined by the 4 C's approach – control, commitment, challenge, and confidence.[29] Control is defined by feeling and acting influential.[29] Commitment refers to the tendency to become involved in an encounter, as opposed to becoming alienated and challenge refers to the belief that life is changeable and that change is an opportunity, not a threat.[29] Confidence is a high sense of self belief.[29] Clough et al has combined these four components to further define mental toughness as "a high sense of self-belief and an unshakable faith that they can control their own destiny".[13] These personal beliefs influence individuals' approach to, response to, and appraisal of adversity, or unexpected and challenging situations, in order to perform exceptionally.[76, 30] Research concerning mental toughness is complicated by a lack of conceptual clarity and little consensus on a concise definition.[29] However, aspects of control, commitment, and challenge have been related to hardiness which research has identified as a buffer to stress and has related to improved physical performance.[29] Research has found that hardy people appraise stressful situations positively, and these findings suggest that individuals who exhibit the 4 C's should be better able to

psychologically and functionally cope with injury. Mental toughness is one component of pain tolerance and so it is related to rehabilitation behavior and recovery.[13, 17, 30, 77]

Mental toughness is associated with greater pain tolerance and is negatively related to catastrophizing, which is expressing pain in an excessive manner.[29, 30] Mentally tough individuals do not dwell upon pain or express despair, most likely because they employ direct psychological coping strategies.[29] This method of coping encompasses any effort directed at altering or managing a stressor, including gathering information, setting goals, managing time wisely, adhering to protocols, and participating in self-talk.[13, 78] Mental toughness is positively correlated with problem-focused coping and negatively correlated with avoidance coping strategies.[13, 29, 30] The latter approach regulates the emotional response to a stressor, such as employing wishful thinking, self-blame, and mental or behavioral withdrawal.[78] Disengagement coping modifies the emotional response to a stressor, but fails to address the actual stimulus. As a result, disengagement coping and anxious or depressed feelings can begin to continually reinforce one another.[36] Individuals become disabled to escaping this vicious cycle of reinforcement and to adopting direct coping strategies to defuse stressors.[36] Higher levels of emotion-focused coping are related to higher levels of depression, anxiety, and general psychological distress.[36] Depression contributes to the subsequent risk of re-injury, and increased anxiety decreases concentration, narrows attentional field, and alters muscle activity, all of which are associated with poor coordination and predisposition to injury.[1, 21] The role mental toughness plays in pain tolerance indicates that it is important to injury recovery, and mental toughness has a relationship with rehabilitation adherence.[29, 30]

Less mentally tough individuals adhere better to rehabilitation because they appraise injury as unfavorable, providing motivation to rehabilitate.[29] Individuals exhibiting high levels of mental toughness perceive injury as less severe and believe they are less likely to become re-injured.[29, 30] As a result of these beliefs, they appraise rehabilitation as less important and do not comply as often as less mentally tough individuals.[29, 30] This risk-taking attitude can result in more serious consequences for active athletes who ignore medical advice.[77, 79] Poor rehabilitation adherence decreases overall outcome, thereby increasing the risk of re-injury.[80] Mental toughness is positively correlated with physical risk-taking and willingness to engage in physical risks allows the mentally tough to avoid stagnation and learn about oneself.[77, 79] Mental toughness has received little attention in the context of ACL and musculoskeletal injury, however the construct's relationship to pain and to rehabilitation adherence indicate it may be an important determinant of functional activity.

Another psychosocial construct related to risk-taking is sensation seeking, a biologically based variable reflective of individualized optimal levels of arousal.[31] Sensation seekers look for complex and intense sensations or experiences, and are willing to take physical and social risks to engage in such experiences.[81] Sensation seeking is influenced by hereditary and environmental factors.[82] Concerning the biological basis, measures of skin conductance and heart rate show high sensation seekers are aroused more by novel stimuli than low sensation seekers, and a relationship exists between the strength of visually evoked potentials in response to increasingly intense stimulation and sensation seeking.[82] A visually evoked potential is an electrical potential recorded from

the CNS in the presence of a visual stimulus.[83] Zuckerman[82] refers to high sensation seekers as "augmenters" because electrical potentials displayed by these individuals increased proportionally with stimulus intensity. On the other hand, low sensation seekers are known as "reducers" because evoked potentials in these individuals did not increase with stimulus intensity, and in fact sometimes decreased at the highest stimulus intensity.[82] Differences in levels of arousal are evident in individuals' tendencies to seek out stimulation and to tolerate emotional arousal.[31] There are two theories of sensation seeking. The risk taking hypothesis contends that high sensation-seekers engage in risky or dangerous behavior, creating a predisposition to athletic injury.[31] A strong relationship exists between sensation seeking and drug use and abuse, and high risk sport participants are more likely to score high on the Sensation Seeking Scale-V (SSS-V) than low risk sport participants, such as marathon runners.[84]

The stress buffering hypothesis purports that high sensation seeking serves as a protective mechanism against life stress because high sensation seekers have an increased ability to tolerate greater amounts of arousal.[31] For example, research has found significant correlations between negative life events and psychological distress in low sensation seekers but not in high sensation seekers.[31] Sensation seeking is related to a lower level of anxiety reactivity, meaning that situations involving physical danger cause minimal anxiety in high sensation seekers willing to engage in such activity.[50] Anxiety reactivity is negatively correlated with the Thrill and Adventure Seeking subscale of the SSS-V in men and women.[50] This subscale refers to outdoor sports involving kinesthetic and autonomic sensation.[50] For instance, regular paragliders and opioid dependent

patients scored higher on the subscale than controls.[51] Tolerance to greater amounts of arousal may result from exposure to diverse experiences, allowing high sensation seekers to develop a greater expanse of psychological coping resources.[31] Physiological distress impairs athletes' ability to self-regulate arousal, however high sensation seekers are able to effectively overcome intense stimulation and compete.[21, 22] The prospective research of Smith et al.[31] in high school athletes supports the stress-buffering hypothesis. A positive relationship existed between self-reported negative sport events and coach-reported injury time loss among low sensation seeking high school athletes.[31] Furthermore, total scores on a self-reported coping measure were significantly higher for high sensation seeking athletes, specifically in four subscales: Freedom from Worry, Concentration, Stress Management, and Peaking under Pressure.[31] However, other research fails to support the hypothesis that high sensation seekers feel and function better than low sensation seekers when aroused.[85] Carrol et al[85] administered stimulants and depressants to high and low sensation seeking medical students and found no interaction between drug and personality. Differences in focused attention also exist between high and low sensation seekers.

Research suggests high sensation seekers learn a multidimensional concept formation task more quickly and demonstrate better focused attention on a dichotic listening task than low sensation seekers.[86] Additionally, high sensation seekers establish focused attention more quickly than low sensation seekers.[86] These findings indicate that, when in an environment with competing stimuli, high sensation seekers are better at focusing attention on relevant stimuli and directing limited attention toward filtering

irrelevant stimuli.[86] According to these findings, ACLD individuals identified as high sensation seekers may be best prepared to resume activity because they possess greater psychological coping resources and greater ability to focus attention in a competitive environment.

ACL injury often results from a non-contact mechanism of injury. Athletes who suffer non-contact ACL rupture have been shown to have impaired reaction times, processing speeds, and visual and verbal memory compared to healthy athletes.[1] Additionally, fMRI and EEG have identified neural changes in cortical activity in members of the ACLD and ACL reconstructed populations.[4-6] Neuropsychological factors may influence behavior following ACL rupture, for instance the ability to functionally cope with injury by developing compensatory dynamic restraint strategies. One psychosocial construct, kinesiophobia, is known to influence return to play among ACL reconstructed athletes, and may similarly affect functional activity in those without the ACL. LOC, grit, mental toughness, and sensation seeking may have similar influences. An investigation of these constructs in ACLD and healthy subjects could provide insight regarding the role of personality in injury predisposition and rehabilitation.

REFERENCES

1. Swanik CB, Covassin T, Stearne DJ, Schatz P. The relationship between neurocognitive function and noncontact anterior cruciate ligament injuries. *The American Journal of Sports Medicine* 2007; 35(6): 943-948.

2. Herrington L, Fowler E. A systematic literature review to investigate if we identify those patients who can cope with anterior cruciate ligament deficiency. *The Knee* 2006; 13: 260-265.

3. Olsen OE, Myklebust G, Engebretsen L, Bahr R. Injury mechanisms for anterior cruciate ligament injuries in team handball a systematic video analysis. *The American Journal of Sports Medicine* 2004; 32(4): 1002-1012.

4. Baumeister J, Reinecke K, Weiss M. Changed cortical activity after anterior cruciate ligament reconstruction in a joint position paradigm: An EEG study. *Scandinavian Journal of Medicine & Science in Sports* 2008; 18: 473-484.

5. Baumeister J, Reinecke K, Schubert M, Weiss M. Altered electrocortical brain activity after ACL reconstruction during force control. *Journal of Orthopaedic Research* 2011: 1383-1389.

6. Kapreli E, Athanasopoulos S, Gliatis J, et al. Anterior cruciate ligament deficiency causes brain plasticity: A functional MRI study. *The American Journal of Sports Medicine* 2009; 37(12): 2419-2426.

7. Ardern CL, Taylor NF, Feller JA, Webster KE. Fear of re-injury in people who have returned to sport following anterior cruciate ligament reconstruction surgery. *Journal of Science and Medicine in Sport* 2012.

8. Ebersbach G, Dimitrijevic MR, Poewe W. Influence of concurrent tasks on gait: A dual-task approach. *Perceptual and Motor Skills* 1995; 81: 107-113.

9. Yoon T, Keller ML, De-Lap BS, et al. Sex differences in response to cognitive stress during a fatiguing contraction. *Journal of Applied Physiology* 2009; 107: 1486-1496.

10. Noteboom JT, Fleshner M, Enoka RM. Activation of the arousal response can impair performance on a simple motor task. *Journal of Applied Physiology* 2001; 91: 821-831.

11. Swanik CB, Harner CD, Lephart SM, Driban JB. Neurophysiology of the knee in Surgery of the Knee. 4th ed. Philadelphia, PA: Churchhill Livingstone Elsevier; 2006.

12. Cappellino F, Paolucci T, Zangrando F, et al. Neurocognitive rehabilitative approach effectiveness after anterior cruciate ligament reconstruction with patellar tendon: A randomized controlled trial. *European Journal of Physical and Rehabilitation Medicine* 2012; 48: 17-30.

13. Nicholls AR, Polman RCJ, Levy AR, Backhouse SH. Mental toughness, optimism, pessimism, and coping among athletes. *Personality and Individual Differences* 2008; 44: 1182-1192.

14. Kvist J, Ek A, Sporrstedt K, Good L. Fear of re-injury: A hindrance for returning to sports after anterior cruciate ligament reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy* 2005; 13: 393-397.

15. Tripp DA, Stanish W, Ebel-Lam A, Brewer BW, Birchard J. Fear of reinjury, negative affect, and catastrophizing predicting return to sport in recreational athletes with anterior cruciate ligament injuries at 1 year postsurgery. *Rehabilitation Psychology* 2007; 52(1): 74-81.

16. Chmielewski TL, Jones D, Day T, Tillman SM, Lentz TA, George SZ. The association of pain and fear of movement/reinjury with function during anterior cruciate ligament reconstruction rehabilitation. *Journal of Orthopaedic & Sports Physical Therapy* 2008; 38(12): 746-753.

17. Podlog L, Eklund RC. A longitudinal investigation of competitive athletes' return to sport following serious injury. *Journal of Applied Sport Psychology* 2006; 18(1): 44-68.

18. Ardern CL, Webster KE, Taylor NF, Feller JA. Return to sport following anterior cruciate ligament reconstruction surgery: A systematic review and meta-analysis of the state of play. *British Journal of Sports Medicine* 2011; 45: 596-606.

19. Chmielewski TL, Zeppieri G Jr., Lentz TA, et al. Longitudinal changes in psychosocial factors and their association with knee pain and function after anterior cruciate ligament reconstruction. *Journal of the American Physical Therapy Association* 2011; 91(9): 1355-1366.

20. Gobbi A, Francisco R. Factors affecting return to sports after anterior cruciate ligament reconstruction with patellar tendon and hamstring graft: A prospective clinical investigation. *Knee Surgery, Sports Traumatology, Arthroscopy* 2006; 14: 1021-1028.

21. Appaneal RN, Perna FM, Larkin KT. Psychophysiological response to severe sport injury among competitive male athletes: A preliminary investigation. *Journal of Clinical Sport Psychology* 2007; 1: 68-88.

22. Appaneal RN, Levine BR, Perna FM, Roh JL. Measuring postinjury depression among male and female competitive athletes. *Journal of Sport & Exercise Psychology* 2009; 31: 60-76.

23. Nyland J, Johnson DL, Caborn DNM, Brindle T. Internal health status belief and lower perceived functional deficit are related among anterior cruciate ligament-deficient patients. *Arthroscopy: The Journal of Arthroscopic and Related Surgery* 2002; 18(5): 515-518.

24. Udry E, Shelbourne D, Gray T. Psychological readiness for anterior cruciate ligament surgery: Describing and comparing the adolescent and adult experiences. *Journal of Athletic Training* 2003; 38(2): 167-171.

25. Murphy GC, Foreman PE, Simpson CA, Molloy GN, Molloy EK. The development of a locus of control measure predictive of injured athletes' adherence to treatment. *Journal of Science and Medicine in Sport 2* 1999; 2(2): 145-152.

26. Dacey M, Newcomer R. A client-centered counseling approach to motivating older adults towards physical activity. *Topics in geriatric rehabilitation* 2005; 21(3): 195-204.

27. Swirtun LR, Renstrom P. Factors affecting outcome after anterior cruciate ligament injury: A prospective study with a six-year follow-up. *Scandinavian Journal of Medicine & Science in Sports* 2008; 18: 318-324.

28. Duckworth AL, Peterson C, Matthews MD, Kelly DR. Grit: Perseverance and passion for long-term goals. *Journal of Personality and Social Psychology* 2007; 92(6): 1087-1101.

29. Levy AR, Polman RCJ, Clough PJ, Marchant DC, Earle K. Mental toughness as a determinant of beliefs, pain, and adherence in sport injury rehabilitation. *Journal of Sport Rehabilitation* 2006; 15: 246-254.

30. Crust L. A review and conceptual re-examination of mental toughness: Implications for future researchers. *Personality and Individual Differences* 2008; 45: 576-583.

31. Smith RE, Ptacek JT, Smoll FL. Sensation seeking, stress, and adolescent injuries: A test of stress-buffering, risk-taking, and coping skills hypotheses. *Journal of Personality and Social Psychology* 1992; 62(6): 1016-1024.

32. Moksnes H, Snyder-Mackler L, Risberg MA. Individuals with an anterior cruciate ligament-deficient knee classified as noncopers may be candidates for nonsurgical rehabilitation. *Journal of Orthopaedic & Sports Physical Therapy* 2008; 38(10): 586-595.

33. Fitzgerald GK, Axe MJ, Snyder-Mackler L. A decision-making scheme for returning patients to high-level activity with nonoperative treatment after anterior cruciate ligament rupture. *Knee Surgery, Sports Traumatology, Arthroscopy* 2000; 8: 76-82.

34. Wallston K. Multidimensional Health Locus of Control (MHLC) Scales. Vanderbilt University School of Nursing Web site. http://www.vanderbilt.edu/nursing/kwallston/mhlcscales.htm. Modified June 15, 2007. Accessed October 2011.

35. Athale, N, Aldridge A, Malcarne VL, et al. Validity of the Multidimensional Health Locus of Control Scales in American Sign Language. *Journal of Health Psychology* 2010; 15(7): 1064-1074.

36. Livneh H, Martz E. The impact of perceptions of health control and coping modes on negative affect among individuals with spinal cord injuries. *Journal of Clinical Psychology in Medical Settings* 2011; 18: 243-256.

37. Grit Scale. University of Pennsylvania Web site. http://www.sas.upenn.edu/~duckwort/images/17-item%20Grit%20and%20Ambition.040709.pdf. Accessed October 2011.

38. Duckworth AL, Quinn PD, Development and validation of the short Grit Scale (Grit-S). *Journal of Personality Assessment* 2009; 91(2): 166-174.

39. Moran AP. Sport and Exercise Psychology a critical introduction. New York, NY: Routledge; 2009.

40. Sensation Seeking Scale –SSS. European Monitoring Centre for Drugs and Drug Addiction Web site. http://www.emcdda.europa.eu/html.cfm/index86974EN.html. Modified August 11, 2009. Accessed October 2011.

41. Ridgeway D, Russell JA. Reliability and validity of the Sensation-Seeking Scale: Psychometric problems in Form V. *Journal of Consulting and Clinical Psychology* 1980; 48(5): 662-664.

42. Painter FM. Tampa Scale for Kinesiophobia. Outcome Assessment Questionnaires. http://www.chiro.org/LINKS/Outcome_Assessment.shtml. Modified February 2, 2013. Accessed October 2012.

43. Kaplan Y. Identifying individuals with an anterior cruciate ligament-deficient knee as copers and non-copers: A narrative literature review. *Journal of Orthopaedic & Sports Physical Therapy* 2011; 41(10): 758-766.

44. Chmielewski TL, Hurd WJ, Snyder-Mackler L. Elucidation of a potentially destabilizing control strategy in ACL deficient non-copers. *Journal of Electromyography and Kinesiology* 2005; 15: 83-92.

45. Irrgang JJ, Snyder-Mackler L, Wainner RS, Fu FH, Harner CD. Development of a patient-reported measure of function of the knee. *The Journal of Bone and Joint Surgery, Incorporated* 1998; 80-A(8): 1132-1145.

46. Wallston KA, Wallston BS. Health locus of control scales. In: Lefcourt HM. Research with locus of control construct (Vol. 1): Assessment methods. New York, NY: Academic Press; 1981: 189-243.

47. Rowland GL, Heatherton T. Social norms for the desirability of sensation seeking. *Personality and Individual Differences* 1987; 8(5): 753-755.

48. Taimela S, Kujala UM, Osterman K. Intrinsic risk factors and athletic injuries. *Sports Medicine* 1990; 9(4): 205-215.

49. Orchard J, Seward H, McGivern J, Hood S. Intrinsic and extrinsic risk factors for anterior cruciate ligament injury in Australian footballers. *American Journal of Sports Medicine* 2001; 29(2): 196-200.

50. Blankstein KR. The sensation seeker and anxiety reactivity: Relationships between the sensation-seeking scales and the activity preference questionnaire. *Journal of Clinical Psychology* 1975; 31(4): 677-681.

51. Franques P, Auriacombe M, Piquemal E, et al. Sensation seeking as a common factor in opioid dependent subjects and high risk sport practicing subjects. A cross sectional study. *Drug and Alcohol Dependence* 2003; 69: 121-126.

52. Hannah SD. Psychosocial issues after a traumatic hand injury: Facilitating adjustment. *Journal of Hand Therapy* 2011; 24: 95-103.

53. Waldron B, Benson C, O'Connell A, et al. Health locus of control and attributions of cause and blame in adjustment to spinal cord injury. *Spinal Cord* 2010; 48(8): 598-602.

54. Jacobs-Lawson JM, Waddell EL, Webb AK. Predictors of health locus of control in older adults. *Current Psychology* 2011; 30: 173-183.

55. Roddenberry A, Renk K. Locus of control and self-efficacy: Potential mediators of stress, illness, and utilization of health services in college students. *Child Psychiatry & Human Development* 2010; 41: 353-370.

56. 10 Leading Causes of Death by Age Group, United States – 2009. Centers for Disease Control and Prevention Web site. Updated March 9, 2012. Accessed July 24, 2012.

57. National Estimates of the 10 Leading Causes of Nonfatal Injuries Treated in Hospital Emergency Departments, United States – 2010. Centers for Disease Control and Prevention Web site. Updated March 9, 2012. Accessed July 24, 2012.

58. Hootman JM, Dick R, Agel J. Epidemiology of collegiate injuries for 15 sports: Summary and recommendations for injury prevention initiatives. *Journal of Athletic Training* 2007; 42(2):311-319.

59. Boden BP, Griffin LY, Garrett WE Jr. Etiology and prevention of noncontact ACL injury. *The Physician and Sports Medicine* 2000; 28(4).

60. Griffin LY, Agel J, Albohm MJ, et al. Noncontact anterior cruciate ligament injuries: risk factors and prevention strategies. *Journal of the American Academy of Orthopaedic Surgeons.* 2000; 8: 141-150.

61. Myklebust G, Maehlum S, Engebretsen L, Strand T, Solheim E. Registration of cruciate ligament injuries in Norwegian top level team handball. A prospective study covering two seasons. *Scandinavian Journal of Medicine & Science in Sports* 1997; 7: 289-292.

62. Boden BP, Dean GS, Feagin JA Jr., Garrett WE Jr. Mechanisms of anterior cruciate ligament injury. *Orthopedics* 2000; 23(6): 573-578.

63. Renstrom P, Ljungqvist A, Arendt E, et al. Non-contact ACL injuries in female athletes: An International Olympic Committee current concepts statement. *British Journal of Sports Medicine* 2008; 42: 394-412.

64. Zantop T, Petersen W, Sekiya JK, Musahl V, Fu FH. Anterior cruciate ligament anatomy and function relating to anatomical reconstruction. *Knee Surgery, Sports Traumatology, Arthroscopy* 2006; 14: 982-992.

65. Siegel L, Vandenakker-Albanese C, Siegel D. Anterior cruciate ligament injuries: Anatomy, physiology, biomechanics, and management. *Clinical Journal of Sport Medicine* 2012; 22(4): 349-355.

66. Barrack RL, Skinner HB, Buckley SL. Proprioception in the anterior cruciate ligament-deficient knee. *The American Journal of Sports Medicine* 1989.

67. Borsa PA, Lephart SM, Irrgang JJ, Safran MR, Fu FH. The effects of joint position and direction of joint motion on proprioceptive sensibility in anterior cruciate ligament-deficient athletes. *The American Journal of Sports Medicine* 1997; 25(3): 336-340.

68. Hurd WJ, Snyder-Mackler L. Knee instability after acute ACL rupture affects movement patterns during the mid-stance phase of gait. *Journal of Orthopaedic Research* 2007; 25(10): 1369-1377.

69. Hahn DB & Payne WA. Focus on health. 6th ed. New York, NY: McGraw-Hill Companies, Inc.; 2003.

70. Lovell MR, Iverson GL, Collins MW, McKeag D, Maroon JC. Does loss of consciousness predict neuropsychological decrements after concussion. *Clinical Journal of Sport Medicine* 1999; 9(4): 193-198.

71. Woo E, Burns Y, Johnston L. The effect of task uncertainty on muscle activation patterns in 8-10-year-old children. *Physiotherapy Research International* 2003; 8(3): 143-154.

72. Pargman D. Psychological bases of sport injuries. 2nd ed. Morgantown, WV: Fitness Information Technology, Inc.; 1999.

73. Wiese-Bjornstal DM. Psychology and socioculture affect injury risk, response, and recovery in high-intensity athletes: A consensus statement. *Scandinavian Journal of Medicine & Science in Sports* 2010; 20 (Suppl. 2): 103-111.

74. Bergvik S, Sorlie T, Wynn R. Coronary patients who returned to work had stronger internal locus of control beliefs than those who did not return to work. *British Journal of Health Psychology* 2011.

75. Duckworth AL, Kirby TA, Tsukayama E, Berstein H, Ericsson KA. Deliberate practice spells success: Why grittier competitors triumph at the National Spelling Bee. *Social Psychological and Personality Science* 2010; 000(00): 1-8.

76. Gucciardi DF. Mental toughness profiles and their relations with achievement goals and sport motivation in adolescent Australian footballers. *Journal of Sport Sciences* 2010; 28(6): 615-625.

77. Crust L, Keegan R. Mental toughness and attitudes to risk-taking. *Personality and Individual Differences* 2010; 49: 164-168.

78. Weinberg RS, Gould D. *Foundations of Sport and Exercise Psychology* (286). Champaign, IL: Human Kinetics; 2007.

79. Coulter TJ, Mallett CJ, Gucciardi DF. Understanding mental toughness in Australian soccer: Perceptions of players, parents, and coaches. *Journal of Sport Sciences* 2010; 28(7): 699-716.

80. Granquist MD, Gill DL, Appaneal RN. Development of a measure of rehabilitation adherence for athletic training. *Journal of Sport Rehabilitation* 2010; 19: 249-267.

81. Zuckerman M, Bone RN, Neary R, Mangelsdorff D, Brustman B. What is the sensation seeker? Personality trait and experience correlates of the sensation-seeking scales. *Journal of Consulting and Clinical Psycholo*gy 1972; 39(2): 308-321.

82. Zuckerman M. The shaping of personality: Genes, environments, and chance encounters. *Journal of Personality Assessment* 2004; 82(1): 11-22.

83. Kremlacek J, Kuba M, Holcik J. Model of visually evoked cortical potentials. *Physiological Research* 2002; 51: 65-71.

84. Ruedl G, Abart M, Ledochowski L, Burtscher M, Kopp M. Self reported risk taking and risk compensation in skiers and snowboarders are associated with sensation seeking. *Accident Analysis and Prevention* 2012; 48: 292-296.

85. Carrol EN, Zuckerman M, Vogel WH. A test of the optimal level of arousal theory of sensation seeking. *Journal of Personality and Social Psychology* 1982; 42(3): 572-575.

86. Ball SA, Zuckerman M. Sensation seeking and selective attention: Focused and divided attention on a dichotic listening task. *Journal of Personality and Social Psychology* 1992; 63(5): 825-831.

Appendix A

INFORMATIONAL BROCHURE AND PERMISSION TO CONTACT FORM

This line of research will help determine if some people can protect their knees better by using their muscles to increase joint stiffness. We will also learn if some personality characteristics are beneficial to improving rehabilitation outcomes following a knee sprain. This will improve your rehabilitation experience and ensure that you are physically and mentally prepared to resume activity. Both physical and mental preparation may be important to reduce the risk of spraining and re-injuring knees.

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.

Room 160 of the Human Performance Lab. The entrance is at 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:

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Newark, De 19716

Description of the Research

This research project will investigate personality differences that may be related to the ability to be physically active after an anterior cruciate ligament (ACL) injury. The study will also examine functional ability after ACL injury by assessing how the knee muscles react during a distracted state.

You will be 1 of 40 male and female subjects between the ages of 18 and 45 years old recruited from local orthopedic clinics with an injured ACL in the last six months. You may not be eligible for testing if you currently experience:

- Difficulty walking
- Decreased knee range of motion
- Constant swelling at the knee
- Any other hip, knee, or ankle injury
- The inability to perform a single-leg hop on the injured leg

Your results will be compared to 20 individuals with healthy knees .

Full participation will require one test session, lasting approximately 90 minutes, in the Human Performance Lab at the Fred Rust Ice Arena.

First, you will complete:

- 1 Demographic Questionnaire and the Physical Activity Readiness Questionnaire
- 5 Personality Questionnaires

Then, you have the ***option*** of :

- Warm-up on a stationary bicycle for 5 minutes
- Stretch your legs for 5 minutes
- Perform a timed hop task on both legs

Next you will complete:

- 3 Knee-Specific Questionnaires

Finally, you will complete:

- A testing session on a seated mechanical device that will safely move the knee in a 40 degree range
- Electrodes will be applied to the skin to record muscle reactions
- A loud sound will be randomly applied during trials to assess responses from distractions

Confidentiality

All information collected during this research study will be kept confidential and will be used for research purposes only. Confidentiality will be maintained by using case numbers.

Risks & Benefits

There are no direct benefits to you as a result of participating in this research project. You may experience muscle and/or joint soreness following the testing session. This soreness is similar to that experienced after weight lifting. While the potential risk for injury exists, similar studies have used this equipment and hop task. Proper warm-up and resting periods will minimize the risk of injury . You will also be supplied with a knee brace to wear for protection.

Compensation

No financial compensation will be given for participation in this research study.

If you are interested in participating in this research study please contact:

Stephanie Segulin, ATC
Graduate Assistant Athletic Trainer
Phone: (330) 310-1180
Email: ssegulin@udel.edu
Brittany Walls, ATC
Graduate Research Assistant
Phone: (484) 667-9832
Email: blwalls@udel.edu
University of Delaware
Newark, De 19716

ACL Study
Comparing joint stiffness and coping after injury

We are recruiting adults, between the ages of 18 and 45 years old, who have a knee sprain that happened in the past 6 months. If you are eligible, you will be asked to participate in one test session at the University of Delaware that aims to determine why some people may recover better than others. If you are interested in participating, please provide your name and contact information so that a member of the University of Delaware Sports Medicine Research Lab can contact you. Thank you for your consideration.

____ **I am <u>not</u> interested in participating. Do <u>NOT</u> contact me.**
(No further information needed.)

____ **I am interested in participating, please contact me.**
(Complete the following.)

First Name: _____
Last Name: _____
Home Phone Number (with area code): _____
Cell Phone Number (with area code): _____
Best time to call: _____

Please return this form before you leave.

STAFF:

Please contact Stephanie Segulin, ATC, (330) 310-1180 / ssegulin@udel.edu or Brittany Walls, ATC, (484) 667-9832 / blwalls@udel.edu. Thank you.

Appendix B

INFORMED CONSENT DOCUMENT

University of Delaware
Informed Consent to Participate in a Research Project

RESEARCH STUDY: The Relationship between Personality and Functional Ability following Anterior Cruciate Ligament Injury

INVESTIGATORS: Stephanie R. Segulin, ATC
Dr. C. Buz Swanik, PhD, ATC

Please read this consent form carefully before you decide to participate in this study.

1. PURPOSE / DESCRIPTION OF THE RESEARCH

You are being asked to participate in a research study conducted at the University of Delaware. The purpose of this research is to examine the relationship between personality and physical activity after a knee sprain. People who twist their knee can tear the anterior cruciate ligament (ACL) and some need surgery while others can return to physical activity with only rehabilitation. Knee strength and flexibility do not seem to influence this decision and so the reason for the different reactions to ACL injury is still unclear. This research project will investigate personality differences that may be related to the ability to be physically active after an ACL injury.

You will be 1 of 60 male and female subjects between the ages of 18 and 45 years old recruited from local orthopedic clinics and the University of Delaware campus to participate in this research project. All subjects recruited will have healthy knees, or will have suffered a knee sprain in the last six months. You cannot participate if you are currently experiencing swelling at the knee joint, a loss of motion at the knee, difficulty walking, any current lower extremity injuries, or if you are unable to perform a single leg hop on the injured leg. Full participation will require one test session lasting approximately 90 minutes in the Human Performance Lab at the Fred Rust Ice Arena. This facility is located on the South Campus of the University of Delaware.

Prior to testing, you will be asked to complete the following required paperwork:

> *1. Demographic and Physical Activity Readiness-Questionnaire (PAR-Q):* You will be asked to complete one questionnaire concerning past and current health events to make sure you are eligible to participate in this study.
>
> *2. Personality Questionnaires*: You will be asked to complete five personality questionnaires. You will be instructed to complete each questionnaire honestly and to the best of your ability. Questions asked will be related to locus of control, grit, mental toughness, sensation seeking, and kinesiophobia.

After filling out all required paperwork, you will be asked if you think you can hop on your injured leg. If you do not think you are able to single-leg hop, then you will not participant in hop testing. If you think you are able to single-leg hop, you will be asked to perform a five minute warm-up on a stationary bicycle. This will be followed by five minutes of stretching for both legs. Stretches will be provided and demonstrated for you.

For hop testing, you will be asked to complete a timed six-meter hop. First, you will perform a single-leg hop on your injured leg at a self-selected level of effort, and then at your maximum ability. Then, you will complete two practice trials and two recorded trials of the timed six-meter hop on your uninjured leg and then your injured leg. A cloth tape measure will be securely adhered to the floor to measure hop distance, and a start and a finish line will be marked on the floor six meters apart. You will begin each trial with your toes behind the start line and will begin hopping on verbal cue. You will be instructed to hop as fast as you feel safe. The investigator will use a manual stopwatch to time this task. Time will begin at the same time you are given the verbal cue to begin hopping and will end when you cross the finish line, six meters away.

Following testing, you will be asked to complete the following required paperwork if you have suffered a knee sprain in the last six months:

> *1. Knee-Specific Questionnaires:* You will be asked to complete three questionnaires concerning your knee injury.

2. CONFIDENTIALITY

All information collected during this research project will be kept confidential and will be used for research purposes only. Confidentiality will be maintained by using case numbers. Each participant will receive a case number that will be present on each questionnaire and that will serve as an identification number for the duration of the research project. The case number ensures questionnaire responses remain anonymous. Only investigators directly involved in this research project will have access to the case numbers. Upon completion of the study, data will be stored electronically for five years. All paper documents will be shredded. Any data used in the publication of results will be reported without identifying any participant. You have the right to choose not to complete any task or not answer any questions that are a part of this research project if they make you feel uncomfortable. This includes individual items on any questionnaire and any physical hop task.

3. RISKS AND BENEFITS

There are no direct benefits to you as a result of participating in this research project. You may experience muscle or joint soreness following the testing session. This soreness is similar to that experienced after weight lifting. There is minimal risk of muscle and/or joint injury (i.e. pulled muscle, sprained joint) as a result of the testing. There is the

potential that you will experience an episode of giving way during the hop tests. In order to reduce this risk, you will be supplied with a knee brace to wear for protection and support. Prior to performing the hop tests, you will be asked to perform a single-leg hop at a level of effort of your choice and at your maximum ability. Proper warm-up and resting periods will minimize the risk of injury associated with the exercises used in this research project. Similar studies have successfully used the hop tests. You will complete each portion of this research project at your own will. You may choose not to participate in any portion of the testing session without consequence. In the event of physical injury as a direct result of these research procedures, you will receive first aid. If you require additional medical treatment, you will be responsible for the cost.

4. FINANCIAL CONSIDERATION

No financial compensation will be given for participation in this research project.

5. CONTACTS

For questions and concerns specific to this research project, please contact:

Stephanie Segulin, ATC
Graduate Assistant Athletic Trainer
University of Delaware
Newark, De 19716
Phone: (330) 310-1180
Email: ssegulin@udel.edu

Dr. C. Buz Swanik, PhD, ATC
Human Performance Laboratory
Fred Rust Ice Arena
University of Delaware
Newark, De 19716
Email: cswanik@udel.edu

For questions and concerns regarding the rights of individuals who agree to participate in research, please contact:

Chair, Institutional Review Board
University of Delaware
Newark, De 19716
Phone: (302) 831- 2137

6. 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.

Consent Signatures

The Relationship between Personality and Functional Ability following Anterior Cruciate Ligament Injury

I have read and understand the procedures explained in this Informed Consent Form. I understand any possible risks I may experience as a participant in this research project. Any questions I may have had regarding my participation have been answered to my satisfaction. I understand my participation is completely voluntary and that I may choose to not participate and/or withdraw my consent from the research project at any time without penalty.

_____	_____
Participant's Name (Please Print)	Date
_____	_____
Signature of Participant	Date
_____	_____
Signature of Primary Investigator	Date

Appendix C

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.

YES	NO	
____	____	1. Has your doctor ever said you have heart trouble? Yes, _____
____	____	2. Do you frequently have pains in your heart and chest? Yes, _____
____	____	3. Do you often feel faint or have spells of severe dizziness? Yes, _____
____	____	4. Has a doctor ever said your blood pressure was too high? Yes, _____
____	____	5. 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? Yes, _____
____	____	6. Is there a good physical reason, not mentioned here, why you should not follow an activity program even if you wanted to? Yes, _____
____	____	7. Are you over age 60 **and** not accustomed to vigorous exercise? Yes, _____
____	____	8. Do you suffer from any problems of the lower back, i.e., chronic pain, or numbness? Yes, _____
____	____	9. Are you currently taking any medications? If YES, please specify. Yes, _____
____	____	10. Do you currently have a disability or a communicable disease? If YES, Please specify. Yes, _____

Appendix D

INVENTORIES

D.1 Multidimensional Health Locus of Control (MHLC)

Instructions: Each item below is a belief statement about your medical condition with which you may agree or disagree. Beside each statement is a scale which ranges from strongly disagree (1) to strongly agree (6). For each item we would like you to circle the number that represents the extent to which you agree or disagree with that statement. The more you agree with a statement, the higher will be the number you circle. The more you disagree with a statement, the lower will be the number you circle. Please make sure that you answer **EVERY ITEM** and that you circle **ONLY ONE** number per item. This is a measure of your personal beliefs; obviously, there are no right or wrong answers.

1=STRONGLY DISAGREE **(SD)** 2=MODERATELY DISAGREE **(MD)** 3=SLIGHTLY DISAGREE **(D)**	4=SLIGHTLY AGREE **(A)** 5=MODERATELY AGREE **(MA)** 6=STRONGLY AGREE **(SA)**

		SD	**MD**	**D**	**A**	**MA**	**SA**
1	If I get sick, it is my own behavior which determines how soon I get well again.	1	2	3	4	5	6
2	No matter what I do, if I am going to get sick, I will get sick.	1	2	3	4	5	6
3	Having regular contact with my physician is the best way for me to avoid illness.	1	2	3	4	5	6
4	Most things that affect my health happen to me by accident.	1	2	3	4	5	6
5	Whenever I don't feel well, I should consult a medically trained professional.	1	2	3	4	5	6
6	I am in control of my health.	1	2	3	4	5	6
7	My family has a lot to do with my becoming sick or staying healthy.	1	2	3	4	5	6
8	When I get sick, I am to blame.	1	2	3	4	5	6
9	Luck plays a big part in determining how soon I will recover from an illness.	1	2	3	4	5	6
10	Health professionals control my health.	1	2	3	4	5	6
11	My good health is largely a matter of good fortune.	1	2	3	4	5	6
12	The main thing which affects my health is what I myself do.	1	2	3	4	5	6
13	If I take care of myself, I can avoid illness.	1	2	3	4	5	6
14	Whenever I recover from an illness, it's usually because other people (for example, doctors, nurses, family, friends) have been taking good care of me.	1	2	3	4	5	6
15	No matter what I do, I 'm likely to get sick.	1	2	3	4	5	6
16	If it's meant to be, I will stay healthy.	1	2	3	4	5	6
17	If I take the right actions, I can stay healthy.	1	2	3	4	5	6
18	Regarding my health, I can only do what my doctor tells me to do.	1	2	3	4	5	6

D.2 Grit Scale

Directions: Please respond to the following 17 items. Be honest – there are no right or wrong answers!

1. I aim to be the best in the world at what I do.
_Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

2. I have overcome setbacks to conquer an important challenge.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

3. New ideas and projects sometimes distract me from previous ones.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

4. I am ambitious.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

5. My interests change from year to year.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

6. Setbacks don't discourage me.
_ Very much like me
_ Mostly like me

_ Somewhat like me
_ Not much like me
_ Not like me at all

7. I have been obsessed with a certain idea or project for a short time but later lost interest.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

8. I am a hard worker.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

9. I often set a goal but later choose to pursue a different one.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

10. I have difficulty maintaining my focus on projects that take more than a few months to
complete.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

11. I finish whatever I begin.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

12. Achieving something of lasting importance is the highest goal in life.

_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

13. I think achievement is overrated.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

14. I have achieved a goal that took years of work.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

15. I am driven to succeed.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

16. I become interested in new pursuits every few months.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

17. I am diligent.
_ Very much like me
_ Mostly like me
_ Somewhat like me
_ Not much like me
_ Not like me at all

D.3 Mental Toughness 18-Item Questionnaire (MT18)

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=** neither agree nor disagree; **4=**agree; **5=** strongly agree. Please answer these items carefully, thinking about how you are **generally.** Do not spend too much time on any one item.

1. Even when under considerable pressure I usually remain calm.	1 2 3 4 5
2. I tend to worry about things well before they actually happen	1 2 3 4 5
3. I usually find it hard to summon enthusiasm for the tasks I have to do	1 2 3 4 5
4. I generally cope well with any problems that occur	1 2 3 4 5
5. I generally feel that I am a worthwhile person	1 2 3 4 5
6. 'I just don't know where to begin' is a feeling I usually have when presented with several things to do at once	1 2 3 4 5
7. I usually speak my mind when I have something to say	1 2 3 4 5
8. When I make mistakes I usually let it worry me for days after	1 2 3 4 5
9. In discussions, I tend to back-down even when I feel strongly about something	1 2 3 4 5
10. I generally feel in control	1 2 3 4 5
11. I often wish my life was more predictable	1 2 3 4 5
12. When I am feeling tired I find it difficult to get going	1 2 3 4 5
13. I am generally able to react quickly when something unexpected happens	1 2 3 4 5
14. However bad things are, I usually feel they will work out positively in the end	1 2 3 4 5
15. I generally look on the bright side of life	1 2 3 4 5
16. I generally find it hard to relax	1 2 3 4 5
17. I usually find it difficult to make a mental effort when I am tired	1 2 3 4 5
18. If I feel somebody is wrong, I am not afraid to argue with them	1 2 3 4 5

D.4 Sensation Seeking Scale-V (SSS-V)

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.

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

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

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

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

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

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

23. A I would like to try parachute jumping.
    B I would never want to try jumping out of a plane with or without a parachute.

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.

D.5 Tampa Scale of Kinesiophobia (TSK)

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 it's actually dangerous	1 2 3 4
17. No one should have to exercise when he/she is in pain	1 2 3 4

Appendix E

FUNCTIONAL ASSESSMENT TOOL

E.1 Six-meter Timed Hop Task

Hop Performance

UNINJURED EXTREMITY **LEFT** **RIGHT**	Practice Trial # 1	Practice Trial # 2	Trial # 1	Trial # 2
Timed Six Meter Hop Test				

INJURED EXTREMITY **LEFT** **RIGHT**	Practice Trial # 1	Practice Trial # 2	Trial # 1	Trial # 2
Timed Six Meter Hop Test				

E.2 Incidences of Giving-way

How many times have you experienced your knee "giving way" or "buckling" since the initial injury? _____

E.3 Knee Outcome Survey-Activities of Daily Living (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.

	I do not have the symptom	I have the symptom but it does not affect my activity	The symptom affects my activity slightly	The symptom affects my activity moderately	The symptom affects my activity severely	The symptom prevents me from all daily activities
Pain						
Stiffness						
Swelling						
Giving way, buckling, or shifting of the knee						
Weakness						
Limping						

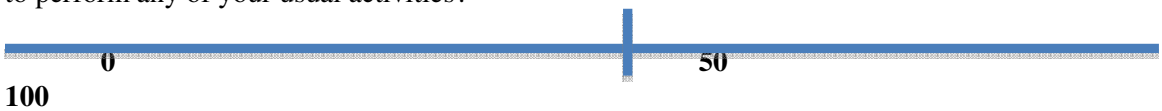
Functional Limitations with Activities of Daily Living

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

	Activity is not difficult	Activity is minimally difficult	Activity is somewhat difficult	Activity is fairly difficult	Activity is very difficult	I am unable to do the activity
Walk						
Go up stairs						
Go down stairs						
Stand						
Kneel on the front of your knee						
Squat						
Sit with your knee bent						
Rise from a chair						

E.4 Global Rating of Knee Function

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?



1. Please mark on the scale above and write the number here _____

2. How would you rate the overall function of your knee during your usual daily activities?
_____ normal _____ nearly normal _____ abnormal _____ severely abnormal

3. As a result of your knee injury, how would you rate your current level of daily activity?
_____ normal _____ nearly normal _____ abnormal _____ severely abnormal

Appendix F

DEMOGRAPHIC QUESTIONNAIRE

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

1. Gender: Male Female

2. Age? _____ years3. Height? _____ inches 4. Weight? _____ pounds

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, knee, or ankle in the past 6 months?

Yes No

If Yes, explain _____

Appendix G

PERMISSION LETTERS

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE: March 14, 2012

TO: Stephanie Segulin
FROM: University of Delaware IRB

STUDY TITLE: [319746-1] The Relationship between Personality and Functional Ability following Anterior Cruciate Ligament Injury

SUBMISSION TYPE: New Project

ACTION: APPROVED
APPROVAL DATE: March 14, 2012
EXPIRATION DATE: March 13, 2013
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 4, 7

Thank you for your submission of New Project 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 Jody-Lynn Berg at (302) 831-1119 or jlberg@udel.edu. Please include your study title and reference number in all correspondence with this office.

RESEARCH OFFICE

210 Hullihen Hall
University of Delaware
Newark, Delaware 19716-1551
Ph: 302/831-2136
Fax: 302/831-2828

DATE: February 14, 2013

TO: Stephanie Segulin
FROM: University of Delaware IRB

STUDY TITLE: [319746-3] The Relationship between Personality and Functional Ability following Anterior Cruciate Ligament Injury

SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: February 14, 2013
EXPIRATION DATE: March 13, 2014
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 4, 7

Thank you for your submission of Continuing Review/Progress Report 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.

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If you have any questions, please contact Jody-Lynn Berg at (302) 831-1119 or jlberg@udel.edu. Please include your study title and reference number in all correspondence with this office.