The Association of Proprioceptive Ability with Rates of Injury in College Athletes

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ABSTRACT:

Background: Proprioception, the ability to determine the spatial location of a given part of the body, may reduce the risk of injury in the general population; however, there is limited research exploring the relationship between proprioception and injury in collegiate athletes. **Purpose**: The purpose of this study was to examine the association between level of proprioception and injury rates among college athletes. **Methods**: Thirteen subjects from the FSC waterski team were recruited for this study. Subjects completed a questionnaire regarding their training methods and injury history. Proprioception was assessed using a cell phone application-based goniometer to measure the participant's ability to replicate the joint angles demonstrated by the research assistant. Both shoulder and knee joints were measured to provide information on both upper and lower body proprioceptive ability. **Results:** Twelve participants (50% male, mean age: 20.08 years). No significant differences existed between participants with a history of injury compared to participants without a severe injury. A trend did exist for participants without a history of injury having more accurate proprioceptive abilities compared to participants with a history of injury (13.17 vs 5.94, p=.08). **Conclusion:** Although no significant differences were found for proprioceptive abilities between the participants with and without a history of injury, there was a trend towards more accurate proprioceptive abilities for participants without an injury history. Future studies should further examine the relationship between injury rate, balance training, and proprioceptive abilities. Findings can inform coaches and trainers to consider incorporating proprioceptive training to enhance athletic performance and reduce injury risk.

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INTRODUCTION:

Proprioception, which can be defined as the ability one has to process internal and environmental sensory information to determine spatial location (Han, Jia, et al., 2016), has been shown to benefit all individuals. Proprioception is necessary for daily function and aids in the prevention of falls or injuries while performing daily tasks. Proprioception allows the body to execute precise movement when the brain communicates a position to a certain part of the body, which includes balance. To control balance, the central nervous system (CNS) integrates visual, vestibular, and proprioceptive information to produce motor commands that coordinate the activation patterns of muscles. Proprioceptors in the muscles of the ankles detect minute changes in movement, and communicate with the brain to maintain stability and balance. Proprioception is used when the brain processes the height of a step from visual cues, and communicates exactly where the foot needs to be to clear the step. The hip, knee, and ankle joints are all involved in the proper placement of the foot, and would not be able to move together with accuracy if not for proprioceptors in and around those joints.

While proprioception is beneficial for everyone, it may be of particular importance for individuals involved in competitive sports (Hagen, Marco, Martin Lemke, and Matthias Lahner, 2018). Previous studies suggest that a high level of spatial awareness may be related to greater athletic performance, particularly in sports involving a high degree of coordination and agility (Hagen, Marco, Martin Lemke, and Matthias Lahner, 2018). Aside from athletic performance, proprioception can be improved with training (Niespodziński, Bartłomiej, et al., 2018; Salles, Jose Inacio, et al., 2015), so athletes tend to have a higher level of proprioception than non-athletes and is considered another reason athletes are better able to prevent injury in general

(Muaidi, Q. I., L. L. Nicholson, and K. M. Refshauge, 2009). What is less well known is the possible association between proprioception and injury rates in athletes.

Injury prevention is important in sports scenarios. If increased levels of proprioceptive abilities are found to be inversely associated with the prevalence of injury, proprioceptive training should be included in training or rehabilitation to reduce the risk of injury. There is limited research on the association between level of proprioception and injury rates in athletes.

Because we used water ski athletes as the subjects of our study, we will provide some background knowledge of the sport. Water skiing involves being towed behind a boat doing one of three events: slalom, trick, or jump. In the jump event, the skier is airborne for ~3 seconds and lands back on the water. In the trick event, the skier uses either hands to spin and flip, or connects the foot to the handle to spin. In the slalom event, the skier is pulled through a course at either 34.2 or 36.0 miles per hour, and releases from the handle six times each pass through the course. In water skiing, knee joint injuries are quite common, with approximately 35% of water ski injuries occurring in the lower body, often to the knee (Baker, Brauneis, & McGwin, 2010). As with many sports that require the execution of air-based techniques, the development of the skier's balance and proprioception skills are vital to ensuring both success and safety (S. Roberts & P. Roberts, 1996).

Golgi tendon organs, muscle spindles, and joint receptors are the mechanical means of proprioceptive function. The golgi tendon organs are in the tendons and detect the amount of force that is being put on the muscle and determine whether or not muscle action should be taken to prevent injury or obtain the desired movement. Muscle spindles are located in skeletal muscle fibers and detect the length of the muscle and the velocity at which the muscle is moving. Muscle spindles can act as a reflex sense or can send information to the brain to be processed prior to a movement. Because of this, it is primarily muscle spindles that detect joint position and movement (Ogard, William K, 2011). Joint receptors detect force, rotation, and angle at the joint, especially at end ranges of motion. Because muscle spindles are located within the muscle, they are susceptible to injury (Lubiatowski, Przemyslaw, et al., 2013). Once damage to the proprioceptors has occurred, instability of the joint is likely; instability increases the risk of further injury (Lubiatowski, Przemyslaw, et al., 2013).

Proprioception in sports, therefore, may also be significant in injury prevention. Foot placement is particularly important in sports such as lacrosse, soccer, football, and other high-agility sports because of the prevalence of ankle sprains in those sports (Hagen, Marco, Martin Lemke, and Matthias Lahner, 2018).

It has been suggested that proprioception may be beneficial in reducing injury risk (Hagen, Marco, Martin Lemke, and Matthias Lahner, 2018; Muaidi, Q. I., L. L. Nicholson, and K. M. Refshauge, 2009). It has also been suggested that proprioception can be improved through training (Salles, Jose Inacio, et al., 2015; Ashton-Miller, James A., et al., 2001). If the findings of this investigation suggest an inverse association between proprioception and injury rates, then this would provide further evidence that proprioceptive training might be beneficial, especially to athletes. Additionally, if injury rates and proprioception are positively correlated, this may suggest that proper proprioceptive training post-injury is beneficial to restoring proprioceptive abilities. Although research demonstrates the importance of spatial awareness in athletes, no studies, to our knowledge, have examined the association between levels of proprioception and rate of injury in sports, specifically water skiing. Such findings may provide insight into whether coaches and trainers should consider proprioceptive training for athletes to achieve optimal performance and prevent injury.

The primary purpose of this investigation was to determine whether proprioception scores in a group of male and female water ski athletes were inversely associated with injury rates. A secondary purpose of the investigation was to examine if any association found between proprioception and injury rates differs consistently across another variable such as gender, position, or anthropometric measures.

RESEARCH DESIGN & METHODS:

Study Type:

This investigation used a cross-sectional study design, with the primary goal being to examine associations between proprioceptive ability and injury history.

Participants & Setting:

The investigation took place at the exercise science laboratory at Florida Southern College (FSC) in Lakeland, FL. Seventeen members of the FSC water ski team were initially recruited for this study, however, due to scheduling issues, only 12 were able to complete all of the measures. Recruitment of participants took place after approval was given by the FSC water ski team head coach. Following approval from the coach, the investigator met with the team as a group and provided information about the study to the student athletes. Interested individuals were given an approved consent form to read and sign (Appendix A), followed by the initial Injury History Questionnaire and Sports History Questionnaire (Appendix B) during the first meeting.

Inclusion/Exclusion Criteria

To be eligible to participate in the proposed study, individuals must meet the following criteria:

- Currently attending Florida Southern College
- Currently on an intercollegiate athletic team
- No current injury that would have limited participation in this study
- No current health condition or use of medication that may have affected spatial awareness

Study Measures

Demographic Information

Participants were administered a demographic questionnaire, for which they answered questions related to age, gender, and year in school.

Anthropometric Measures

Following completion of the demographic questions, the student investigator measured participant height and weight using a Detecto Model 439 Beam Balance Scale and Stadiometer (Detecto, Webb City, MO). Following measurement of height and weight, body fat percentage was measured using an Omron HBF-306C hand-held bioelectrical impedances analyzer (Omron, Kyoto, Japan).

Sport History Questionnaire

The participants were asked questions regarding their sport-specific training, and any proprioceptive or balance training they may have participated in.

Injury History Questionnaire

Using a modified version of the Sport Injury Surveillance Survey (Gabbe and Finch, 2000), participants were asked to recall any injuries they sustained in the previous year that resulted in any or all of the following: 1) missing two or more training sessions; 2) one or more competitions; 3) requirement of treatment from a health professional. Participants were also asked to report the number of injuries sustained, body region injured, and the diagnosis/treatment of the injuries.

Proprioception Measures

To measure proprioception, the study conducted active movement extent discrimination assessment (AMEDA) of shoulder (glenohumeral) and knee joints (Han et al. 2016; Waddington and Adams, 1999). The AMEDA method has shown to have better ecological validity and test validity compared to other proprioception measures, and has been recommended for use in athletic populations (Han et al. 2016).

The tool we used during the study to measure proprioception was a smartphone application ("app") called "Goniometer," purchased from the Apple App Store. A study by Mourcou, et. al, tested the validity of a number of smartphone applications (some very similar in function to the Apple Goniometer application) used to measure joint angles used for proprioceptive testing. All of the applications were determined to have acceptable reliability (Mourcou, et al, 2015). In particular, the "Simple Goniometer" application was found to be reliable when using the same protocol used in the current study (joint angle reproduction).

Shoulder assessment:

For the second meeting, the participants met in the FSC Exercise Science lab, where the researchers obtained height and weight values using the Detecto Model 439 Beam Balance Scale and Stadiometer (Detecto, Webb City, MO), and body fat percentage was assessed using a Omron HBF-306C hand-held bioelectrical impedances analyzer (Omron, Kyoto, Japan).

The physical proprioceptive test began when the participant was briefly explained the procedure, and then blindfolded. The subject was then instructed to stand with his/her arm relaxed to the side, and then the student investigator aligned the Goniometer phone app goniometer with the humerus. The investigator moved the arm so that the shoulder joint was in 60º of flexion (active assisted motion). This position was held actively by the participant for 3 seconds and then returned to resting at 0º of flexion for ~5 seconds. The participant then attempted to recreate the same reference position. The investigator measured the attempt, and the original reference position and the recreated position were recorded. The participant repeated the attempt of 60º of shoulder flexion once more on the original side. This procedure was duplicated bilaterally. A shoulder flexion angle of 60º was chose for this investigation, as this angle has been used in similar studies (Han et al. 2016; Waddington and Adams, 1999).

Knee assessment:

Participants remained standing for this test, with their eyes covered, and supporting themselves by holding onto a chair. Participants were asked to stand on one leg while keeping their other foot off the ground. The participant was then instructed to slowly flex the lower extremity (the weight-bearing leg) until told to stop, reaching the angle of 20º past neutral. The participant was then asked to hold this position for 3 seconds to sense the knee joint position. The participant then returned to their original standing position with both feet on the ground for ~5 seconds. Participants were then asked to recreate that same angle without any direction from the investigator. Response position was measured as the angle at which participants stopped. Participants were asked to repeat this attempt again, with no further direction from the student investigator. This procedure was duplicated bilaterally.

Statistical Analysis

Descriptive statistics were assessed for all variables. Independent samples t-tests were conducted to determine differences in proprioception values between participants who had sustained shoulder injuries and those that did not. T-tests were repeated for knee injuries and proprioceptive levels. Exploratory analyses were conducted to determine whether any differences in proprioceptive levels exist between males and females. All analyses were conducted in SAS Version 9.4 with a significance level set at $p<0.05$.

Protection of Human Rights

Prior to any testing, all prospective participants read and signed an informed consent document that was approved by the Florida Southern College Human Subjects Committee. This document outlined the potential risks and benefits of participating in the investigation. All participants were made aware that their involvement in this investigation is completely voluntary and that they may elect to drop out of the study at any point. All data collected was stored on a password-protected computer, with only the senior members of the research team having access to the data.

RESULTS:

Demographic Characteristics

A total of twelve participants (50% female, mean age: 20.8 yrs) were included in this study. Demographic characteristics are presented in Table 1. Originally, 17 participants were recruited for this study; however, due to scheduling issues, only 12 were able to complete all measures. A little over half of the sample currently engages in some form of balance/proprioception training, and have been involved in waterskiing on average for 10.08 ± 2.87 years.

Table 1: Demographic Characteristics (n=12)

Factors	N (%)	Mean (SD)
Females	6 (50%)	
Year in School		
1	3 (25%)	
2	2 (17%)	
3	5 (42%)	
4	2 (17%)	
Age		20.08 (1.78)
BMI		22.74 (3.01)
Body fat %		15.21 (5.12)
Years playing sport		10.08 (2.87)
Balance Training	7 (67%)	

Injury History

Table 2 displays both shoulder and knee injury history of all participants. Three out of the 12 participants (25%) had previously experienced a significant injury to their shoulder, and on average, took around 6 months off of waterskiing. Five of the 12 participants had previously experienced a significant knee injury (42%), taking an average of 2.5 months off from waterskiing.

Table 2: Injury History (n=12)

Shoulder	N (%)	Knee	N (%)
Previous Injury to shoulder	3 (25%)	Previous Injury to knee	5 (42%)
Shoulder surgery	1 (8%)	Knee surgery	0
Time off from sport (days)*	190 (5)	Time off from sport (days)*	75 (30)

*mean (SD)

Comparison of Proprioceptive Values Between Participants with Injury History and Participants with no History of Injury

Results from the t-tests revealed no significant differences in proprioceptive values between participants with a history of shoulder injury and those without for either the right (13.17 vs 5.94, p=.08) or left shoulder joint (1.17 vs. 1.1, p=.96) (Table 3). There was a trend, however, towards participants with no injury history having more accurate proprioceptive levels in the right shoulder compared to those with injury history. For knee joint proprioception, there were no significant differences in any of the knee joint angles between groups (Table 4).

Table 3: Proprioception Values in Shoulder joint between Injured vs Non-injured

Factor	Injured (n=3)	Non-Injured (n=9)	p-value
Right Shoulder	13.17 (5.11)	5.94 (5.78)	.08
Left Shoulder	1.17 (.76)	1.1 (1.65)	.96

Table 4: Proprioception Values in Knee joint between Injured vs Non-injured

Factor	Injured (n=5)	Non-Injured (n=7)	p-value
Thigh Right Knee	3.3 (3.7)	3.93 (3.4)	.77
Calf Right Knee	1.4 (1.08)	3.89 (2.89)	.1
Thigh Left Knee	4.1 (3.73)	8.29 (8.26)	.32
Calf Left Knee	4 (3.52)	4.57 (4.56)	.82

Exploratory Analyses

Descriptive Characteristics Between Male and Female Participants

Table 5 compares participant characteristics between males (n=6) and females (n=6). Males had significantly lower body fat percentages compared to females (12.12% vs. 18.03%, p=.03), and a trend existed for males having a history of knee injuries compared to females (67% vs 17%, p=. 08).

Table 5: Descriptive Statistics Between Males (n=6) & Females (n=6)

Factors	Males	Females	p-value
Age; M (SD)	20.5 (2.07)	19.67 (1.51)	.44
BMI ; M (SD)	23.98 (2.48)	21.5 (3.18)	.16
Body fat %; M (SD)	12.12 (3.18)	18.3 (4.95)	.03
Years playing sport; M (SD)	9.5 (2.59)	10.67 (3.23)	.51
Balance Training; N (%)	4 (67%)	3 (50%)	.56
Shoulder Injury; N (%)	2 (33%)	1 (16%)	.51
Shoulder – days off ; M (SD)	195 (106)	180	N/A
Knee Injury; N (%)	4 (67%)	1 (17%)	.08
Knee – days off; M (SD)	78.75 (33.26)	60	N/A

Proprioceptive Values Between Male and Female Participants

Table 6 displays the differences in proprioceptive values between males and females. Although not statistically significant, males appeared to have more accurate proprioceptive numbers compared to females for both thigh (3.75 vs 9.33, p=.18) and calf (1.92 vs. 3.75, p=.23) left knee measurements.

Table 6 Comparison of Proprioceptive Values Between Males (n=6) & Females (n=6)

Factors	Males	Females	p-value
Right Shoulder	7.58 (6.59)	7.92 (6.62)	.93
Left Shoulder	0.83 (.61)	1.42 (2)	.52

Thigh Right Knee	3.25 (3.69)	4.08 (3.69)	.69
Calf Right Knee	4.25 (3.27)	4.42 (4.93)	.95
Thigh Left Knee	3.75 (2.82)	9.33 (8.75)	.18
Calf Left Knee	1.92 (2.29)	3.75 (2.7)	.23

DISCUSSION:

As this study only included 12 participants and all participants were water ski athletes, the results of the study cannot be generalized. However, the results of this small population will be discussed to provide a potential for further experiments based off of this one that could be generalized and beneficial to multiple sports domains, and maybe even the general population.

As the results showed, there was no significant difference between proprioceptive abilities of the water ski athletes after an injury of the knee or the shoulder. This could imply that the athletes' proprioceptive abilities did not decrease as a result of an injury, that the rehabilitative techniques utilized by the athletes that sustained an injury were effective in restoring the athletes' proprioceptive abilities, or that the small population was not enough to be able to see noticeable results.

It is important to mention, however, that a trend existed demonstrating that athletes with no history of a substantial shoulder injury tended to have more accurate proprioceptive abilities in the shoulder joint. Unfortunately, the sample size was too small to detect significant differences between the groups.

As the literature does not fully support the notion of proprioceptors in the ligaments (Gillquist, 1996), if the athlete's injury was ligamentous, proprioceptors would theoretically not have been damaged. However. it is possible that there could have been some muscular damage during the injury, which could have affected the proprioceptors.

Exploratory analyses were conducted to examine any differences in proprioceptive abilities between male and female water skiers. Although no significant differences were found for proprioceptive values between males and females for either the shoulder or knee joint, a trend was identified regarding proprioception in the knee joints, with males showing more accurate repositioning of the femoral knee joint angle. This finding is supported by a study by Muaidi (2017) who found that males had higher levels of proprioception acuity for the internal rotation of the knee compared to females, however, no differences were found for proprioception values for external rotation of the knee joint. The small sample size may have contributed to the non-significant findings, and thus a larger sample size is needed to better determine if significant differences exist between male and female athletes in the current study.

During rehabilitation, the injured body part is the primary focus, so the neuromuscular pathways to the injured body part have the ability to be restored after the injury and before returning to play. In addition, if the brain is now primed to focus on this body part, there will be more neuromuscular emphasis on that body part once full participation in the sport resumes. The proprioceptive abilities of the athlete may increase post-injury because of this (Burfiend & Chimera, 2015).

Another notable finding is that the sample of athletes had an average body fat percentage of 15.21±5.12%, which is below average of 28.51±9.26% for the general population (Sladjana et. al, 2019). This could potentially reduce the external validity of the study as well, because if the results of the study were at all dependent on the body fat percentage of the subjects, the results of the study would most likely be different in another population.

Several studies have previously demonstrated that athletes have better joint position sense (JPS) compared to the general population (Salles et al. 2015), however, whether this ability is due to training specifically targeting proprioception is unclear. Future research should compare differing training protocols that include either balance training, strength training, or a combination of both training modes to better understand the independent effects of balance training on proprioception levels in athletes. By better understanding the training components involved in enhancing proprioceptive abilities, coaches will be able to better implement training programs that optimize proprioception, which is critical for sports such as water skiing.

Limitations

The current study contains several limitations that should be noted. First, the sample size is small, which impedes our ability to detect significant differences between the comparison groups. Secondly, the injury history questionnaire did not factor in the dates of previous injuries, which could have affected the relationship with proprioception. Additionally, the sports training questionnaire did not assess the duration or frequency of balance training of each participant, which also may have affected results. Future studies should collect more detailed information on injury history and training regimens to better understand their role with proprioceptive abilities.

A source of error is the effort levels of the subjects; if the subjects were not putting forth full effort, the results could have been different. The last source of error of the study was the potential for the participants being involved in other activities or habits that inadvertently improve their proprioception. This would cause the participants' data to be higher than usual, with a cause unknown to the investigator.

Future Directions

In addition to a larger sample size and the inclusion of additional information regarding injury history and training regimen, future studies should consider a prospective study to examine balance training and injury rate over a longer duration. Additionally, it may be important to examine exercises prescribed during rehabilitation to determine the extent that proprioception training may be included in treatment programs.

Conclusion

The current study is the first to our knowledge that examines the association of proprioception with injury rate in collegiate water skiers. Given the literature on the importance of balance training for sports, such as water skiing, that involve a blend of skills, such as muscular strength, coordination, and dynamic balance (Mullins, 2007), the inclusion of proprioceptive training may both reduce injury risk, while at the same time, enhancing athletic performance. This could be the basis for further studies examining other factors regarding the sport of water skiing. The uses for these types of studies include potential improvements in rehabilitative practices, the knowledge of a potential characteristic of high-level athletes, or baseline and post-rehabilitation testing for proprioception.

Works Cited

Albert, Frederic, et al. "Proprioceptive feedback in humans expresses motor invariants during writing." *Experimental brain research* 164.2 (2005): 242-249.

Ashton-Miller, James A., et al. "Can proprioception really be improved by exercises?." *Knee surgery, sports traumatology, arthroscopy* 9.3 (2001): 128-136.

Baker, J. I., Griffin, R., Brauneis, P. F., Rue III, L. W., & McGwin Jr, G. (2010). A comparison of wakeboard-, water skiing-, and tubing-related injuries in the United States, 2000-2007. *Journal of sports science & medicine*, *9*(1), 92.

Collins, David F., et al. "Cutaneous receptors contribute to kinesthesia at the index finger, elbow, and knee." *Journal of Neurophysiology* 94.3 (2005): 1699-1706.

Findlater, Sonja E., and Sean P. Dukelow. "Upper extremity proprioception after stroke: bridging the gap between neuroscience and rehabilitation." *Journal of motor behavior* 49.1 (2017): 27-34.

Gabbe B and Caroline Finch. “A pilot case-control study to identify injury risk factors in community-level Australian football players”. *Journal of Science in Medicine and Sport* (2000)*:* 3*;* S23*–30.*

Gillquist, Jan. “Knee ligaments and proprioception.” *Acta Orthopaedica Scandinavica,* (1996) *67:6, 533-535.*

Hagen, Marco, Martin Lemke, and Matthias Lahner. "Deficits in subtalar pronation and supination proprioception in subjects with chronic ankle instability." *Human movement science* 57 (2018): 324-331.

Han, Jia, et al. "Assessing proprioception: a critical review of methods." *Journal of Sport and Health Science* 5.1 (2016): 80-90.

Lubiatowski, Przemyslaw, et al. "Measurement of active shoulder proprioception: dedicated system and device." *European Journal of Orthopaedic Surgery & Traumatology* 23.2 (2013): 177-183.

Mourcou, Q., Fleury, A., Diot, B., Franco, C., & Vuillerme, N. (2015). Mobile phone-based joint angle measurement for functional assessment and rehabilitation of proprioception. *BioMed research international*, *2015*.

Muaidi, Q. I., L. L. Nicholson, and K. M. Refshauge. "Do elite athletes exhibit enhanced proprioceptive acuity, range and strength of knee rotation compared with non−athletes?." *Scandinavian journal of medicine & science in sports* 19.1 (2009): 103-112.

Nagai, Takashi, et al. "Analysis of Lower Extremity Proprioception for Anterior Cruciate Ligament Injury Prevention: Current Opinion." *Sports Medicine* 48.6 (2018): 1303-1309.

Niespodziński, Bartłomiej, et al. "Relationship between Joint Position Sense, Force Sense, and Muscle Strength and the Impact of Gymnastic Training on Proprioception." *BioMed research international* 2018 (2018).

Ogard, William K. "Proprioception in sports medicine and athletic conditioning." *Strength & Conditioning Journal* 33.3 (2011): 111-118.

Roberts, S. N., & Roberts, P. M. (1996). Tournament water skiing trauma. *British journal of sports medicine*, *30*(2), 90-93.

Salles, José Inácio, et al. "Effect of specific exercise strategy on strength and proprioception in volleyball players with infraspinatus muscle atrophy." *Scandinavian journal of medicine & science in sports* (2018).

Salles, Jose Inacio, et al. "Strength training and shoulder proprioception." *Journal of athletic training* 50.3 (2015): 277-280.

Sladjana, R., Milivoj, D., Marina, D.-N., Nadja, V., Violeta, D., Milos, M., … Dragan, M. (2019). Profile and Reference Values for Body Fat and Skeletal Muscle Mass Percent at Females, Aged from 18.0 to 69.9, Measured by Multichannel Segmental Bioimpedance Method: Serbian Population Study. *International Journal of Morphology*, *37*(4), 1286–1293.

Steinberg, Nili, et al. "Can textured insoles improve ankle proprioception and performance in dancers?." *Journal of sports sciences* 34.15 (2016): 1430-1437.

Winter, J. A., T. J. Allen, and U. Proske. "Muscle spindle signals combine with the sense of effort to indicate limb position." *The Journal of physiology* 568.3 (2005): 1035-1046.

Yoon, Jung-Ro, et al. "Proprioception in patients with posterior cruciate ligament tears: A meta-analysis comparison of reconstructed and contralateral normal knees." *PloS one* 12.9 (2017): e0184812.

APPENDIX A:

QUESTIONNAIRES:

ID:______________ **Date:______________**

DEMOGRAPHIC QUESTIONNAIRE

Date of birth (month/day/year): ____________________

Gender: ____________________

Height: _____ ft. _____ in.

Weight (lbs)___________

Body fat %___________

Year in School (1st, 2nd, 3rd, 4th): _____________

Sports History and Injury Questionnaire

ID:______________ **Date:______________**

Player Background & Training Methods Survey:

1. In what sport do you compete?___________________________

2. For how long have you been participating in your current sport?____________ years

3. What is the average frequency of practice for your sport? ________________ days/week
4. On average, how many minutes per day are you training for your sport?
   ____________ minutes per day

5. What percentage of practice time is spent in moderate-to-vigorous intensity?
   ____________%

6. For how long have you been training at this frequency?____________ years

7. Do you do any type of strength training for your sport (yes/no)?
   a. If so, please describe
      ____
   b. How often do you do strength training for your sport?
      ______ days per week _____ minutes per day

8. Do you do any type of balance training for your sport (yes/no)?
   a. If so, please describe
      ____
   b. How often do you do balance training for your sport?
      ________ days per week ______ minutes per day

9. At what level would you classify yourself in your sport? (Example: professional, expert, skilled)__________________

10. Between the ages of 13 – 18, did you play any other sports besides your current sport? Yes/No If yes, what sports:____

11. What is your current position on your sports team (if applicable):____

Injury History Questionnaire

1. Have you ever sustained a shoulder injury as a result of your sport (yes/no)?
2. Have you ever sustained a shoulder injury as a result of an activity besides your sport (yes/no)?
3. If you answered yes to either of the previous questions, have you undergone rehab for your injury (yes/no)?
4. What was the date of the injury?___________________
5. Have you ever had surgery on your shoulder (yes/no)?
6. How much time were you required to take off of your sport?____________
7. What was the duration of the entire recovery process?_____________________
8. Have you ever sustained a knee injury as a result of your sport?
9. Have you ever sustained a knee injury as a result of an activity besides your sport?
10. If you answered yes to either of the previous questions, have you undergone rehab for your injury?
11. What was the date of the injury?
12. Have you ever had surgery on your knee?
13. How much time were you required to take off of your sport?
14. What was the duration of the entire recovery process?

APPENDIX B:

Title of research study: The Association of Proprioception and Injury Rate in College-Level Athletes

Principle Investigator: Samantha Stackpole
Faculty Advisor: David Rice, PhD
Study Location: Exercise Science Lab (Ordway 111A)

***Key Information*:** The following is a short summary of this study to help you decide whether or not to be a part of this study. More detailed information is listed later on in this form.

Why am I being invited to take part in a research study?

We invite you to take part in a research study because you are currently participating on a Florida Southern College Athletic Team and between the ages of 18-25 years.

Why is this research being done?

We are conducting this research to determine whether a specific type of spatial awareness, namely proprioception, may be associated with injury rate. Findings from this study could provide evidence for coaches to consider incorporating proprioception training into their weekly practice sessions.

How long will the research last and what will I need to do?

We expect that you will be able to complete your participation in this research study in about 30 – 45 minutes

The entire protocol will consist of one study visit. You will be asked to answer questions regarding your participation in sports and injury history. You will also have your height and weight measured, and be asked to complete a spatial awareness assessment

More detailed information about the study procedures can be found under ***"What happens if I say yes, I want to be in this research?"***

Is there any way being in this study could be bad for me?

There are no risks associated with this study. Participation in this study will not interfere with your current practice or competition schedule in any way.

Will being in this study help me any way?

There are no direct benefits to you from your taking part in this research. Possible benefits to others include using knowledge gained from this investigation to better understand the association between proprioceptive ability and injury history.

What happens if I do not want to be in this research?

Your participation in this study is completely voluntary. You are free to withdraw your consent and discontinue participation in this study at any time without prejudice or penalty. Your decision to participate or not participate in this study will in no way affect your continued enrollment, grades, employment or your position on your current athletic team.

<u>Detailed Information:</u> The following is more detailed information about this study in addition to the information listed above.

What should I know about this research study?

- Someone will explain this research study to you.
- Whether or not you take part is up to you.
- You can choose not to take part.
- You can agree to take part and later change your mind.
- Your decision will not be held against you.
- You can ask all the questions you want before you decide.

Who can I talk to?

If you have questions, concerns, or complaints, or think the research has hurt you, contact the principle investigator at Samantha.stackpole@frontier.com, or the faculty advisor, Dr. David Rice, at drice@flsouthern.edu, or 863-680-5061.

This research has been reviewed and approved by the Florida Southern College Institutional Review Board ("IRB"). If you have concerns/complaints and you are unable to reach either the principal investigator or the faculty advisor, you may contact the IRB directly by email at fscirb@flsouthern.edu.

How many people will be studied?

We expect approximately 30-40 people will be in this research study.

What happens if I say yes, I want to be in this research?

We will ask you to come to our lab for a single visit that will consist of the following procedures:

1. Questionnaires
    a. Demographic Questionnaire: We will ask you to complete questions regarding your age, gender, and race.

   b. Sports Participation and injury history questionnaire: We will ask you to complete questions regarding your participation in sports, your current training schedule, and your injury history.

2. Anthropometric Measures

   a. Height/Weight: We will measure your height and weight using a calibrated scale and stadiometer.

   b. Body Composition: We will measure your body composition using bioelectrical impedance analysis (BIA)

3. Proprioception Assessment

   a. Upper & Lower body Measurement: We will use a goniometer to help assess your spatial awareness for both your upper and lower body. For the upper body, we will move your shoulder joint to a certain position at a given angle, hold it for 3 seconds, and then return it to resting position. We will then ask you to reproduce that angle. We will then repeat this procedure with your knee joint

This entire visit is expected to last no longer than 30 – 40 minutes.

What happens if I say yes, but I change my mind later?
You can leave the research at any time it will not be held against you.

What happens to the information collected for the research?
Efforts will be made to limit the use and disclosure of your personal information, including research study records, to people who have a need to review this information. We cannot promise complete secrecy. Organizations that may inspect and copy your information include the IRB and other representatives of this organization.

Your information or samples that are collected as part of this research will not be used or distributed for future research studies, even if all of your identifiers are removed.

We will do our best to keep your records private and confidential. We cannot guarantee absolute confidentiality. Your personal information may be disclosed if required by law. Certain people may need to see your study records. The only people who will be allowed to see these records are: the Principal Investigator, Advising Professor, and Florida Southern College Institutional Review Board (IRB).

Signature Block for Capable Adult

Your signature documents your permission to take part in this research.

Signature of subject	Date
Printed name of subject	
Signature of person obtaining consent	Date
Printed name of person obtaining consent	