THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF KINESIOLOGY

COMPARATIVE STUDY OF POSTURAL CONTROL AND FUNCTIONAL PERFORMANCE BETWEEN COLLEGIATE WOMEN'S ICE HOCKEY AND SOCCER ATHLETES

HAN SOL SONG
SPRING 2013

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Kinesiology

Reviewed and approved* by the following:

WE Buckley
Professor of Exercise & Sport Science and Health Education
Thesis Supervisor

Jinger Gottschall
Assistant Professor of Kinesiology
Honors Adviser

Giampietro "John" Vairo
Instructor of Kinesiology
Director, Athletic Training and Sports Medicine Research Laboratory
Co-Thesis Supervisor

* Signatures are on file in the Schreyer Honors College.

ABSTRACT

COMPARATIVE STUDY OF POSTURAL CONTROL AND FUNCTIONAL PERFORMANCE BETWEEN COLLEGIATE WOMEN'S ICE HOCKEY AND SOCCER ATHLETES

Song H, Buckley WE, Vairo GL: Athletic Training and Sports Medicine Research Laboratory, Department of Kinesiology, The Pennsylvania State University, University Park, PA

Context: Based on injury statistics published by the National Collegiate Athletic Association(NCAA), women's ice hockey demonstrates a lower incidence for anterior cruciate ligament (ACL) injury compared with other women's sports such as soccer, which is associated with a greater incidence. However, limited evidence exists to explain this phenomenon. **Objective:** To investigate differences in postural control and functional performance between collegiate women's ice hockey and soccer athletes as a means to identify factors that may address the disparity in ACL injury incidence. We hypothesized that women's ice hockey participants would display better outcome measures than women's soccer participants. **Design and Settings:** A descriptive study was conducted in a controlled research laboratory. **Participants:** Ten NCAA D-I women's ice hockey athletes (19.3 ± 1.06 years, 1.64 ± 0.91 m, 64.25 ± 6.59 kg, 24.43 ± 5.79 % body fat) were matched by approximate age, height, mass and body fat percentage to 10 soccer athletes (19.5 ± 1.51 years, 1.69 ± 0.06 m, 64.69 ± 6.72 kg, 18.62 ± 7.23 % body fat) enrolled in the research study. **Interventions:** Center of pressure (COP) path length was measured via a reliable force platform protocol under eyes-opened and eyes-closed conditions as the static balance measure. Normalized reach distances were measured using the reliable Star Excursion Balance Test (SEBT) for the dynamic balance measures. The normalized crossover hop for distance was conducted for the functional performance measure. Group means and standard deviations were calculated per group. Separate two-sample tests were calculated to examine differences for the dependent variables between groups. $P < 0.05$ denoted statistical significance. **Results:** No statistically significant differences were found between the static and dynamic balance measures as well as the crossover hop test for the dominant leg. Statistical significance (P=0.028) was found with non-dominant leg crossover hop distance in women's ice hockey athletes. **Conclusion:** A lack of group difference in postural control may suggest that balance may not be a factor influencing ACL injury rates for collegiate women's soccer and ice hockey. Greater non-dominant leg crossover hop distance may indicate that functional performance potentially contributes to fewer ACL injuries in ice hockey. However, the difference in the nature of sport as well as the difference of the competitiveness should be considered.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTS

There are many people who contributed to making this research possible for me. I would like to thank all the Penn State women's ice hockey and women's soccer athletes who volunteered for this study. I would like to thank Dr. John Miller who helped me find related research articles and provided guidance to understanding scientific research. I would like to thank Dr. WE Buckley who supervised my research by keeping me motivated and helped me in revising the contents in the process. I would like to give special thanks to "JV," Dr. John Vairo who allowed me to start this study and thoroughly supervised me through each and every step of the research. JV kept me inspired when I was exhausted and burned out with the burden of research and college. He showed me what it is like to be in the field of research and guided me with his expertise in the kindest manner. I would also like to thank Dr. Jinger Gottschall who is my honors adviser and helped my college days shine by providing me the best advice at all times. I would never forget her kindness when she trusted and allowed me to enroll in her independent study to help me make up for my previous struggles and difficulties earlier in college.

I would like to give the most sincere thanks to my mom and dad who supported my international studies from high school to the end of college. I truly respect my parent's sacrifice and cannot express how grateful I am, but by saying I love you. I am very blessed to have such a mom and a dad and it is an honor to be your son.

Lastly, I give wholehearted thanks to God who is alive and is my creator and father, to Jesus Christ who saved me, and to the Holy Spirit who guides me.

CHAPTER 1: INTRODUCTION

The anterior cruciate ligament (ACL) injury is categorized as a severe type of injury and has significant traumatic short-term effects on performance in certain sports.[15] It is known that female athletes have a higher risk of ACL injury, which is 4 to 6 times higher than that of male athletes.[18] The severity of the ACL injury is high as it leads to substantial time loss from a sport such as soccer.[16] Furthermore, the rate of ACL injury is considerably higher in women than in men according to collected data from the National Collegiate Athletic Association (NCAA) Injury Surveillance System (ISS) since 1988.[2] It has been reported that athletic women experience a 3 to 3.6-fold higher rate of ACL injury relative to athletic men competing in the same sports.[25] Annually, it has been estimated that there are 38,000 ACL injuries among women athletes.[3] Subsequently, 10-20 years after reconstruction of the ACL, the increase in severity and prevalence of arthritic changes in the knee was reported in 60-90% of all patients.[6] Along with the unfavorable cessation from any sport activity for a considerably long period, other grave issues regarding the injury includes its extraordinary cost in treatment. The average cost of a surgical ACL reconstruction has been reported to range from $4,622.00 to $5,694.00 with the complete cost of treating each injury estimated at approximately $17,000.[4]

Review of NCAA Division I (D-I) data indicates women ice hockey athletes suffer a noticeably lower incidence of ACL injury compared with soccer. Accordingly, the NCAA ISS data indicates a large discrepancy between ice hockey (0.03 injuries per 1,000 athletes) and soccer (0.28 injuries per 1,000 athletes) in inspecting the sport-specific differences in women's ACL injury rates.[2] Currently, there are no valid explanations for this phenomenon. However, it has been reported that the high risk of

ACL injury in female athletes may be predicted from Star Excursion Balance Test (SEBT) as it quantifies dynamic postural-control of any deficit of the lower extremity impairment.[26] Thus, we intended to descriptively profile postural control as a means to identify a potential physical performance measure that underpins this phenomenon between collegiate women ice hockey and soccer athletes.

Specifically comparisons were made between static and dynamic balance assessments as well as the crossover hop for distance test. Respectively, we hypothesized that ice hockey athletes will demonstrate better performance measures in postural control and functional performance than soccer athletes.

These data could be used as a means to provide information that offers insight into this phenomenon as well as in developing progressive preventative ACL injury programs for women athletes.

CHAPTER 2: MATERIALS AND METHODS

Experiment Design & Setting:

The study was completed in the Athletic Training and Sports Medicine Research Laboratory at The Pennsylvania State University. Prior to this study, the research protocol was approved by Institutional Review Board (IRB). For this study, 10 competitive collegiate women's ice hockey athletes and 10 women's soccer athletes volunteered. Each participant was asked to complete an informed consent before the experiment began. At first, each volunteer participant's height, weight, leg dominance, and level of physical activity using the Tegner Activity Level Scale were recorded. Then, each participant was asked to lie on their back on an examination table in order to measure the participant's right and left leg length. To record leg length, the distance between the participant's anterior superior iliac spine and medial malleolus using a standard tape measure was used. This measure was used to standardize reach distances performing the single-leg balance reach task to facilitate comparisons across the participants. Prior to testing each participant completed a dynamic warm-up by walking on a flat treadmill (Woodway USA, Waukesha, WI) parallel with the ground at a common speed of 1.2m/s for five minutes. The order of testing was determined by using a statistical software package to generate random permutations, which helped prevent an order effect. Based on randomization process, a participant's static balance was measured via the quiet single-leg balance task; dynamic balance was measured via Star Excursion Balance Test (SEBT); and functional performance via the crossover hop test.

Participants

Ten NCAA D-I women's ice hockey athletes (19.3 ± 1.06 years, 1.64 ± 0.91 m, 64.25 ± 6.59 kg, 24.43 ± 5.79 % body fat) were matched by approximate age, height, mass and body fat percentage to 10 women's soccer athletes (19.5 ± 1.51 years, 1.69 ± 0.06 m, 64.69 ± 6.72 kg, 18.62 ± 7.23 % body fat). All had no traumatic spine or lower extremity injury history.

Laboratory Techniques

Static Balance: *Quiet Single-leg Balance Task*

Static balance of participants was measured via the Quiet Single-leg Balance Task. Prior to testing, a demonstration was given to each participant. In this task, a participant was asked to stand barefoot and single-legged on a flat-base AccuSway force plate (AMTI Corp., Watertwon, MA) for a 10-second period while maintaining balance.[8] The stance foot was placed on the same position on the force plate for each trial and it was accomplished by tracing the outline of the foot. While balancing, participants were asked to stare at a reference point at eye-level, 10 feet away from the platform. Simultaneously, participants were also asked to keep the non-stance leg knee flexed to 45º with the hip flexed to 30º and avoid the non-stance leg making contact with the stance leg while keeping their hands on their hips. During testing, a trial was discarded and repeated if a participant lifted their hands from their hips or lost balance and touched the ground with the non-stance leg. Each participant was given three practice trials and completed three test trials. For each leg, eyes opened and eyes closed conditions, randomly allocated, were separately measured. In between, each trial, a 30-second rest period was given. The path length in centimeters was measured as the center of pressure excursion by using accompanying Balance Clinic computer software (AMTI Corp., Watertwon, MA). This force platform testing technique has been shown to be reliable and valid in previous similar research studies.[9,10]

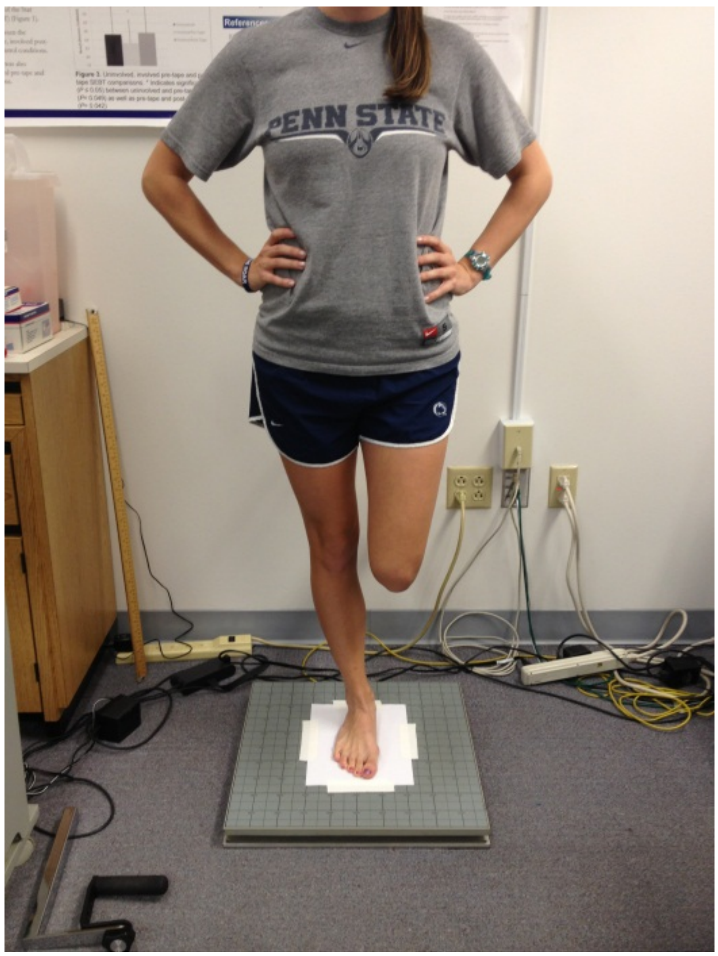


Figure 2.1 Quite Single-leg Balance

Dynamic Balance: Modified *Star Excursion Balance Test (SEBT)*

The SEBT has been shown to be a reliable and a valid testing method for dynamic balance.[11,12] This testing method was described to be a reliable technique as a functional screening tool that measures lower extremity reach while challenging the associated limitations of joint stability. The core goal of this task is to reach as far as possible with one leg in a specified direction while maintaining balance upon the opposite leg and the upper body. Considerable amounts of ankle, knee and hip range of motion as well as sufficient strength, proprioception and neuromuscular control skills are required to perform this task. Prior to the experiment, a demonstration was presented to each participant. Each participant was given four practice reaches and three test trials in the anterior, posteromedial, and posterolateral directions for each leg. Participants were given 5-minute rest session between each practice and test trial. Also, participants were given 15-second, and 1-minute rest intervals between reaches and changes in direction, respectively.

This SEBT was performed with a participant standing at the center of an outlined floor grid with eight lines extending at 45 degrees angle from the center of the grid. The lines positioned on the grid are labeled according to the direction of excursion relative to the stance leg. The grid was made by using a protractor and 3 inch (7.62cm)-wide adhesive tape enclosed in a 182.9 cm by 182.9 cm square on the hard bare floor. While maintaining a single leg stance, a participant was asked to reach as far as possible with the non-stance leg in a specified direction by a toe-touch using minimal pressure on the tape in order to ensure that stability is achieved through sufficient neuromuscular control of the stance leg. A participant was asked to return to a single leg standing position after each trial. If a participant failed to return to this position, the trial was discarded and repeated. After each trial, the investigator marked the point of the touch and measured the distance from the center of the grid with a tape measure in centimeter within one millimeter of precision. For each specified direction, three testing trials were performed and the farthest distance reached was counted for each direction’s final measure. All trial measures were normalized to leg length of each participant in order to gain the standardized value to be compared across the participants.

Figure 2.2 Posterolateral Direction of the SEBT

Figure 2.3 Anterior Direction of the SEBT

Figure 2.4 Posteromedial Direction of the SEBT

Functional performance: *Crossover Hop Test for Distance*

The crossover hop test is a functional testing technique that has been shown to be a highly reliable measurement.[13,14] The goal of this test is to cover as much distance as possible with three consecutive single-leg hops. Prior to the experiment, a demonstration was presented to each participant. On a hard floor, the testing zone was constructed with tape-marked area of 20 cm wide by 900 cm long. A participant was asked to stand on one leg with the lateral portion of the foot in line with the contralateral edge of the course.[14] A participant was asked to perform three consecutive hops crossing over the course with each hop. The trial was discarded and repeated if a participant lost balance during a trial and touched a ground with the non-stance leg. The distance covered was measured using a tape measure in centimeter. Each participant was given three practice trials and three testing trials. Each participant was given five-minute rest sessions between the practice and test trials and one-minute rest intervals between hops.

Figure 2.5 The Progression of the Crossover Hop Test

Statistical Analysis

Descriptive statistics, including group means and standard deviations were computed for the dependent variables of interest. Separate two-sample tests were calculated to examine differences between the dependent variable means for both groups. Normal probability and randomness plots were implemented in order to confirm the data met the necessary assumptions for t-test analysis. An *a priori* alpha level of $P < 0.05$ denoted statistical significance.

CHAPTER 3: RESULTS

There were no statistically significant differences found in static postural control and dynamic postural control outcome measures. However, there was a statistically significant difference found in non-dominant leg outcome measures of crossover hop.

Static Postural Control

Normal probability and randomness examination of the data confirmed it met the necessary assumptions for t-test analysis. There were no statistically significant differences between groups for all single-leg balance static postural control measures with both the dominant and non-dominant legs (**Table 3.1**).

Table 3.1. Quiet Single-Leg Balance Center of Pressure Path Length Measures

Group Comparisons (D)	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Eyes Opened (cm)	31.37 ± 7.05	36.77 ± 8.96	0.153	(-13.01, 2.21)	15.85
Eyes Closed (cm)	82.9 ± 16.2	77.3 ± 10.7	0.379	(-7.52, 18.63)	6.99

Group Comparisons (ND)	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Eyes Opened (cm)	31.73 ± 8.19	37.60 ± 7.21	0.107	(-13.15, 1.41)	16.93
Eyes Closed (cm)	80.8 ± 20.8	80.9 ± 10.8	0.997	(-16.06, 16.00)	0.12

Values are mean ± standard deviation;
% Δ = percent difference; *CI* = confidence interval;
$P < 0.05$ denotes statistical significance;
D = Dominant leg; ND = Non-dominant leg

Dynamic Postural Control

Normal probability and randomness examination of the data confirmed it met the necessary assumptions for t-test analysis. There were no statistically significant differences between groups for all SEBT reach distance directions with both the dominant and non-dominant legs (**Table 3.2**).

Table 3.2. SEBT Reach Distance Direction Measures

Group Comparisons (D)	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Anterior (%LL)	73.90 ± 5.24	78.83 ± 7.19	0.099	(-10.90, 1.03)	6.46
Posteromedial (%LL)	95.24 ± 8.59	89.57 ± 8.22	0.15	(-2.26, 13.60)	6.14
Posterolateral (%LL)	85.7 ± 11.1	86.98 ± 5.56	0.751	(-9.78, 7.23)	1.48

Group Comparisons (ND)	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Anterior (%LL)	74.07 ± 6.43	75.80 ± 5.31	0.519	(-7.30, 3.83)	2.31
Posteromedial (%LL)	95.99 ± 9.61	91.1 ± 10.5	0.292	(-4.60, 14.40)	5.23
Posterolateral (%LL)	87.9 ± 10.2	85.9 ± 10.4	0.668	(-7.72, 11.75)	2.30

Values are mean ± standard deviation;
% Δ = percent difference; *CI* = confidence interval;
$P < 0.05$ denotes statistical significance;
D = Dominant leg; ND = Non-dominant leg

Crossover Hop for Distance

Normal probability and randomness examination of the data confirmed it met the necessary assumptions for t-test analysis. A statistically significant difference was found between soccer and hockey athletes when assessing the non-dominant leg measures **(Figure 3.1**). There was no statistically significant difference when assessing the dominant leg measures (**Table 3.3)**.

Table 3.3. Crossover Hop Measures

Group Comparisons	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Dominant Leg (%LL)	406.6 ± 79.0	479.5 ± 79.7	0.056	(-147.7, 2.0)	16.45

Group Comparisons	**Soccer**	**Hockey**	***P***	**95% *CI***	**% Δ**
Non Dominant Leg (%LL)	410.4 ± 70.5	482.8 ± 64.2	0.028*	(-136.1, -8.9)	16.21

Values are mean ± standard deviation;
% Δ = percent difference; *CI* = confidence interval;
* denotes statistical significance ($P < 0.05$);
D = Dominant leg; ND = Non-dominant leg

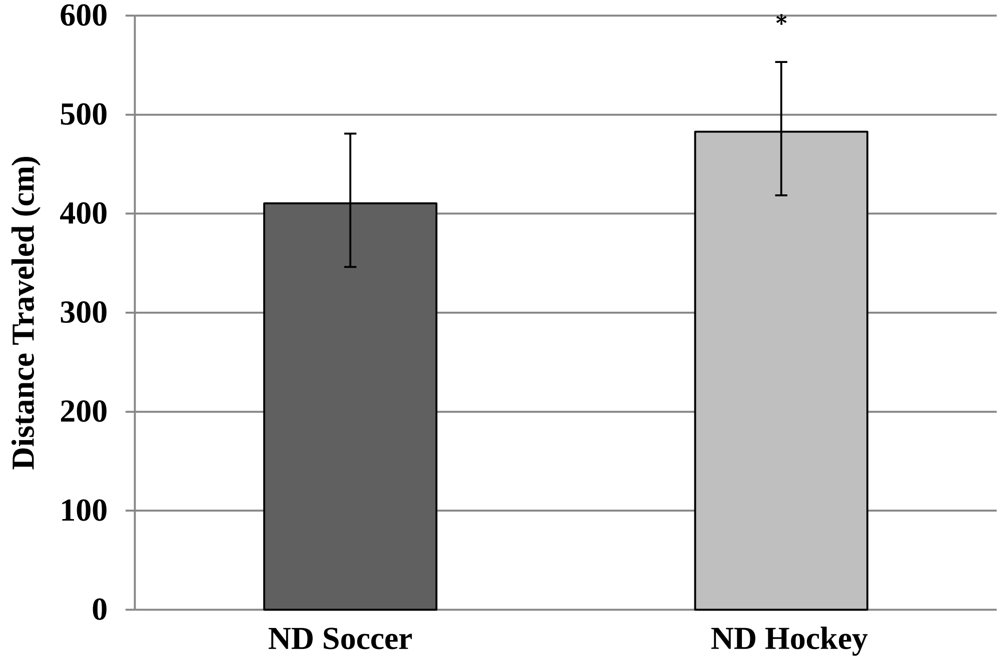


Figure 3.1. Crossover Hop Test Measures in Non-Dominant Soccer vs. Non-Dominant Hockey.

Error bars represent standard deviation of the group mean

* denotes statistical significance ($P < 0.05$)

CHAPTER 4: DISCUSSION

The purpose of this study was to examine differences in static and dynamic balance as well as functional performance between collegiate women's ice hockey and soccer athletes. From the context of collegiate women's ice hockey athletes suffering fewer ACL injuries, we hypothesized that these participants would show better performance measures of two measurements of postural control and a functional performance. The results indicated that there was no statistical significance in static balance and dynamic balance for both the dominant and non-dominant leg. Similarly, there was no statistical significance in functional performance with the dominant leg was involved. However, there was a statistical significance for functional performance with the non-dominant leg.

It has been reported that postural control is regarded as one of the most important factors that predict lower extremity injury, such as rupture of the ACL.[27,28] We hypothesized that women's ice hockey athletes would exhibit better postural control than soccer athletes based on data reported by Hoffman et al[27]. However, we found no significant differences between groups with measures of static and dynamic balance for both the dominant and non-dominant leg, which may suggest that these variables may not necessarily explain the considerable difference in ACL injury between collegiate women's ice hockey and soccer athletes. However, we did find that ice hockey athletes performed the crossover hop for distance better with the non-dominant leg than soccer athletes, which may somewhat explain the difference in ACL injury statistics between the two groups. Based on the outcomes of Alentorn-Geli et al[16], we may propose that the ice hockey player's higher level of functional performance potentially diminish one's chance of getting an ACL injury; although, additional research is necessary to confirm or discredit this statement.

Due to a lack of differences discovered in this research study, other factors may contribute to the incidence of ACL injury in these two groups that explain the large difference in risk. Thus, the frequency of getting an ACL injury may be associated with the very nature of the sport. For example, important factors that could be potentially responsible include the onset of fatigue. As we look closely at physical demands of each sport, it can be found that soccer consists of two 45-minutes with only three substitutes allowed. In comparison, ice hockey consists of three 20-minutes periods while all the athletes can be substituted without any restriction. Therefore, this difference is noteworthy because the onset of fatigue can be a significant influence on postural control and hence knee injury.[27] Acknowledging the difference in the nature of the sport is quite critical as Dick et al[17] reported that the risk of ACL injury is considerably higher in the last 15 minutes of play as an athlete gets tired. It suggests that muscular fatigue potentially increases the risk for non-contact ACL injuries as a result of decreases neuromuscular control ability.[16] Thus, the difference in the nature of sports may be a contributing factor in regard of the difference of ACL injury occurrence in two sports.

Another possible difference between women's soccer and ice hockey is competitiveness level. The women's NCAA collegiate soccer championship was established in 1982 while the ice hockey championship began in 2001. Agel et al[22] reports that women's ice hockey is in emerging status in regard to its competitiveness as well as the level of related athletic performance and skills compared to women's soccer. Thus, as the level of performance develops, the overall force production of the sport movements in players is increased. It may lead to a greater chance of getting injury.[22] The occurrence frequency of injury is highly related to the competitiveness level of sport, according to Agel et al[20]. It states that an overall injury rate was greater in varsity high school ice hockey than junior varsity at 49.7 and 30.3 per 1,000 hours of game-exposures, respectively. Accordingly, Molsa et al[24] reported that rates of injury for elite Finnish ice hockey players increased from 54.0 to 83.0 per 1,000 game-hours of exposures form the 1970s to the 1990s, respectively as the competitiveness level developed over time. Along this theme lower injury rates per game has been observed in collegiate men's ice hockey Division III than in Division I league.[21] In another supporting article, Upjohn et al[19] reported that forces exposed to the knee of high-calibre player's greater than that of low-calibre players as the high-calibre players exhibit an increased stride rate and a decreased amount of time spent in single and double support moves. Upjohn et al[19] indicate that higher knee valgus and rate of knee extension in propulsion and weight acceptance were measured in high-calibre than low-calibre players and that these factors may contribute to greater stress at the knee. Thus, with a trend for an increase in the number of high-calibre collegiate women's ice hockey players, a higher incidence of knee injuries would be expected as the competitiveness level of the sport is rising.

Another potential reason for women's ice hockey having a low incidence of ACL injury is the fact that body checking is banned in the women's ice hockey game.[22] This is reasonable because in women's ice hockey, the rate of general injuries was five-fold greater in games than practices. Furthermore, the higher percentage of injuries that occurred in games was from player-to-player contact whereas the injuries occur in practices were mainly non-contact based.[22]

From Imwalle et al[15] ACL injury may be caused from the two common maneuvers, one being landing from a jump with higher measures of knee valgus and the other pivoting with a fast change in direction while running. In the context of this study, with women's ice hockey there is no jumping movement involved in the sport whereas in soccer, both common maneuvers are often accountable for ACL injuries.

Clinical Implications

With the outcomes of this study, clinicians may consider focusing on improving functional performance level in order to prevent ACL injury. This is especially applicable as Dick et al[17] state incorporating programs to emphasize increasing a female athlete's flexibility, plyometric, strength and neuromuscular condition, clinicians may reduce the chance of getting an ACL injury.

Limitations

One of the limitations of our study was that the subject size was too small, with 10 participants each, to represent the entire sports population in NCAA. When the study was executed in larger number of participants involved, stronger outcomes would possibly result. The difference of the competitiveness level of two sports may have affected data as Penn State women's soccer has won record-breaking 15 consecutive Big Ten titles through 2012 season whereas Penn State women's ice hockey just joined the NCAA in the beginning of 2012-13 seasons. Further study in this field would be recommended to decide the effect and relationship of postural control and functional performance in their prevention of ACL injury with more validity. Furthermore, as the competitiveness level of women's ice hockey reaches higher in comparison to women's soccer, the results may change. Additionally, if the study was performed in a double blinded setting, it may have prevented possible examiners' bias.

CHAPTER 5: CONCLUSION

The postural control and functional performance outcome measures among ice hockey and soccer athletes were investigated in our research study. A lack of group difference in postural control may suggest that balance may not be a factor influencing ACL injury rates for collegiate women's soccer and ice hockey. Greater non-dominant leg crossover hop distance may indicate that functional performance potentially accounts for fewer ACL injuries in ice hockey. However, the difference in the nature of sport as well as the difference of the competitive level should be considered. Further research would be recommended to examine the relationship of postural control and functional performance in the prevention of ACL injury.

REFERENCES

1. Renstrom P, Ljungqvist A, Arendt E. Non-contact ACL injuries in female athletes: An International Olympic Committee current concepts statement. *Br J Sports Med.* 2008;42:394-412.

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

3. Toth AP, Cordasco FA. Anterior cruciate ligament injuries in the female athlete. *J Gend Specif Med*. 2001;4:25-34.

4. Cole D, Ginn T, Chen G, Smith B, Curl W, Martin D, Poehling G. Cost comparison of anterior cruciate ligament reconstruction: Autograft versus allograft. *Arthroscopy.* 2005;21(7):786-790.

5. hewett T, Stroupe A, Nance T, Noyes F. Plyometric training in female athletes: decreased impact forces and increased hamstring torques. *Am J Sports Med*. 1996;24:765-773.

6. Ross H, Adalberth T, Dahlberg L, Lohmander LS. Osteoarthritis to the knee after injury to the anterior cruciate ligament or meniscus: the influence of time and age. *Osteoarthritis Cartilage*. 1995;3(4): 261-267.

7. Zazulak BT, Hewett TE, Reeves NP, Goldberg B, Cholewicki J. The effects of core proprioception on knee injury: a prospective biomechanical-epidemiological study. *Am J Sports Med.* 2007 Mar;35(3):368-73.

8. Gribble PA, Hertel J, Denegar CR. Chronic ankle instability and fatique create proximal joint alterations during performance of the Star Excursion Balance Test. *Int J Sports Med.* 2007;28:236-242.

9. LeClair K, Riach C. Postural stability measures: what to measure and for how long. *Clin Biomech.* 1996;11:176-178.

10. Palmieri RM, Ingersoll CD, Stone MB, Krause BA. Center-of-pressure parameters used in the assessment of proprioception and muscular strength. *J Sport Rehabil.* 2002;11:51-66.

11. Hertel J, Miller S, Denegar C. Intratester and intertester reliability during the Star Excursion Balance Test. *J Sport Rehabil.* 2000;9:104-116.

12. Kinzey SJ, Armstrong CW. The reliability of the Star-Excursion Test in assessing dynamic balance. *J Orthop Sports Phys Ther.* 1998;27(5):356-360.

13. Bolgla LA, Keskula DR. Reliability of lower extremity functional performance tests. *J Orthop Sports Phys Ther.* 1997;26(3):138-142.

14. Clark NC, Gumbrell CJ, Rana S, Traole CM, Morrissey MC. Intratester reliability and measurement error of the adapted crossover hop for distance. *PhysTher Sport.* 2002;3:143-151.

15. Imwalle LE, Myer GD, Ford KR, Hewett TE. Relationship between hip and knee kinematics in athletic women during cutting maneuvers: A possible link to noncontact anterior cruciate ligament injury and prevention. *J Strength Cond Res.* 23(8)/2223-2230.

16. Alentorn-Geli E, Myer GD, Silvers HJ, Samitier G, Romero D, Lázaro-haro C, Cugat R. Prevention of non-contact anterior cruciate ligament injuries in soccer players. Part1: Mechanisms of injury and underlying risk factors. *Knee Surg Sports Traumatol Arthrosc.* 2009:17:705-729.

17. Dick R, Putukian M, Agel J, Evans TA, Marshall SW. Descriptive epidemiology of collegiate women's soccer injuries: National collegiate athletic association injury surveillance system, 1988-1989 through 2002-2003. *J Athl Train.* 2007;42(2):278-285.

18. Vrbanić TS, Ravlić-Gulan J, Gulan G, Matovinović D. Balance index score as a predictive factor for lower sports results or anterior cruciate ligament knee injuries in Croatian female athletes – preliminary study. *Coll. Antropol.* 2007:1:253-258.

19. Upjohn T, Turcotte R, Pearsall DJ, Loh J. Three-dimensional kinematics of the lower limbs during forward ice hockey skating. *Sports Biomech.* May 2008; 7(2): 206-221.

20. Agel J, Dompier TP, Dick R, Marshall SW. Descriptive epidemiology of collegiate men's ice hockey injuries: National collegiate athletic association injury surveillance system, 1988-1989 through 2003-2004. *J Athl Train.* 2007;42(2):241-248.

21. Rishiraj N, Lloyd-Smith R, Lorenz T, Niven B, Michel M. Sport injuries and rehabilitation. *J Sports Med Phys Fitness*. Jun 2009;49, 2; 159-166.

22. Agel J, Dick R, Nelson B, Marshall SW, Dompier TP. Descriptive epidemiology of collegiate women's ice hockey injuries: National collegiate athletic association injury surveillance system, 2000-2001 through 2003-2004. *J Athlc Train.* 2007;42(2):249-254.

23. Smith AM, Stuart MJ, Wiese-Bjornstal DM, Gunnon C. Predictors of injury in ice hockey players: a multivariate, multidisciplinary approach. *Am J Sports Med.* 1997;25;500-507.

24. Molsa J, Kujala U, Nasman O, Lehtipuu T, Airaksinen O. Injury profile in ice hockey from the 1970s through the 1990s in Finland. *Am J Sports Med.* 2000;28:322-327.

25. Agel, J, Arendt, EA, and Bershadsky, B. Anterior cruciate ligament injury in national collegiate athletic association basketball and soccer: a 13-year review. *Am J Sports Med.* 2005;33:524-530

26. Gribble, PA, Hertel J, Plisky, P. Using the Star Excursion Balance Test to assess dynamic postural-control deficits and outcomes in lower extremity injury:a literature and systematic review. *J Athl Train.* 2012;47(3):339-357.

27. Hoffman M, Schrader J, Koceja D. An investigation of postural control in postoperative anterior cruciate ligament reconstruction patients. *J Athl Train*. 1999;34:130-136.

28. Krauspe R, Schmidt M, Schaible HG. Sensory innervation of the anterior cruciate ligament: an electrophysiological study of the response properties of single identified mechanoreceptors in the cat. *J Bone Joint Surg Am.* 1992;74:390-397

29. Kennedy JC, Weinberg HW, Wilson AS. The anatomy and function of the anterior cruciate ligament as determined by clinical and morphological studies. *J Bone Joint Surg Am.* 1974;56:223-235.

LITERATURE REVIEW

The Anterior cruciate ligament (ACL) injury is categorized as a severe type of injury and has significant traumatic short-term effects on the performance in a certain sports.[15] It is known that female athletes have a higher risk of ACL injury, which is 4 to 6 times higher than that of male athletes.[18] According to Imwalle et al[15] ACL injury may be caused from the two common maneuvers, landing from a jump with higher measures of knee abduction and pivoting with a fast change in direction while running. Imwalle et al[15] specifically noted greater degrees of internal hip and internal knee rotation angles when the cutting maneuver was performed at a 90° angle compared to 45°.[15] This increased transverse plane rotation at the hip and knee, which may cause high loads at the knee when an athlete executes cutting movements at a sharper angle.[15] This may be an important contributing factor for the risk of ACL injury. It is also indicated in Imwalle et al[15] that hip adduction increases the chance of getting ACL injury during side-step cutting maneuvers as it increases knee load. The hip adduction to knee abduction correlation is important as excessive knee abduction with functional tasks like landing or when pivoting increases the risk of ACL injury, particularly in women.[15]

The rate for non-contact ACL injuries has been reported to account for 70 to 84% of all ACL tears in both female and male athletes, and most ACL tears in soccer occur when there is no player-to-player contact present.[16] Anterior cruciate ligament injuries in soccer mainly occurred as one decelerates in a task with excessive internal knee extension torque combined with a dynamic valgus load along with shifting body weight over the involved leg.[16] Alongside these mechanisms of injury, it is reported that sex hormones may cause a reduction of motor coordination in female athletes.[16] Similarly, Dick et al[17] indicated that the risk of ACL injury is considerably higher in the last 15 minutes of the play as an athlete gets tired, which suggests muscular fatigue potentially increases the risk for non-contact ACL injuries as a result of decreases neuromuscular control ability.[16] Therefore reasons for the higher rate of ACL injuries in female athletes could be explained by the decrease of neuromuscular control along with biomechanical risk factors and hormonal differences.[16] It is reported that the rate of ACL injuries has not changed much even though the level of competitiveness has been risen over the 15-year period.[17] This is possibly due to strategies many collegiate athletic programs, such as soccer, have implemented to emphasize increasing a female athlete's flexibility, plyometric, strength and neuromuscular condition.[17]

It is indicated that the stability of knee is closely related to operation of the neuromuscular system, feedback mechanisms inclusive to ligaments and joint surface contact forces.[18] Vrbanić et al[18] suggested that the development of neuromuscular balance is recommended to decrease the risk of ACL injury as it shortens the period of time required to execute a certain protective task. Consequently, the effectiveness neuromuscular training programs in preventing ACL injuries has been established.[17]

In women's ice hockey, the rate of general injuries was five-fold greater in games than practices.[22] Furthermore, the higher percentage of injuries occurred in games was from player-to-player contact whereas the injuries in practices were mainly non-contact based.[22] Subsequently, the fact that body checking is legally banned in women's ice hockey, could potentially be a reason the incidence of ACL injury is low.[22] Women's ice hockey is in emerging status in regard to its competitiveness as well as the level of related athletic performance and skills compared to women's soccer.[22] Thus, the lower rate of

ACL injury in women's ice hockey players could be explained by this very fact. Therefore, in ice hockey, as the level of performance develops, the overall velocity of the movements in players is increased and potentially causing a greater chance of injury.[22] A study by Agel et al[20] supports this phenomenon as it states the greater overall injury rate was reported in varsity high school ice hockey players than that of junior varsity players at 49.7 and 30.3 per 1000 hours of game-exposures, respectively. This is further evident when comparing the data of Agel et al[20] to the higher rates of injury for elite Finnish ice hockey players at 54.0 to 83.0 per 1000 game-hours of exposure in 1970s and in 1990s, respectively.[24] The pattern for this phenomenon was also observed in collegiate men's ice hockey as it was reported that a significantly lower injury rate per game existed in Division III than Division I.[21]

The high-calibre players' force applied to the knee joint was expected to be greater than that of low-calibre players as the high-calibre players show an increased stride rate and a decreased amount of time spent in their both single and double support moves than that of low-calibre players.[19] Upjohn et al[19] reports that no significant measure of deceleration in the novice skater was observed when the significant deceleration of hip and knee extension was observed and this suggests that kinematics take an important role in describing the difference between high-calibre and low-calibre players. Upjohn et al says that the higher knee abduction and knee flexion, hip flexion, rate of knee extension and plantar flexion in propulsion and weight acceptance were measured in high-caliber than low-caliber players and these may possibly contribute to the greater power generation and more stress to the knee.[19] As Imwalle et al[15] indicated, increased knee abduction contributes to a higher risk of ACL injury; thus, this theme may also explain why ACL injury is more prevalent in high-caliber than low-caliber players. Also, the greater range of motion for most segments and joint angles along with the longer stride patterns were observed in high-caliber players than in low-caliber players in the same stride rate as these result suggest that greater force generation at propulsion.[19]

The postural control is regarded one of the valuable factors that indicate the neurologic structure and the function of ACL as it is reported that ACL contains a direct pathway to the central nervous system via the posterior articular and sciatic nerves.[27,28] As the repeated episodes of microtrauma results the decreased level of sensory information at the knee, the postural control may be affected as well.[29] Hoffman et al[27] reports that there is significant differences between the ACL and control groups in dynamic control system in the measures of dynamic-phase duration and peak torque while static postural control did not show any considerable difference.

Appendix A

PENNSTATE

1855

Athletic Training & Sports Medicine

Research Volunteers Needed

Are you a collegiate ice hockey, basketball or soccer athlete at the varsity or club sports level?
If so, you may be interested in participating in our research study.

Physical measurements: Core strength, leg strength and endurance, static and dynamic balance as well as functional performance

Purpose: To study the physical measurement differences among women collegiate ice hockey, basketball and soccer athletes that may help explain why ice hockey athletes' injury their anterior cruciate ligament less

One visit to the Athletic Training & Sports Medicine Research Laboratory in 21D&E Recreation Building lasting about 2 hours is required

Requirements:

- Women ages 18 – 25 years old
- Good general health
- Physically-active by participating in women's collegiate ice hockey, basketball or soccer at the varsity or club sports level

Dr John Vairo, Dr Cayce Onks, Dr Dov Bader, Dr Wayne Sebastianelli,
Dr S John Miller and Dr William Buckley

Departments of Kinesiology and Orthopaedics & Rehabilitation

For more information, please contact John Vairo at
glv103@psu.edu or 814-865-2725

PENNSTATE

1855

Title of Project: Biophysical Performance Analyses of Women Ice Hockey Athletes

Principal Investigator: Giampietro L Vairo, PhD, ATC, ACI

Other Investigator(s): Cayce Onks, MD; Dov Bader, MD; Wayne J Sebastianelli, MD; S John Miller, PhD, PT, ATC; William Buckley, PhD, MBA, ATC

Script: Participants

Hello, my name is (*Penn State Institutional Review Board-approved investigator*) and I work with the Athletic Training and Sports Medicine Research Laboratory at Penn State. I am currently looking for research volunteers and was wondering if you would be interested in participating or at least hearing more about this study. I am looking for a group of women collegiate ice hockey, basketball and soccer athletes that participate at the varsity or club sports level and who are 18 to 25 years old and in good general health. Participants that are under the age of 18 years old may not participation in this research study. I will be examining the differences among physical testing measures for these athletes. Specifically I am interested in studying differences for core strength, leg strength and endurance, static and dynamic balance as well as functional performance. If participants are interested in participating, they would be required to come to the Athletic Training and Sports Medicine Research Lab in 21D&E Recreation Building at Penn State's University Park Campus for one visit that lasts approximately two hours. I will be happy to provide participants with their specific measurement results. If you are a patient of one of the physicians taking part in this research study, please know that your participation in the research study or decision not to participate will have no effect on the treatment you will receive as a patient. If you are interested in participating in the study, have any questions or need to get in touch with my research group for any reason, please contact John Vairo at 814-865-2725 or glv103@psu.edu. Thank you.

PENNSTATE

1855

Title of Project: Biophysical Performance Analyses of Women Ice Hockey Athletes

Principal Investigator: Giampietro L Vairo, PhD, ATC, ACI

Other Investigator(s): Cayce Onks, MD; Dov Bader, MD; Wayne J Sebastianelli, MD; S John Miller, PhD, PT, ATC; William Buckley, PhD, MBA, ATC

Screening Checklist: Participants

Participant Identification Number: ________________________________

As a general health screen, you must be able to answer 'YES' to the following questions:

1. Are you between 18 to 25 years old? **Yes** **No**
2. Do you speak English? **Yes** **No**
3. Can you read at the mimimum of an eighth-grade level? **Yes** **No**
4. Do you play women's ice hockey, basketball or soccer at the varisoty of clubs sports level? **Yes** **No**
5. Are you generally healthy (BMI[1] under 30 kg/m^2 and a non-smoker or non-consumer of nicotine products)?
   Yes **No**

As a general health screen, you must be able to answer 'NO' to the following questions:

1. Do you have a history of musculoskeletal or neurological injury to the low-back or lower body within the last six months? **Yes** **No**
2. Do you have a history of low-back or lower body surgery? **Yes** **No**
3. Have you sustained a concussion within the past six months? **Yes** **No**
4. Have you followed a formal physical rehabilitation program in the last six months?
   Yes **No**

5. Do you have low-back or lower body pain described as above ‘1’ on a 10-point scale? **Yes** **No**

6. Are you diabetic or suffer from peripheral neuropathy? **Yes** **No**

7. Do you currently have any lower body joint swelling? **Yes** **No**

8. Are you in the third trimester of pregnancy? **Yes** **No**

[1]United States Government. (2010) Defining Overweight and Obesity. Center for Disease Control and Prevention.

APPENDIX B

PENNSTATE 1855

Informed Consent Form for Biomedical Research
The Pennsylvania State University
PARTICIPANTS

ORP OFFICE USE ONLY
DO NOT REMOVE OR MODIFY
IRB#38361 Doc. #1001
The Pennsylvania State University
Office for Research Protections
Institutional Review Board
Approval Date: 02/25/2013- PCF
Expiration Date: 11/13/2013- PCF

Title of Project:	Biophysical Performance Analyses of Women Ice Hockey Athletes

Principal Investigator:

Giampietro "John" L Vairo, PhD, ATC, ACI
Instructor of Kinesiology
Department of Kinesiology
146 Recreation Building, University Park PA 16802
glv103@psu.edu 814-865-2725

Co-Investigators:

Cayce Onks, MD
Primary Care Sports Medicine Fellow
Department of Orthopaedics and Rehabilitation
1850 East Park Avenue, Suite 112, State College PA 16803
conks@hmc.psu.edu 814-865-3566

Dov A Bader, MD
Assistant Professor of Orthopaedics and Rehabilitation
Department of Orthopaedics and Rehabilitation
1850 East Park Avenue, Suite 112, State College PA 16803
dbader@hmc.psu.edu 814-865-3566

Kimberly K Lew, BS, ATC
Master of Science Candidate in Kinesiology
Department of Kinesiology
kkl128@psu.edu 415-279-3331

Wayne J Sebastianelli, MD
Professor of Orthopaedics and Rehabilitation
Department of Orthopaedics and Rehabilitation
1850 East Park Avenue, Suite 112, State College PA 16803
wsebastianelli@hmc.psu.edu 814-865-3566

S John Miller, PhD, PT, ATC
Assistant Professor of Kinesiology
Department of Kinesiology
146 Recreation Building, University Park PA 16802
sjm221@psu.edu 814-865-6782

William E Buckley, PhD, MBA, ATC
Professor of Exercise & Sport Science and Health Education
Department of Kinesiology

146 Recreation Building, University Park PA 16802
web5@psu.edu 814-863-9730

Han Sol Song
Schreyer Honors College Student
Department of Kinesiology
hxs5064@psu.edu

1. **Purpose of the study:** The purpose of this research is to study some of the differences among women collegiate ice hockey, basketball and soccer athletes for strength, endurance, balance and functional performance. A total of 45 women between the ages of 18-25 years old will be taking part in this study.

2. **Criteria for inclusion of participants:** You are being invited to participate in this research study because you are a healthy, physically active woman and between the ages of 18-25 years old. You have no history of lower body or back injuries within the last six months and have never undergone surgeries for injuries to these areas. You are also not diagnosed with diabetes or peripheral neuropathy and are not in your third trimester of pregnancy.

3. Procedures to be followed: If you chose to participate in this research study, you will be asked to perform the following procedures:

Procedures

A. We will begin the study by measuring your height and weight. We will also ask you what leg you like to kick a ball with. We will ask you to rate your physical activity level with a short survey. We will then ask you to lie on your back on an exam table so we can measure your right and left leg lengths. To calculate the length of your legs we will measure the distance between your hip and ankle bones.

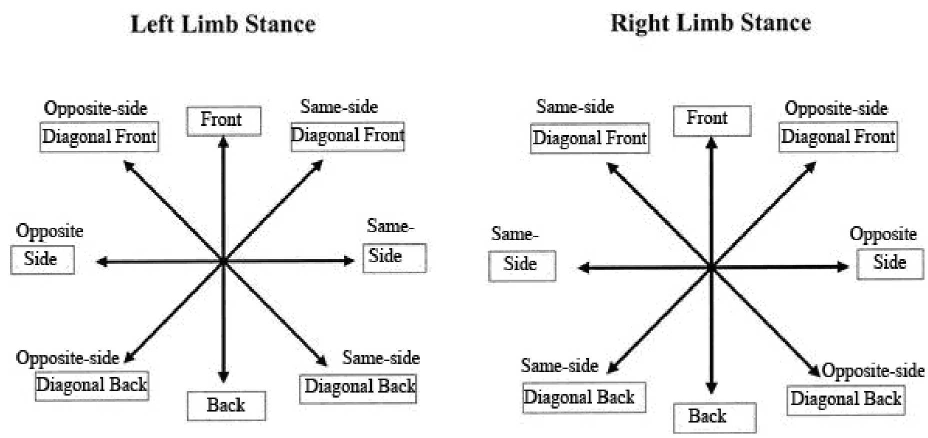
B. You will then be asked to warm-up by walking at a common walking speed for five minutes on a flat electronic treadmill.

C. We will also ask you to perform three core exercises therafter. One exercise will require you to do a static sit-up, another will require a static back extension and lastly, you will be asked to do a static lateral plank. All will be measured to maximum hold in seconds. Rests will be held between each measurement.

D. We will then measure the strength and endurance of your leg muscles with an electronic exercise machine. You will be secured in the machine while asked to bend and straighten your knee against two different resistances. We will ask you to perform three maximum effort repetitions against a high resistance to measure strength. We will ask you to perform as many repetitions as you can in 45 seconds against a low resistance to measure endurance. You will be given practice trials and rest between strength and endurance tests. You will be asked to perform strength and endurance tests for both legs separately.

E. You will then be asked to perform a quiet single-leg balance stance task. You will be standing barefoot on one leg with your hand on your hips while bending your knee on the opposite leg. You will be asked to keep balance for 10 seconds. We will ask that you complete three trials with your eyes open and then three trials with your eyes closed. Your balance performance will be measured by a force platform, which stays still on the floor and is electronically hooked up to a computer. You will be asked to perform the single-leg balance stance task for both of your legs.

F. You will then be asked to perform a single-leg balance reach task. You start the single-leg balance reach task by standing in place on one leg in the middle of an asterisk drawn on the floor. You then reach as far as possible with your other leg in each of the following directions: front, opposite-side diagonal back, same-side diagonal back. A picture of the single-leg balance reach task is below.



You will be asked to complete three trials in each direction. You will be given practice trials and rest between each trial. You will be asked to perform the single-leg balance reach task for both of your legs.

G. For your last measurement, you will be asked to do a maximum crossover hop test. You will perform three consecutive single-leg hops, aiming for maximum distance, while crossing a line between each hop. You will be given practice and then three hops will be measured.

After you are done with procedures A through G your participation in the research study is over.

4. **Discomforts and risks:** The discomforts and risks with participation in this type of research study are minimal.
The tests used are within expected ranges for physically active people. Possible discomforts may be mild skin irritation or bruising from the electronic exercise machine straps. Additional discomforts may be muscle soreness for two to three days after testing. It is possible that unknown harmful effects may happen. However, the chance for injury in this type of research study is minimal and happens in less than 1 % of people. Examples of injuries that may happen are muscle strains, ligament sprains or bone breaks. We will make every possible effort to watch for and help prevent against any discomforts and risks.

5. **Benefits:** There is no direct benefit to you from participating in this research study. The benefits to society include possibly finding differences among women ice hockey, basketball and soccer athletes, which may explain why women ice hockey athletes injury their ACL much less than basketball and soccer athletes.

6. **Duration/time of the procedures and study:** One 120-minute testing session. All testing takes place in the Athletic Training and Sports Medicine Research Laboratory in 21D&E Recreation Building on Penn State's University Park Campus.

7. **Alternative procedures that could be utilized:** There are no known alternative procedures used to answer the research questions of this study.

8. **Statement of confidentiality:** Your participation in this research study is strictly confidential. All research records from your participation in this study will be kept confidential similar to medical records at your doctor's office or a hospital. All records will be secured in locked file cabinets at the Athletic Training and Sports Medicine Research Laboratory. A unique case number will indicate your identity on research records. In the event of any publication resulting from this research study, no personally identifiable information will be disclosed. Penn State's Office for Research Protections, the Institutional Review Board and the Office for Human Research Protections in the Department of Health and Human Services may review records related to this research study. Penn State policy requires that research records be kept for a minimum period of three years at the end of the study. Three years following the end of this research study all records will be appropriately destroyed.

9. **Right to ask questions:** Please contact Giampietro "John" L Vairo at 814-865-2725 or 412-225-5276 with questions, complaints or concerns about this research. You can also call this number if you feel this study has harmed you. If you have any questions, concerns, problems about your rights as a research participant or would like to offer input, please contact Penn State University's Office for Research Protections at 814-865-1775. The Office for Research Protections cannot answer questions about research procedures. Questions about research procedures can be answered by the research team. Additional medical information for those who wish to seek it is available by contacting doctor(s) Cayce Onks or Dov Bader at 814-865-3566.

10. **Voluntary participation:** Your decision to be in this research study is voluntary. You can stop at any time. You do not have to answer any questions you do not want to answer. Refusal to take part in or withdrawing from this research study will not involve penalty or loss of benefits you would receive otherwise. You may be removed from this research study by investigators in the event you cannot complete the testing procedures.

11. **Injury clause:** In the unlikely event you become injured as a result of your participation in this research study, medical care is available. If you become injured during testing procedures the investigators listed on this informed consent form will provide you with appropriate first aid care and instruct you on proper steps for follow-up care. If you were to experience any unexpected pain or discomfort from participating in this research study after leaving the Athletic Training and Sports Medicine Research Laboratory please contact Giampietro "John" L Vairo immediately at 814-865-2725 or 412-225-5276. If you cannot

reach John please leave him a voicemail and contact doctor(s) Cayce Onks or Dov Bader at 814-865-3566.

If you are a Penn State student and cannot reach John or doctor(s) Cayce Onks or Dov Bader please leave them voicemails and contact Penn State University Health Services at:

Student Health Center
University Park PA 16802
814-863-0774

If you are not a Penn State student and cannot reach John or doctor(s) Cayce Onks or Dov Bader please leave them voicemails and contact your private medical provider.

It is the policy of this institution to provide neither financial compensation nor free medical treatment for research-related injury. By signing this document, you are not waiving any rights that you have against The Pennsylvania State University for injury resulting from negligence of the University or its investigators.

12. **Abnormal test results:** In the event that abnormal test results are obtained, you will be made aware of the results in three days and recommended to contact your private medical provider for follow-up.

You must be 18 years of age or older to sign consent for participating in this research study. You may not participate in this research study if you are under the age of 18 years old. If you agree to participate in this research study as described in this informed consent form, please sign your name and indicate the date below.

You will be given a copy of this signed and dated consent form for your records.

____ ____________________

Participant Signature Date

____ ____________________

Person Date

ACADEMIC VITA

Han Sol Song (Hansol Song)
Email: hxs5064@psu.edu / run5331@gmail.com
Address: Primeville 401, 664-15, Jayang 2-Dong, Gwangjin-Gu, Seoul, Korea (ROK), 143-783
Phone: 82-10-9482-0001 (ROK) | 1-610-730-3571 (USA)

Education

B.S., Kinesiology, Expected in May 2013, The Pennsylvania State University, University Park, Pennsylvania
The Schreyer Honors College

Honors and Awards

Dean's list — Fall 2009 - Current
Penn State University Special Collections Library contest *"I Found it in the Archives"* - 1st Place — Jan, 2012
Pennsylvania State University Noll Underhill Marie Sport Scholarship — June, 2011
Internal Schreyer Honors Scholarship — June, 2011
Pennsylvania AA Boys 4x100m 1st Place - State Champion — May, 2008

Association Memberships/Activities

Kinesiology Diversity & Culture Committee Undergraduate Representative — Fall'12 - Spring'13
Served as a volunteered clinical assistant at The Village at Penn State — April, 2012

Professional Experience

Helped to construct Kinesiology 350 Exercise Physiology class lab section — Fall 2011
Wrote research paper *"Jesse Arnelle and His Influence on the Society as a Powerful African American Star"* (16 pgs, expected to be in the contents of Dr. Dyreson's article – in progress) — May, 2011
Lab Assistant in Professor Dr. Gottschall's Biomechanics Lab — Jan, 2012
Teaching Assistant in Kinesiology 202 - Human Anatomy — Fall, 2011

Professional Presentations

Presented *"Jesse Arnelle paper"* at NASSH International conference at Univ. of Texas at Austin — May, 2011