

THE RELATIONSHIP AMONG HIP ABDUCTOR STRENGTH,
DYNAMIC BALANCE, AND FUNCTIONAL BALANCE ABILITY

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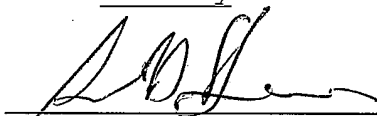
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INTRODUCTION

Athletes typically require a high level of balance ability to perform athletic movements and to decrease risk of injury.¹⁻⁴ When any external forces act to alter balance, athletes move the center of gravity (COG) to control their body stability.^{1,3} Thus, an athlete usually has better balance ability than the non-athletic population.^{1,2} Moreover, higher competition levels and longer careers have been shown to positively affect balance ability.³⁻⁵

Balance is the single most important element dictating movement strategies within the closed kinetic chain.¹ Vision, vestibular, and somatosensory information is collected in order to determine the timing, direction, and amplitude of corrective postural actions.^{2,4,6,7} These three systems work together as well as compensate for each other.^{2,7,8} According to Guskiewicz et al¹ balance can be categorized in four different states: static, semidynamic, dynamic, and functional. Dynamic and functional balance involve the maintenance of the COG over a moving base of support which is more critical for athletic movement than static and semidynamic balance.^{1,9} There are various factors

that affect balance such as proprioceptive deficits, muscle weakness, and sport participation.²⁻⁶ When considering the relationship between muscle weakness and balance, usually main focus is hamstring and quadriceps muscles. However, more proximal muscle structures also have an important role in maintaining balance.

Gluteus medius is known as a primary hip abductor muscle and plays a role in stabilizing the pelvis which, in turn, helps to prevent the Trendelenburg position, or contralateral hip drop, and ipsilateral genu valgus.¹⁰⁻¹² In other words, weakness of this muscle may cause inappropriate lower extremity alignment including a valgus (inward) position of the knee and foot pronation. This condition may lead more stress on the joint and poor tracking ability of the patella.¹³ Therefore, the weakness of the gluteus medius muscles may increase risk of lower extremity injuries such as anterior cruciate ligament (ACL) sprains, iliotibial band friction syndrome, and patellofemoral pain syndrome.^{10,12-19}

Since hip abductor muscles help to control efficient lower kinetic movement, use of these muscles is one of the key components to perform athletic movement effectively. For this reason, previous researchers recommend to add hip abductor strengthening exercises to injury prevention

program as well as rehabilitation for lower extremity injuries.^{12,13,15,16,19} Since hip abductor muscles stabilize the pelvis and control the lower limb during the gait cycle, strength and control of these muscles may help to control balance during athletic activity.¹³ Moreover, control of the pelvic motion is critical to maintain total body balance because weight of the hand, arm, and trunk acts downward through the pelvis.¹⁶ Previous researches have demonstrated that weakness of the hip abductors alters lower extremity alignment and it correlated to falls in elderly people as well as balance ability in individuals with chronic ankle instability.^{9,20,21} Since sports utilize complicated movements, it is critical to clarify the relationship among hip abductor muscles and specific balance ability such as dynamic and functional balance. Therefore, the purpose of this study was to examine the relationship among hip abductor muscle strength, dynamic balance, and functional balance ability in collegiate athletes.

METHODS

Research Design

This study used a descriptive correlational design. The variables included the overall limits of stability (LOS) score as measured by the Biodex Balance System (BBS), the average of normalized eight directional excursion score on Star Excursion Balance Test (SEBT), and the hip abduction strength as measured by the Lafayette Manual Muscle Test System (MMTS). Based on our preliminary study, all subjects began with the hip abductor muscle strength test (ABDT) to reduce local fatigue followed by two balance tests. The balance tests and strength measurement were performed on same day. The combination of measurement of two different balance abilities and specific muscle strength made this study valuable in addressing the correlation among dynamic and functional balance, and hip abductor muscle strength. Findings might be limited to the specific age group, and National Collegiate Athletic Association (NCAA) Division II athletes.

Subjects

Twenty healthy NCAA Division II athletes, 18 years or older from California University of Pennsylvania were asked to participate in this study. Subjects volunteered to participate in this study with no coercion from coaches or faculty after the researcher had explained the purpose. Prior to any testing, subjects read and signed the Information Consent Form (Appendix C1) and a Subject Information Sheet (Appendix C2). Each subject was assigned to all three tests on the same day. Any athletes who suffered from visual, vestibular, balance disorder, severe lower extremity injury which prohibited them from participation, and/or a concussion within last six months was excluded from this study as these conditions may interfere with accurate balance assessment.

Preliminary Research

Preliminary research was designed to familiarize the researcher with the LOS test, SEBT, and ABDT, and for a determination of the time necessary to test each subject. Procedures for each test was based on manufacturer's

suggestion and previous valid research.²²⁻²⁴ Scoring of the SEBT using an average distance per leg was considered, as eight direction of scores (distance in centimeters) are the functional scores used for analysis. All of the tests were conducted on three adult volunteers who are studying or working at California University of Pennsylvania within the same age range as the desired population. The pilot research helped to determine adequate practice times, as well as appropriate the level of forceplate stiffness for LOS test. It was determined that the level eight (most stable) was appropriate for LOS test, and that three practice trials of SEBT were adequate for subjects to become familiar with the SEBT and sufficiently minimize learning effects.

Instruments

The instruments used in this study were a Subject Information Sheet (Appendix C2), the BBS, the SEBT, the MMTS, and test score sheets (Appendix C3).

Biodex Balance System (BBS)

The overall LOS score and time to complete the test can be measured by the BBS(Appendix C4). The LOS test

measured by BBS examines dynamic balance ability by challenging the subjects to move and control their center of gravity (COG) within their base of support.²³⁻²⁵ LOS is defined as the outermost range of an area in space that a person can lean from the vertical position in any direction without changing his or her base of support.²⁶ During the test trial, the subjects had to shift their weight on a moveable platform to move the cursor displayed on an eye-level screen from the center target to a blinking target, and back as quickly and with as little deviation as possible.^{24,27} The platform tilts a maximum of 20°(from horizontal plane) in all directions.^{24,26,27} The BBS offers eight different levels of difficulty by changing the amount of stiffness in the platform: L1 is the least stable and L8 is the most stable. The test protocol can be set up for a bilateral or unilateral stance and includes a grid on the foot platform to record the foot position for re-testing.²⁵ However, the LOS test using the unilateral stance protocol is a challenging task even at the least difficult level for a healthy athletic population.²⁸ Thus, bilateral stance was used in this study. Ishizuka⁸ used two practice trials before the test trial, but suggested that the practice trials should be four to minimize learning effect. Therefore, four practice trials were performed in this

study. The LOS test score can be represented by the overall LOS score and time to complete the test. In this study, only the overall LOS score was used and was recorded on the Test Score Sheet (Appendix C3). To calculate the overall LOS score, the following formula was used.²⁴

$$\text{LOS score \%} = \frac{\text{Straight line distance to target} \times 100}{\text{Actual distance traveled}}$$

$$\text{Overall LOS score} = (\text{LOS scores})/8$$

Scores range from zero to 100 in which a higher score indicates better control of the COG within the LOS.

Intraclass correlation coefficients (ICCs) for the LOS test have ranged from .77 to .89.²⁴

Star Excursion Balance Test (SEBT)

The SEBT is a functional test of dynamic balance that has high intratester and intertester reliability while challenging an individual's LOS on solid ground.²² The SEBT uses a star on the floor with eight lines extending at 45° increments from the center of the grid (Appendix C4)^{22,29} The line was measured and marked every 1cm from the center of the grid for all eight directions for the measurement of the excursion distance.^{22,29} The eight lines were named anterolateral (AL), anterior (A), anteromedial (AM), medial

(M), posteromedial (PM), posterior (P), posterolateral (PL), and lateral (L), according to the direction of excursion in relation to the stance leg; thus the labeling of the grid was different for the right and left legs.²² During three test trials, the distance between center of the grid and the point the subject's leg touched was recorded, according to suggested test protocols.²² The total mean score of three tests indicated the mean score of each excursion. Total mean score of each leg was calculated by adding all eight mean scores of each excursion. For experimental or clinical purposes, excursion distances were normalized to leg length to allow for a more accurate comparison of performance among participants.²⁹ Means for the three test trials in each leg calculated for each of the eight excursions. Then, the mean of the three test trials were divided by a subject's leg length to normalize the score.²⁹ ICCs for intratester reliability ranged from .78-96.²² Higher scores in centimeters indicated better balance.

The Lafayette Manual Muscle Test System (MMTS)

The Lafayette Manual Muscle Test System (MMTS) is a portable device that can be used to obtain more discrete, objective measures of strength during manual muscle testing

(MMT) than can be achieved via traditional MMT(Appendix C4).¹⁹ Although most of the research has involved the use of the same type of hand-held dynamometer with elderly or physically impaired populations, the reliability of the device has been high.^{11,16} Intratester reliability for hip abduction particularly has been reported at .932 to .984 for the elderly population, and .92 to .97 for healthy young adults.^{23,30} MMTS provides muscle peak force in kg or lb. Peak force was recorded for each trial and the following formula was used to calculate normative strength.³¹ Distance was defined as between force application at the level of the femoral condyle and the pivot point which was the hip joint in this study. The distance was measured as the distance from the greater trochanter to the lateral knee joint line of the leg.³² Higher peak force values indicate more strength.

Newtons conversion: 1kg = 9.81N

Torque = (Force in Newtons) x (distance in meter)

Strength = Torque / Body weight in kilograms

Procedures

The study was approved by the California University of Pennsylvania Institutional Review Board (IRB) (Appendix C5). Prior to the study, the researcher had a meeting with all potential subjects to explain the concept of the study and offer the Informed Consent Form (Appendix C1) so that each subject understood the requirement and risks of involvement in the study. Qualifications for the subjects (mentioned in the subject section), requirements, testing date, and approximate time frame for entire study, one hour, were also announced.

Before the tests, qualifications for the subjects were presented again. Once understanding and approving, subjects signed the Informed Consent Form (Appendix C1) and completed the Subject Information Sheet (Appendix C2). Tests were given in the described random order, but with the MMT being tested first. Prior to beginning each test, the researcher explained the test procedure and method.

Hip abductor muscle strength test (ABDT)

Procedures for measuring isometric muscle strength of hip abductor muscles was base on those described by Andrews.²³ The distance between the greater trochanter and

lateral knee joint line was measured in meters.³² For test trials, the isometric "make" test was used rather than "break" test to obtain a more reliable measurement.³³ The subjects were asked lie supine on the treatment table. During the "make" test, the researcher was holding the MMTS perpendicular to the thigh at the lateral femoral epicondyle while the athlete built force gradually to a maximum voluntary effort for two seconds.^{23,32} Then the subject was asked to maintain maximum effort for five additional seconds.^{23,32} The restraints was used to stabilize the subject's hips in neutral position. To prevent alterations in muscle recruitment and compensation during testing, the subjects were also instructed to keep their toes pointed towards the ceiling and not to bend their knees. Subjects were given two practice trials to familiarize this procedure as well as the feel of pushing against the MMTS.²³ One minute of the recovery time was provided between each test, and the test was taken a total of three times for each limb. These tests were then averaged and recorded into the test score sheet (Appendix C3).

Limits of Stability test (LOS test)

The researcher set up the BBS and computed the information including subject's height, weight, and platform firmness using the bilateral stance. The bilateral stance balance test was performed with the LOS test and the platform firmness was set at level eight which was used in previous study and determined during preliminary study.⁸ The subjects were asked to stand on the BBS platform on both feet and maintain their balance while chasing the cursor. During the trial, subjects had to move the platform while chasing the blinking targets which were appeared randomly on the BBS computer screen. Four practice sessions were provided before one test trial as recommended by previous literature.^{8,25} After each trial, the LOS score was recorded on the test score sheet (Appendix C3).

Star Excursion Balance Test (SEBT)

Procedures for measuring functional balance ability was base on those described by Hertel.²² Each subject's leg length was measured bilaterally in centimeters as the distance between the anterior superior iliac crests and the medial malleolus.²⁹ The subject stood on one leg while placing the heel on the center of the star. The subjects were also instructed to hold their hands on their hip, and

asked to reach the opposite leg to make a light toe touch along the chosen line. The subject then returned the reaching leg back to the center, while maintaining single-leg stance with the other leg. The subject was allowed to move their torso or lean during this test. The reached distance was marked along the line and the researcher measured the distance in centimeters from the center of the grid to the mark with a tape measure. The test needed to be repeated if the reach foot was used to provide support when touching the ground, if the subject lifted the stance foot from the center of the grid, or if the subject lost his or her equilibrium at any point in the trial.²²

Previous researcher²² suggested performing six practice trials in order to minimize learning effect. However, our preliminary study showed that three practice trials would be adequate. Thus, the subject performed three bouts of practice trials followed by three test trials in each of the eight directions to minimize learning effect.

Half of the subjects began all bouts by performing the right-stance-leg tests first, and the other half of the subjects began by first performing the left-stance-leg tests. The subjects had 15s of resting time between each trial. The order of testing for all subjects was AL, A, AM, M, PM, P, PL, and L. When the subject was reaching in the

lateral and posterolateral line, one had to reach behind the stance leg to complete the task. After performing all excursions on the initial stance leg, the same protocol was repeated with the contralateral leg serving as the stance leg. The mean for the three test trials in each leg was calculated for each of the eight excursions. Then, the mean of the three test trials were divided by a subject's leg length to normalize the score.²⁹

Hypothesis

The following hypothesis was tested in this study: There will be a positive correlation among SEBT, LOS, and ABDT peak force scores, for functional balance, dynamic balance, and hip abductor muscle strength.

Data Analysis

A Pearson Product Moment Correlation coefficient was used to determine the relationship among balance (LOSW and SEBT) and hip abductor muscle strength (ABDTW). The data analysis was performed using the SPSS 16.0 statistical software package at an alpha level of ≤ 0.05 .

RESULTS

The purpose of the study was to examine the relationship among hip abductor muscle strength, dynamic balance, and functional balance ability in healthy athletes. Subjects were tested by using the ABDT, the LOS, and the SEBT. The ABDT was used to measure subjects' hip abductor muscle strength, and the LOS and SEBT were used to measure dynamic balance and functional balance respectively.

Demographic Data

A total of 20 subjects (11 males, 9 females) completed this study. All of the subjects were volunteers and were physically active individuals, participating in NCAA Division II football (n = 9), soccer (n = 1), track (n = 2), or swimming team (n = 8) at California University of Pennsylvania. Demographic data (Table 1) were collected by the researcher at the beginning of the study.

Table 1. Demographic Data

Male (N = 11)					
		Minimum	Maximum	Mean	SD
Age	(yrs)	19	22	20.55	1.13
Height	(cm)	172.7	195.6	182.19	6.44
Weight	(kg)	74.8	108.9	88.45	13.12
Female (N = 9)					
Age	(yrs)	18	23	20.33	1.73
Height	(cm)	157.5	179.0	165.61	6.35
Weight	(kg)	53.5	81.6	64.20	8.47

Hypothesis Testing

Hypothesis testing was performed by using data from the 20 subjects who completed all tests at an alpha level of ≤ 0.05 . Descriptive statistics for the SEBT, LOSW, and ABDTW are shown in Table 2.

Table 2. Descriptive statistics for ABDTW, LOSW, and SEBT

	Minimum	Maximum	Mean	SD
SEBT	.84	1.15	.9520	.08286
LOSW	.13	.86	.4221	.20809
ABDTW	.94	2.04	1.4561	.28620

Hypothesis: There will be a positive correlation among SEBT, LOS, and ABDT scores, for functional balance, dynamic balance, and hip abductor muscle strength. A Pearson Product Moment Correlation coefficient was calculated to examine the linear relationship among all three variables.

Prior to calculating the correlation for the three variables, the following two additional analyses were performed. If appropriate, each variable was reduced to one total score using either average right and left limb, and/or normalized test scores.

Dependent t-tests were performed between right and left limb scores for ABDT and SEBT. Because no significant differences were identified between limb for ABDT ($t = -1.259$, $P = .223$), or SEBT score ($t = 1.073$, $P = .297$), data from the right and left limb trials were averaged and analyzed as one variable for the main hypothesis.

A Pearson Moment Correlation coefficient as calculated for the averaged scores of SEBT, LOS, ABDT, height, and weight and indicated that weight, was significantly correlated to ABDT and LOS scores. ($r = .740$, $P < .001$, $r = -.772$, $P < .001$) Therefore, ABDT and LOS scores were divided by body weight to normalize the data, and analyzed as one variable for the main hypothesis (ABDTW and LOSW respectively).

Conclusion: A significant moderate correlation between hip abductor muscle strength (normalized ABDTW) and functional balance (SEBT) ability was present ($r = .514$, $P = .021$). However, there were no significant correlation between functional balance (SEBT) and dynamic balance

(normalized LOSW), or between dynamic balance and hip abductor muscle strength (Table 3).

Table 3. Correlations among SEBT, LOSW, and ABDTW

		SEBT	LOSW	ABDTW
SEBT	Pearson Correlation	1.000	.382	.514*
	Sig. (2-tailed)		.097	.021
LOSW	Pearson Correlation	.382	1.000	-.037
	Sig. (2-tailed)	.097		.878
ABDTW	Pearson Correlation	.514*	-.037	1.000
	Sig. (2-tailed)	.021	.878	

*. Correlation is significant at the 0.05 level (2-tailed)

Additional Findings

An additional Pearson Product Moment correlation was performed to examine the relationship among SEBT, LOSW, ABDTW, and gender. A significant correlation between gender and LOSW ($r = .690$, $P = .001$) was recorded, and further analyzed for gender by LOSW using a one way ANOVA as LOS is correlated to weight. However, a significant difference was found between males and females ($F = 16.352$, $P = .001$), whereby females scored significantly better LOS scores even when normalized by weight.

DISCUSSION

Discussion of Results

The main finding was that hip abductor muscle strength was positively moderately correlated to functional balance ability as measured by a standing reach test (the SEBT). This finding between hip abductor strength and functional balance extends and is consistent with findings of previous studies.^{20,21} Trudelle-Jackson et al²⁰ reported differences between healthy old women who had a history of falling within one year and who had no history of fall. They reported that weakness of the hip abductor strength was one of the predictive factors in subjects who had a history of falling. However, the history of falls was self-reported and did not provide objective data about balance ability.

Hubbard et al²¹ examined various correlations among multiple measures of functional and mechanical instability 30 young adults (15 males and 15 females with an average age of 20.3 years old) who had chronic ankle instability. The activity level of the subjects was not stated. Hubbard reported that hip abduction and hip extension strength positively correlated with SEBT. In other words, again,

increased hip abductor strength correlated with functional balance. Interestingly, while there was significant correlation between hip abductor strength and functional balance, dynamic balance did not correlate to hip abductor strength which we did not expect. This different correlation may be due to the use of different types of movement strategy during the tests. As well, when the hip abductors, particularly gluteus medius is strong, the stance leg during a one-legged reach will be more stable and not result in a "dropped" hip (the Trendelenberg sign). In other words, maintaining correct lower extremity alignment during single leg stance may minimize the unnecessary stress at the knee and the ankle by preventing excessive knee adduction or foot pronation, which in turn, helps other kinetic chain structures to work efficiently.

Balance is achieved through a compilation of sensory, motor, and biomechanical processes.^{1,3,5,9} Muscle coordination and sensory organization are two important components of the central nervous system (CNS) which serve to maintain upright position. Three different movement strategies are used to prevent oneself from falling.²⁵ The most effective and common strategy is the ankle strategy that is used when small postural sway adjustment is needed.^{1,16} However, if the COG is near to the LOS perimeter, a hip strategy is

used to prevent the ankle from excessive movement that involves the large and rapid motions at the hip.¹ The ankle strategy may be used during the LOS test because it challenged the subjects to move and control their COG on the movable platform without changing the base of support which required minimum joint movement. However, SEBT is a more challenging dynamic task than LOS test. Subjects were required to move their torso during SEBT to reach as far as they could while maintaining their balance; this task involved larger joint movement than the dynamic balance (LOS) test. Thus, during a standing reach test (the SEBT), subjects may have used the hip strategy rather than ankle.

Previous findings³⁴ also imply that an ankle strategy is used during dynamic balance tasks. Croft et al³⁴ examined the joint angles and muscle activity during static and dynamic balance tasks using EMG and force plate data. Subjects stood on the three different surfaces (solid, foam, and air-filled disc) and performed single leg balance. Although they used single leg stance and different device to examine the relationship between balance ability and particular muscles, their dynamic balance test protocol was similar to our LOS test; standing on the movable base but the subjects do not require large joint movement to maintain their balance. The authors reported EMG activity

of the gastrocnemius and peroneus longus relative to center of pressure (COP) displacement, but did not identify the correlation between gluteus medius activity and COP displacement. As a result, their subjects may have used the muscles surrounding their ankle rather than their proximal muscles, such as gluteus medius, to complete their dynamic balance task. This finding supports the notion that our subjects used an ankle strategy for balance during the LOS test rather than hip.

We did not find a significant correlation between dynamic and functional balance ability that has been reported in a previous study.³⁵ Nakagawa and Hoffman³⁵ evaluated individuals with recurrent ankle sprains for static, dynamic balance, and the SEBT. However, only a very weak correlation among SEBT score, static balance, and dynamic balance ability was reported. These results, particularly combined with our findings, suggest that each test might measure different aspects of neuromuscular control.

Conclusions

Functional balance and hip abductor muscle strength appears to be moderately related in healthy Division II

collegiate athletes. However, there was no significant correlation between hip abductor muscle strength and dynamic balance, and between functional balance and dynamic balance ability indicating that these tests require different neuromuscular control. Additionally, body weight appears to correspond to dynamic balance and hip abductor muscle strength, which may result in a heavier athlete scoring poorer dynamic balance and higher muscle strength unless the data is normalized.

Recommendations

Our findings suggest that weakness of the hip abductor muscle may lead poor performance on functional balance tasks that involve reaching with one leg while standing on the other. As previous researchers reported, weak hip abductor may cause inappropriate lower extremity alignment which may increase the risk of injury.¹⁰⁻¹⁹ Therefore, strengthening the hip abductor muscles may not only improve functional balance, but also reduce the risk of injury. As there are limited studies available that have assessed the relationship among these three variables, further research is needed in this area. Moreover, as body weight appears to be significantly correlated to dynamic balance as well

as hip abductor muscle strength, any dynamic balance ability that is measured using the Biodex Balance System (BBS) for LOS, as well as muscle strength measured by a hand-held dynamometer should be normalized by body weight when comparing scores among athletes.

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APPENDIX A

Review of Literature

Balance is the single most important element dictating movement strategies within the closed kinetic chain.¹ Also it is the single most important component of athletic ability because of its implicit involvement in nearly all forms of movement.^{2,3} As Trendelenburg's test indicates, the gluteus medius muscle plays a great role in maintaining pelvic alignment in a single-leg stance.⁴ The gluteus medius provides hip abduction movement as well as external rotation of the femur.^{4,5} The weakness of the hip abductor muscle may cause Trendelenburg position and inappropriate lower extremity alignment which potentially increase risk of injury.^{4,6} Therefore, strengthening this muscle group may help to decrease lower extremity injuries including overuse injuries and knee sprains.^{4,7-9} From this fact, it is not difficult to associate static balance and gluteus medius strength. Moreover, it has been found that there is significant correlation between hip abductor weakness and experience of fall in healthy old women as well as balance ability in the individuals who has chronic ankle instability.^{10,11} However, since sports utilize more complicated movements, it is critical to clarify the relationship between hip abductor strength and specific balance ability such as dynamic and functional balance. Thus, the purpose of this review of literature is to

discuss the relationship among hip abductor muscle strength, dynamic balance, and functional balance. The topics that will be discussed include the balance and measurement tools, factors that affect balance, and role of the hip abductor muscle.

Balance and Measurement Tools

Balance is the single most important element dictating movement strategies within the closed kinetic chain.¹ Therefore, balance ability is necessary for our general life activity as well as for athletic performance.^{2,3} The term "postural equilibrium" is more commonly used for balance. However, while postural equilibrium is used as a broader term, balance is specifically defined as ability to maintain the body's center of gravity (COG) within the base of support provided by the feet.^{1,2,12}

Mechanisms of Balance

Balance is achieved through a compilation of sensory, motor, and biomechanical process and maintain balance is a function of a number of sensory inputs to the central nervous system (CNS).^{2,14,15} Muscle coordination and sensory organization are the two important components of the CNS to

maintain upright position. Muscle coordination determining the temporal sequencing and distributing muscle contraction of the legs and trunk that promote maintaining balance, whereas sensory organization involves information from visual, vestibular, and somatosensory systems and it coordinates postural control.^{2,14,16} Vision measures the orientation of the eyes and head in relation to surrounding objects. Vestibular information is collected from the inner ear which measure gravitational, linear, and angular accelerations of the head in relation to inertial space. This sense has a minor role in the maintenance of balance when the other two senses are providing accurate information.^{1,13,17}

Somatosensation or proprioception is defined as specialized variation of the sensory modality of touch that recognize the sensation of joint movement and joint position.^{1,2,18} Since this sense provides the CNS with information related to movement and posture, it works closely with balance. Muscle spindles, Golgi tendon organs, and joint receptors are included for the proprioceptors. While muscle spindles provide information about the relative muscle length, Golgi tendon organs work as safety devices by recognizing the tension developed by muscle. The joint receptors provide sensation about the orientation of

body parts as well as feedback about the rates of limb movement.¹ If any component of the visual, vestibular, and/or somatosensory sense disrupted, balance may be impaired.¹⁴ At the same time, these three systems work together as well as compensate for each other.¹⁻³

Movement Strategies

People use a variety of different balance strategies when asked to perform balance tasks. To prevent oneself from falling, the body must control the COG within safer limits of stability (LOS), which is defined as the outermost range of an area in space that a person can lean from the vertical position in any direction without changing his or her base of support.¹² Afferent sensory information from the ankle, knee, and hip joints have responsible to initiate the postural control through the three different movement strategies.¹ All strategies, ankle, hip, and stepping strategy, focus movement to one primary joint complex.

Ankle strategy is used when small postural sway adjustment is needed by rotating the body as a rigid mass about the ankle joint.^{1,20} This is the most effective and common strategy to be selected when there is any type of somatosensory problem and when COG is within the LOS.^{1,14} If

excessive displacement of COG occurs and the ankle is unable to control the sway, hip strategy is initiated.²⁰ The hip strategy helps to prevent the ankle from excessive movement to prevent further harm by initiating the large and rapid motions at the hip joints. This strategy is most effective when COG is near to LOS perimeter or when boundary of the LOS is narrow.¹ Since musculoskeletal abnormality can reduce range of motion of the joint, ankle sprain and knee sprain shrink the LOS and increase the risk for a fall.^{1,21} Whenever the COG is the outside of LOS, a step or stumble is the only choice for the person which is named the stepping strategy.^{17,22}

Classification of Balance

Commonly balance is categorized as static and dynamic because balance has both static and dynamic processes.^{1,3} However, since an athlete typically performs more complicated movements, to be more clinically accurate Guskiewicz et al¹ states that balance should be categorized in four different states: static, semidynamic, dynamic, and functional balance. Static balance is referred as the ability to maintain the COG within a fixed, stable base of support such as single-leg stance on a level floor, whereas semidynamic balance is either the ability to maintain the

COG over a fixed support while standing on a moving surface or unstable surface such as the biomechanical ankle platform system (BAPS) board.^{1,2} Dynamic balance involves the maintenance of the COG within the LOS over a moving base of support.^{1,2} Functional balance is similar to dynamic balance with the inclusion of sport-specific tasks such as throwing and catching.^{1,2}

Assessment of Balance

There are several ways to measure balance including the Biodex Balance System (BBS), Romberg test, Star Excursion Balance Test (SEBT), and Balance Error Scoring System (BESS).^{1,12,23-26} The Romberg test is one of the traditional methods used to assess static balance. However, in a clinical setting, it has been criticized due to lack of sensitivity and objectivity.²⁷ The BESS is another subjective assessment tool which is recommended over the Romberg test.^{1,26} The subject performs the test without visual information in three different leg stances on the two different surface. The performance is scored by adding one error point such as hands lifted off iliac crests. BESS is known as a reliable test but only for static balance ability.

SEBT is a functional test of dynamic balance that has high intratester and intertester reliability while challenging an individual's LOS.²³ The SEBT uses a star on the floor with eight lines extending at 45° increments from the center of the grid.²⁴ The line is marked by 5cm from the center of the grid for all eight directions for the measurement of the excursion distance.²⁴ The eight lines outline the anterolateral (AL), anterior (A), anteromedial (AM), medial (M), posteromedial (PM), posterior (P), posterolateral (PL), and lateral (L), according to the direction of excursion in relation to the stance leg; thus the labeling of the grid will be different for the right and left legs.²³ For experimental or clinical purposes, excursion distances are normalized to leg length to allow for a more accurate comparison of performance among participants.²⁴ Each excursion distance is divided by a participant's leg length, and then multiplied by 100 to normalize the score.²⁴ ICCs for intratester reliability range from .78-96.²³

The BBS can be used to measure individual's LOS which examines dynamic balance ability by challenging the subjects to move and control their center of gravity (COG) within their base of support.²⁸ During the test trial, the subjects must shift their weight to move the cursor from

the center target to a blinking target, which is displayed on BBS computer screen, and back as quickly and with as little deviation as possible.²⁸ The platform is moveable and tilts a maximum of 20°(from horizontal plane) in all directions.¹² The BBS offers eight different levels by changing the amount of stiffness in the platform: L1 is the least stable and L8 is the most stable. The test protocol can be set up for either bilateral or unilateral stance and includes a grid on the foot platform to record the foot position.¹² However, the LOS test with unilateral stance protocol is a challenging task even at the least difficult level for a healthy athletic population.²⁵ Intraclass correlation coefficients (ICCs) for the LOS study ranged from .77 to .89.¹²

Factors that Affect Balance

As mentioned in the previous section, balance is maintained by many structures including the CNS. From a clinical perspective, separating the sensory and motor processes of balance means that a person may have impaired balance due to one or both of the following: (1) the position of the COG relative to the base of support is not accurately sensed by visual, vestibular, and/or

somatosensory input, and or (2) the automatic movements required to bring the COG to a balance position are not timely or effectively coordinated. Thus, balance deficits can be related to sensory or motor issues.^{1,17}

Proprioceptive Deficit

Related to COG, one study demonstrated that muscular weakness, proprioceptive deficits, and range of motion (ROM) deficits may cause the athlete to lose their balance because it challenge a person's ability to maintain their COG within the body's base of support.¹ For example, when an athlete has a lateral ankle sprain, joint proprioceptors are believed to be damaged. This damage may cause joint deafferentation, and leads to diminished supply of messages from the injured joint via afferent pathway.¹ Since the stability of the ankle joint is paramount when considering regulation of balance, this disruption of proprioceptive function would greatly affect on balance ability, especially with dynamic balance.^{2,29}

Sports Participation

Sports participation enhances the ability to use somatosensory and otolithic information.^{3,13,14,18,26,30-32} Thus, an athlete usually has better balance ability than the non-

athletic population.^{3,18} Several studies have been performed on different group of athletes but the balance ability differences between sports participation has been different depending on researchers.^{3,13,14,26,30} In any sports, the vestibular, visual, and/or somatosensory are increased in some way. Perrin¹⁸ compared static and dynamic balance among high-level judoists, professional dancers, and controls. Controls are defined as women and men in similar age who are not held a sports license nor practiced leisure physical activities at a level liable to modify their postural control. While judoists and dancers had superior balance ability than control subjects with eyes open, only judoists retained a significantly better stance with eyes closed. This result indicates that vision is essential component to maintain balance for dancers whereas Judo training leads the best abilities in all balance circumstances. Other than type of sports, the participation level and the length of career are also related to their balance ability.^{13,14,31} In a study examining soccer and basketball players, the longer the career in the sport and/or higher competition level they participate, the better the balance ability.^{13,14,31}

Other Factors That Affect Balance

One of the factors that cannot be eliminated is age. Several studies have demonstrated that dynamic balance is greatly related to age; an older population has decreased dynamic balance.³² As people get older, their joint ROM as well as strength level usually decreases. While decreased joint ROM reduces individual's LOS, muscle weakness itself could decrease balance ability.¹ More importantly, these factors lead to a change in their movement strategies. While a young population typically uses the ankle strategy, older populations as well as the injured athletes more commonly use the hip strategy that controls the balance with large movement at the hip.³³

Fatigue from exercise also negatively affects balance.^{29,34-36} While the most effective movement strategy is the ankle strategy, people change their postural control strategy in fatigued situation.³⁵ The main muscles to control balance in ankle strategy are the anterior tibialis and calf muscle and they control small sway.¹ However, when these muscles are fatigued, the efficiency of muscle contraction reduces, and coordination of the sway is decreased. One study suggested that it would take 10 minutes to recover from fatigue.³⁴ However, during this time

period, the athletes' postural sway will increase because they potentially return to the ankle strategy.^{34,35}

Balance Training

Balance exercise programs have been performed particularly for decreasing injury rates. Although Soderman³⁷ concludes that there were no positive or negative effect of balance training on injury prevention, several other studies have shown positive results.^{2,21,38,39} Because poor balance ability is not the only factor that causes injury, it is not easy to say if balance training itself effects injury prevention. However, a numbers of studies, utilizing various methods and various athletes, have been performed with the majority showing positive results.^{2,21,38,39} Thus, the effects of balance ability on injury prevention can be reliable. Even if the training program is only 10-15min per day, the results were significant.⁴⁰

Ankle sprains have also benefit from balance training. While inappropriate care of ankle sprain causes recurrent injury, balance and coordination training during the recovery phase from a recurrent ankle sprain reduced the risk for up to one year.³⁹ Not limited to ankle sprains, the risk of traumatic and overuse injuries can also be decreased by an ankle disk and functional exercise.⁴⁰ While

balance training helps to decrease risk of injury as well as helps to recover from proprioceptive deficit, muscle strengthening is another key component for athletes.

Role of the Hip Abductor Muscles

The control of the pelvic motion is critical to maintain total body balance because the weight of the head, arm, and trunk acts downward through the pelvis.²⁰ Hip abductor muscles such as gluteus medius muscle are known as pelvic stabilizers.⁴ The weakness of the hip abductor muscles may cause Trendelenburg position and inappropriate knee alignment which potentially increase risk for overuse knee injury or non-contact ACL tears.⁴ Moreover, the weakness of these muscles may lead to postural sway; in other words, negatively affect balance ability.

Hip Abductor Muscle Anatomy

The proximal lower extremity strength is believed to be vital for control of hip joint position and the resultant alignment of the distal segments.⁴¹ While Gottschalk⁵ states that the function of gluteus medius is primarily as a hip stabilizer, pelvic rotator, and regards the role in the initiation and assistance in abduction as a

secondary function, gluteus medius is still recognized as the main hip abductor muscle in general.⁴

Gluteus medius is a broad, thick radiating muscle on the outer surface of the pelvis.⁵ Gluteus medius is curved and fan-shaped and tapers to a strong tendon which is attached to the anterosuperior portion of the greater trochanter of the femur.^{4,5} The muscle bulk has three distinct parts making up the fan shape.^{4,5,42} These parts are equal in volume, have separate nerve innervations, and act in different direction during gait.^{5,42} The posterior fibers run almost parallel to the neck of the femur and stabilize the hip joint by causing the femoral head to be drawn into the acetabulum.^{4,5,42} The middle fibers tend to be more vertically oriented and initiate abduction of the hip during stance. The anterior fibers run almost vertically from the anterior iliac crest to the top of the trochanter and function to abduct and internal rotate the hip joint.^{4,5,42} During gait, the posterior part contracts first, followed by the middle and anterior part.⁵

Gluteus Medius Function and Injury

Gluteus medius is a strong abductor and medial rotator of the thigh and important to pelvic stabilization.^{4,5} As contraction of the gluteus medius prevents contralateral

hip drop and ipsilateral genu valgus that is known as Trendelenburg position.⁶ Weakness of the hip abductor muscle may provoke the function of the lower leg kinematics. Kollock⁴⁷ reported that weakness of the gluteus medius may not effectively resist adduction of the femur and may place the femur in a more medially rotated position. Also, Hollman⁴⁸ found that weak gluteus medius associated with increased pronation at the foot. These factors may also leads to increased tension on the iliotibial band, abnormal patella pressure, and cause abnormal patella movement within the trochlear groove.^{4,43} Thus, it may predispose athlete to various overuse knee injuries such as iliotibial band tightness, and patella-femoral pain syndrome.^{4,43} More importantly, weakness of gluteus medius potentially increases the risk of non-contact ACL injury. The ACL tear is one of the very common injuries in athletic field especially in female. The common mechanism of non-contact ACL injury is sudden deceleration while cutting or pivoting and landing from a jump.^{6,44} Jacobs⁴⁵ examined the relationship between hip abductor function and landing kinematics between men and women. In this study, women demonstrated lower hip abductor peak torque and increased knee valgus peak joint displacement when landing from a jump. Valgus loading can increase relative ACL strain and

may reach levels high enough to cause ligamentous failure.⁶ Even though the increased risk of ACL injuries is likely multifactorial, with no single structural, anatomical, or biomechanical feature solely responsible for this increased rate, gluteus medius weakness could be one of the risk factors.⁴⁴

Gluteus medius contraction during single-leg stance prevent Trendelenburg position, providing stability for lower extremity motion.⁴ It is reported that the weakness of the glutei in general leads to progressive muscular atrophy and the swaying gait but the absence of waddling.⁵ Even though it does not cause waddling, increased sway during gait and diminished stability influences balance ability. Trudelle-Jackson et al¹⁰ measured muscle strength and postural stability, and asked to report incidence of falls over the past year in elderly healthy women. They concluded that the weak hip flexor and abductor muscle, as well as lower values of postural stability were significantly correlated to incidence of fall. Although weakness of hip flexor muscle is also included to the predictor, this study still implies the connection between hip abductor muscle strength and balance.

SUMMARY

Balance ability is a vital component in the closed kinetic chain and necessary to be a successful athlete.¹⁻³ Balance is defined as the ability to maintain the body's COG within the base of support provided by the feet and is controlled by the CNS.^{1,2,13,14} Three important information of sensory sources are involved in balance ability: vision, vestibular, and somatosensory. When all three information sources are available, balance can be at its best. However, when one of them is not provided, other two components cover the gap.¹⁻³ According to Guskiewicz¹ balance can be categorized as static, semidynamic, dynamic, and functional balance. There are different types of device to measure specific balance ability. The BBS is high reliable in assessing static, semidynamic, and dynamic balance ability, whereas the SEBT has demonstrated high reliability for testing functional balance.^{1,12,23}

Balance ability can be affected by many factors. One of the most important factors for balance is proprioception. When injury occurs such as an ankle sprain, it is believed to cause damage to proprioceptors which in turn diminish the ability of the CNS to control balance.^{1,14} Other factors such as sport participation, positively effects balance

ability whereas older age, fatigue, and muscle weakness have a negative influence on balance.^{3,13,14,26,29,30,32,34,35}

Weakness of the gluteus medius may increase the risk of lower extremity injuries as well as affect balance. Since the gluteus medius acts to prevent valgus positions at the knee as well as pronation of the foot, it may decrease stress on knee and ankle.⁴⁶ The weak gluteus medius is typically seen in athletes who suffer from Patella-femoral pain syndrome, ankle sprain, and ACL sprain. Therefore, several researchers suggest that strengthening of the gluteus medius should be considered for rehabilitation programs for these injuries as well as injury prevention programs.^{6,47} From the concept of Trendelenburg's test, it is not difficult to see that weak gluteus medius has a negative influence on static balance. However, it is important to clarify the relationship among weak gluteus medius, dynamic balance, and functional balance. If there is also negative influences on balance ability, strengthening of gluteus medius could potentially help to increase balance ability as well as prevent injury.

APPENDIX B

The Problem

Statement of the Problem

All athletes require highly developed balance ability to perform athletic movements and to prevent injury.¹ Specifically, dynamic and functional balance could help athletes to compete at a higher level the sport.¹⁴ Hip abductor muscles are important for athletes to develop because they function to stabilize the pelvis and control lower limb.^{6,46,48} Strengthening of this muscle group may also help to prevent inadequate joint alignment in the lower extremity and reduce stress on the soft tissues around these joints.⁴⁶ Therefore, the purpose of this study was to examine the relationship among hip abductor strength, dynamic balance, and functional balance ability in collegiate athletes.

Definition of Terms

The following definitions of terms were used for this study:

- 1) Athlete - a person who currently participates in an NCAA Division II collegiate sport team.
- 2) Balance - ability to maintain the body's COG within the base of support provided by the feet.¹
- 3) Biodex Balance System (BBS) - a devise with a circular balance platform that quantifies the ability to

maintain dynamic bilateral and unilateral balance, as well as dynamic LOS.²⁸

- 4) Break test - strength testing method with hand-held dynamometer. The examiner pushes the dynamometer against the subject's limb until the subject's maximal muscular effort is overcome and the joint gives way.⁴⁹
- 5) Dynamic balance - the maintenance of the COG within the LOS over a moving base of support.¹
- 6) Functional balance - the maintenance of the COG within the LOS over a moving base of support with the inclusion of sport-specific tasks.¹
- 7) Lafayette Manual Muscle Test System (MMTS) - a hand-held device for objectively quantifying muscle strength.
- 8) Limits of stability (LOS) - the outermost range of an area in space that a person can lean from the vertical position in any direction without changing his or her base of support.¹²
- 9) Make test - strength testing method with hand-held dynamometer. The examiner holds the dynamometer stationary while the subject exerts a maximal force against the dynamometer and examiner.⁴⁹
- 10) Semidynamic balance - it involves one of two possible activities: (1) the person maintains their COG over a

fixed base of support while standing on a moving surface or unstable surface or (2) the person transfers their COG over a fixed base of support to selected ranges and/or directions within the LOS while standing on a stable surface.¹

- 11) Somatosensation - a specialized variation of the sensory modality of touch that encompasses the sensation of joint movement and joint position.¹
- 12) Star Excursion Balance Test (SEBT) - a functional, unilateral balance test that integrates a single-leg stance of one leg with maximum reach of the opposite leg.⁵⁰
- 13) Static balance - the COG is maintained over a fixed base of support either unilateral or bilateral while standing on a stable surface.¹
- 14) Trendelenburg position - contralateral hip drop and ipsilateral genu valgus that may occur with a weak gluteus medius muscle.⁵

Basic Assumptions

The followings were basic assumptions for this study:

- 1) All participants will fully understand the instructions provided and give a maximum effort during testing.

- 2) The subjects are honest in completing the demographic form.
- 3) The BBS and MMTS will be calibrated and work properly during this study.
- 4) Testing instruments (LOS testing, SEBT, and ABDT) are valid and reliable tools for measuring the dependent variables.
- 5) All subjects will volunteer with no coercion from coaches or faculty.

Limitations of the Study

Test results can be generalized for only the NCAA Division II collegiate athletes. Since testing was done in the lab, the results could represent assumptive functional measures of balance.

Significance of the Study

The scope of this study was to examine the relationship among hip abductor strength, dynamic balance, and functional balance ability in Division II collegiate athletes. Balance is a necessary component to perform athletic movement because athletes need to move their center of gravity continuously to prevent falling.² Hip abductor muscles has important role in athletic performance

as well. Weakness of this muscle group cause Trendelengburg position and it may lead lower extremity injury.⁴ Because of this, hip abductor strengthening is recommended to add for lower extremity injury prevention programs as well as rehabilitation programs.^{4,6,7,9,20,43,45,46} Since hip abductor muscles function as stabilizers for the pelvis and control the lower limb, hip abductor strength may correlate with balance ability.⁴⁶ Previous research has found relationship between hip abductor strength and experience of fall in healthy old women as well as balance ability in individuals with chronic ankle instability.^{5,10,11} However, since sports utilize more complicated movements, it is critical to clarify the relationship among hip abductor muscles and specific balance ability such as dynamic and functional balance. This information may assist athletic trainers and conditioning coaches in determining exercises that may best prevent injury as well as improve balance ability.

APPENDIX C

Additional Methods

APPENDIX C1

Informed consent form

Informed Consent Form

1. *Mizue Iwamoto*, has requested my participation in a research study at this institution. The title of the research is *The Relationship among Hip Abductor Strength, Dynamic Balance, and Functional Balance Ability*.
2. I have been informed that the purpose of the research is to examine the relationship among hip abductor muscle strength, dynamic balance, and functional balance ability in NCAA Division II collegiate athletes.
3. My participation will involve the Limits of Stability (LOS) test using the Biodex Balance System (BBS), functional balance test using the Star Excursion Balance Test (SEBT), and hip abductor muscle strength test (ABDT) using the Lafayette Manual Muscle Test System (MMTS). LOS test is one of the balance tests which I will stand on a movable platform which tilt up to 20° in all directions. I will move the platform back and forth, chasing the target which will be displayed on the screen. SEBT is another balance test that uses a star on the floor with eight lines extending at 45° increments from the center of the grid. I will stand on the center of the grid with one leg and reach with the opposite leg to touch the farthest point on the line. During ABDT, I will lie down on my back on the treatment table and my shoulder and hip will be strapped with a belt to stabilize my body. I will push against the researcher's hand with maximal effort as instructed. All of the testing will be conducted on one day in the B5 laboratory room and the athletic training room in Hamer Hall for approximately one hour for each subject.
4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. The possible risk is a falling during the LOS testing on the BBS and functional balance testing using the SEBT where the risks of falling will be minimized by the researcher as a spotter. Any injuries that may occur during the balance testing can be treated at the athletic training room at Hamer Hall provided by the researcher, Mizue Iwamoto, under the supervision of any certified athletic trainer from California University of Pennsylvania. The risk is no more than normal physical activity that normal athletes would be exposed during daily activity. There is no associated risk in ABDT.
5. There are no feasible alternative procedures available for this study.
6. I understand that the possible benefit of my participation in the research are contribution to existing research and may aid in enhancing injury prevention program and/or rehabilitation program for lower extremity injury by strengthen hip abductor muscles.
7. I understand that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my

records, Mizue Iwamoto will maintain all documents in a secure location in which only the student researcher and research advisor can access.

8. I have been informed that I will not be compensated for my participation.
9. I have been informed that any questions I have concerning the research study or my participation in it, before or after my consent, will be answered by

Student Researcher:

Mizue Iwamoto
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Graduate Faculty Thesis Advisor:

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10. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.
11. I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to myself. In signing this consent form, I am not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me upon request.

Subject's signature _____ Date _____

Other signature (if appropriate) _____ Date _____

12. I certify that I have explained to the above individual the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.
13. I have provided the subject/participant a copy of this signed consent document if requested.

Investigator's
signature _____ Date _____

Approved by the California University of Pennsylvania IRB:

Start date ____/____/____, *End Date:* ____/____/____

APPENDIX C2

Subject Information Sheet

Subject Information Sheet

Subject # _____ Date _____

Age: _____ Gender: _____

Leg dominance: _____

Height: _____ cm (_____ in)

Weight: _____ kg (_____ lb)

Sport(s) _____

APPENDIX C3
Test Score Sheets

Test Score Sheet

Subject #: _____

Date: _____

LOS score

Px trial 1	Px trial 2	Px trial 3	Px trial 4	Test trial

ABDT peak force (kg)

Distance: _____ m

	Px 1	Px 2	Test 1	Test 2	Test 3	Mean peak force of 3 tests
Left leg						
Right leg						

L mean peak force(_____kg) x 9.81 = _____N

R mean peak force(_____kg) x 9.81 = _____N

L Torque = mean force(_____N) x distance(_____m)

= _____Nwm

R Torque = mean force(_____N) x distance(_____m)

= _____Nwm

SEBT record sheet: (Date: _____ Leg length: R: _____ cm, L: _____ cm)

Subject's #: _____

stance leg/ direction	Px 1	Px 2	Px 3	Px 4	Px 5	Px 6	Test 1	Test 2	Test 3	Total mean score of 3 tests
L/AL										
L/A										
L/AM										
L/M										
L/PM										
L/P										
L/PL										
L/L										
R/AL										
R/A										
R/AM										
R/M										
R/PM										
R/P										
R/PL										
R/L										

L stance leg total mean score = _____
 R stance leg total mean score = _____
 L excursion score = $L \text{ mean } (\quad) / L \text{ leg length } (\quad) = \quad$
 R excursion score = $R \text{ mean } (\quad) / R \text{ leg length } (\quad) = \quad$

APPENDIX C4

Pictures of Each Test

Star Excursion Balance Test (SEBT)



(<http://www.hhdev.psu.edu/atlab/postmed.html>)

Limits of Stability test (LOS) on Biodex Balance System (BBS)



(boyntonsportandbackpt.com/services)

Hip abductor muscle strength testing (ABDT) measured by the Lafayette Manual Muscle Test System (MMTS)

MMTS

ABDT



(http://www.alimed.com/resources/common/images/products/full/6132_d.jpg)

(<http://www.somatics.de/Image7.gif>)

The researcher will be holding the MMTS perpendicular to the thigh at the lateral femoral condyle while subject build their force gradually to a maximum voluntary effort.

APPENDIX C5

Institutional Review Board



California University
of Pennsylvania

Proposal Number

08-044

Date Received

1/28/08

PROTOCOL for Research Involving
Human Subjects

Expedited

Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects

(Reference IRB Policies and Procedures for clarification)

Project The Relationship Among Hip Abductor Strength, Dynamic and Functional Balance Ability

Researcher/Project Director Mizue Iwamoto

Phone # 716-400-3060 **E-mail Address** iwa7465@cup.edu

Faculty Sponsor (if required) Dr. Rebecca Hess

Department Health Science and Sport Studies

Project Dates January 2009 to May 2009

Sponsoring Agent (if applicable) _____

Project to be Conducted at Athletic Training Room and B5 laboratory room in Hamer Hall at California University of Pennsylvania

Project Purpose: *Thesis* *Research* *Class Project* *Other*

Keep a copy of this form for your records.

Required IRB Training

The training requirement can be satisfied by completing the online training session at <http://cme.nci.nih.gov/>. A copy of your certification of training must be attached to this IRB Protocol. If you have completed the training at an earlier date and have already provided documentation to the California University of Pennsylvania Grants Office, please provide the following:

Previous Project Title _____

Date of Previous IRB Protocol _____

Please attach a typed, detailed summary of your project AND complete items 2 through 6.

1. *Provide an overview of your project-proposal describing what you plan to do and how you will go about doing it. Include any hypothesis(es) or research questions that might be involved and explain how the information you gather will be analyzed. For a complete list of what should be included in your summary, please refer to Appendix B of the IRB Policies and Procedures Manual*

The purpose of this study will be to examine the relationship among hip abductor muscle strength, dynamic balance, and functional balance ability. Healthy National Collegiate Athletic Association (NCAA) Division II collegiate athletes from California University of Pennsylvania are expected to participate in this study (N~30). Subjects who suffer from any visual, vestibular, balance disorder, serious lower extremity injury and/or a concussion in the last six months prior to the test, and/or currently suffering from lower extremity injury will be excluded from this study. Each subject who signed the informed consent (attached) will have two measures of balance and one measure of strength performed. These include the limits of stability (LOS) test that is provided by the Biodex Balance System (BBS), a functional balance test using the Star Excursion Balance Test (SEBT), and hip abductor muscle strength test (ABDT) using the Lafayette Manual Muscle Test System (MMTS). All subjects will start with ABDT to reduce local fatigue followed by the two balance tests. The order of the two balance tests will be randomized. Each subject will perform practice trials for all tests as recommended in the literature. This will allow each subject to become familiar with the test as well as to minimize the learning effect. Pictures of each test are attached.

During ABDT, the subject will be supine on the treatment table. The subject will be asked to build their hip abduction force gradually to a maximum voluntary effort for 2s and maintain maximum effort for additional 5s while the researcher is holding the MMTS perpendicular to the thigh at the level of the lateral femoral condyle (at the knee). Three ABDT test trials will be performed after two practice trials.

For LOS test, the subject will take a bilateral stance on the movable BBS platform. The BBS offers eight different levels of difficulty by changing the amount of the stiffness in the platform. Since no level of difficulty has been addressed in previous research, the level of difficulty will be determined during preliminary study. While standing on the BBS platform, the subject will be asked to move the platform back and forth from the central box to chasing the moving target which will be displayed on the BBS computer screen. Four practice sessions and one test trial will be performed, as recommended by the literature.

Before the SEBT, each subject's leg length will be measured bilaterally in centimeters as the distance between the anterior superior iliac crests and the medial malleolus to normalize the SEBT score (Photo attached). The subject will report the preferred leg that is determined by push/tap test, stork stand, and kicking ball. The subject will stand up straight with both feet placed together during push/tap test. The researcher will gently push the subject forward from behind until the subject is forced to step forward to maintain balance. The foot that is used by the subject to catch himself/herself will be considered as preferred leg. For stork stand test, the subject will be asked to stand up straight with both legs and then asked to stand on one leg without instruction. The supporting leg will be considered as preferred leg in this test. For kicking ball test, the subject will be asked the leg the subject preferred to kick a ball. The leg used to kick a ball will be considered as preferred leg. The SEBT uses a star on the floor with eight lines extending at 45° increments from the center of the grid. The subject will stand on one leg while place the heel on the center of the star and hold the hands at the hip. Then the subject will reach with opposite leg to touch as far as possible along the chosen line. The subject touched the farthest point possible on the line with the most distal part of their reach foot. The subject then returns to a bilateral stance while maintaining equilibrium. The subject will perform six bouts of practice trials followed by three test trials in each of the eight directions with each leg. If a subject loses their balance during a trial, they will be asked to repeat the trial.

The data will be analyzed using a Pearson product moment correlation coefficient provided by SPSS 16.0. It is hypothesized that there is a positive correlation among LOS score, SEBT score, and ABDT score.

2. *Section 46.11 of the Federal Regulations state that research proposals involving human subjects must satisfy certain requirements before the IRB can grant approval. You should describe in detail how the following requirements will be satisfied. Be sure to address each area separately.*

- a. *How will you insure that any risks to subjects are minimized? If there are potential risks, describe what will be done to minimize these risks. If there are risks, describe why the risks to participants are reasonable in relation to the anticipated benefits.*

The possible risks and/or discomforts are very minimal include falling down during the LOS testing and SEBT. The BBS has handrails around the balance platform in case of loss of balance. In both the LOS test and the SEBT the researcher will further minimize the risk of falling by acting as a spotter. No tests are physically invasive. If an injury was to occur, the researcher will take care of the subjects under the supervision of certified athletic trainer in the Athletic Training Room in Hamer Hall.

- b. *How will you insure that the selection of subjects is equitable? Take into account your purpose(s). Be sure you address research problems involving vulnerable populations such as children, prisoners, pregnant women, mentally disabled persons, and economically or educationally disadvantaged persons. If this is an in-class project describe how you will minimize the possibility that students will feel coerced.*

All subjects will be volunteers who are eighteen years or older and are NCAA Division II collegiate athletes at California University of Pennsylvania. Prior to the study, an informational meeting will be held with the potential subjects to explain the concept of the study in the absence of the coach. Any athlete who suffers from any visual, vestibular, balance disorder, serious lower extremity injury and/or a concussion six month prior to the test, and/or currently suffering from lower extremity injury not be included in this study as these conditions may interfere with accurate balance assessment. This exclusion due to these medical conditions will be performed by the supervising Certified Athletic Trainer while maintaining patient confidentiality.

- c. *How will you obtain informed consent from each participant or the subject's legally authorized representative and ensure that all consent forms are appropriately documented? Be sure to attach a copy of your consent form to the project summary.*

An informed consent form (attached) will be completed and signed by all subjects before participating in this study on the day of the testing. Each signed form will be kept by the researcher.

- d. *Show that the research plan makes provisions to monitor the data collected to insure the safety of all subjects. This includes the privacy of subjects' responses and provisions for maintaining the security and confidentiality of the data.*

Data will be collected during the spring semester. All subjects will come in once for measuring balance and strength. All collected data which will be identified by subject number will be maintained by the researcher in a secure location in which only the researcher and research advisor can access.

3. Check the appropriate box(es) that describe the subjects you plan to use.

<input checked="" type="checkbox"/> <i>Adult volunteers</i>	<input type="checkbox"/> <i>Mentally Disabled People</i>
<input checked="" type="checkbox"/> <i>CAL University Students</i>	<input type="checkbox"/> <i>Economically Disadvantaged People</i>
<input type="checkbox"/> <i>Other Students</i>	<input type="checkbox"/> <i>Educationally Disadvantaged People</i>
<input type="checkbox"/> <i>Prisoners</i>	<input type="checkbox"/> <i>Fetuses or fetal material</i>
<input type="checkbox"/> <i>Pregnant Women</i>	<input type="checkbox"/> <i>Children Under 18</i>
<input type="checkbox"/> <i>Physically Handicapped People</i>	<input type="checkbox"/> <i>Neonates</i>

4. Is remuneration involved in your project? Yes or No. If yes, explain here.
5. Is this project part of a grant? Yes or No. If yes, provide the following information:
 Title of the Grant Proposal _____
 Name of the Funding Agency _____
 Dates of the Project Period _____
6. Does your project involve the debriefing of those who participated? Yes or No
 If Yes, explain the debriefing process here.

If your project involves a questionnaire interview, ensure that it meets the requirements of Appendix __ in the Policies and Procedures Manual.

Project Director's Certification
Program Involving HUMAN SUBJECTS

The proposed investigation involves the use of human subjects and I am submitting the complete application form and project description to the Institutional Review Board for Research Involving Human Subjects.

I understand that Institutional Review Board (IRB) approval is required before beginning any research and/or data collection involving human subjects. If the Board grants approval of this application, I agree to:

1. Abide by any conditions or changes in the project required by the Board.
2. Report to the Board any change in the research plan that affects the method of using human subjects before such change is instituted.
3. Report to the Board any problems that arise in connection with the use of human subjects.
4. Seek advice of the Board whenever I believe such advice is necessary or would be helpful.
5. Secure the informed, written consent of all human subjects participating in the project.
6. Cooperate with the Board in its effort to provide a continuing review after investigations have been initiated.

I have reviewed the Federal and State regulations concerning the use of human subjects in research and training programs and the guidelines. I agree to abide by the regulations and guidelines aforementioned and will adhere to policies and procedures described in my application. I understand that changes to the research must be approved by the IRB before they are implemented.

Professional Research


Project Director's Signature

Department Chairperson's Signature

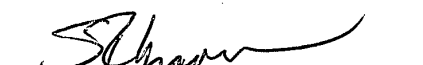
Student or Class Research



Student Researcher's Signature



Supervising Faculty Member's
Signature if required



Department Chairperson's Signature

ACTION OF REVIEW BOARD (IRB use only) _____

The Institutional Review Board for Research Involving Human Subjects has reviewed this application to ascertain whether or not the proposed project:

1. provides adequate safeguards of the rights and welfare of human subjects involved in the investigations;
2. uses appropriate methods to obtain informed, written consent;
3. indicates that the potential benefits of the investigation substantially outweigh the risk involved.
4. provides adequate debriefing of human participants.
5. provides adequate follow-up services to participants who may have incurred physical, mental, or emotional harm.

was amended
 Approved Disapproved



Chairperson, Institutional Review Board

Draft, April 7, 2005

02-06-09

Date

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ABSTRACT

Title: THE RELATIONSHIP AMONG HIP ABDUCTOR STRENGTH, DYNAMIC BALANCE, AND FUNCTIONAL BALANCE ABILITY

Researcher: Mizue Iwamoto

Advisor: Dr. Rebecca Hess

Date: May 2008

Research Type: Master's Thesis

Context: Current research has indicated that weakness of the gluteus medius influences balance ability in healthy old women and people with functional ankle instability. Previous studies have not examined the relationship among hip abductor strength and different balance ability, such as dynamic and functional balance, in healthy athletes.

Objective: The purpose of this study was to examine the relationship among hip abductor muscle strength, dynamic balance, and functional balance ability in collegiate athletes.

Design: A descriptive correlational design was used to determine a relationship among hip abductor strength, dynamic balance, and functional balance.

Setting: The testing was performed in a controlled laboratory setting by the researcher.

Participants: Twenty Division II collegiate athletes volunteered (male=11, female=9) for this study that were currently free of injury.

Interventions: Each subject was tested on one day. All subjects were tested by using the hip abductor hip strength test (ABDT), the Limits of Stability (LOS) test, and the Star Excursion Balance Test (SEBT). The ABDT was used to measure subjects' hip abductor muscle strength, and the LOS and SEBT were

used to measure dynamic balance and functional balance, respectively.

Main Outcome Measures:

LOS score, SEBT score, and ABDT score were computed from all test trials and correlation was examined among all three variables.

Results:

A significant correlation between hip abductor muscle strength and functional balance ability was present ($r = .514$, $P = .021$). However, there were no significant correlation between functional balance and dynamic balance ($r = .382$, $P = .097$), or between dynamic balance and hip abductor muscle strength ($r = -.037$, $P = .878$).

Conclusion:

Functional balance and hip abductor muscle strength appears to be moderately related in healthy Division II collegiate athletes. Since weak hip abductor may cause inappropriate lower extremity alignment and may increase the risk of injury, strengthening the hip abductor muscle may help to prevent injury as well as enhance athletes' performance by providing better balance ability.

Word Count: 322