A CORRELATION BETWEEN MUSCULAR IMBALANCES OF THE LOWER EXTREMITY (H:Q RATIO) AND FORCE PRODUCTION

A THESIS

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By

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THESIS APPROVAL

Graduate Athletic Training Education

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INTRODUCTION

Each and every day, we perform tasks that are of second nature to us. These tasks may seem miniscule and effortless, however they require muscular strength, recruitment, coordination and balance. The repetition of a singular or similar movement over a prolonged period of time may lead to significant damage to the human body. Muscular imbalance, which can occur between any agonist and antagonist, is a ratio of force production that becomes "unbalanced" where one group of prime movers is producing more force or higher strength than normal, compared to the other groups. Although the causes of muscular strength imbalances in the population are diverse, it seems logical to assume that muscular strength imbalances could be present in both athletes and non-athletes of both genders. This is especially likely considering the vast number of factors that may lead to developing a muscular strength imbalance. These components may include overtraining, task repetition, and lack of integrated strength training.

An exhaustive search of the literature suggests there have been no studies that have investigated muscular strength imbalances comparing non-athletes and premiere athletes or if one group is more likely to develop a muscular strength imbalance. Presently, research has primarily been focused on determining how a muscular strength imbalance of the lower extremities can increase injury rates of certain populations such as females and athletes. Current theories suggest that muscular strength imbalances predispose athletes to higher rates of injury; therefore having the potential to decrease playing time, leading to decreased performance. There is currently little agreement in the literature to quantify the amount of muscular strength imbalance that must be present before a detrimental effect is seen in an athlete's performance, or if a specific imbalance ratio can clearly indicate the likeliness of sustaining an injury.[1]

Previous research has determined the fact that muscular imbalances can lead to injury; however, little research has been found showing quantitative data on how a muscle imbalance can affect sport-specific movements. It is important to collect this data because not only will it result in increased knowledge of the topic data but could help in redefining the accepted hamstring: quadriceps ratios of certain populations, most closely researched by Perrin et al, and Coombs et al. [2,3] Perrin et al has determined in his works on isokinetic exercise and assessment that general populations fall into a H:Q ratio of .60. [2] Coombs et al, questions the usage of H:Q ratios and how it is used to interpret muscle balance or symmetry. The complaint is that the joint angle has never been factored into the normative value of 0.6. This debate will continue until more research continues to accept or refute the currently accepted ratio.[3]

To prevent the potential negative effects of muscular imbalances, more attention needs to be focused on neuromuscular training and rehabilitation to achieve a balanced ratio between agonist and antagonist muscle groups.[4] The purpose of this study is to determine the effects of hamstring to quadriceps (H:Q) ratio muscular imbalances on force production during the vertical jump and landing phases of drop-jump testing.

The current research will attempt to quantitatively assess how muscular imbalances affect force production, force attenuation and certain movement patterns associated with sport performance. Previous research has determined the potential negative effects of muscular imbalances and the increased rate of injury they include. However, the normal values of H:Q ratio as stated by Perrin et al at 60% are outdated and include a sample size of the general population.[2] The purpose of the current research is to examine the relationship between muscular imbalances and their effect on force production during a drop-jump test.

METHODS

In order to determine the prevalence of muscular imbalances and their effect on force production (jumping force and landing force), a series of tests were conducted. The study required the participants to complete a brief warm-up, a series of drop to vertical jumps on a force platform, and a muscular strength test on a Biodex isokinetic dynamometer. This section includes the research design, subject selection, instrumentation, procedures, hypotheses, and data analysis.

Research Design

The research was conducted utilizing a cross-sectional observational, within subjects design. Relationships were assessed between participants based upon presence of muscular imbalance, landing force production, vertical jumping force production and change in rectus femoris knee angle.

Subjects

A total of 30 volunteers (16 males and 14 females), 18 years of age or older were used for this study. The full-time California University of Pennsylvania students were required to be considered apparently healthy, according to American College of Sports Medicine (ACSM) standards, and also have completed the modified PAR-Q form.[5] Each subject was required to fall into a "physically active" category. This definition reads that each research subject participates in physical activity that raises their heart rate to at least 50% maximum (i.e. aerobics, organized sport, weight training) at least three times per week and must not have suffered from any major or long-term debilitative injuries to the lower extremities.

Exclusion criteria consist of participants not fulfilling the requirements of minimum physical activity per week. Participants were also excluded if they currently had any injuries that required surgical intervention, or injuries that would impede their ability to complete physical tasks that are required by the study or are not considered apparently healthy, according to ACSM standards.[5] Participants were also excluded from this study if they were currently suffering from any illnesses which may have significantly limited their ability to perform physical tasks to the best of their ability.

Instrumentation

- Biodex Isokinetic Dynamometer System 3

    Biodex Medical Systems

    20 Ramsay Road, Shirley, New York, 11967-4704

The Biodex Isokinetic Dynamometer System 3 was used to test each participant, bilaterally, for lower extremity strength, torque values and to measure H:Q ratio. This was accomplished through a custom 3-speed test for seated knee flexion and extension.

- Force Platform

    Advanced Mechanical Technology, Inc.

    176 Waltham St. Watertown, MA, 02472-4800

        AMTI Serial #- 5386

        Model Number- OR6-7-2000

        Type- High Frequency

The force platform from AMTI was used as a landing and take-off point for each trial of the drop-jump test. It recorded the peak jump and landing force in Newtons.

- Stationary Bike

    Monark 828E Ergomedic

The Monark Ergomedic was used as the warm-up portion of the research study. Each participant was required to ride at 60 rpms till their heart rate reached 50% of their maximum heart rate, equated by Karvonen's equation.

- Digital Video Camera

  Panasonic HandyCam DV Camcorder

  DCR-PC120 NTSC

  Panasonic MiniDV ME DVM69 Cassette

The Panasonic HandyCam DV Camcorder was used as the video recorder for the video analysis portion of the research study. Each participant was recorded performing each of the three trials of the drop-jump test. The video frames were shot from the mid-section down. The video was loaded into analysis software where the anatomical markers could be tracked.

- Height Platform

The height platform was used as part of the drop-jump testing. Participants used this platform as their starting point for each trial. The platform is 20 inches from the floor and was measured no more than 15 inches from the force platform during each trial to reduce forward momentum of the drop-jumps.

- DartFish ProSuite Version 4.5.1.0

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  Licensed to California University of PA

The DartFish ProSuite software was used in conjunction with the video recordings of each participant. This software allowed for slide-by-slide 2D video analysis of each trial of the drop-jump testing. The selected trial was broken down and the rectus femoris angles were calculated on the software during the two crucial frames.

- AMTINetForce Version 2.0

    Copyright 1999 Advanced Mechanical Technology, Inc.

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AMTINetForce was a software application that ran the system for the force platform. Calibration, platform zeroing and the testing trials were run through this software. It allowed correction for body weight, start and stop each trial, and re-run trials if necessary.

- Biosoft Version 2.3.0

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The Biosoft software program was used in conjunction with the force platform and AMTINetForce. After running each trial through AMTINetForce, data was reconfigured and accessed through Biosoft. Biosoft provided raw data, graphical analysis and charted comparison between trials.

- DELL Latitude D6000 Laptop

    Model- PP05L

The Dell Latitude D6000 Laptop was the unit that stored each software program and was the where all of the data was uploaded to and saved. Each test and all of the analysis, along with SPSS statistical analysis, took place on this unit. All of the data and analysis has been saved and coded. The files are all password protected.

Procedure

Participants were studied strictly on a volunteer basis. Participants were recruited from education programs as well as through sign-ups available to varsity athletes at California University of Pennsylvania. All participants were volunteers with no coercion by faculty, researcher or superiors, and with no compensation.

Testing Protocol

This study required each participant to complete a brief warm up, a series of drop to vertical jumps onto a force platform, and a muscular strength test on a Biodex isokinetic dynamometer. The warm-up was held in the Human Performance Lab B5 in Hamer Hall, on the Monark 828E Ergomedic stationary bicycle where 60 revolutions per minute with one-kilogram resistance was maintained until 50% of age-predicted maximum heart rate, using Karvonen's equation, was achieved. A drop jump test followed the warm-up procedure. The procedure for completing the drop-jump trials was adapted from the protocol created by Frank Noyes in association with the Cincinnati Sports Medicine and Orthopedic Center.[6] Prior to the test, reflective anatomical markers were placed bilaterally on a series of bony landmarks (anterior superior iliac spine, superior pole of the patella, medial and lateral epicondyles of the femur, medial and lateral malleoli), to assist in data collection and analysis through a computer biomechanical program. These markers were referenced as part of the modified anatomical Helen-Hayes model.[7] The researcher demonstrated the bilateral drop to vertical jump sequence to each subject, and one practice trial was conducted to ensure complete understanding of the procedure. The subjects were not provided with any verbal instruction regarding how to land or jump, only to land straight on the force platform, so that the camera would record properly.[6] The subjects then performed the drop to vertical jump sequence by first jumping off the box, landing bilaterally, and immediately performing a maximum vertical jump, and then finally landing back on the force platform. This sequence was repeated for three trials. The peak force of each landing phase and jumping phase was recorded and the trial that best represented qualitative excellence and highest force output was selected for analysis. Each force was measured in Newtons (N).

Each subject was video taped during each of the testing trials from the anterior view. The main focus in this view was determining if the knees deviated to a varus or valgus position. Each participant wore anatomical markers so that the post-analysis could be concluded with less researcher error. The same researcher placed each marker. The video taped results obtained from the analysis of the jumps of the participants were analyzed using DartFish ProSuite to determine if muscular imbalances affected knee angle during jumping and landing technique. DartFish ProSuite is a 2-D digital biomechanical analysis program that allows video to be uploaded and reviewed in stop-motion. From the anterior view, two frames were used to determine change in the rectus femoris angle: (1) land, the frame in which the subject was at the initial bilateral full-foot landing on the platform; and (2) takeoff, the frame that demonstrated the initial forward and upward movement of the arms and the body as the athlete prepared to perform the maximum vertical jump.

A muscular strength test, using a Biodex isokinetic dynamometer, was conducted to determine concentric hamstring to concentric quadriceps strength ratios non-gravity corrected. Participants were fitted to the equipment according to the Biodex Protocol Manual. The Biodex Dynamometer set-up protocol, which was followed when testing participants for muscular strength, can be found in Appendix C: Additional Methods. Participants were tested bilaterally using three speeds of isokinetic movement (120, 180 and 300 degrees per second). A trial period preceded each testing trial. The trial period allowed the subjects to become comfortable with the equipment, to reduce any learning effect, and to allow acclimatization to the motions necessary to complete the test. Participants were required to do repetitions until: (1) the program customized for the research test was complete, (2) fatigue occurred or (3) the test was voluntarily stopped by the participant with the comfort stop option. Fatigue was based on the perception of the participant of the workload required. The researcher provided no verbal encouragement during the trials other than asking that the participants perform the required knee extension and flexion movements through the entire range of motion, with as much force and speed as possible. The results of this test were used to calculate the hamstrings to quadriceps strength ratio, and used to determine if strength imbalances were present in each of the participants.

Hypotheses

The following hypotheses were tested:

1. The presence of a muscular strength imbalance through the H:Q ratio will result in decreased peak jump force production.
2. The presence of muscular strength imbalances through the H:Q ratio will result in an increased drop-jump landing force.
3. If muscular imbalances are present, an increase in rectus femoris angle will occur from landing to jumping phases to compensate for strength imbalances.

The hypotheses were based on the research literature reviewed on muscular strength imbalances of the lower extremities in athletic populations. Additional investigation will be based on the differences between muscular imbalance ratio presence and force production/attenuation. These differences were based on the perceptions of previous research found on gender and athletic status and how these components would play on strength, coordination, and certain movement patterns.[8,9]

Data Analysis

Statistical significance was assessed using a series of Pearson Product Moment Correlations. This equation also enabled the relationships of terms within the hypotheses to be viewed. An Independent-sample t-test was used to determine if H:Q ratio has a relationship with knee angle (rectus femoris). All statistical tests will be performed using SPSS 16.0.

RESULTS

Demographic Data

The sample that was used in the research study consisted of 30 physically active individuals. Each participant was enrolled as a full-time student at California University of Pennsylvania and was also characterized as a legal adult (n $\geq$ 18 years of age). Within the sample 53% were males (n=16) and females were represented by 47% (n=14) of the sample. Each of the subjects also provided leg dominance. Nearly 93% of participants reported use of their right leg (n=28) during kicking and frontal plane balancing, while only 7% preferred their left leg (n=2).

Table 1 depicts the demographic characteristics of the participants in this research study.

Table 1. Characteristics of Participants

Demographic	**Range**	**Mean ± SD**
Age (yrs.)	18-23	20.73 ± 1.68
Weight (lbs.)	293-110	182.4667 ± 53.8149

Table 2 displays the academic rank of participants as of the semester they participated.

Table 2. Participants' Class Rank

Academic Rank	**Frequency**	**Percent**
Freshman	7	23.3%
Sophomore	10	33.3%
Junior	5	16.6%
Senior	0	0%
Graduate	8	26.7%

Hypothesis Testing

Each of the hypotheses was tested using a confidence interval of 95%.

Hypothesis 1: The presence of a muscular strength imbalance through the H:Q ratio will result in decreased peak jump force production.

A Pearson Product Moment Correlation was calculated to determine whether there is a relationship between Bilateral H:Q Ratio Deviation (H:QDAVG) and the Peak Jump Force (PJF) during a drop-jump test. Table 3 shows the results of the Pearson Product Moment Correlation for Hypothesis 1.

Table 3. Pearson Correlation for H:Q Ratio Deviation Average (H:QDAVG) and Peak Jump Force (PJF)

Variable	**N**	**r**	**P**
H:QDAVG and PJF	30	-.115	.545

* p < .05

Conclusion: No correlation was found ($r_{30} = -.115$, $p > .05$), indicating that no significant relationship exists between the two variables. Participants' peak jump force was independent of their H:Q ratio.

Hypothesis 2: The presence of muscular strength imbalances through the H:Q ratio will result in an increased drop-jump landing force.

A Pearson Product Moment Correlation was calculated to determine whether there is a relationship between Bilateral H:Q Ratio Deviation (H:QDAVG) and the Peak Landing Force (PLF) during a drop-jump test. Table 4 shows the results of the Pearson Product Moment Correlation for Hypothesis 2.

Table 4. Pearson Correlation for H:Q Ratio Deviation Average (H:QDAVG) and Peak Landing Force (PLF)

Variable	**N**	**r**	**P**
H:QDAVG and PLF	30	-.263	.161

* p < .05

Conclusion: No correlation was found ($r_{30} = -.263$, $p > .05$), indicating that no significant relationship exists between the two variables. Participants' peak landing force was independent of their H:Q ratio.

Hypothesis 3: If muscular imbalances are present, an increase in rectus femoris angle will occur from landing to jumping phases to compensate for strength imbalances.

An Independent-samples t-test was performed to determine whether the presence of a muscular imbalance had an effect on the rectus femoris angle during both the initial landing and initial jumping phase of the drop-jump test. The rectus femoris angle was assessed during each phase on each leg and the absolute value of the Average Bilateral Change (ABSBIDELTA) between the Landing and Jumping Phases was recorded. The grouping variables for the independent-samples were Group 1: Normal Ratio/Muscular Balance and Group 2: Non-normal ratio/Muscular imbalance. Normal ratios values were determined as of 60% ± 5%, while equal variances were assumed. The Group Statistics detailing the Independent-samples t-test of the Average Bilateral Change between the Landing and Jumping Phases (ABSBIDELTA) on Muscular Imbalance Presence is depicted in Table 5.1. Table 5.2 shows the results of the Independent-samples t-test for Hypothesis 3.

Table 5.1. Group Statistics of Average Bilateral Change between the Landing and Jumping Phases (ABSBIDELTA) on Muscular Imbalance Presence

	Normal Ratio?	N	Mean	SD
ABSBIDELTA	Yes:1	7	16.90	6.39
	No: 2	23	8.24	1.72

Table 5.2. Independent-sample t-test of Average Bilateral Change between the Landing and Jumping Phases (ABSBIDELTA) on Muscular Imbalance Presence

	T	Sig.(2-tailed)	Mean Dif.
ABSBIDELTA (equal variances assumed)	1.642	.112	7.58

* $p < .05$

Conclusion: No significance was found ($t = 1.642$, $p > .05$), in the relationship between H:Q values and Δ average bilateral rectus femoris angle.

Additional Findings

In addition to the hypotheses testing, a group of Pearson Correlations was performed to investigate other independent variables involved in this research study. The average of the bilateral H:Q ratios was determined and was used to filter each participant into one of two groups: Overall Hamstring Driven or Overall Quadriceps Driven.

Each group was prepared for analysis through the aforementioned group of Pearson Correlations.

A Pearson Product Moment Correlation was calculated to determine if a relationship between the Overall Quadriceps Driven (AVGOVRDRVN) Group and Peak Jump Force (PJF) exists. Table 6.1 details the Descriptive Statistics for the Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance. Table 6.2 shows the results of the Pearson Product Moment Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance.

Table 6.1. Descriptive Statistics of Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance

	N	**Mean**	**Std. Dev**
AVGOVRDRVN	5	-8.5133	9.60036
PJF (N)	5	2231.5940	914.29607

Table 6.2. Pearson Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance

Variable	**N**	**r**	**P**
AVGOVRDRVN and PJF	5	-.905	.035*

$* p < .05$

Conclusion: A significant correlation was supported ($r_5 = -.905$, $p < .05$), indicating that a significant relationship exists between the two variables. Most of the participants that have been filtered as part of the Overall Quadriceps Driven Group, had a better performance in their Peak Jump Force during the drop-jump test.

A Pearson Product Moment Correlation was calculated to determine if a relationship between the Overall Quadriceps Driven (AVGOVRDRVN) Group and Peak Landing Force (PLF) exists. The Descriptive Statistics, Table 7.1, are listed for the Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance. Table 7.2 shows the results of the Pearson Product Moment Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance.

Table 7.1. Descriptive Statistics of Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance

	N	**Mean**	**Std. Dev**
AVGOVRDRVN	5	-8.5133	9.60036
PLF (N)	5	3998.4766	294.93693

Table 7.2. Pearson Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance

Variable	**N**	**r**	**P**
AVGOVRDRVN and PLF	5	.663	.223

* p < .05

Conclusion: No correlation was found ($r_5 = .663$, $p > .05$), indicating that no significant relationship exists between the two variables. Participants' peak landing force was independent of the filtered group of Overall Quadriceps Driven.

A Pearson Product Moment Correlation was calculated to determine if a relationship between the Overall Hamstring Driven (AVGOVRDRVN) Group and Peak Jump Force (PJF) exists. The Descriptive Statistics of the Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance is depicted in Table 8.1. Table 8.2 shows the results of the Pearson Product Moment Correlation for Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance.

Table 8.1. Descriptive Statistics of Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance

	N	Mean	Std. Dev
AVGOVRDRVN	25	12.3233	10.10326
PJF (N)	25	2401.3761	812.92427

Table 8.2. Pearson Correlation for Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Jump Force (PJF) Performance

Variable	N	r	P
AVGOVRDRVN and PJF	25	-.326	.112

* $p < .05$

Conclusion: No correlation was found ($r_5 = -.326$, $p > .05$), indicating that no significant relationship exists between the two variables. Participants' peak jump force was independent of the filtered group of Overall Hamstring Driven.

A Pearson Product Moment Correlation was calculated to determine if a relationship between the Overall Hamstring Driven (AVGOVRDRVN) group and Peak Landing Force (PLF) exists. The Descriptive Statistics of the Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance is depicted in Table 9.1. Table 9.2 shows the results of the Pearson Product Moment Correlation for Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance.

Table 9.1. Descriptive Statistics of Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance

	N	**Mean**	**Std. Dev**
AVGOVRDRVN	25	12.3233	10.10326
PLF (N)	25	3490.6652	487.60783

Table 9.2. Pearson Correlation for Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance

Variable	**N**	**r**	**P**
AVGOVRDRVN and PLF	25	-.162	.439

* $p < .05$

Conclusion: No correlation was found ($r_5 = -.162$, $p > .05$), indicating that no significant relationship exists between the two variables. Participants' peak landing force was independent of the filtered group of Overall Hamstring Driven.

A Pearson Product Moment Correlation was calculated to determine if a relationship existed between the Peak Landing Force (PLF) and Peak Jump Force (PJF) of the Overall Quadriceps Driven (AVGOVRDRVN) group. Table 10 shows the results of the Pearson Product Moment Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak

Landing Force (PLF) Performance vs. Peak Jump Force (PJF) Performance.

Table 10. Pearson Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance vs. Peak Jump Force (PJF) Performance

Variable	**N**	**r**	**P**
PLF and PJF	5	-.346	.568

* p < .05

Conclusion: No correlation was found ($r_5 = -.346$, $p > .05$), indicating that no significant relationship exists between the two variables in the filtered group. Participants' peak landing force and peak jump force were not significantly related as part of the filtered group of Overall Quadriceps Driven.

A Pearson Product Moment Correlation was calculated to determine if a relationship existed between the Peak Landing Force (PLF) and Peak Jump Force (PJF) of the Overall Hamstring Driven (AVGOVRDRVN) group. Table 11 shows the results of the Pearson Product Moment Correlation for Overall Quadriceps Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance vs. Peak Jump Force (PJF) Performance.

Table 11. Pearson Correlation for Overall Hamstring Driven (AVGOVRDRVN) Group on Peak Landing Force (PLF) Performance vs. Peak Jump Force (PJF) Performance

Variable	**N**	**r**	**P**
PLF and PJF	25	.197	.345

* p < .05

Conclusion: No correlation was found ($r_5 = .197$, $p > .05$), indicating that no significant relationship exists between the two variables in the filtered group. Participants' peak landing force and peak jump force were not significantly related as part of the filtered group of Overall Hamstring Driven.

Additional Numeric Findings from data collection have been provided to allow for further analysis and comprehension. These findings can be viewed in Table 12.

Table 12. Additional Numeric Findings

Variable	**Range**	**Mean ± SD**
Peak Landing Force (N)	4508.5-2100.9	3575.3 ± 495.7
Peak Jump Force (N)	3532.6-1178.1	2373.0 ± 816.3
Bilat. H:Q Ratio Dev.	40.2-1.6	12.2 ± 9.5
Bilat. Overall Driven	40.2- -20.9	8.8 ± 12.6
Bilat. Abs. Δ knee angle	44.7-1.2	12.7 ± 11.0

DISCUSSION

In the discussion section of the research, the following sections are presented: 1) Discussion of Results, 2) Conclusions on research, and 3) Recommendations.

Discussion of Results

This study focused on the presence of muscular imbalances and the implications of the H:Q ratio on sport specific factors, such as landing and jumping forces. In physical activity of all types, especially those classified as multi-planar, the ability to react to stimuli (i.e. ball movement, personnel shift) is an important attribute for a participant. These multi-planar shifts and moves create stress on the body and more specifically joints of the lower extremity. The human body adapts to its environment and is able to work through these changes and absorb the forces safely. Through the bony skeletal and muscular make-up, the kinetic chain of the human body enables us to make these moves without a second thought. If the body were to break down or be insufficient in a certain area, then clearly the performance may suffer as well. Muscular imbalances can lead to serious injury due to over active musculature (agonist), under active musculature (antagonist) and the inability of the body to control each joint in kinesthetic space properly.

The data published on the H:Q ratio states that the hamstring group has been shown to produce only about 60% of the torque that is produced by the reciprocal quadriceps group.[2] As illustrated prior, when this percentage is significantly higher or lower, there can be deficits throughout performance due to injury, body kinetics and overall biomechanics. There is a large base of literature that has been able to make a correlation between muscular imbalances of the H:Q ratio, change in knee angle during activity and force production and injuries of the lower extremity, especially catastrophic injury in the female knee. [4,6,7,8] The risk of injury, past history with injury and poor biomechanics can have an affect on sport performance.

The thought process determining the composition of the first hypothesis is that if a muscular imbalance is present, in either direction (e.g. + Hamstring driven, - Quadriceps driven) a decrease in peak jump force would result because of poor kinetic chain use, poor kinematics and inability to transfer force properly for explosive performance. Similarly, the second hypothesis which was asking about the H:Q ratio and effect on landing forces was not found to be significant. Justification for this hypothesis showed that inability to control the body and it’s limbs proprioceptively throughout time and space would allow for larger forces to act on the body and absorption to occur less effectively. No significance was found. So, what do muscular imbalances have an effect on if not performance ability and environment awareness? The third hypothesis attempted to answer this question by compounding the results along with the participant’s neuromuscular control during motion analysis. No significance was found when sampling H:Q ratio and change in rectus femoris angle over time.

There were several additional findings that whether showing significance or not, have given an interesting insight into the spectrum of performance enhancement. A correlation in the study looked at the relationship of the peak jump force versus the peak landing force in both filtered H:Q ratio groups. Neither group showed any significance meaning that one’s ability via the peak jump force had no relationship with that same individual’s ability with peak landing force.

The goal for this type of data is to once again quantify an acceptable H:Q ratio for certain populations with general physical activity and to hopefully allow further research to create safe, acceptable ratios for several different levels and areas of competition. Is it safe for athletes that compete in terminal patterns to be overactive along with primarily vertical athletes? Should multi-planar athletes be focusing on other aspects of lower extremity kinematics rather than H:Q ratio? These are questions that need further research as athletes and their participation evolve.

Conclusions

This study demonstrated that the H:Q ratio as measured with knee flexion/extension has little impact on the ability to produce maximal vertical force and absorb landing ground forces. This study did find however, that individuals that have a lower H:Q ratio, showing that their hamstring groups are much weaker than their quadriceps group, in the allotted ratio, are able to produce more peak jump force than any other group. A strong relationship is shown in that quadriceps driven individuals will produce more vertical force. When performing the same correlation with the hamstring driven group, no significance was reported, noting that hamstring driven athletes may or may not be able to produce the highest peak jump force. No relationship was granted for this statistic. In the opposite correlation where peak landing force was recorded against the two filtered groups, no significance was cited in either direction. One implication that can be drawn from this data is that if you are training for a competition that is terminal in direction and the main goal is to produce the highest peak jump force and highest vertical jump height, training for a low H:Q ratio would be beneficial. The problem with this and why these findings have little statistical significance in the clinical setting is that most participation in athletics requires the multi-planar movement. In order to accomplish this effectively and safely, the reciprocal muscles must act in a respective fashion to allow for proper movement. The fact that little significance was shown in this research compounds the questions that we have no answers to in regards to muscular imbalances and performance.

The most important conclusion that we can take from this research is that more must be done to further our knowledge. Few questions have been answered with the significance found in this research and many more have been brought up with the lack of relationships cited. The current research has provided us with insight to the issues, but as stated earlier as athletes, competition and performance evolve, the necessity for knowledge to not only reduce injuries in the clinic but to also prophylactically prepare athletes for competition at the highest level of safe performance possible will only help us deepen our understanding of the underlying issues.

Recommendations

While this study was effective and efficient in its methods, more advanced technology and analysis is necessary for further research. The ability to reproduce data and have it available to other analysis will only help answer questions on this issue. An interesting correlation that should be looked at is the effect of the H:Q ratio on different types of athletes as previously mentioned. Terminal athletes will present differently from multi-planar athletes and their results may help to answer the individual H:Q ratio concerns.

The data collection performed for this research was completed throughout the month of April. Not only were physically active individuals used, but also full-time athletes that may have been in-season, pre-season training or off-season conditioning. It is important in further research to test multiple times throughout the training periods to ensure for appropriate acclimatization to training regimens.

Most previous research regarding the H:Q ratio and injury has examined gender differences and compared males and females as part of their statistical testing. While, the current researcher is very aware that gender differences do occur and can lead to staggering differences in injury rates, this was not the specific focus of this research. Several studies of gender differences were referenced throughout this research to provide insight for the sample as well as general information. Both genders were examined as part of this research and tested within subjects. Further research should call for continued testing of gender differences, specifically sport specific differences.

Difference in population for testing would also be an imperative tool. Perrin et al[2] has published numerous normative values for different populations however, changes in populations and participation requires continued research in these areas.

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APPENDICES

APPENDIX A

Review of Literature

REVIEW OF LITERATURE

The use of strength and conditioning as well as physical performance enhancement specialists has become an increasingly new tool in the preparation and training methods of elite athletes. Their knowledge and know-how in the realm of body input and output is necessary to help prevent injury and to increase athletic performance during competition.

One issue that plagues athletes, through most of their skillful movements, is the imbalance of agonist and antagonist muscles. Athletic trainers and performance enhancement specialists are uniquely positioned to assist athletes with this problem. Muscular imbalances, which are difficult to find, can act as a silent menace. The body still continues to perform its tasks, including activities of daily living or competitive movements, although with much risk to the body. Early identification and reduction of these imbalances can reduce the risk of harm during movement.

Imbalances can lead to a number of physical compensations such as muscular tightness to increase mechanical advantage over a joint, increasing the likelihood of posture misalignment, musculoskeletal injuries and a decrease in athletic performance.[1] The purpose of this literature review will be to discuss the prevalence of muscular imbalances and their effect on athletic performance. The review of literature will be separated into the following sections: (1) muscular imbalances, (2) muscular strength, (3) movement patterns, and (4) anatomical gender differences.

Muscular Imbalances

Muscular strength imbalances result when agonist and antagonist muscle groups do not have comparable strength levels. Muscle strength imbalances and the inhibition of muscle groups can lead to several debilitating injuries, potential joint instability, and postural misalignments of the kinetic chain. These limitations can decrease athletic ability or decrease the ability to complete activities of daily living in individuals, as well as increase the risk of injury during these tasks.[2,3] Imbalances are theorized to lead to an increase in injury rates; however, there is little agreement in the literature to determine which intrinsic or extrinsic factors may influence muscular imbalances. There is currently no concrete evidence determining which factors, such as age, gender, level of competition, leg dominance, or neuromuscular control, may affect muscular imbalances of the lower extremities.

As a result of muscular imbalances, more attention needs to be focused on neuromuscular training and rehabilitation to target a balanced ratio between agonist and antagonist muscle groups. Previous research has defined the fact that muscular imbalances can lead to injury and ultimately decrease performance. Little research has been found by the current researcher showing quantitative data on how a muscular imbalance can affect sport-specific movements. It is important to collect this data because not only will it result in increased knowledge of the topic data but could help in redefining the accepted hamstring: quadriceps ratios of certain populations, most closely researched by Perrin et al[6] and Coombs et al[4].

The severity of one specific muscular imbalance can be calculated by measuring an individual’s hamstring to quadriceps strength ratio (H:Q) by using isokinetic testing. Computation of this ratio has come under much debate because of accuracy concerns as well as its ability to determine risk of injury as previously indicated.[4] Conventional measuring of the H:Q ratio is most commonly used to measure strength differences; however, “since opposing muscles are not capable of simultaneous concentric muscle actions, the value of the conventional ratio has been questioned".[5] A controversial point in H: Q ratio testing is calculating the "normal" values for each participant in comparison to a population. Most research has indicated that the range or value should be close to .60.[6] This value indicates that the hamstring muscle group should be able to produce force 60% of what the quadriceps muscles are able to produce. The concept of the value of .60, is to enable researchers to determine if a significant muscular imbalance is present between the agonist and antagonist muscle groups of the upper leg.[4]

Muscular Strength

Muscular strength plays an important role in functional ambulation, however, "it is unclear whether muscle contraction, evaluated in terms of strength, imbalance of extensors relative to flexors, or reaction time, is a risk factor for injury".[7] Soderman, Alfredson, and Pietila found a decreased ratio of hamstring to quadriceps strength to increase the likeliness of incurring a traumatic leg injury, as well as an increase in overuse injury in female soccer players.[8]

Barber-Westin, Galloway, Noyes, Corbett and Walsh performed a study of neuromuscular control on male and female nine and ten year olds. Several studies had been completed prior to this study, but none found significant results with prepubescent athletes. This study tested different methodologies, such as drop-jump testing and single leg hops. The strength of the quadriceps and hamstrings were tested isokinetically at 180 degrees/second on a Biodex dynamometer. The drop jump, single leg hop, and Biodex dynamometer were chosen to compare between genders because previous data had found an increase in ligamentous injury in females (up to 4 to 8 times) as opposed to males at the adolescent to adult age level. Results showed that males demonstrated a normal knee and ankle separation on the drop-jump test. Seventy six percent of males and 90% of females demonstrated ankle distances of 60% or less of the hip separation distance, which is indicative of a valgus alignment. No differences were cited between males and females in quadriceps/hamstring peak torque, quadriceps/hamstring ratio, total work, and lower limb symmetry values after being examined on the Biodex dynamometer.[9]

In a similar study, Noyes, Barber-Westin, Fleckenstein, Walsh and West described and tested a similar methodology as the study completed by Barber-Westin, Galloway, Noyes, Corbett, and Walsh. Past studies and research scientists have described “differences between sexes in neuromuscular indices, such as muscle strength, running, cutting, sidestepping, and landing characteristics”.[9] The increase in number of non-contact ligamentous injuries in male and female athletes has triggered the study of knee alignment during movement patterns. The reason why the drop-test is an efficient and effective test to perform as part of methodology is the fact that it can be visualized from several angles and can differentiate between alignments of the lower extremity.[10] Alignment and biomechanics are necessary to perform at one’s highest level. This study was able to point out valgus, varus, and neutral alignments between male and female athletes and the correlation that they had with injury rate. A valgus or varus alignment with an anterior load force can lead to knee ligamentous injury.[11] Comparable to Barber-Westin et al., Noyes et al. showed results of unmarked differences between males and females in the drop-jump test. A valgus alignment was evident in the majority of the male and female athletes.[9,10]

According to Noyes et al., few studies have been able to accurately measure the distance of separation between the hips, knees, and ankles between any of the phases of landing or take-off of a drop-jump. This study has triggered a large interest in methods that will allow further studies to test in this fashion.[10]

Movement Patterns

Several researchers have used jumping and landing phases of the drop jump test as a method to determine movement pattern characteristics. The individual must be observed from three views: anterior, posterior, and lateral; and must be assessed several times from each view.[12] For the anterior view, the main focus is on determining if the foot is in normal or toe out position (toe out defined as when the 2nd metatarsophalangeal joint rotates outward and appears lateral to the medial malleolus), as well as if the knee deviates inward instead of staying in a neutral position. For the lateral view it is important to assess the trunk and the upper extremities. For this view, it is important to observe the placement of the arms, as well as evaluating excessive trunk lean, where the trunk does not appear to remain parallel with the lower leg during the descent phase of the squat. The knee must also be viewed for tracking over the toes during flexion.

During the posterior view, it is important to note if flattening of the medial longitudinal arch occurs (longitudinal arch is defined as the curvature of the hind and mid-foot).[13] This type of qualitative analysis has been used frequently in the research done prior in assessing neuromuscular control of participants. This type of research has led to findings of differences between male and female control, specific sport control changes and training adaptations to neuromuscular control.[14,15] This previous data calls for further research into the introduction of training programs to increase neuromuscular control in an effort to control catastrophic injuries, allowing the individuals to adapt to unique situations, similar to that in geriatric balance or gait training.[16]

Part of the movement analysis incorporates limb dominance as well. The rate of injury, more specifically non-contact ACL injury, has increased as individuals increase in sport participation. Factors like field surface changes and lack of recovery/strengthening period can also lead to similar injuries of this type.[17,18]

Gender Differences

"Anterior cruciate ligament injury occurs with a 4- to 6-fold greater incidence in female athletes compared with male athletes playing the same landing and cutting sports. The elevated risk of ACL injury in women, coupled with the 10-fold increase in high school and 5-fold increase in collegiate sport participation in the past 30 years, has led to a rapid rise in ACL injuries in female athletes."[19] Buchanan and Vardaxiz compared both male and female basketball players to assess hamstring and quadriceps strength in 11-13 year olds and 15-17 year olds. In order to conduct this test a Cybex II dynamometer was used to determine the isokinetic concentric peak torques relative to the body mass. These basketball players went through six trials of each leg performing a maximum concentric knee extension and flexion. The study showed how age and gender differences affect hamstring and quadriceps strength. When comparing 15-17 year old males to females, males have a greater peak torque: body mass ratio than females; where as 11-13 year old males and females have the same peak torque: body mass ratio. When looking at age differences (15-17 year olds) relative to gender, males were 50-60% stronger in the quadriceps and hamstrings, whereas females were stronger by 20% in their hamstrings but showed no difference in quadriceps strength.[20]

There is significant data describing the rates of ACL injuries compared to gender and what pre-disposing factors cause these injuries; however, this only strengthens the need to continue research of the H:Q ratio and how it can hinder or ultimately help an individual with injuries and performance.[21,22] A study completed by Newton et al. assessed the relationship between dominant and non-dominant legs in 14 female Division 1 college softball athletes, as well as assessed the differences in muscular strength between the left and right leg.[3] The purpose of this study was to determine functional strength imbalances of the lower extremities and to investigate possible relationships among assorted unilateral and bilateral closed kinetic chain tests and conventional isokinetic dynamometry used to determine strength imbalances. The participants were tested using a series of jumping tests and isokinetic testing using the dynamometer to assess antagonist and agonist muscle groups. The results found that there were significant differences when comparing the dominant and non-dominant legs for all tests, except the average ground force production during single leg jumps.[3] However, no consistent differences were found in test performance while comparing strength differences between the left and right leg. These findings could conclude a weight shift or differential load in the jumping and landing phase of an individual, possibly predisposing them to further injury. Other research has found similar findings in that no significant differences could be cited between dominant and non-dominant lower limbs of the participants tested.[23,24]

Conclusion

The necessity for more in-depth and precise research investigating with the effects of muscular imbalance and the toll they have on the body is evident. Increased injury rates and decreased performance levels are two things that are proposed to be significantly tied to muscular imbalances. Further research in this area could lead to more breakthroughs in the non-contact ACL area of study. However, it is fully possible that muscular imbalances are a factor in these injuries, the possibility that specific muscular imbalance for specific event or training may actually be appropriate, once again challenging the previous research of Perrin et al.[6] The general population has been defined by a certain numerical value, as have some subsets of athletic populations;

however, an extension of this research could ultimately lead to controlling muscular imbalances to improve performance through training techniques specific to gender, age, sport, and deficiency.[25,26] The purpose of the current study is to determine the effects of the H:Q ratio muscular imbalance of the leg on force production during the jumping and landing phases of drop-jump testing. Several areas of research and extensive knowledge bases are coming together to help form the current research and allow these findings to benefit numerous concepts of sport, movement, biomechanics, and kinematics.

APPENDIX B: THE PROBLEM

THE PROBLEM

Definition of Terms

The following definitions of terms will be defined for this study:

1) Physically active: any individual that participates in physical activity at least 3 times a week that raises their heart rate to 50% maximum heart rate (i.e. intramural or varsity sports, weightlifting, cardiovascular walking/jogging etc.)

2) Muscular imbalance: when agonist and antagonist muscle groups do not have comparable strength levels. Specifically defined for physically active non-disabled individuals by Perrin et al. at a .60 value. This value represents that the hamstring group has been shown to produce about 60% torque of what the reciprocal quadriceps group can. An imbalance is being recorded for any value that falls out of ± 5% of the ratio (<55% or >65%).

3) Injured: Currently have any injuries which require surgical intervention, or injuries which would

impede your ability to complete physical tasks that are required by this study or are not considered apparently healthy; according to ACSM standards. Currently have any illnesses (fever, mononucleosis, pneumonia etc.), which may significantly limit your ability to perform physical tasks.

4) College student: any full time student of California University of Pennsylvania.

5) Dominant limb: the limb with which an individual performs kicking motions most frequently or preferably. Forward balancing will also occur on this leg.

6) Rectus femoris angle: the inside angle of the limb measured between dissecting lines from anterior superior iliac spine (ASIS) to superior pole of patella and superior pole of patella to dome of the talus, located at the midpoint of the ankle between the lateral and medial malleoli.

Assumptions

The following assumptions were made for the study:

- Participants were cooperative while completing the informed consent and general medical history form, and were truthful with their answers.
- Participants fully understood the outlined parameters, which were used to classify participation, and were honest with their answers.
- Participants performed the Biodex Dynamometer strength test and drop-vertical jump test to the best of their ability.
- The Biodex dynamometer for each participant was appropriately fitted to use the equipment, as well as a clear explanation of the test was offered.
- The drop-vertical jump test was clearly explained and all questions were answered so that the participants could perform effectively.
- Instrumentation has been calibrated and is in proper working order to ensure accurate data collection.
- All participants are volunteers with no coercion by faculty, researcher or superiors, with no compensation.

Limitations

The results of this study may be limited by the following:

- The participation rate of California University of Pennsylvania students
- Male and female participant ratios
- Equal representation of members from each gender to adequately display the population.
- Individuals’ pre-disposed anatomical abnormalities, which may result in less skillful movement patterns independent of technique, strength, or flexibility.
- 2D video analysis may not be the most accurate or efficient tool in recording and reviewing movements of drop-vertical jump testing.
- Subjects may have varying experience with maximal jumping and drop jump methodology.
- Examination of the biomechanical video analysis and data from the force platform may be inexact.

Delimitations

This study will be delimited by:

- Only full-time students of California University of Pennsylvania will participate in the study.
- Participants must be classified as physically active in order to continue in the research.

- Participants must not have received any injuries that significantly altered their physical activity or health status within one calendar year.

Significance of the Study

This study holds several practical and clinical implications and for these reasons the research is being performed. Muscular imbalances cause injury, as seen in previous research; however, their effect upon quantitative performance has not seen significant research performed. It is necessary to re-evaluate the normal values of H:Q ratio as applies to different populations and determine if muscular imbalances if controlled can be beneficial to the physically active population. This data could lead to a new quantitative definition of the H:Q ratio and therefore could lead sports medicine professionals and athletes to potentially train for a specific H:Q ratio to increase functional performance.

APPENDIX C: ADDITIONAL METHODS

Setup and Positioning

1. Seat participant on chair.
2. Rotate chair to 90 degrees.
3. Rotate dynamometer to 90 degrees. Slide dynamometer along travel to position outside leg to be tested or exercised.
4. Attach knee attachment to dynamometer. Align dynamometer shaft red dot with red dot on attachment.
5. Move participant into position.
6. Align participant knee axis of rotation with dynamometer shaft. Raise/lower seat or move participant toward/away from dynamometer to fine adjust.
7. Adjust knee attachment so that it is proximal to medial malleoli. Secure with strap.

NOTE: Moving the pad proximally has been demonstrated to decrease anterior tibular translation.

8. Stabilize participant with shoulder, waist and thigh straps.
9. Set range of motion (ROM) stops.

Opposite Side

1. Unstrap participant’s knee from attachment and thigh strap.
2. With participant remaining in chair, slide chair back away from dynamometer.
3. Press Hold button to retain dynamometer shaft position. Remove attachment. Get knee attachment for opposite side.
4. Rotate dynamometer to 90 degrees on opposite side. Slide dynamometer to opposite side of patient.
5. Attach knee attachment to dynamometer. Align dynamometer shaft red dot with red dot on attachment.
6. Move participant into position.

7. Align participant knee axis of rotation with dynamometer shaft. Raise/lower seat or move participant toward/away from dynamometer to fine adjust.
8. Adjust knee attachment so that it is proximal to medial malleoli. Secure with strap.
9. Stabilize participant with shoulder, waist and thigh straps.
10. Reset ROM stops.

Table 1. Coronary Artery Disease Risk Factors Thresholds

Risk Factors: (Positive)	*Defining Criteria*
Family History	Myocardial infarction, coronary revascularization, or sudden death before 55 years of age in father or other male first-degree relative (i.e., brother or son), or before 65 years of age in mother or other female first-degree relative (i.e., sister or daughter)
Cigarette Smoking	Current cigarette smoker or those who quit within the previous 6 months.
Hypertension	Systolic blood pressure of ≥140 mm Hg or diastolic ≥90 mm Hg, confirmed by measurements on at least 2 separate occasions, or on antihypertensive medication.
Hypercholesterolemia	Total serum cholesterol of >200 mg/dl (5.2 mmol/L) or high-density lipoprotein cholesterol of <35 mg/dL (0.9 mmol/L), or on lipid-lowering medication. If low-density lipoprotein cholesterol is available, use >130 mg/dL (3.4 mmol/L) rather than total cholesterol of >200 mg/dL.
Impaired Fasting Glucose	Fasting blood glucose of ≥110 mg/dL (6.1 mmol/L) confirmed by measurements on at least 2 separate occasions
Obesity	Body Mass Index of ≥30 mg/m, or waist girth of >100 cm (≈39.4 inches).

Sedentary Lifestyle	Persons not participating in a regular exercise program or meeting the minimal physical activity recommendations from the U.S. Surgeon Generals' Report.

Whaley, M. H. & Brubaker, P. H. (Eds.) ACSM's Guidelines for Exercise Testing and Prescription. Lippincott Williams & Wilkins, 2006: 7.

ACSM Risk Stratification Categories

1. Low risk: Men <45 years of age and women <55 years of age who are without symptoms and meet no more than one risk factor threshold.

2. Moderate risk: Men ≥45 years and women ≥55 years or those who meet the threshold for two or more risk factors.

3. High risk: Individuals with one or more signs and symptoms or known cardiovascular, pulmonary, or metabolic disease.

Whaley, M. H. & Brubaker, P. H. (Eds.) ACSM's Guidelines for Exercise Testing and Prescription. Lippincott Williams & Wilkins, 2006: 7.

Informed-Consent Form

1. James Daley, a graduate assistant athletic training student and Master's degree candidate, has requested my participation in a research study at California University of Pennsylvania. The title of the research is: *A correlation between muscular imbalances of the lower extremity (H:Q ratio) and force production*.

2. I have been informed that the purpose of the research is to examine the relationship between muscular imbalances determined by the measured Hamstring: Quadriceps ratio and their effect on force production during phrases of a drop-jump test. I understand that I have been asked to participate, along with 29 other participants because I am operationally defined as "physically active". A "physically active" person is defined as one that participates in physical activity raising heart rate to at least 50% maximum (i.e. cardiovascular training, weight lifting, athletics) at least 3 times per week on average. I am also allowed to participate in this research study because I have not suffered any long term or debilitating previous injury to my lower extremities, I am of good general health, I do not know of any personal medical reason that would prevent me from participating, I am legally an adult and I am currently a full-time student at California University of Pennsylvania. I understand that my participation is strictly on a volunteer basis, with no coercion by faculty, researcher or superiors.

3. My participation will involve a physical warm-up on a stationary bicycle to 50% of my maximum age-adjusted heart rate, a drop-jump/vertical jump test onto a force platform, and a muscular strength test utilizing the Biodex Isokinetic Dynamometer. Each test will include a trial practice period and 3 testing trials. My participation in this study will consist of one testing period equaling no more than 120 minutes. I will be asked to wear fitting shorts that do not cover my knees, to tuck in my shirt and to wear athletic shoes. I understand that prior to the test, reflective anatomical markers will be placed on both my hips and lower extremities, on a series of bony landmarks

(anterior superior iliac spine, superior pole of the patella, medial and lateral epicondyles of the femur, and medial and later malleoli). The researcher will videotape each participant and the video will be used in a video biomechanical analysis. The anatomical markers are necessary to assist in the data collection for this analysis.

4. I understand there are foreseeable risks or discomforts to me if I agree to participate in the study. The possible risks and/or discomforts include injury/re-injury, mild muscle soreness/discomfort, feelings of fatigue, and/or possible systemic complications (myocardial infarction, cardiac failure, etc.) Risks and discomforts can result from all three exercises. Muscle fatigue, soreness and/or systemic complications can result from the warm-up protocol. Injury/re-injury, mild muscle soreness/discomfort, feelings of fatigue, and/or possible systemic complications can result from the muscular strength testing including muscular strain, total muscular failure and muscular spasm. The drop-jump/vertical jump test could result in injury to the lower extremity, as well as the back or upper extremity product of a fall. Muscular discomfort and general fatigue may also result. However, these risks will be minimized in the following ways: I am required to complete a general information and eligibility form, a modified physical activity readiness questionnaire, a supervised warm up prior to physical activity, and am responsible to inform the researchers of any abnormal responses during the physical activity so that the test may be terminated. I understand that these risks are reasonable because they will allow for research into an area of study not completely satisfied. There are minimal risks associated with this study that are different from risks involved in regular physical activity or activities of daily living.

5. I understand that in case of injury I can expect to receive emergency treatment and first aid care from the primary researcher, James Daley. The researcher is First Aid, AED, and CPR certified. Additional services needed for prolonged care past 3 days will be referred to the attending physician at the Student Health Services located in the Wellness Center –

Carter Hall (724 938 4232) located at California University of Pennsylvania.

6. There are no feasible alternative procedures available for this study.

7. I understand that the possible benefits of my participation in the research are the increased knowledge of musculature of the lower extremities. This knowledge may help improve performance, correct faulty movement patterns, and decrease the likeliness of sustaining an injury. The research results may also lead to a better qualitative and quantitative definition of a muscular imbalance. These results, paired with further research, may help to further improve corrective training techniques used to decrease injury in susceptible populations. The information gathered from the results of this research study could potentially impact the Exercise and Sport Sciences field, because no conclusive data has been determined to accurately measure how muscle imbalances affect quantitative athletic performance.

8. 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, James Daley will maintain all documents in a secure location in which only the student researcher and research advisor can access. Any information obtained during this study that could identify you will be kept strictly confidential, and any information will be coded numerically based on demographic information. This information may be published in professional (or scientific) journals or presented at professional meetings, but your identity will be kept strictly confidential. I am aware that each trial of each physical test will be recorded on videotape for the sole purpose of continued data analysis for this study. The tape will be locked and stored in the locked private residence of the researcher. Upon data transfer to the computer, each video segment will be saved on a laptop which is password protected, which will be stored in a locked office adjacent to the Human Performance Lab B5 in Hamer Hall. As a participant, you have the right to view the video segments you completed, and also have the right to refuse permission to use the video

segments for any other use besides the educational purposes of this project. Any additional information obtained from this study will be stored in the locked private residence of the researcher. The data will be used to assess muscular imbalances and movement patterns, and upon the completion of this project the data will be stored in a locked location and destroyed within one year of the completion of this project.

9. I have been informed that I will not be compensated for my participation.

10. 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 James Daley, DAL3467@cup.edu, 532 Third Street California, PA 15419, (401) 378-8433 and/or Dr. Edwin Zuchelkowski, Zuchelkowski@cup.edu, 250 University Ave/ Frich Hall 406 California, PA 15419, (724) 938-4202.

11. I understand that written responses may be used in quotations for publication but my identity will remain anonymous.

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 waving 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__________

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.

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
This approval is effective (2/17/2009) and expires on (2/16/2010).

Name of Investigator: James Daley
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Faculty/ Staff Sponsor: Edwin Zuchelkowski, Ph.D.
Zuchelkowski@cup.edu

INFORMED CONSENT

Title of project: A correlation between muscular imbalances of the lower extremity (H:Q ratio) and force production

Invitation to Participate: You are invited to participate in this research study. The following information is provided to help you make an informed decision whether or not to participate. If you have any questions, please do not hesitate to ask.

Purpose: The purpose of the current research is to examine the relationship between muscular imbalances and their effect on force production during phases of a drop-jump test.

Subjects:

You are eligible to participate because you are:

1. Over 18 years of age.
2. Of good general health, with no major or long term debilitative injuries to the lower extremities.
3. A "physically active" person is defined as one that participates in physical activity raising heart rate to at least 50% maximum (i.e. cardiovascular training, weight lifting, athletics) at least 3 times per week on average.
4. A full time student at California University of Pennsylvania.

You are not eligible to participate in this study if:

1. You currently do not categorize yourself as "physically active" as defined as you do not participate in physical activity (i.e. cardiovascular training, weight lifting, athletics) on average at least 3 times per week.
2. You currently have any injuries, which require surgical intervention, or injuries that would impede your ability to complete physical tasks that are required by this study.
3. You currently have any illnesses (fever, mononucleosis, pneumonia etc.), which may significantly limit your ability to perform physical tasks.

Procedures:

If you decide to participate in this research project, you will be asked to complete the following physical tasks:

- Participants will be asked to wear fitting shorts that do not cover the knee and athletic shoes preferably low cut. Participants will also be asked to tuck in their shirt to allow for visual of the anatomical markers by the camera and researcher.

- A brief warm-up will be held in Hamer Hall on a stationary upright bicycle where 60 revolutions per minute with one kilogram of resistance must be maintained until 50% of maximum heart rate, calculated through Karvonen's formula, is achieved.
- A measurement of concentric hamstrings and concentric quadriceps strength using the Biodex equipment will be performed. This is a device that measures the strength of opposing muscle groups by completing the same movement at the same angular velocity throughout the testing session (similar to fully extending your leg like a kick, and then pulling your leg back against resistance). Three testing trials will be performed.
- A measurement of force production and force attenuation using a series of drop-jump tests will be performed. Prior to the test, reflective anatomical markers will be placed bilaterally on a series of bony landmarks (anterior superior iliac spine, superior pole of the patella, medial and lateral epicondyles of the femur, medial and later malleoli), to assist in data collection through a computer biomechanical analysis. The drop-jump will require the participants to jump from a minimal height and land on a force platform. The participants will then subsequently perform a maximal vertical jump. Three testing trials will be performed.
- All testing measurements will allow for a practice trial period prior to the testing trials to adjust for learning effect.

Some of these physical tests will be recorded on videotape, and the tape will be locked and stored in the private residence of the researcher. Upon data transfer to the computer, each video segment will be saved on a laptop which is password protected, which will be stored in a locked office adjacent to the Human Performance Lab B5 in Hamer Hall. Only the researcher and the faculty representative will have access to this data. As a participant, you have the right to view the video segments you completed, and also have the right to refuse permission to use the video segments for any other use besides the educational purposes of this project. Any additional information obtained from this study will be stored in the locked private residence of the researcher. The data will be used to assess muscular imbalances and movement patterns, and upon the completion of this project the data will be stored in a locked location and destroyed within one year of the completion of this project.

Alternatives:
No alternative procedures are available to complete the physical tasks as outlined above. If you are unable to complete any of the tasks, you will be excluded from this study.

Timetable:
Participation in this study will warrant one individual meeting per participant with the investigators, which will approximately last for a maximum 120 minutes that will be scheduled after IRB approval.

Risks:
Whenever one participates in physical activity, there are inherent risks. For the tests in this study, physical risks that may occur due to the completion of this study are the potential for injury/reinjury, mild muscle soreness/discomfort, and feelings of fatigue. However, these risks will be minimized in the following ways:

1. You will complete a general information and eligibility form as well as a modified PAR-Q form
2. You will complete a supervised warm up prior to physical activity
3. There will be a researcher present for all physical activity.
    - The researcher is First Aid, AED, and CPR certified.
        - An AED is available on site (1st floor Hamer Hall) if necessary.

- Physical activity will occur in Hamer Hall, where there is easy access to a phone to activate an emergency action plan if necessary.

4. You will be informed of your responsibility to inform the researchers of any abnormal responses during the physical activity so that the test may be terminated.
5. You are encouraged to contact Student Health Services located in the Wellness Center – Carter Hall (724 938 4232) located at California University of Pennsylvania if there are any delayed adverse physical responses to the testing protocols.

Benefits:
Benefits that will be expected for participants are the increased knowledge of musculature of their lower extremities. This knowledge may help improve performance, correct faulty movement patterns, and decrease the likeliness of sustaining an injury. The information gathered from the results of this research study could potentially impact the Exercise and Sport Sciences field, because no conclusive data has been determined to accurately measure how muscle imbalances affect quantitative athletic performance.

Compensation for Participation:
There is no compensation for participation in this study.

Confidentiality:
Any information obtained during this study that could identify you will be kept strictly confidential, and any information will be coded numerically based on class, gender, and athletic status. This information may be published in professional (or scientific) journals or presented at professional meetings, but your identity will be kept strictly confidential.

Right to Refuse or Withdraw:
You may refuse to participate and still receive the care you would receive if you were not in the study. You may change your mind about being in the study and quit after the study has started. If the study design or use of the data is changed, you will be informed and your consent will be obtained for the revised research study.

Questions:
If you have any questions at this time, please ask them. If you have additional questions later, please contact the investigator or faculty/staff by using the above listed phone number or email addresses, and we will be happy to answer them.

Your signature below indicates that you have voluntarily decided to participate in this research project as a subject and that you have read and understand the information provided above.

______________________________________ _______________________

Subject's signature Date

____

Subject's printed name

My signature as witness certifies that the subject voluntarily signed this consent form in my presence. (required only for research with greater than minimal risk)

__________________________________ ____________________________
Witness signature Date

____
Witness' printed name

In my judgment, the subject is voluntarily and knowingly giving informed consent to participate in this research study.

_____________________________________ __________________________
Investigator's signature Date

___________________________________ ___________________________
Investigator's printed name Date

GENERAL INFORMATION AND ELGIBLITY

PLEASE DO NOT WRITE YOUR NAME ON THIS FORM

Please circle*:* **Female** or **Male**

Current Class Level: Freshman Sophomore Junior Senior Graduate

Please read the following to determine your eligibility for this study, if at any time you have any questions in regards to any of the material please do not hesitate to ask the investigator.

You are eligible to participate because you are:

1. Over 18 years of age.
2. Of good general health, with no major or long term debilitative injuries to the lower extremities.
3. **A "physically active" person defined as that you participate in physical activity (i.e. cardiovascular training, weight lifting, athletics) on average at least 3 times per week.**
4. You are a full time student at California University of Pennsylvania.

You are not eligible to participate in this study if:

1. **You currently do not categorize yourself as "physically active" as defined as you do no participate in physical activity (i.e. cardiovascular training, weight lifting, athletics) on average at least 3 times per week.**
2. You currently have any injuries, which require surgical intervention, or injuries, which would impede your ability to complete physical tasks that are required by this study.
3. You currently have any illnesses (fever, mononucleosis, pneumonia etc.), which may significantly limit your ability to perform physical tasks.

MODIFIED PAR-Q FORM

Please circle the appropriate response.

If you answer yes to any of the following questions, please discontinue filling out this form as you will be unable to participate in this study.

<u>Have you suffered any significant injury to the lower extremities in the past four weeks that may limit physical activity?</u>

Yes or No

<u>Have you had any lower extremity surgeries in the past year?</u>

Yes or No

<u>Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by a doctor?</u>

Yes or No

<u>Do you feel pain in your chest during physical activity or at rest?</u>

Yes or No

<u>Do you lose your balance because of dizziness or do you ever lose consciousness?</u>

Yes or No

<u>Has a doctor ever said your blood pressure was too high?</u>

Yes or No

<u>Are you currently taking any medications that may hinder participation in short bursts of physical activity?</u>

Yes or No

<u>Do you have any joint or bone problems that will not allow you to exercise or may be aggravated by participating in physical activity?</u>

Yes or No

<u>Is there a good physical reason, not mentioned here, why you should not follow an activity program even if you wanted to?</u>

Yes or No

Please note that if your health changes within the time of completing this form and the date of participation, please notify the investigator.

I have read, understood and completed this questionnaire to the best of my knowledge.

____ ____________________________________

Participant's signature Date

____ ____________________________________

Participants' printed name Date

____ ____________________________________

Witness signature Date

____ ____________________________________

Witness' printed name Date

California University of Pennsylvania

Proposal Number 08-045

Date Received 02-05-09

exempt

PROTOCOL for Research Involving Human Subjects

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: A correlation between muscular imbalances of the lower extremity (H:Q ratio) and force production

Researcher/Project Director: James Thomas Daley

Phone: 401-378-8433 *E-mail Address:* DAL3467@cup.edu

Faculty Sponsor (if required) Dr. Edwin Zuchelkowski

Department Health Sciences and Sports Studies

Project Dates January 2009 *to* May 2009

Sponsoring Agent (if applicable) ____________________

Project to be Conducted 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(ses)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*

Purpose:

The purpose of the current research is to examine the relationship between muscular imbalances and their effect on force production during phases of a drop-jump test.

Hypotheses:

1. The presence of a muscular strength imbalance through the Hamstring: Quadriceps ratio will result in decreased peak jump force production.
2. The presence of muscular strength imbalances through the Hamstring: Quadriceps ratio will result in an increased drop-jump landing force.
3. If muscular imbalances are present, an increase in rectus femoris angle will occur during the jumping and landing phase to compensate for strength imbalances.

Procedures:

The researcher will apply for Institutional Review Board Approval at California University of Pennsylvania before conducting any research. Participants will be studied strictly on a volunteer basis. Participants will be recruited from accompanied education programs as well as through sign-ups available to varsity athletes. All participants are volunteers with no coercion by faculty, researcher or superiors, with no compensation.

- Participants will be asked to wear fitting shorts that do not cover the knee and athletic shoes preferably low cut. Participants will also be asked to tuck in their shirt to allow for visualization of the anatomical markers by the camera and researcher.
- A brief warm-up will be held in Hamer Hall on a stationary upright bicycle where 60 revolutions per minute with one kilogram of resistance must be maintained until 50% of age-adjusted maximum heart rate, calculated through Inbar's formula (HRmax=205.8-0.685(age)) is achieved.
- A measurement of concentric hamstrings and concentric quadriceps strength will be performed using the Biodex equipment; which is a device that measures the strength of opposing muscle groups by completing the same movement at the same angular velocity throughout the testing session (similar to fully extending your leg like a kick, and then pulling your leg back (bending your knee) against resistance). 3 testing trials will be performed.
- A measurement of force production and force attenuation using a series of drop-jump tests will be performed. Prior to the test, reflective anatomical markers will be placed bilaterally on a series of bony landmarks (anterior superior iliac spine, superior pole of the patella, medial and lateral epicondyles of the femur, medial and later malleoli), to assist in data collection through a computer biomechanical analysis. The drop-jump will require the participants to jump from a minimal height and land on a force platform. The participants will then subsequently perform a maximal vertical jump. 3 testing trials will be performed.
- All testing measurements will allow for a practice trial period prior to the testing trials to adjust for learning effect.

Data Analysis:

- The video taped results obtained from the analysis of the jumps of the participants will be analyzed using DartFish to determine if muscular imbalances affect knee angle during jumping and landing technique. DartFish is a digital biomechanical program that allows video to be uploaded and reviewed in stop-motion.

- Data obtained from the force platform testing will be analyzed using NetForce. The data will be synchronized with the video from DartFish to allow for easier analysis.
- A statistical analysis will be performed using Statistical Package for Social Sciences (Version 16.0, SPSS, Inc., Chicago, IL) to run a stepwise regression analysis allowing for a quadratic curvilinear. This equation will also enable squared terms to go along with the hypotheses that the H:Q ratio will be able to determine the jumping force production and inversely will be able to determine landing force absorption or production. A Pearson's correlation coefficient will be used to determine if H:Q ratio has a relationship with knee angle (genu valgum).

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.***

Whenever one participates in physical activity, there are inherent risks. For the tests in this study, physical risks, which may occur due to the completion of this study, are the potential for injury/reinjury, mild muscle soreness/discomfort, and feelings of fatigue. However, these risks will be minimized in the following ways:

1. Each subject will complete a general information and eligibility form as well as a modified physical activity readiness questionaire form
2. Each subject will complete a supervised warm up prior to physical activity
3. There will be a researcher present for all physical activity.
   - The researcher is First Aid, AED, and CPR certified.
     - An AED is available on site (1st floor Hamer Hall) if necessary.
   - Physical activity will occur in Hamer Hall, where there is easy access to a phone to activate an emergency action plan if necessary.
4. Each subject will be informed of his/her responsibility to inform the researchers of any abnormal responses during the physical activity so that the test may be terminated.
5. Each subject is encouraged to contact Student Health Services located in the Wellness Center – Carter Hall (724 938 4232) located at California University of Pennsylvania if there are any delayed adverse physical responses to the testing protocols.
6. These risks are reasonable because they will allow for research into an area of study not completely satisfied. There are minimal risks associated with this study that are different from risks involved in regular physical activity or activities of daily living

   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.***

Participants will be studied strictly on a volunteer basis. Participants will be recruited from education programs as well as through sign-ups available to the general student population including varsity athletes. All participants are volunteers with no coercion by faculty, researcher or superiors, with no compensation.

Individuals are eligible to participate are:

1. Over 18 years of age.

2. Of good general health, with no major or long term debilitative injuries to the lower extremities.

3. A "physically active" person is defined as one that participates in physical activity raising heart rate to at least 50% maximum (i.e. cardiovascular training, weight lifting, athletics) at least 3 times per week on average.

4. A full time student at California University of Pennsylvania.

Individuals are not eligible to participate in this study if they:

1. Currently do not categorize yourself as "physically active" as defined as you do no participate in physical activity raising heart rate to at least 50% maximum (i.e. cardiovascular training, weight lifting, athletics) at least 3 times per week on average.

2. Currently have any injuries, which require surgical intervention, or injuries, which would impede their ability to complete physical tasks that are required by this study.

3. Currently have any illnesses (fever, mononucleosis, pneumonia etc.), which may significantly limit their ability to perform physical tasks.

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.***

Informed consent will be obtained at the beginning of the testing period, prior to any procedures beginning, from the participant or legally authorized representative. They will be required to read through the material and the researcher will be available to answer any questions prior to testing. See Informed Consent Attached.

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.***

Each participant, after receiving consent, will be coded and his or her identity will not appear on any of the research material, other than a coding sheet. Some of these physical tests will be recorded on videotape, and the tape will be locked and stored in the locked private residence of the researcher. Upon data transfer to the computer, each video segment will be saved on a laptop which is password protected, which will be stored in a locked office adjacent to the Human Performance Lab B5 in Hamer Hall. Only the researcher and the faculty representative will have access to this data. As a participant, you have the right to view the video segments you completed, and also have the right to refuse permission to use the video segments for any other use besides the educational purposes of this project. Any additional information obtained from this study will be stored in the locked private residence of the researcher. The data will be used to assess muscular imbalances and movement patterns, and upon the completion of this project the data will be stored in a locked location and destroyed within one year of the completion of this project. Any information obtained during this study that could identify you will be kept strictly confidential, and any information will be coded numerically based on class, gender, and athletic status. This information may be published in professional (or scientific) journals or presented at professional meetings, but your identity will be kept strictly confidential.

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

☐ *Adult volunteers*	☐ *Mentally Disabled People*
☒ *CAL University Students*	☐ *Economically Disadvantaged People*
☐ *Other Students*	☐ *Educationally Disadvantaged People*
☐ *Prisoners*	☐ *Fetuses or fetal material*
☐ *Pregnant Women*	☐ *Children Under 18*
☐ *Physically Handicapped People*	☐ *Neonates*

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.

as amended

☑ Approved ☐ Disapproved

Chairperson, Institutional Review Board | Date 02-17-09

• Certificate of Completion

Certificate of Completion

The National Institutes of Health (NIH) Office of Extramural Research certifies that **James Daley** successfully completed the NIH Web-based training course "Protecting Human Research Participants".

Date of completion: 06/14/2008

Certification Number: 48734

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ABSTRACT

Title:	A CORRELATION BETWEEN MUSCULAR IMBALANCES OF THE LOWER EXTREMITY (H:Q RATIO) AND FORCE PRODUCTION
Researcher:	James T. Daley
Advisor:	Dr. Edwin Zuchelkowski
Date:	May 2009
Research Type:	Master's Thesis
Purpose:	The purpose of the current research is to examine the relationship between muscular imbalances and their effect on force production during a drop-jump test.
Problem:	The question proposed of this study is whether or not muscular imbalances have a significant effect on force production of the lower extremity. Imbalances can lead to a number of physical compensations such as muscular tightness to increase mechanical advantage over a joint, increasing the likelihood of posture misalignment, musculoskeletal injuries. There is currently no concrete evidence determining which factors, such as age, gender, level of competition, leg dominance, or neuromuscular control, may affect muscular imbalances of the lower extremities.
Method:	The research was conducted utilizing a cross-sectional observational, within subjects design. Relationships were assessed between participants based upon presence of muscular imbalance, landing force production, vertical jumping force production and change in rectus femoris knee angle. Each of the hypotheses was tested using a confidence interval of 95%. The

subjects (n=30) consisted of a convenience sample of physically active full-time students from California University of Pennsylvania. 16 males and 14 females were tested as part of this sample. They performed an appropriate warm-up of 50% maximum HR prior to testing. Three trials of a drop-jump test were performed from a height platform (20 in.) onto a force platform. Three trials of varying speeds (120, 180 and 300 deg./sec.) were performed bilaterally on the Biodex dynamometer.

Findings: No significant difference was found for the presence of muscular imbalances on peak landing force or peak jump force. The presence of a muscular imbalance also did not exhibit a significant relationship with the change in rectus femoris angle between landing and take-off phase of a drop-jump test. Participants that were characterized as part of the Quadriceps Dominant Driven Group did exhibit a significant correlation to Peak Jump Force.

Conclusion: The presence of a muscular imbalance through the H:Q ratio does not show to have any significance in the role of force production or absorption during functional sport specific loading and unloading on the lower extremity. Research must continue to focus on the effects of muscular imbalances of the H:Q ratio and how they are quantitatively manipulating physically active individuals. Further recommendations are being made to research sport and position specific differences of lower leg function during activity.