BILATERAL ASYMMETRIES IN FLEXIBILITY,STRENGTH, AND MUSCLE ENDURANCE ASSOCIATED WITH PREFERRED AND NONPREFERRED LEG

A Dissertation Submitted to

THE TAMILNADU Dr. M.G.R. MEDICAL UNIVERSITY

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MASTER OF PHYSIOTHERAPY

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Submitted by

Reg. No. 27102009

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Under the Guidance of

Dr. Manikandan MPT (SPORTS)

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Dissertation evaluated on --

Internal Examiner External Examiner

CERTIFICATE BY THE HEAD OF THE INSTITUTION

This is certify that the dissertation entitled **"BILATERAL ASYMMETRIES IN FLEXIBILITY, STRENGTH, AND MUSCLE ENDURANCE ASSOCIATED WITH PREFERRED AND NONPREFERRED LEG"** is a bonafide compiled work, carried out by Register No. **27102009**, Nandha College of Physiotherapy Erode – 638 052, in partial fulfillment for the award of Degree in Master of Physiotherapy as per the doctrines of requirements for the degree of the TAMILNADU DR.M.G.R. MEDICAL UNIVERSITY CHENNAI – 32. This work was guided and supervised by **Dr. Manikandan MPT (SPORTS)**

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CERTIFICATE BY THE GUIDE

This is to certify that the dissertation entitled **“BILATERAL ASYMMETRIES IN FLEXIBILITY,STRENGTH, AND MUSCLE ENDURANCE ASSOCIATED WITH PREFERRED AND NONPREFERRED LEG”** submitted by **(Reg No. 27102009)** is a record of original and independent work done by the candidate during the period of study under my supervision and guidance. The dissertation represents entirely an independent work on the part of the candidate but for the general guidance by me.

Guide

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"AT THE VERY OUSET, I THANK THE ALMIGHTY FOR HIS BLESSINGS TO ENABLE ME TO COMPLETE THIS PROJECT AND I OFFER THIS PROJECT AT HIS FEET AS MY HUMBLE PRAYER"

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ABSTRACT

BILATERAL ASYMMETRIES IN FLEXIBILITY, STRENGTH, AND MUSCLE ENDURANCE ASSOCIATED WITH PREFERRED AND NONPREFERRED LEG

The uninjured limb is commonly used as a pre-injury model because of the assumption that the limbs are symmetrical. Unfortunately, this may not be true in all athletes. One-legged athletes (1LA) (e.g., jumpers/kickers) may develop bilateral asymmetries as a result of specific training. The purpose of this study was to determine whether asymmetries in flexibility, strength, and muscular endurance existed in the preferred and nonpreferred legs of 1LA athletes. Five characteristics were measured in three groups of subjects: nonathletes (NAS) (n=8), age 21.0 + 1.2 y, height 170.1 + 6.9 cm, weight 68.5 + 13.1 kg); two-legged athletes (2LA) (n=8), age 20.8 + 1.3 y, height 169.9 + 8.6 cm, weight 66.3 + 10.0 kg), and one-legged athletes (n=8, age 20.3 + 1.4 y, height 179.7 + 11.0, weight 72.9 + 13.9 kg). Quadricep and hamstring flexibility were measured using an inclinometer during a passive prone knee-flexion test and a supine passive straight-leg raise, respectively. Quadricep and hamstring strength at 60°/sec and muscle endurance at 180°/sec were measured isokinetically. Leg preference was determined using three tasks: kicking a soccer ball, stepping on an object, and smoothing out sand. Twelve 2x3 ANOVAs were used to determine if differences existed in the legs (preferred, nonpreferred) by group (NAS, 1LA, 2LA) for flexibility,strength, and muscle endurance. Tukey's HSD post hoc test was performed to locate any significant

differences. Results revealed no significant interactions in leg preference by group (NAS, 2LA, 1LA) for flexibility,strength, or muscle endurance. However, main effects among groups were revealed when the means of both legs were combined. Tukey's post hoc test revealed that 1LAs were significantly stronger isokinetically (quadricep and hamstring) and jumped significantly farther compared to the NASs and 2LAs. Observed differences among groups could be a result of training level differences (i.e., varsity vs. recreational) affecting exercise volumes and intensities. The lack of significant asymmetries between preferred and nonpreferred legs suggests that an inadequacy in training elicited asymmetrical adaptations. In conclusion, asymmetries in the preferred and nonpreferred legs do not exist; hence, leg preference could not be associated with asymmetries in flexibility, strength, or muscle endurance.

INTRODUCTION

CHAPTER 1

INTRODUCTION

An athlete's safe, swift injury rehabilitation process and return-to-play leads to success for that athlete or team. For professional athletes, it may mean financial prosperity; for nonprofessional athletes (i.e., high school, amateur, or recreational), rewards include league championships or best personal performances. Health care professionals working with athletes need to ensure a safe and speedy return-to-play with minimal risk of re-injury. Deficiencies in a limb's physical traits (i.e., range of motion, flexibility, strength,endurance, or sport-specific functionality) as a result of injury should be quickly and safely reduced to levels almost identical to those of the uninjured limb.46,47,52-54,68 Using the uninjured limb as a pre-injury model is very common because of the assumption that the limbs are physically and functionally symmetrical.

Statement of the Problem

Unfortunately, the limbs may not be perfectly symmetrical when observing left and right physical characteristics.68,75,90,91 This is apparent in the upper extremity, where the dominant arm is usually stronger and more versatile.28,75,80 In the lower extremity, the differences may not be as obvious in two-legged athletes14,20,63 (e.g., sprinters and swimmers) and nonathletes60,101 (e.g., sedentary population). However, one-legged athletes (e.g., long jumpers and high jumpers) may develop a significant bilateral asymmetry due to a constant training overload on the jumping leg.38,75 The ability to determine any training or injury-induced asymmetries would be valuable to the clinician and researcher. Clinically, a bilateral comparison is performed between limbs with the assumption that the limbs are symmetrical. However, pre-injury asymmetries between the limbs may invalidate this bilateral comparison and complicate the rehabilitation process. Assuming pre-injury symmetry or asymmetry when the opposite exists, sets erroneous functional progression criteria. Establishing incorrect functional rehabilitation progression criteria may delay an athlete's progress through the rehabilitation process. In research, assuming bilateral symmetry offers a simpler methodological approach, but possible data misinterpretation if asymmetry exists. If asymmetry does exist, then lower extremity research methodology needs to be stringent and consistent among subjects and among studies to prevent misinterpretations. If symmetry between the limbs existed, one leg could be tested and representative of both. Also, subjects would not have to be grouped based on athlete type. The test leg would be randomly chosen. If limb asymmetry is wrongly assumed, the naive researcher might waste valuable time on a tedious methodology to account for false asymmetries.

For both the clinician and researcher, problems of misinterpretation arise when incorrect assumptions are made. Depending on the type of activity, level of participation, or training regimen, the limbs may or may not be symmetrical. As a result, rehabilitating athletes and experimental validity are affected. Therefore, this study attempted to answer the following questions:

- Are there physical and or functional asymmetries between the right and left legs of one-legged athletes?
- Are there physical and or functional asymmetries between the right and left legs of two-legged athletes?
- Are these asymmetries associated with the preferred leg?

Hypotheses

Three hypotheses were developed from the review of literature.

H1: There will be asymmetries between the lower limbs of one-legged athletes as measured by the following tests.

- Quadricep and hamstring strength
- Quadricep and hamstring flexibility
- Quadricep and hamstring muscle endurance

H2: There will be no differences between the lower limbs of two-legged athletes as measured by the following tests.

- Quadricep and hamstring strength
- Quadricep and hamstring flexibility
- Quadricep and hamstring muscle endurance

H3: It is hypothesized that the preferred legs of one-legged athletes will be associated with greater hamstring flexibility, and quadricep strength. Additionally, it is hypothesized that the nonpreferred leg will be associated with greater quadricep flexibility,greater hamstring strength and
time to fatigue.

Definition of Terms

The following terms have been defined for the present study

- Asymmetry: imbalance, unequal and non-proportionate.
- Dominance: the central nervous system (CNS) phenomenon in which one side of the brain plays a major role in a specific function.
- Lateral dominance: the preferred use and superior performance of one side of the body as compared to the other side.
- Laterality: a phenomenon that occurs in an organism with paired faculties (hands, ears, feet, eyes), whereby the performance of certain tasks is better on one side.
- Nonpreferred leg: the leg that is used to support the activities of the preferred leg by lending postural support and stability.
- One-legged athlete: an athlete that trains and competes in a skill that mainly focuses on one leg (e.g. long jumpers, high jumpers, football kickers, etc.).
- Preference: one’s subjective choice of limb use that is a result of laterality.
- Preferred leg: the leg used to manipulate an object or to lead out during a jump; determined by using the following tasks: kicking a ball, stepping on an object and smoothing out sand. The leg that consistently performs 2 out of the 3 tasks will be designated as the preferred leg.15

. Two-legged athlete: traditional athletes that train and compete in an activity that does not focus on one leg (e.g. sprinters, swimmers, long-distance runners).

Assumptions

This study was conducted with several assumptions.

- All subjects will answer all questions pertaining to their personal history truthfully.
- Habitually, the lower extremities have been used equally and without voluntary preference during activities of daily living.
- Subjects will perform the tests with maximal physical effort.
- Subjects will interpret the questions on the leg preference inventory identically and answer the leg preference questionnaire truthfully.
- All athletes tested have trained in their respective sports using specific volumes and intensities, but have all completed work adequate enough to elicit a training response.
- Physical or performance changes or lack thereof in subjects' bodies were a result of their respective training programs.
- Performance on the battery of tests will not affect their subjective preference.

REVIEW OF LITERATURE

CHAPTER 2

REVIEW OF LITERATURE

Flexibility

1. Agre et al. determined flexibility and strength differences between the dominant and nondominant legs in 25 male collegiate soccer players. Flexibility measures for hip flexion via a straight-leg raise were not significantly different between the dominant and nondominant leg.

2. Knapik et al.51 observed the relationship between preseason strength and flexibility measures with athletic injuries in 138 female college students between the ages of 16 and 21 y that participated in one or two of the following activities: soccer, volleyball, field hockey, tennis, fencing, basketball, squash, and lacrosse.

3. Agre et al.2 and Knapik et al.51 measured hamstring flexibility via passive straight-leg raise and an active straight-leg raise, respectively. Knapik et al.51 measured quadricep flexibility with active knee flexion.

4. Webright et al. measured hamstring flexibility using a supine active knee extension test with the hip flexed at 90º in 40 undergraduate males and females to compare the effect of repetitive knee extension movements in a slump position with a static stretching technique on hamstring flexibility.

5. Brandy et al.measured hamstring flexibility using a knee extension test with the hip flexed at 90º; however, the knee extension movement was passive instead of active.

6. Hsieh et al.42 examined the reliability of three instruments used when measuring hamstring flexibility during a passive straight let raise in 4 men and 6 women between the ages of 26 to 36 y. Supine subjects were instructed to remain relaxed while the tester raised the leg with the knee fully extended to the point in the range when the tester palpated a small amount of pelvic movement. Hamstring flexibility was measured using a goniometer, flexometer and tape measure. The results suggested high intrasession reliability at 0.99, 0.97, and 0.99, for the goniometer, flexometer and tape measure, respectively. Intersession reliability was lower at 0.88 for the goniometer and flexometer, and 0.74 for the tape measure.

7. Henricson et al.39 also measured hamstring flexibility using a passive straight-leg raise. The hamstring flexibility of 30 healthy students and athletes between the ages of 25 and 39 years old was measured in order to examine the effect of heat, stretching, and heat and stretching combined on hip range of motion.

8. Bohannon9 measured hamstring flexibility using a passive straight-leg raise. Nine women and 2 men from 20 to 32 years old were used in this study cinematographically comparing the angle of straight leg raising in relation to the horizontal with the same angle in relation to the pelvis. In this method, pelvic stabilization was accomplished by strapping down the contralateral leg and anterior

pelvis. Knee extension was maintained using a three-point splint. The subject's leg was pulled into hip flexion with a loaded pulley attached to the ankle via a stirrup. The load on pulley was initially less than 10% of the subject's stated weight and was reduced according to the subject's discomfort tolerance. The authors noted the importance of pelvic stabilization during a passive straight-leg raise test when measuring true hamstring flexibility reliably. Pelvic rotation adds to hip flexion range of motion giving the false impression of increased hamstring flexibility.

9. Violan et al.98 examined the effect of karate training on flexibility, muscle strength and balance in 14 males between the ages of 8 and 13 y. Ten males were also asked to volunteer for the study and served as the control group. Flexibility, static balance, handgrip strength, and leg muscle strength were assessed before and after 6 months of biweekly karate training. Hamstring flexibility was measured with the hip and knee initially positioned at 90º of flexion, and then passively moving the knee into extension until muscle resistance was felt. Quadricep flexibility was measured by flexing the prone subject's knee until muscle resistance was felt or until the hip flexed indicated by the rising of the buttocks. In this study, preferred leg was not determined and the side tested was not mentioned. Regardless, the authors suggested significant increased quadricep and hamstring flexibility after the 6 months of training.

Strength

1. Spry et al.93 examined quadricep and hamstring isokinetic strength bilaterally in 43 male and 33 female nonathletes using the Cybex IIIsokinetic Dynamometer at 60°/sec. Leg dominance was established using Chapman's et al.15 11-item inventory for foot preference. Peak torque was noted as the highest value of 3 trials for knee flexion and extension. Results revealed insignificant differences in the dominant and nondominant leg.

2. Greenberger and Paterno34 also used nonathletes, but assessed concentric knee extensor strength isokinetically at 240°/sec on the KinCom to determine the relationship between knee extensor strength and performance on a one-legged hop for distance test. They obtained mean peak torques of 3 maximal repetitions in 7 male and 13 female college students and suggested no significant differences in the dominant and nondominant leg.

3. Costain and Williams20 examined bilateral quadricep and hamstring strength of 16 female high school soccer players using the Cybex II Isokinetic Dynamometer concentrically at slow speeds (30°/sec) and high speeds (180°/sec). Means of the 4 repetitions at slow speeds and 3 repetitions at high speeds were obtained and compared. Results demonstrated no significant differences in concentric quadricep and hamstring torques between the two legs.

4. Mangine et al.63 suggested no significant differences in knee extensor and flexor isokinetic strength existed between the two legs of 83 soccer players. Unlike Costain and William's20 study, Mangine et al.63 used the Biodex

Isokinetic Dynamometer at 60 and 450°/sec to evaluate isokinetic knee flexor and extensor strength in soccer players who were male and elite (Olympic level).

5. McLean and Tumility66 examined isokinetic knee flexion and extension on the Cybex II Isokinetic Dynamometer at 60, 180, and 240°/sec in 12 elite Australian soccer players with a mean age of 16.8 + 0.7 y to investigate asymmetry in the characteristics of the low drive and chip kicks. Kicking leg was not established, however, authors revealed a significantly greater mean torque for the 3 trials for right knee extension versus mean torque for left knee extension at all testing speeds. In addition, performance of the low drive kick by the right leg was significantly better than the left.

6 Kellis et al.48 measured concentric and eccentric knee extension and flexion peak torques at 60,120, and 180°/sec using the Cybex Norm dynamometer, and determined leg preference with the ball kicking task in 158 soccer players 13 + 2.1 years old. Authors suggested a significantly stronger preferred leg than the nonpreferred leg.

7. Chin et al.16 measured knee flexion and extension strength in the dominant and nondominant legs of 20 elite Asian soccer players between 16 and 18 years old. In their study, peak torque during 5 repetitions of concentric knee flexion and extension was measured on the Cybex II Isokinetic Dynamometer at 60 and 240°/sec. Results showed significantly greater dominant leg knee flexor strength versus the nondominant leg at both speeds and no significant differences in knee extensor strength.

8. Knapik et al.51 measured preseason strength and flexibility imbalances in 138 female collegiate athletes from 8 weight-bearing sports: soccer, volleyball, field hockey, tennis, fencing, basketball, squash, and lacrosse. Knee flexion and extension peak torques from 3 to 5 test repetitions were measured isokinetically on the Cybex II dynamometer at 30 and 180°/sec. Since the authors were observing incidence of injury related to strength and flexibility measures, resultant measures suggested stronger right knee flexors 15% greater than left knee flexors at 180°/sec which correlated with a trend for higher injury rates.

9. Yamamura et al.100 examined concentric mean torque of both legs for knee flexion and extension performed on the Lido Active System at 60°/sec in 16 elite female synchronized swimmers. Since swimmers used both limbs equally during training and competition, combined mean torque values between the right and left limbs were used during the analysis. Although isokinetic strength was examined in swimmers, no bilateral comparison was attempted.

Muscular Endurance

1. Nyland et al.70 fatigued 20 female intramural athletes (soccer, basketball, flag football, and tennis) aged 21.1 + 1.6 y to assess fatigue induced dynamic stability at the knee during a crossover movement. Hamstring fatigue was induced isokinetically using Biodex isokinetic dynamometer and defined when eccentric knee flexion reached 20% peak torque production on 3 consecutive repetitions. The results showed a decrease in dynamic transverse knee plane control resulting

from fatigue as measured by increased internal tibial rotation during a crossover movement. The authors suggested decreased knee joint stability during a pivoting movement resulting from fatigue. Increasing one's endurance capacity allows an athlete to prolong the time to performance deficits. Returning an athlete to competition with muscular endurance deficits may predispose them to early fatigue, submaximal performance, and possibly re-injury.

2. Demura et al.24 examined lateral dominance in maximal muscle power, muscular endurance, and grading ability in 50 healthy active male subjects between 19 and 23 years of age. To assess muscular endurance, 30 reciprocal knee flexion and extension movements were performed continuously at 180°/sec. An endurance ratio consisting of the sum of total work in the first 6 trials divided by the sum of the last 6 trials multiplied by 100, represented muscular endurance. Dominant and nondominant leg were established using 6 tasks from a previous inventory15 and results of the muscle endurance test revealed no significant differences between the limbs.

3. Pincivero et al.77 suggested a difference in the reliability of the fatigue index between the dominant and nondominant leg. Eight male and 8 female volunteers aged 22.1 + 1.9 y were used to evaluate test-retest reliability of 2 different measures of muscle fatigue. Subjects performed 30 reciprocal concentric isokinetic knee extension and flexion movements at 180°/sec with maximal effort on 2 separate occasions separated by a 1 to 2 week period. Muscle endurance was represented by a fatigue index (work performed during the last 5 repetitions

divided by work done during the first 5, multiplied by 100), and the slope of work performed (determined via linear regression analysis by plotting the work values for each repetition across the 30 contractions for each subject). Results illustrated significantly lower reliability using the fatigue index for the dominant leg compared to the nondominant leg at 0.26 and 0.82, respectively. Reliability of the linear model was significantly greater for the dominant leg (0.82) and indifferent to the fatigue index reliability value of the nondominant leg (0.78). The difference in fatigue index reliability between the dominant and nondominant legs is not an indication that asymmetry exists; rather, the method of muscular endurance assessment is inconsistent.

4. Perrin suggested that an endurance ratio is an unreliable indication of muscle endurance. Fifteen male college students with a mean age of 20.53 y underwent isokinetic testing for knee flexion and extension at 60 and 180°/sec. Reliability was determined by repeating the test protocol 1 week following initial testing. Subjects performed 25 maximal knee flexion and extension repetitions to produce an endurance ratio (total work in last 5 repetitions compared to total work done in the first 5). Reliability of the endurance ratio was poor ranging from 0.21 to 0.62. In the literature, other muscle endurance protocols have been suggested and their reliabilities established.

5. Burdett and Swearingen13 tested the reliabilities of 2 methods of measuring quadricep endurance using the Cybex II at 180 and 240°/sec in the dominant leg (undefined) 36 health young adults. A ratio of the work done during the first 5 and the last 5 of 25 repetitions was compared to the number of

contractions until peak torque fell below 50% of initial peak torque. Testing occurred at both speeds on 2 separate occasions separated by a minimal 2-day rest period. Results suggested work ratio reliabilities were 0.48 and 0.56 at 180 and 240°/sec, respectively. Conversely, the number of contractions until 50% of initial peak torque as a test for quadricep muscle endurance was more reliable at 0.85 and 0.74 at 180 and 240°/sec, respectively.

METHODS

CHAPTER 3

METHODS

Subjects

College aged subjects (males and females aged 18-25 years old) was selected from three populations: sedentary/nonathletes (NAS), one-legged athletes (1LA), and two-legged athletes (2LA). NAS was classified as those individuals that regularly participate in non-specific training or recreational physical activity less than 3 days a week, less than 1 hour each day. 2LA were classified as those individuals that specifically train and compete at their particular activity 3 or more days a week, 1 or more hours each day. In addition, the training or activities that these individuals complete do not focus on one leg. 1LA was classified as those individuals that also specifically train and compete at their particular activity 3 or more days a week, 1 or more hours each day. However, their training or activities focus primarily on one leg. All athletes who participated in this study have been participating in their respective activity for at least 1 year prior to being tested.

Certain factors may affect test performances; therefore subjects were screened prior to enrollment. Subjects who have suffered any injuries to either lower extremity or lumbar spine 6 months prior to the start of the study and who have not completed a standard rehabilitation program was excluded from the study. Subjects with any vestibular disturbances, regardless of origin (e.g., ear infection, head trauma), were excluded as proprioceptive performance may be affected by such disturbances.

Instrumentation

Forms

Subjects completed a Subject General Information Form (APPENDIX A) and an Athlete Classification Form (APPENDIX B). The Subject General Information obtains general information (age, height, weight, age, gender, and previous injuries) about each subject. The Athlete Classification Forms was used to assign each subject to one of the three groups: NAS, 2LA, and 1LA.

Warm-Up

Subjects warmed up before any testing. They pedaled comfortably for 5 minutes on a Monark cycle ergometer (Monark Exercise AB, Varberg, Sweden).

Flexibility

Flexibility measurements of the hamstring was measured using an inclinometer (Johnson Level and Tool Mfg. Co, Mequon,WI) during the passive straight-leg raise. Quadricep flexibility was measured using the inclinometer during passive prone knee flexion.

Strength

Concentric and eccentric strength for the knee extensors and flexors were assessed. Strength was measured isokinetically using the KinCom Isokinetic Dynamometer and accompanying software (Chattanooga Group, Hixson, TN).

Muscle Endurance

Muscle endurance for knee extensors and flexors was assessed. Endurance was evaluated isokinetically the KinCom Isokinetic Dynamometer and accompanying software (Chattanooga Group, Hixson,

Measurements

Flexibility

Hamstring flexibility was measured using the passive straight-leg raise technique described by Hsieh et al.42 VelcroTM straps was attached to both lower legs of the supine subject 5 cm proximal to the lateral malleoli. The inclinometer was attached to one leg resting on the table so that it reads 0°. Subjects were instructed to keep both legs relaxed while the test leg is raised passively into hip flexion. The leg was raised to the point in the range where the tester detects pelvic rocking while maintaining full knee extension. The leg was raised and lowered several times through a small arc to detect the onset of pelvic rocking. Inclinometer reading at the onset of pelvic rocking was recorded. Hsieh's et al.42 passive straight-leg raise technique accounts for pelvic rotation, quadricep weakness, subjects with poor flexibility, and subjects with excessive flexibility. Intersession and intrasession reliability was reported as 0.97 and 0.88, respectively.42 A pilot study assessing intersession reliability was conducted and established at 0.93.

Quadricep flexibility was measured using a passive prone knee-flexion test and recorded in degrees. Subjects started prone with the legs beside each other and their feet hanging off the edge of the table. VelcroTM straps were positioned on each leg 5cm proximal to the malleoli. The inclinometer was attached to the test leg so that reads 0°. The knee was moved into flexion until pelvic movement is detected upon anterior superior iliac spine (ASIS) palpation. The knee was flexed and extended several times in a small arc until the onset of pelvic movement is detected. Inclinometer reading at the onset of pelvic movement was recorded. Intrasession reliability was established during a pilot test by the primary investigator at 0.98. All flexibility measures were recorded in degrees and used in the analysis. Three inclinometer readings for the hamstring and the quadricep were recorded in degrees and the highest value was used in the analysis.

Strength

Concentric strength of the knee flexors and extensors was assessed using similar methods described by Quittan et al.,81 but using the KinCom Dynamometer. Subjects were seated in the upright position with their lateral femoral condyle aligned with the lever arm axis of rotation. According to the device's guidelines, stabilization straps around the thigh and chest were used to fix the knee and trunk, respectively. The resistance pad attached to the lever arm was secured around the distal tibia. Gravity correction procedures were followed according to the device's guidelines and distance between the tibial resistance pad and lever arm axis considered during protocol setup. Knee range of motion was set between 10 and 90° of flexion with the mechanical stops fixed according to the device's guidelines. Subjects kept their arms crossed during familiarization and testing. Subjects performed 3 sets of 3 submaximal concentric repetitions at 60°/sec with increasing effort for familiarization. After a 1-minute rest period, subjects performed 3 maximal knee flexion and extension repetitions concentrically. Highest peak torque values were recorded in Nm at 60 and 180°/sec. Reliability values for concentric knee flexion and extension were reported in the literature at 0.96 to 0.99 and 0.82 to 0.96, respectively. Eccentric knee flexion and extension strength was assessed using similar methods described by Li et al..[58] Eccentric strength was assessed at 60°/sec. Subjects performed 3 sets of 3 submaximal eccentric repetitions with increasing effort for familiarization. After a 1-minute rest period, subjects performed 3 maximal knee flexion and extension repetitions eccentrically and highest peak torque values in Nm were recorded. Test-retest reliability values for eccentric knee flexion and extension were reported in the literature to range from 0.82 to 0.91.[58] Highest peak torque values for concentric and eccentric knee flexion and extension were recorded and used in the analysis.

Muscular Endurance

Muscle endurance was assessed last in all subjects to ensure that fatiguedeveloped from the endurance test does not influence the performance during any of the other tests. Endurance was assessed using the protocol described by Burdett and Swearingen,13 but using the KinCom Dynamometer. Subject positioning and stabilization was carried out according to the device's guidelines and identical to the methods described during the isokinetic strength assessment. At 180°/sec, subjects were instructed to continuously flex and extend their knee with maximal effort through the full range of motion (0 to 90°). The number of contractions performed until torque produced falls below 50% of their peak torque for 2 consecutive contractions was recorded and used in the analysis. Reliability of this protocol was reported in the literature at 0.85.13

Leg Preference

Subjects filled out a questionnaire to determine leg preference (APPENDIX C). The questionnaire consists of 3 questions pertaining to task performance: the ball-kicking task,15,35,71 stepping on an object,35 and smoothing out sand.15 The leg that performs 2 out of the 3 tasks was designated as the preferred leg.

Procedures

A total of 24 subjects (n=8) were asked to participate in the study.Procedures of the study were explained to the subjects and written consent was obtained.Subjects reported to the testing area comfortably dressed, wearing shoes and socks.After consent has been received the Subject General Information and Athlete ClassificationForms were given to the subject to complete.The order of the following 5 tests has been established to reduce the testing/reactivity effect. Flexibility was measured first followed by stability and power. Strength was tested in the following order succeeding the other tests: concentric quadricep and hamstring strength at 60°/sec, eccentric quadricep and hamstring strength at 60°/sec, concentric quadricep and hamstring strength at 180°/sec. Finally, muscle endurance was tested at 180°/sec. Subjects rested for 2 minutes between performance tests. For all tests, both legs were alternately tested. Choosing a number (1 or 2) out of a hat established the first leg tested. Last, subjects completed the Leg Preference Questionnaire.

Data Analysis

The dependent variables for this investigation are flexibility (hamstring,quadricep), strength (hamstring and quadricep, concentric and eccentric), and muscular endurance (number of repetitions to 50% of initial peak torque). All measurements for each test were recorded as left leg and right leg performance on the data collection sheet (APPENDIX D). The independent variables for this investigation are leg preference (left, right) and group (NAS, 1LA, 2LA).

Outcome measures were analyzed using 2 x 3 (leg preference x group) ANOVAs for the dependent measures of flexibility, stability, power, strength, and muscular endurance. If any significant differences are revealed by the ANOVAs, Tukey’s HSD Post Hoc Tests were performed to establish where the significant differences occur. Pearson Correlation Coefficients were calculated to determine if there are associations in the preferred leg or nonpreferred leg with the following characteristics: flexibility, stability, power, strength, and or muscular endurance.

Data were analyzed using SPSS 10.0 (SPSS, Chicago, IL). The level of significance was set a priori at $P < 0.05$.

RESULTS

CHAPTER 4

RESULTS

The purpose of this study was to determine if asymmetries in flexibility,strength, and endurance existed between right and left legs. Additionally, asymmetries and their association with leg preference were examined. College aged males and females were recruited and grouped according to type of activity and total weekly participation time. Raw flexibility,strength, and endurance data and leg preference data were collected and analyzed. Appendix E contains the raw data.

Two-way ANOVAs determined if any interactions occurred in leg preference (preferred, nonpreferred) by group (NAS, 1LA, 2LA). If significant differences were revealed Tukey's HSD post hoc analysis was used to locate where the differences occurred. ANOVA tables can be found in Appendix F.

Subject Demographics

A total of 24 subjects participated in this study. There were 4 males and 4 females in each of the 3 groups (n=8). The NAS and 2LA group consisted of college of nandha students considered inactive or active, respectively, based on the inclusionary criteria. The 1LA group consisted of college of nandha track athletes (hurdlers, long jumpers, high jumpers) who also fulfilled the inclusionary criteria. The mean age, height, and weight of all subjects (N=24) was 20.7 + 1.3 y, 173.5 + 9.7cm, and 69.3 + 12.3 kg, respectively. Twenty-one of 24 subjects had a right leg preference and 3 had a left leg preference (Table E-7). Descriptive statistics by group are listed in the Table 4-1.

Table 4-1 Descriptive statistics by group (mean ± SD)

	Age (y)	Height (cm)	Weight (kg)
NAS	21.0 ± 1.2	170.8±6.9	68.5±13.1
2LA	20.8±1.3	169.9±8.6	66.3±10.0
1LA	20.3±1.4	179.7±11.1	72.9±14.0

Flexibility

Quadricep (Table 4-2) and hamstring (table 4-3) flexibility means and standard deviations for each leg and each group were recorded. The ANOVA revealed no significant interactions in leg preference (preferred, nonpreferred) by group (NAS, ILA, 2LA) for quadriceps ($F_{(2,21)}$ = 1.643, P=0.217) and hamstring flexibility $F_{(2,21)}$ = 1.849, P=0.182)

Table 4-2 Quadricep Flexibility (mean ± SD)

	Non preferred	Preferred
NAS	121 ±15^0	125 ±17^0
2LA	120 ±16^0	124 ±13^0
1LA	126 ±6^0	125 ±8^0

Table 4-3 Hamstring Flexibility (mean ± SD)

	Non preferred	Preferred
NAS	56 ±16^0	59 ±11^0
2LA	65 ±15^0	65 ±11^0
1LA	71 ±6^0	69 ±6^0

Table 4-4 Vertucal force center of pressure (mean ± SD)

	Non preferred	Preferred
NAS	1116 ±306 msec	1203 ±280 msec
2LA	1374 ±413 msec	1482 ±398 msec
1LA	1464 ±448 msec	1556 ±320 msec

Table 4-5 Anterior-posterior center of pressure (mean ± SD)

	Non preferred	Preferred
NAS	1582 ±262 msec	1686 ±201 msec
2LA	1657 ±226 msec	1723 ±284 msec
1LA	1529 ±345 msec	1606 ±201 msec

Table 4-6 Medial-lateral center of pressure (mean ± SD)

	Non preferred	Preferred
NAS	1514 ±294 msec	1455 ±200 msec
2LA	1417 ±267 msec	1596 ±270 msec
1LA	1531 ±346 msec	1373 ±412 msec

Strength

Concentric quadriceps and hamstring strength means and standard deviations were recorded in Table 4-8 and 4-9, respectively. The ANOVA revealed no significant interactions in leg preference by group for concentric quadriceps strength ($F_{(2,21)}$ = 0.069,, P=0.933) and concentric hamstring strength ($F_{(2,21)}$ = 0.964, P=0.398). A significant main effect among groups was noted when preferred and nonpreferred legs were pooled together ($F_{(2,21)}$ = 6.525, P=0.006). Tukey's HSD post hoc analysis revealed that ILA had greater concentric quadriceps strength than 2LA and NAS. Similarly, ILA had greater concentric harmstring strength than 2LA and NAS

Table 4-7 Quadricep concentric strength (mean ± SD)

	Non preferred	Preferred	Combined
NAS	105.00 ±28.69 nm	103.25±20.35 nm	104.13±23.05 nm
2LA	111.38±30.52 nm	111.13±32.27 nm	111.25±30.34 nm
1LA	164.88±54.14 nm	165.63±49.50 nm	165.25±50.12 nm*

ILA significantly greater than 2LA and NAS (P<0.05)

Table 4-8 Harmstring concentric strength (mean ± SD)

	Non preferred	Preferred	Combined
NAS	76.88 ±23.98 nm	87.63±23.82 nm	82.25±23.75 nm
2LA	82.25±19.42 nm	77.63±25.59 nm	79.94±22.62 nm
1LA	119363±35.22 nm	125.88±46.38 nm	122.75±39.91nm*

*ILA significantly greater than 2LA and NAS ($P<0.05$)

Quadricep and hamstring eccentric strength means and standard deviations were recorded in Table 4-10 and 4-11, respectively. The ANOVA revealed no significant interactions in leg preference by groups for eccentric quadriceps strength $F_{(2,21)} = 0.301$, P=0.743). However, when the preferred and nonpreferred legs were pooled together, main effects were noted for eccentric hamstring strength $F_{(2,21)} = 4.455$, P=0.024). Tukey's post hoc analysis showed greater eccentric hamstring strength in ILA compared to NAS.

Table 4-9 Quadricep eccentric strength (mean ± SD)

	Non preferred	Preferred	Combined
NAS	134.00 ±37.98 nm	131.25±37.10 nm	132.63±36.26 nm
2LA	135.13±34.10 nm	136.25±42.89 nm	135.69±37.44 nm
1LA	187.25±54.28 nm	179.13±55.94 nm	183.19±53.41 nm

Table 4-10 Hamstring eccentric strength (mean ± SD)

	Non preferred	Preferred	Combined
NAS	85.63 ±17.95 nm	91.63±25.72 nm	88.63±21.65 nm
2LA	92.75±17.29 nm	89.50±31.46 nm	91.13±24.58 nm
1LA	125.63±36.78 nm	130.63±51.72 nm	128.13±43.43 nm*

* ILA significantly greater than NAS (P< 0.05)

Muscle Endurance

Quadricep and harmstring muscle endurance was recorded as the number of repetitions to 50% initial peak torque. The means and standard deviations were recorded in Table 4-12 and 4-13. The ANOVA revealed no significant interactions in leg preference by group for quadriceps $F_{(2,21)}$ = 0.864, P=0.436) and the hamstring $_{(2,21)}$ = 0.252, P=0.779) endurance.

Table 4-11 Quadricep muscle endurance (mean ± SD)

	Non preferred	Preferred
NAS	26.8 ±5.1 reps	29.8 ±6.2 reps
2LA	27.1 ±7.6 reps	26.0 ±6.1 reps
1LA	27.1 ±5.3 reps	28.0±4.7 reps

Table 4-12 Hamstring muscle endurance (mean ± SD)

	Non preferred	Preferred
NAS	27.1 ±6.1 reps	25.8 ±7.4 reps
2LA	28.1 ±7.5 reps	27.5 ±4.4 reps
1LA	30.0 ±6.7 reps	27.4±7.4 reps

DISCUSSION

CHAPTER 5

DISCUSSION

The purpose of this study was to determine if asymmetries in flexibility, strength, and muscular endurance existed between the preferred and nonpreferred legs of athletes and nonathletes; in addition, whether a relationship existed between these asymmetries and leg preference. This was the first study that compared physical and functional characteristics in the preferred and nonpreferred legs of NAS, 2LA, and 1LA. Three hypotheses were examined in this study.

The first hypothesis stated that there would be physical and functional asymmetries in the preferred and nonpreferred legs of 1LA as measured by the following tests: flexibility (quadricep and hamstring), strength (quadricep and hamstring, concentric and eccentric), or anaerobic endurance (quadricep and hamstring). The results of this study failed to reject the null hypothesis by revealing no significant differences in the preferred and nonpreferred legs of 1LA in any of the tests.

The second hypothesis stated that there would be no physical or functional asymmetries in the preferred and nonpreferred legs of 2LA. The results of this study failed to reject this hypothesis by revealing no significant differences in the preferred and nonpreferred legs of 2LA in any of the tests. The third hypothesis stated that the preferred legs would be associated with greater hamstring flexibility and quadricep strength compared to the nonpreferred legs in 1LA. Additionally, the nonpreferred leg would be associated with greater quadricep flexibility, greater hamstring strength, and greater time to fatigue. The third hypothesis could not be supported since the results of this study failed to reveal significant differences in the preferred and nonpreferred legs of the 1LA; hence, no associations with leg preference could be made.

Flexibility

Similar to Agre et al..2 and Knapik et al..51 the present study found no significant differences in the preferred and nonpreferred legs for hamstring and quadricep flexibility. However, neither Agre et al..2 or Knapik et al..51 strictly examined NAS or 1LA. Agre et al..2 did not report significant differences for hamstring flexibility in the preferred and nonpreferred legs of college aged soccer players. Hamstring flexibility was determined by using a goniometer measuring hip flexion at the greater trochanter during a passive straight-leg raise. They concluded that although favoring one leg more for kicking and handling the ball, soccer players did not develop any asymmetries in flexibility. In this study, only male soccer players were assessed.

Knapik et al..51 did not report significant differences for quadricep flexibility, as measured by prone active knee flexion at the knee with a goniometer, in the legs of female athletes from a variety of sports. Additionally, no significant differences were reported for hamstring flexibility measured during an active straight-leg raise with a goniometer at the greater trochanter. Both studies used collegiate athletes; however, Knapik et al.. only used female athletes.

The present study is in contrast to Sullivan et al..94 who reported a significant difference in the legs for hamstring flexibility. They examined pelvic position and stretching method on hamstring muscle flexibility in 10 male and 10 female NAS subjects. Hamstring flexibility was measured using an inclinometer during an active knee extension test (starting hip and knee position at 90° flexion). Each subject was randomly assigned a static stretching (SS) protocol on one leg and a proprioceptive neuromuscular facilitation stretching (PNF) protocol on the other to determine the effect of each technique on flexibility. Since, leg preference was not considered in this study, the difference was attributed to stretching technique efficacy.

In the present study, it was hypothesized that quadricep and hamstring flexibility would be symmetrical in NAS and 2LA. The results of this study support this hypothesis. However, it failed to support the hypothesis that the preferred leg hamstring and the nonpreferred leg quadricep would have greater flexibility than their twin on the contralateral side as a result of training in 1LA. Hence, leg preference could not be associated with flexibility.

In the present study, quadricep flexibility was determined using a prone knee-flexion test; however, unlike the method used by Knapik et al..51 knee flexion was passive. Like Agre et al..,2 hamstring flexibility was evaluated using a passive straight-leg raise. However, an inclinometer around the lower leg was used instead of a goniometer at the greater trochanter. The inclinometer reading at initial ASIS movement, not tissue resistance, was recorded. Intratester reliability for measuring quadricep flexibility was ICC (2,1)=0.98 and hamstring flexibility was IC (2,1)=0.93.

Measurements may potentially have been affected by several factors.Subcutaneous adipose over the ASIS on some athletes and abdominal movement during respiration possibly obscured the palpation. Also, the weight of the subject’s leg made it difficult for the tester to focus on ASIS movement. Nevertheless, reliability for the methods assessing flexibility was high.

The preferred leg was deemed the leg that performed 2 or more of the following tasks: kicking a soccer ball, stomping on an object, and smoothing out sand. The preferred leg was deemed the leg that performed 2 or more of the following tasks: kicking a soccer ball, stomping on an object, and smoothing out sand. A stretching program or movements requiring above average quadricep or hamstring flexibility may not be performed on a regular basis (as in the NAS and 2LA). As a result, specific adaptations in the legs may not have developed. Results of this study fail to reject the null hypothesis suggesting that flexibility asymmetries between the legs do not exist.

However, if a specific stretching program or movements requiring muscle flexibility were repeated with volition over a significant amount of time, adaptations should occur. In 1LA, the quadricep of the nonpreferred leg and the hamstring of the preferred leg would have greater flexibility than their twin on the contralateral side. The results of this study failed to reject the null hypothesis.

Some ideas may explain why these adaptations did not occur in 1LA. The Overload Principle suggests that physical changes occur in tissues if imposed stresses are greater than what the tissues are accustomed.38 The volume of exercise and the range of motion (ROM) of the movements needed to elicit changes in flexibility may have been inadequate. The preferred leg is the leg used to manipulate an object or to lead out during a jump.75 This widely used definition suggests that leg preference is independent of volume of exercise or ROM. Even the 1LA group was not able to illicit expected differences between the legs due to inadequate asymmetrical exercise volume or flexibility training modification. Additionally, the relative amount of work performed by one leg versus two is minute compared to the relative amount of work performed by one arm versus two. Krahl et al..55 noted significant structural asymmetries between the arms of tennis players. These athletes during training and activities of daily living (ADL) notably use one arm more than the other. However, jumping and kicking athletes, even during training do not use one leg independently of the other for long periods of time. With ADLs, the sole repeated use of one leg is scarce.

Strength

The present study revealed similar results to studies done by Greenberger and Paterno,34 Perrin et al.,74 Parkin et al.,72 Costain et al.,20 Capranica et al.,14 Spry et al.,93 Lucca and Kline,60 and Quittan et al..81 In contrast to the present study, Siqueira et al.,92 Thomas et al.,96 Kellis et al.,48 McLean and Tumilty,66 and Chin et al.,16 revealed strength differences in the legs.

Similar to the present study, Greenberger et al.34 evaluated concentric knee extensor strength isokinetically on the Kinetic Communicator (KinCom) at 240º/sec in 20 male and female students and reported no significant differences in the dominant and nondominant legs. Spry et al.93 evaluated knee extensor and flexor strength of 76 male and female students, however, they used the Cybex II isokinetic dynamometer at 60º/sec. The authors did not state whether concentric or eccentric strength was evaluated. Like Greenberger et al.,34 Spry et al.93 also reported no significant differences in the legs.Lucca and Kline60 tested knee extensors and flexors as well. Concentric strength of 54 male and female students was evaluated using the Cybex II isokinetic dynamometer at 60, 120, and 240º/sec. The authors reported no significant differences between the legs, suggesting that the legs have less opportunity to develop asymmetric strength and dexterity since lower extremity work (e.g., walking, running, stair climbing) is commonly bilateral. Unlike the previously mentioned studies, Quittan et al.81 examined an older population (56 + 8 y) on the Cybex 6000 at 60º/sec. No significant differences in the legs for concentric knee extensor and flexor strength were revealed.

Many studies have researched bilateral isokinetic knee strength in non-athletic individuals and reported symmetry between the lower limbs. A few studies examined athletes and reported similar findings. Costain and Williams20 studied knee extensor and flexor strength concentrically in teenage female soccer athletes. Results revealed no significant differences in the legs after being tested on the Cybex II at 30 and 180º/sec. Capranica et al.14 tested preadolescent male soccer players and a non-athletic control group. Unlike the previous studies and the present study, the authors used an isokinetic bicycle ergometer and tested subjects at 5 isokinetic loads. Regardless, no significant differences in the preferred and nonpreferred legs were exposed. The authors explained that subjects participated in soccer training that does not favor one leg, resulting in lateral dominance. Two-thirds of practice time was designed to enhance physical fitness activities emphasizing symmetrical bilateral development. Parkin et al.72 investigated strength asymmetries in male oarsmen and nonathletes. Testing concentric and eccentric knee flexion and extension at 3.5 and 1.75 radians revealed no significant differences between the right and left legs. Unlike studies previously mentioned, Perrin et al.74 studied bilateral strength in different types of athletes and a control group. Concentric knee extension and flexion was assessed in baseball pitchers, swimmers, and nonathletes. Evaluation on the Cybex II at 60 and 180º/sec revealed no significant differences in the legs.

In contrast to the present study, several studies reported significant differences in the lower limbs. Kellis et al.48 reported a significant main effect suggesting greater knee strength in the preferred leg than the nonpreferred leg of soccer players. Concentric and eccentric knee extensor and flexor strength was tested using the Cybex Norm dynamometer at 60, 120, and 180º/sec. Authors could not make specific inferences on muscle group (extensors, flexors) or action (concentric, eccentric) because no significant interactions were revealed. McLean and Tumilty66 also reported strength differences in the legs of soccer players. Knee extensor strength testing using the Cybex II at 60, 180, and 240º/sec revealed a significantly stronger right knee compared to the left at each speed. Like Kellis et al.48 and McLean and Tumilty,66 Chin et al.16 reported asymmetries in the legs of soccer players. They reported stronger knee flexors in the dominant leg compared to the nondominant leg with no difference in the extensors. They evaluated isokinetic knee extensor and flexor strength on a Cybex II isokinetic dynamometer at 60 and 240º/sec.

Thomas et al.96 examined physiological and psychological correlates of success in track athletes and measured bilateral quadricep and hamstring concentric strength using the Cybex II at 60º/sec. The authors expressed amount of asymmetry with a low-high (e.g., weaker-stronger) strength ratio. An indication of which leg is stronger was not given. Relatively low ratios for the quadricep (0.86) of jumpers and sprinters compared to runners (0.93) suggested greater quadricep strength asymmetry in these athletes; however, statistical significance was not calculated.

Only one study closely parallels the present study; however, with conflicting results. Siqueira et al.92 investigated concentric knee extensor and flexor strength in the dominant and nondominant legs of 3 groups: nonathletes, jumpers (triple and distance), and runners/sprinters. After testing subjects on the Cybex 6000 at 60 and 240º/sec the following points were made: in nonathletes at 60º/sec, dominant leg flexors were significantly stronger than the nondominant flexors; although, dominant leg extensor strength was higher, the difference was not statistically significant; in jumpers and runners at 240º/sec, nondominant leg extensors were significantly stronger than dominant leg extensors.

In the present study, it was hypothesized that knee strength would be symmetrical in NAS and 2LA. The results of this study support this hypothesis. However, it failed to support the hypothesis that the nonpreferred limb would be significantly stronger than the preferred limb in 1LA. As a result, leg preference could not be associated with strength.

Differences in subjects, sample size or methods between the present study and previous studies may have attributed to conflicting results. In the present study, the sample of convenience was limited to 4 males and 4 females for the 1LA group. Hence, 4 males and 4 females for each group were tested to attain a better representation of the population. In contrast, the studies done by Siqueira et al.92 and Thomas et al.96 tested 54 and 39 male subjects, respectively. Chin et al.,16 Kellis et al.,48 and McLean and Tumilty66 did not specify whether they used males, females, or both. In contrast to the present study and the studies done by Siqueira et al.92 and Thomas et al.,96 Chin et al.16 tested elite Asian athletes (N=21), Kellis et al.48 examined elite Greek athletes (N=158), and McLean and Tumilty66 assessed elite Austrialian athletes (N=12).

Subjects in the present study were grouped according to training regime. NAS rarely exercised (less than 3 days/week, less than 1 hour/session), and 2LA and 1LA exercised regularly (3 or more days/week, 1 hour or more/session). 1LA trained for a specific task/skill involving one leg (e.g., jumping/kicking). In contrast to the present study Siqueira et al.92 described athletes (jumpers, runners) as those who have been training 6 days/week, 3 hours daily for at least 1 year. Nonathletes were those that did not meet these criteria. Similarly, Chin et al.16 used athletes that trained 6 days/week, 3 hours daily for 10 months of the year. These discrepancies in inclusionary criteria may be related to the differences in results between the present study and others.

In the present study, quadricep and hamstring strength was tested concentrically and eccentrically at 60º/sec on the KinCom. No two studies had identical protocols. Although methods differed among studies in muscles tested (flexors, extensors, or both), muscle action (concentric, eccentric, or both), testing speed (ranged from 30 to 240º/sec, 1.75 to 3.5 radians), warm-up protocol (cycle ergometer for 5 or 15 minutes), familiarization repetitions (3 to 5 submaximal and 3 to 5 maximal), test repetitions (3 to 5), order of testing (speed, muscle action, muscle group), rest periods (30 seconds to 5 minutes), variable measured (peak torque, average torque, total work) and equipment used (Cybex or KinCom), comparisons between the legs are still valid as long as methods on the one side are identical to those on the other.

Several factors that may have affected strength results were addressed. To negate a learning effect between limbs, the order for leg tested first was randomized. After testing on one side, subjects were unstrapped and allowed to actively recuperate before testing on the opposite side. Subjects were encouraged to physically remember seated position and strap tightness (over the shoulders, hips and thigh) so that they can be positioned and secured identically. Dynamometer head height, lever length, seat angle, and seat height were kept constant. Bilateral structural differences in anatomy (tibial or femoral length) may affect positioning (lever arm length and axis alignment), thereby affecting torque readings. Verbal encouragement and subject mannerisms (breathing pattern, choice of visual feedback) during maximal exertion were consistent. Motivation may affect effort and torque readings. Regardless of testing protocol and considering possible confounding variables, isokinetic assessment of knee flexor and extensor strength was found to be reliable.44,58, 73

Although the methods and procedures used to assess concentric and eccentric quadricep and hamstring strength were consistent between the legs and subjects in the present study, several ideas may explain why the results failed to support the third hypothesis. Capranica et al.14 assessed knee flexor and extensor strength in young soccer players. Subjects who participated in this study trained for at least 2 y, 2 days/week, and at least 90 minutes/practice. The authors stated that since the majority of time spent during practice sessions was donated to enhancing fitness by utilizing soccer specific drills emphasizing symmetrical development, asymmetry in the preferred and nonpreferred legs did not develop. Likewise, a 1LA may spend the majority of practice time enhancing performance; however, the amount of time diverted to focusing on unilateral development may not have been significant enough to elicit significant asymmetries. In the present study, 1LA trained 3 or more days/week, 1 or more hours each/session at their track event (high jump, triple jump, long jump, hurdles). It is unclear how much of this time was dedicated to specific one-leg training. Specific details of daily training schedule of the 1LA were unknown. Regardless, no differences in the legs were revealed.

As noted earlier, 1LA displayed significantly stronger concentricquadricep and hamstring and eccentric quadricep strength than 2LA and NAS. Eccentric hamstring strength in 1LA and 2LA was greater than NAS. Again, this was probably due to the difference in training regimens among the groups. Although the athletic groups (1LA and 2LA) and the non-athletic group were divided by weekly volume of activity (3 days/week, 1 hour each day) differences between the 2 athletic groups were revealed. The 1LA group consisted of varsity track athletes that actually trained 6 days per week, 2 hours per day. The 2LA group consisted of athletes that varied weekly volume between 3 and 6 days per week, 1 to 3 hours each day. The large disparity among weekly volumes may have influenced this difference among groups.

Muscle Endurance

Only one study evaluated asymmetries in the preferred and nonpreferred legs for muscle endurance. Similar to the results of the present study, Demura et al.24 reported no significant differences in the dominant and nondominant legs. The authors assessed endurance ratio in the dominant and nondominant legs of 50 inactive males. Knee flexion and extension were tested on the Cybex 325 at 180º/sec. The endurance ratio consisted of total work during the first 6 of 30 repetitions divided by the last 6 repetitions multiplied by 100. The authors suggested this symmetry stemmed from consistent use of both legs during ADL. Interestingly, they noted that the nondominant leg showed superior muscular endurance and the dominant leg showed superior power exerAlthough the difference in the legs for endurance tended to be larger than the difference for power, none were statistically significant.

In contrast, the present study tested 2LA and 1LA along with NAS, using a more reliable endurance protocol. Burdett and VanSwearingen13 reported a high reliability value (ICC=0.84) when counting the number of repetitions a muscle group performs to where torque produced is below 50% initial peak toque for 2 consecutive repetitions. Perrin73 and Burdett and VanSwearingen13 assessed endurance ratio reliability and reported low ICC values (.21-.62 and .48, respectively).

In the present study, it was hypothesized that quadricep and hamstring muscle endurance would be symmetrical in NAS and 2LA. The results of this study support this hypothesis. However, it failed to support the hypothesis that the preferred limb would have better endurance in 1LA. Hence, leg preference could not be associated with muscle endurance.

1LA training regimen and testing methods may explain why the results failed to support this third hypothesis. As mentioned in the previous section, subjects physically active 3 or more days/week, 1 or more hours each/session were classified as 2LA or 1LA depending on their activity. Although 1LA trained several times during the week, the amount of specific asymmetrical training during that time is unknown. Results imply that the amount of asymmetrical training was inadequate to stimulate testable differences.

The endurance protocol was performed after the isokinetic strength testing on the KinCom. Although testing procedures were identical on both sides, methodological inconsistencies in subject setup and leg testing may have influenced results. In setting up the subject, several factors were considered. Varying tightness in the straps around the torso, thigh, and lower leg may affect torque output. Asymmetries in tibial length affect lever length and distance from axis of rotation hence torque. Asymmetrical femur length may affect axis of rotation alignment also affecting distance between axis of rotation and lever length, hence torque. Keeping setup parameters consistent between the legs minimizes this confound. Testing one leg first may produce a learning effect on the opposite leg. Randomization of the leg tested first eliminated this problem. Finally, verbal instructions and encouragement during the test was kept consistent to maintain a high level of motivation and effort.

Leg Preference

Gender and age were addressed due to their potential impact on the results of the present study. Sex related asymmetries have been previously studied. Levy and Levy57 observed right-handed males with larger right feet and right-handed females with larger left feet sugesting that sex steroids govern cerebral and pedal asymmetrical maturation.Interestingly,others have found asymmetries in the opposit direction.In contrast, Means and Walters reported a significant association between hand size asymmetry and handedness, but no significant association with foot-size. Since structural asymmetries in the legs may be influenced by gender, keeping gender consistent may eliminate this potential confound. Unfortunately, inferences made by the results would be limited to that gender. The present study examined males and females to obtain a better representation of the population. Additionally, since the sample of convenience consisted of 4 males and 4 females, combining the two genders increased sample size. left feet suggesting that sex steroids govern cerebral and pedal asymmetrical maturation. Interestingly, others have found asymmetries in the opposite direction (e.g., right-handed males with larger left feet and right-handed females with larger right feet).64 In contrast, Means and Walters67

Age related asymmetries have also been noted previously. Gentry and Gabbard31 observed choice of foot preference in 956 males and females of different age groups between 4 and 20 years of age and suggested that footedness in the younger groups was nonspecific. However, they noticed a significant shift towards right-footedness between 8 and 11 years old, after which preferences remained stable. Researchers examining preference behaviors or asymmetries in younger individuals14,48 must be cautious in interpreting their results. In the present study, this was not a concern.

Leg preference was established using tasks focusing on manipulation of an object (e.g., kicking a soccer ball, smoothing sand, stomping on an object). However, leg preference did not always dictate take-off leg in the present study. Since the preferred leg has been defined as the leg that manipulates or leads out during a jump and the nonpreferred leg as the leg that supports the activities of the preferred leg,75 it would be expected that a preferred right leg individual would always jump off their left leg.

However, this was not the case. In the present study, 3 out of the 8 1LA jumped off their preferred leg. If the athlete's hand preference were opposite to their leg preference, this may explain why they jump off the nonpreferred leg. Sport skills involving unilateral upper limb manipulation (e.g., throwing, basketball lay-up) usually involve contralateral lower limb support. For example, the support leg during the follow-through phase in a baseball pitch or take-off leg during a right handed lay-up. Interestingly, those 3 jumpers have a leg preference on the same side as their hand preference and their take-off leg. Further research is necessary to explain these inconsistencies.

Since no asymmetries were revealed in the present study, the preferred leg could not be associated with physical and functional characteristics. Therefore, leg preference does not influence or predict asymmetries in flexibility, stability, power, strength, and muscle endurance in the lower extremities. Regardless of whether leg preference is inherent,79 matures over time,31 or develops over task repetition,33,38 it is not expressed as a physical or functional asymmetry.

SUMMARY

The results of the present study demonstrated that no asymmetries in flexibility, strength, and muscle endurance in the preferred and nonpreferred legs existed in NAS, 2LA, and 1LA. Hence, limb asymmetry is not associated with leg preference. Therefore, a bilateral comparison is a valid pre-injury model for the injured lower limb allowing clinicians to accurately organize rehabilitation goal and return-to-play criteria. Also, researchers may simplify methods by testing flexibility, stability, power, strength, and muscle endurance of one lower extremity and not be concerned with the confounding variable of asymmetry.

CONCLUSIONS

The following conclusions may be drawn from this study:

- No asymmetries in flexibility,strength, muscle endurance exist in the preferred and nonpreferred legs of 1LA

- No asymmetries in flexibility,strength, and muscle endurance exist in the preferred and nonpreferred legs of 2LA.

- Limb asymmetry is not associated with leg preference in athletes and nonathletes.

APPENDIX

APPENDIX A

SUBJECT INFORMATION FORM

SUBJECT

NAME : ……………………………………………………….

ADDRESS : ………………………………………………………..

PHONE AND EMAIL : ……………………………………………….………

DATE………………………TIME…………..………….

MALE ………..….FEMALE………………..……………

AGE…………………………….

HIGHT………………………..….

WEIGHT…………………………

DOMINATION HAND R L

ANY LOWER EXTREMITY OR VESTIBULOCOCHILEAR (INNER EAR) INJURIES

WITH THE LAST 6 MONTHS

____

____

CATEGORY

- NONATHILETE/SEENTARY
- TEWO-LEGGED ATHLETE

ONE LEGGED ATHLETE (take-off leg)…………………….

APPENDIX B

ATHELETEE CASSIFACTION FORM

SUBJECT

1. Which activities have you participated in before? (circle all that apply)

   a. Soccer (striker/mid/defense, keeper) (kicking leg R or L)

   b. Basketball

   c. Baseball (Pitcher, fielder, catcher)

   d. Football (DB/receiver, lineman, QB, kicker,/Punter)

   e. Ice hockey (offence/defense, goalie)

   f. Rugby

   g. Field hockey (offense/defense, goalie)

   h. Lacrosse (offense/defense, goalie)

   i. Swimming

   j. Water polo

   k. Wrestling

   l. Jogging

   m. Short sprints (100m, 200m)

   n. Long jump (take off leg R or L)

   o. High jump (take off leg R or L)

   p. Sort hurdles (60m, 100m) (trail leg R or L)

   q. Pole Vault

r. Other……………………………………….

2. What have been your three main activities over the last year? (List in order of most dedication first) State the level at which you train or compete at (varsity, intramural, club, recreational).

i. ………………………………

ii ………………………………

iii ………………………………

3. How much time during the week do you dedicate to each of your three main activities?

Days/week – less than (<) 3 days or more

Hours/day – less than (<) I1 hour, 1 hour or more

Activity	Days/week	Hours/day

APPENDIX C

LEG PREFERENCE QUESTIONNAIRE

1. Which leg would you like a soccer ball with?

   Left Right

2. Which leg would you step on an object with? (eg. Step on a bug)

   Left Right

3. Which leg would you use to smooth out sand with?

   Left Right

APPENDIX D

DATA COLLECTION FORM

SUBJECT…………………

ATHLETE TYPE: Sedentary/Nonathlete ………………………..

Two-legged athlete ………………………..

One-legged athlete ………………………..

Flexibility (degrees)

Extensors (quadricep)		Flexors (hamstring)	
Left	Right	Left	Right

Strength (N*m)

	Left		Right	
	Extensors	Flexors	Extensors	Flexors
Concentric peak torque 60 0/sec				
Concentric peak torque 180 0/sec				
Concentric peak torque 60 0/sec				

Muscular endurance (number of repetitions)

	Left		Right	
	Extensors	Flexors	Extensors	Flexors
50% PT				

LEG PREFERENCE R L

APPENDIX E

RAW DATA

Table E-1 Subject demographic raw data

Subject	Age (Y)	Height (cm)	Mass (kg)
1	21	172.72	61.29
2	20	162.56	55.39
3	23	175.26	77.18
4	21	172.72	65.83
5	19	160.02	47.67
6	22	167.64	77.18
7	21	175.26	77.18
8	21	180.34	86.26
9	20	152.40	52.21
10	22	170.18	70.73
11	19	162.56	63.56
12	20	175.26	69.92
13	21	172.72	63.56
14	20	177.80	74.91
15	23	170.18	54.03
16	21	177.8.	81.72
17	19	182.88	70.82
18	19	193.04	97.61
19	19	185.42	72.64
20	21	195.58	89.89
21	22	167.64	61.29
22	21	172.72	70.37
23	19	170.18	59.02
24	22	170.18	61.74

Table E-2 quadricep and hamstring flexibility raw data (degrees)

Subject	NPQ flex	PQ flex	NPH flex	PH flex
1	131	135	78	74
2	125	132	65	66
3	101	96	48	48
4	20	134	61	63
5	149	148	64	67
6	121	125	39	45
7	115	122	49	58
8	104	105	45	49
9	131	135	64	60
10	115	129	61	58
11	146	147	96	83
12	128	126	52	59
13	125	120	46	48
14	99	114	70	72
15	120	115	70	67
16	97	105	62	70
17	125	120	76	71
18	115	118	66	68
19	122	12	65	64
20	125	126	67	65
21	131	136	70	68
22	126	116	66	63
23	136	135	74	74
24	129	129	83	80

Table E-3 Quadricep and hamstring conscentric raw data (Nm)

Subject	NPQ CON	NPHCON	PQCON	PHCON
1	97	72	95	77
2	82	58	95	65
3	157	82	130	111
4	123	82	126	92
5	70	52	71	53
6	11	61	121	84
7	92	79	93	92
8	108	129	95	127
9	85	59	71	50
10	118	82	123	81
11	67	59	85	42
12	125	93	102	84
13	116	84	110	85
14	130	101	136	87
15	87	68	90	64
16	163	112	172	128
17	207	161	203	123
18	184	127	175	213
19	214	145	193	125
20	245	168	252	175
21	111	90	104	80
22	124	96	124	107
23	103	78	125	80
24	131	92	149	104

Table E-4 Quadricep and hamstring Eccentric raw data (Nm)

Subject	NPQECC	NPHECC	PQECC	PHECC
1	108	84	104	73
2	143	92	139	84
3	191	110	171	113
4	192	91	192	119
5	99	58	80	49
6	106	62	106	85
7	111	86	117	85
8	122	102	141	125
9	111	84	100	68
10	145	93	132	93
11	113	71	98	37
12	129	106	132	112
13	133	96	138	99
14	169	92	169	81
15	87	75	98	82
16	194	125	223	144
17	229	180	227	126
18	245	135	165	204
19	221	124	206	128
20	241	177	262	193
21	107	86	82	44
22	171	115	174	134
23	123	87	131	87
24	161	101	186	129

Table E-5 Quadricep and hamstring Muscle endurance raw data (Repetitions)

Subject				
1	21	18	29	16
2	20	33	26	31
3	28	19	20	26
4	33	34	36	36
5	26	28	36	16
6	23	28	23	25
7	30	25	33	23
8	33	32	35	33
9	22	25	25	25
10	28	26	14	27
11	16	26	23	26
12	27	31	28	21
13	26	26	34	29
14	43	42	31	35
15	26	16	24	25
16	29	33	29	32
17	28	36	27	35
18	27	27	29	19
19	26	27	33	25
20	39	29	35	30
21	22	19	24	24
22	23	28	25	27
23	24	33	30	19
24	28	41	21	40

Table E -6 Limp Preference raw data

Subject	Preferred Hand	Preferred Leg	Take off Leg
1	R	R	
2	R	R	
3	R	R	
4	R	R	
5	R	R	
6	R	R	
7	L	L	
8	R	R	
9	R	R	
10	R	R	
11	R	R	
12	L	L	
13	R	R	
14	R	R	
15	R	R	
16	R	R	
17	R	R	L
18	R	R	R
19	R	R	L
20	R	R	L
21	R	R	L
22	L	L	L
23	R	R	L
24	R	R	R

APPENDIX F

ANOVA TABLES

Table F – 1 Quadricep Flexibility (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	56.333e	1	56.333	2.846	0.106
Group x preference	65.042	2	32.521	1.643	0.217
Error	415.625	21	19.792		

Table F- 2 Quadricep Flexibility between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	11.292	2	57.146	0.171	0.844
Error	7026.375	21	334.589		

Table F – 3 Hamstring Flexibility (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	0.187	1	0.187	0.017	0.897
Group x preference	40.625	2	20.313	1.849	0.182
Error	230.688	21	10.985		

Table F – 4 Hamstring Flexibility between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	1276.792	2	638.396	2.988	0.076
Error	4594.187	21	218.771		

Table F – 5 Quadriceps Concentric Strength (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	2.083	1	2.083	0.023	0.881
Group x preference	12.67	2	6.333	0.069	0.933
Error	1916.250	21	91.250		

Table F – 6 Quadriceps Concentric Strength between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	35749.500	2	17874.750	6.525	0.006
Error	57526.750	21	2739.369		

Significant at $P < 0.05$

Table F – 7 Hamstring Concentric Strength (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	204.188	1	204.188	0.788	0.385
Group x Preference	499.875	2	249.937	0.964	0.398
Error	5444.437	21	259.259		

Table F – 8 Hamstring Concentric Strength between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	18552.042	2	9276.021	5.750	0.010
Error	33880.437	21	1613.354		

Table F – 9 Quadriceps Eccentric Strength (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	126.750	1	126.750	0.507	0.484
Group x Preference	172.625	2	86.313	0.345	0.712
Error	5247.645	21	249.887		

Table F – 10 Quadriceps Eccentric Strength between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	52718.375	2	12859.187	3.463	0.050
Error	779990.62	21	3713.839		

Table F – 11 Hamstring Eccentric Strength (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	80.083	1	80.083	0.234	0.634
Group x Preference	206.167	2	103.083	0.301	0.743
Error	7195.750	21	342.655		

Table F – 12 Hamstring Eccentric Strength between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	15656.000	2	7828.000	4.455	0.024
Error	36899.250	21	1757.107		

Significant at $P < 0.05$

Table F – 13 Quadriceps Muscle Endurance (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	10.083	1	10.083	0.512	0.482
Group x Preference	34.042	2	17.021	0.864	0.436
Error	413.875	21	19.708		

Table F – 14 Quadriceps Muscle Endurance between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	23.042	1	11.521	0.228	0.798
Error	1060.875	21	50.518		

Table F – 15 Hamstring Muscle Endurance (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Preference	28.521	1	28.521	1.763	0.199
Group x Preference	8.167	2	4.083	0.252	0.779
Error	339.813	21	16.182		

Table F – 16 Hamstring Muscle Endurance between Groups (ANOVA)

Source	Sum of Squares	d.f	Mean Square	F	Significance
Group	41.167	2	20.583	0.283	0.756
Error	1527.312	21	72.729		

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