2024

Comparisons of Unilateral and Limb Symmetry Indexes Between Fixed Dynamometry Testing Modes

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An Honors Thesis submitted in partial fulfillment of the requirements for Honors in *Biodynamics and Human Performance.*

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ABSTRACT

Hamstring muscles strains are extremely common and can vary in severity. The biarticular structure of the hamstring groups is one reason that they are more susceptible to injuries. The recurrence of these injuries is also common even after they have been through a rehabilitation phase in their recovery. This project aims to compare and associate knee flexion and extension muscle performance characteristics between isometric, isotonic, and isokinetic assessment modes. These different modes of assessment will test analyze muscle performance under varying muscle lengths, movement velocities and biomechanical load modes. The data collected from this testing will be analyzed to see if each assessment test is providing different perspectives on muscle performances. Muscle injuries require proper healing and restrengthening periods, and there is a lingering debate on when it is safe for a patient to return to activity.

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May 2024
Biodynamics and Human Performance
Honors College
Georgia Southern University

Acknowledgements

I would like to thank my mentor Dr. Riemann for helping me with this study as well as the entire Biodynamics and human performance team, especially Kasey and Mat

Muscles play a critical role in the life of a human. Without muscles humans would be unable to move and function. Muscles have two primary functions: to generate motion and to generate force. Skeletal muscle is connected to bones to control body movement (Silverthorn, pp. 395-396). Muscles have to be able to perform efficiently to allow proper movement and performance levels.

The purpose of this research project is to compare and associate muscle performance characteristics between isometric, isotonic, and isokinetic assessment modes. To understand the definitions of isometric, isotonic, and isokinetic, it is important to know that the prefix iso- means same. Isometric contraction is when the "torque produced by the muscle is equal and opposite to the external torque" and there is no movement of the limb (Whiting, 2019, p. 82). In simpler terms, the muscle remains the same length throughout the muscle action. Isotonic muscle actions involve the muscle creating force to move a constant resistive load. (Silverthorn, pp. 395-396). Because the resistive torque remains the same, t the muscle is able to freely produce torque at varying velocities. Isokinetic muscle action is an action that occurs at a constant angular velocity (Whiting, 2019, p. 84). For example, the isokinetic dynamometer will remain at the same velocity that it is set to, no matter how hard the person performing the protocol is pushing. For that reason, isokinetic offers accommodating resistance and thus is the gold standard of muscle assessment in clinical environments. The examination of all three assessment modes will allow a full examination of muscle performance. This project will focus on the performance of the hamstring and quadriceps muscle groups. This project focuses on the knee joint, which is very commonly injured with disruptions in muscle function is a common sequela.

Of the three testing modes mentioned, isometric is commonly used first, followed by isokinetic. The current challenge of the isokinetic is with it not being a functional movement during physical activity. Isotonic, unlike isokinetic, allows for free acceleration that may be more representative of muscle function during physical activity

Specifically, the purpose of this investigation is to compare isometric, isotonic, and isokinetic assessment modes for evaluating knee flexion and extension muscle performance. Muscle performance will be evaluated using unilateral (hamstring to quadriceps ratios) and bilateral (dominant to nondominant) ratios. The hypothesis for this research is that the different assessment modes will show a difference in muscle performance between assessment modes and limb sides. The different perspectives will provide multiple areas of focus during a patients' rehabilitation period. The null hypothesis is that they will not provide any different muscle performances. However, we would like to see our alternative hypothesis being supported by a less than 0.5 magnitude correlation to support the premise that each is providing different perspectives of muscle performance. This would mean that the different perspectives would provide multiple areas of focus during patients' rehabilitation periods, which can help better train the muscles and prevent recurrence of their injuries.

Background and Rationale

Muscles are able to perform under stressful situations, while producing high amounts of forces through contraction; however, too much force can cause injury to the muscle. Another reason could be if these movements happen too quickly the possibility of an injury increases considerably (Whiting, 2019). Not only does shear force cause muscle injuries but also muscle weakness is another common risk factor for injuries. However, if the muscles are weak, they will not be able to tolerate the counter force being another muscle group, which will increase the risk of injury. Injuries that occur in skeletal muscles are common and can vary in severity. Muscle strains are divided into three different degrees depending on severity. The first degree is a mild strain where there are tears in a few muscle fibers with minor swells and little to no loss of strength. The second degree is moderate strain where there is a significant amount of muscle fibers torn, and there is a considerable amount of swelling. The third degree is severe and is characterized by a complete tear across the muscle body with total loss of muscle function (Järvinen, 2000, p. 155).

Muscle injuries, along with any other injury, takes time to heal. Sometimes, depending on the severity, muscle tears can sometimes require surgeries and a rehabilitation period overseen by a physical therapist. When muscles are healed, they often exhibit weakness due to the trauma of the strain and the fact that they have not been used. Even when the primary injury has been resolved, the residual muscle strength and power deficits can still be present. Physical therapists work to restore the patient to their normal functional ability in order to move and function in an efficient manner. There are three basic phases of rehabilitation. Phase one is to restore static stability, phase two is to restore dynamic stability, and phase three is to restore and develop neuromuscular control (Whighting, 2019). With time and training patients will eventually be able to return to their daily lifestyle. Unfortunately, the length of the rehabilitation period is hard to determine because every patient is different. Some patients will simply need to just perform an average functional level, and some will require more training to regain high level abilities. For example, an elderly patient will have different demands than a high school athlete. However, when it comes to the rehabilitation period, it is hard to determine when a patient is ready to return to activity.

The importance of this project is to analyze the difference between these three modes of performance to help spot muscle weakness, discrepancies, and to evaluate the muscle performance. This evaluation will compare and associate these muscle performances and will compile data to help determine when it is safe for a patient to return to activity. This data is important to look at, because if this testing recognizes muscle weakness or discrepancies, then it would be unsafe for the patient to return to their daily activities, and they would need additional work to fully regain their abilities. The full recovery of the patient is also important to prevent recurrence of the injury. If there is weakness or defects left unchecked, that could lead to re-injury and would once again put the patient back at the starting line of their rehabilitation period. The goal is to recover the patient and enhance their abilities, to decrease the chance of them getting injured again. This project can help determine whether or not it is safe for the patient to return to activity.

There is an infinite amount of research on knee injuries, the rehabilitation periods, and protocols for how to progress the patient. However, there is no research that compares the isometric, isokinetic, and isotonic contractions to each other in order to see the different muscle performance levels. There are various opinions on which techniques are best for rehabilitation; however, this experiment will help isolate training areas and areas of muscle function that need to be addressed.

The data that will be used during this project will be collected using the Biodex System 4. Muscle dynamometry is a frequently used method of assessing muscle performance. Volunteers will be brought in to assess their muscle strengths and endurances. Isometric, isotonic, and isokinetic contractions assessments will be used to evaluate voluntary muscle performances, such as strength and endurance. Isometric assessment methods consist of a voluntary contraction where the joint angle and muscle length do not change. Since the isometric tests are angle specific, there will be multiple tests run at different angles to obtain data about muscle performance through a range of motion. Isotonic muscle contractions refer to a concentric or eccentric contraction where there is no appreciable change in the load on the muscle. With the isotonic methods of strength assessment, the outcome measure is typically the actual or estimated one repetition maximum load which is then used as a reflection of maximal strength. Isokinetic assessment methods evaluate performance of the muscle group through a set range of motion at a set constant velocity and evaluate concentric and eccentric strength. Isokinetic testing on the Biodex System 4 provides peak and average torque, work, power, and coefficient of variability.

METHODS

All of the protocols in this study were approved by the Georgia Southern University Institutional Review Board and all patients signed a written informed consent form at the beginning of their laboratory session.

Participants

This study had a sample size of twenty participants, thirteen of which were women and seven were males. All of our participants had an age between the age of 18 and 45. All participants were healthy individuals that participated in regular recreational activity and were screened for any medical issues prior to being allowed to participate in the laboratory session. None of the participants hand any history of knee injuries.

Procedures

Each participant had a 60-minute laboratory session that included a five-minute warm up at the start of the session that followed their paperwork. Each warm-up consisted of 5 squats, 5 lunges on both legs, and 5 power skips on both legs. After the warmup the participant went through the muscle dynamometry protocol. There were 3 dynamometry modes used for assessment. The isometric mode was set at 30 degrees of knee flexion and 60 degrees of knee flexion. The isokinetic mode used 60 degrees per second, 120 degrees per second, and 240 degrees per second as constant velocities. The isotonic protocol used 15 percent of the participants' peak torque at 60 degrees of knee flexion. This study used a between participant randomized order, meaning each participant had a different randomized order of protocols

For the Biodex set up (Figure 1) each participant has padded straps across their chest, pelvis, and thigh. They also have padded cuff at the distal end of the knee attachment that secures the attachment. Both the chair and dynamometer can be moved to allow for knee joint axis alignment with the dynamometer. Additionally, the position of the seatback is adjustable by a crank mechanism.

Figure 1- Biodex Set up

Statistical Analysis

For the statistical analysis we used the peak torque from the isometric and isokinetic modes and the peak velocity from the isotonic mode. We examined normality and sphericity of the data using an exploratory data analysis. Following normality and sphericity we were able to use two separate two by six repeated measures ANOVAs, one for unilateral ratios comparing hamstrings to quadriceps, and one for limb symmetry indexes hamstrings and quadriceps. If any statistical significance is reached a Bonferroni pairwise post hoc test to reduce the chance of a type one error. In order to reach statistical significance, we must obtain an alpha level less than 0.05.

RESULTS

There were no significant differences (Figure 2) between the dominant and nondominant limbs as evidenced by the mode by limb interaction ($F_{5,95}$=1.81, P=.118, η^2_p=.087) and limb main effect ($F_{1,19}$=0.97, P=.337, η^2_p=.049). There was a significant difference for test mode ($F_{5,95}$=81.1, P<.001, η^2_p=.810). Post hoc analysis (Figure 3) revealed the hamstring to quadriceps ratios to be significantly higher for the isometric 30° and isotonic tests compared to the isometric 60°, isokinetic 60°/s, isokinetic 180°/s and isokinetic 240°/s.

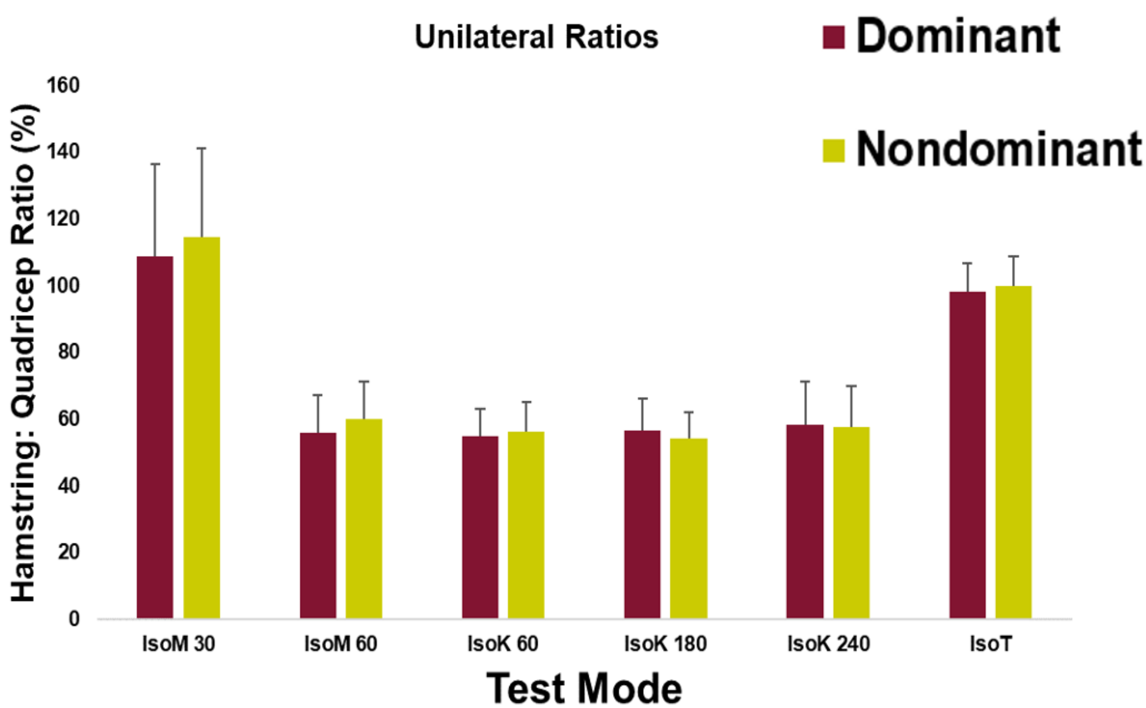

Figure 2 - Statistical analysis for the unilateral ratios: On the horizontal axis there is the test mode, and on the vertical axis is the hamstring to quadricep ratio percentage. The red bar represents the dominant limb, and the yellow bar represents the nondominant limb. The lines above each bar represent one standard deviation from the mean. With this graph we found that the interaction between the limb and test mode was not statistically significant.

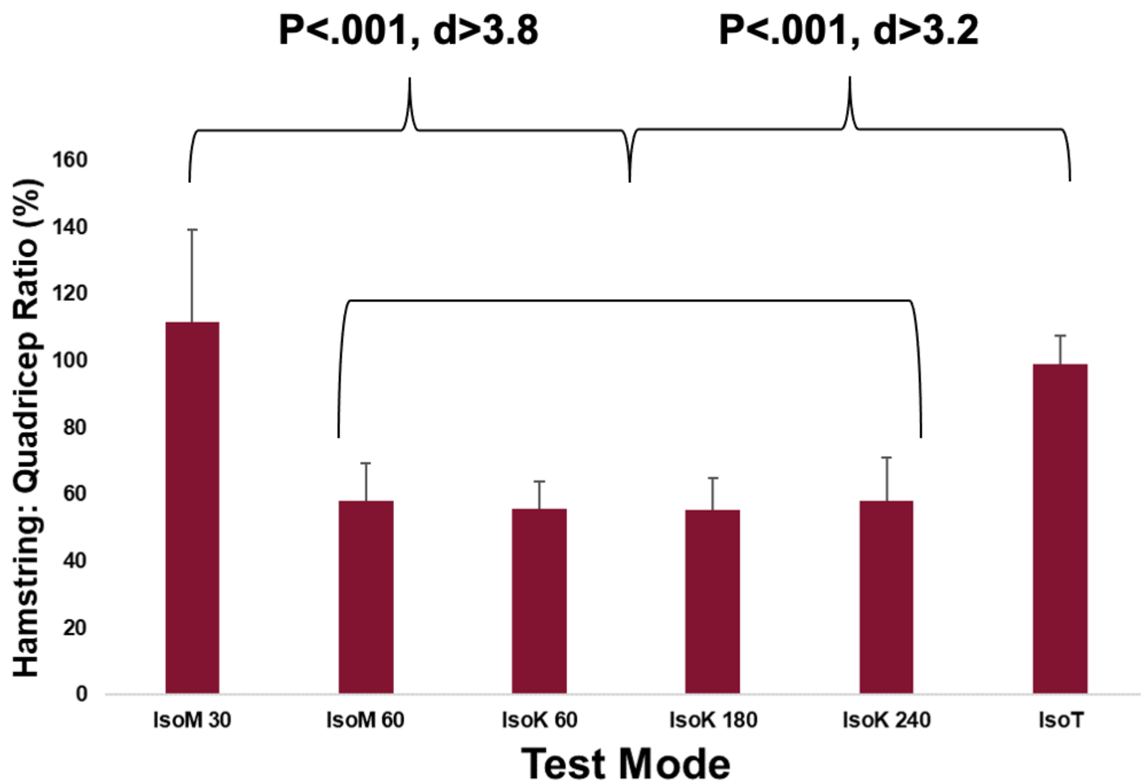

Figure 3 - Statistical analysis for the unilateral ratios: On the horizontal axis there is the test mode, and on the vertical axis is the hamstring to quadricep ratio percentage. The red bar represents the data from both dominant limb and the nondominant limb. The lines above each bar represent one standard deviation from the mean. Here we collapsed our data for dominant limb and the nondominant limb to look at the test modes. According to our data there is a main effect for test mode. The Bonferroni adjusted post hocks revealed no difference between isometric 60 and the three isokinetic ratios. However, both the isometric 60 and Isotonic ratios were significantly greater than Isom 60 and the Isokinetic ratios with standardized effect sizes greater than 3.2, which is how far apart in standard deviation units.

There were no significant differences (Figure 4) between directions ($F_{1,19}$=0.45, P=.509, η^2_p=.023), test modes ($F_{5,95}$=.419, P=.834, η^2_p=.022) nor the direction by test mode interaction ($F_{5,95}$=1.83, P=.114, η^2_p=.088).

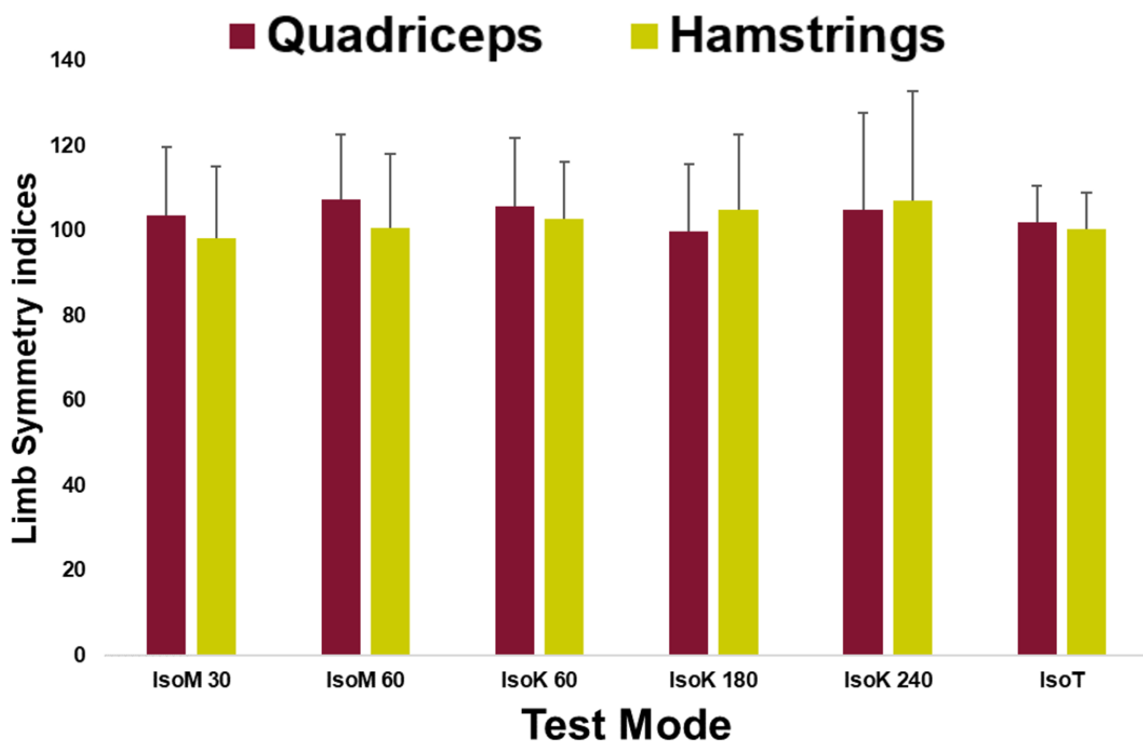

Figure 4 - Statistical analysis is for the limb symmetry indices: On the horizontal axis there is the test mode, and on the vertical axis is the limb symmetry indices. ratio percentage. The red bar represents the quadriceps, and the yellow bar represents the hamstrings. The lines above each bar represent one standard deviation from the mean. With this graph we found that the limb symmetry indices had no significant effects for direction of mode.

DISCUSSION

Ultimately, these results support clinicians making bilateral comparisons in their return to activity decisions. These results help us formulate a continuum of return to activity dynamometry battery following injury. This research consisted of a novel comparison of isotonic dynamometry to traditional isometric and isokinetic testing. Another unique aspect of this study was the consideration of two isometric knee positions: 30 degrees of knee flexion and 60 degrees of knee flexion.

References

Järvinen, T. A., Kääriäinen, M., Järvinen, M., & Kalimo, H. (2000). Muscle strain injuries. *Current opinion in rheumatology*, *12*(2), 155-161. Accessed on April 29, 2023.

Silverthorn, D. U. (2019). *Human Physiology: An Integrated Approach* (8th ed.). Pearson Education Inc. Accessed on April 29, 2023.

Whiting, W. C. (2019). *Dynamic Human Anatomy* (2nd ed.). Human Kinetics. Accessed on April 29, 2023.