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Electromyographic Activity of Hamstrings and Quadriceps Muscles during Jumping and Landing: Pilot Study

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This Scholarly Project, submitted by Joseph Burckhard, Tyler Kemnitz, Mikaela Dick and Alexandria Sweeney in partial fulfillment of the requirements for the Degree of Doctor of Physical Therapy from the University of North Dakota, has been read by the Advisor and Chairperson of Physical Therapy under whom the work has been done and is hereby approved.

(Graduate School Advisor)

(Chairperson, Physical Therapy)

PERMISSION

Title Electromyographic Activity of Hamstrings and Quadriceps Muscles During Jumping and Landing: Pilot Study

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ABSTRACT

Background and Purpose. The purpose of this pilot study was to find if there was a difference in the activation and firing time of the quadriceps (vastus medialis and vastus lateralis) compared to activation times of the hamstrings (biceps femoris and semitendinosus) in active males and females.

Methods

Subjects consisted of two male and two female athletes in good physical condition with no previous knee pathologies. During each of the trials, the muscle activity of each muscle was recorded. The EMG activity recorded using a Noraxon† TeleMyo2400 G2 telemetry unit with a sampling rate of 1 kHz which was transmitted to a TeloMyo PC interface card connected to a laptop computer. Data analysis was performed using the MyoResearch XP 1.07 software. EMG activity was recorded by placing Blue Sensor (model M-00-S) surface electrodes on the skin over each of the muscles under study. Before applying the electrodes, skin was cleansed with isopropyl alcohol. The electrodes were placed in accordance with standardized lead positions.[1,2] A foot switch placed inside the shoe was used to determine when the subject's foot was on or off the ground. The electrodes were placed on the vastus medialis, vastus lateralis, biceps femoris, and semitendinosus. The participants were then asked to perform a series of five consecutive jumps. EMG data was collected during five consecutive jumps from each participant. A marker was placed at the beginning and end of each jump to indicate the time that the foot was on the floor between jumps. A Noraxon Standard Timing Analysis was used to measure onset time and firing

order for the four muscles. A threshold of both 2 and 3 standard deviations (SD) was used as the criteria for onset activity. A Noraxon Standard EMG Analysis was used to compare the muscle activity during the jump activity with the MVC activity and reported as a percent of the MVC.

Results

The results of this study showed the male subjects splitting dominance between hamstring and quadriceps muscle activation in regards to which muscle fired first when landing after a jump. Female subjects showed greater quadriceps activity than hamstring activity, and the quadriceps appeared first in the firing order. One female participant showed very little hamstring electromyography (EMG) activity upon landing a jump. Strength training that targets the hamstring muscle group, and that maintains a good quadriceps to hamstring ratio should be utilized to try and prevent injury of the ACL, especially in female athletes.

Conclusion

Further research is needed to confirm these conclusions and demonstrate clinical relevance.

CHAPTER I

Introduction

The purpose of this pilot study was to find if there was a difference in the activation and firing time of the quadriceps (vastus medialis and vastus lateralis) compared to activation times of the hamstrings (biceps femoris and semitendinosus) in active males and females. In the past, athletes that showed dominance of the quadriceps (females in particular) were more vulnerable to anterior cruciate ligament (ACL) injury. Current research has shown that the ratio of quadriceps to hamstring activation throughout exercise, has been related to the incidence of ACL injury. However, current research lacks analysis of the specific firing order of these muscle groups. This study was conducted to look at the specific firing times of these muscle during the landing phase from five consecutive vertical jumps. Researchers of this pilot study hypothesized the male participants' hamstring muscles would fire first prior to the quadriceps. Researchers predicted the female participants would present with the opposite results, with the quadriceps firing, and potentially dominating, the landing phase. This hypothesis is derived from the overabundance of evidence indicating a higher prevalence of ACL injuries amongst female athletes.

CHAPTER II

Methods

During each of the trials, the muscle activity of each muscle was recorded. The EMG activity recorded using a Noraxon† TeleMyo2400 G2 telemetry unit with a sampling rate of 1 kHz which was transmitted to a TeloMyo PC interface card connected to a laptop computer. The digitized information was stored on a laptop computer. Data analysis was performed using the MyoResearch XP 1.07 software. EMG activity was recorded by placing Blue Sensor (model M-00-S) surface electrodes on the skin over each of the muscles under study. The muscles that were monitored were the: 1) vastus lateralis, 2) vastus medialis, 3) biceps femoris and 4) semitendinosus. Before applying the electrodes, the skin was cleansed with isopropyl alcohol. The electrodes were placed in accordance with standardized lead positions.1,2 A foot switch placed inside the shoe was used to determine when the subject's foot was on or off the ground. The EMG and footswitch outputs were connected to the TeleMyo 2400 G2 transmitter, worn on a belt pack and transmitted to the Telemyo PC interface card connected to a laptop computer.

CHAPTER III

Results

Using the muscle activation criteria of 3 standard deviations, the male participants demonstrated EMG activity in the biceps femoris and semitendinosus earlier than EMG activity in the quadriceps on landing from the jumps. The female participants tended to show EMG activity in the quadriceps prior to activity in the hamstrings. Using the muscle activation criteria of 2 SD , the results showed the activation of the semitendinosus to precede that of the quadriceps. Table 1 shows the results for participants EMG activity with 3 SD from the mean voltage. In this data analysis, three subjects recorded firing the VLO first, while one subject fired the semitendinosus first. Table 2 demonstrates 2 SD from the mean voltage, meaning that less muscle EMG activity was required for a muscle to reach firing levels (in comparison to Table 1). In this data analysis, three subjects fired the semitendinosus first and one subject fired the VMO first followed by semitendinosus. Because of the anterior sheer force exerted on the tibiofemoral joint by the quadriceps muscles after a jump, if the hamstrings lack the optimal contraction necessary to counter the quadriceps contraction the anterior shear of the tibia may put excessive tension on the ACL. Previous research has hypothesized that females may have a reduced or slower contraction of the biceps femoris and semitendinosus in the firing order in comparison to the vastus medialis and vastus lateralis resulting in excessive tension on the ACL which could explain the increased prevalence of ACL tears in

females as opposed to males. However, the results of this pilot study showed a great amount of variability depending on the criteria used in analysis of the muscle timing.

Table 1. Firing Order of the Quadriceps and Hamstrings Using 3 SD Criteria

FIRING ORDER	VLO	VMO	Biceps Femoris	Semitendinosis
Subject 1 (F)	1	---	2	3
Subject 2 (F)	1	---	---	---
Subject 3 (M)	1	---	2	---
Subject 4 (M)	3	---	1	2

Vastus Lateralis Oblique (VLO), Vastus Medialis Oblique (VMO)
*Indicates that the information did not meet the criteria of 3 SD for analysis.

Table 2. Firing Order of the Quadriceps and Hamstrings Using 2 SD Criteria

FIRING ORDER	VLO	VMO	Biceps Femoris	Semitendinosus
Subject 1 (F)	4	1	3	2
Subject 2 (F)	3	4	2	1
Subject 3 (M)	2	3	4	1
Subject 4 (M)	3	4	2	1

Vastus Lateralis Oblique (VLO), Vastus Medialis Oblique (VMO)

CHAPTER IV

Discussion and Limitations

The recruitment of the quadriceps versus the hamstring muscle group in regards to ACL injuries has been a debated topic for many years. In this research study, data analysis of the quadriceps to hamstring activation times showed females may activate the quadriceps (particularly the VLO) more readily than the hamstrings during jumping and landing. This may relate to the high incidence of female athletes that have an injury to the ACL during sports that require a quick landing and twisting movement due to the anterior shear unbalance quadriceps activation may have on the ACL. Research has shown that the quadriceps to hamstring ratio is significant in preventing ACL injuries, and it requires a balance between the two major muscle groups, since the hamstrings act to prevent the anterior translation of the tibia on the femur. In summary, our findings were not enough to make a generalized statement about the recruitment and timing of the quadriceps versus hamstring muscle groups. However, since this is a pilot study, it is the belief of these researchers to would recommend further exploration into the activation time and recruitment instead of emphasizing the muscle strength. However, further exploration in subsequent studies that analyze the activation timing between quadriceps and hamstrings firing rates may be beneficial in analyzing the discrepancies between ACL tear frequency in men and women.

Limitations

This pilot study had significant limitations that must be considered when analyzing the quality of the results. The experimenters had difficulty obtaining sufficient readings from the footswitch utilized during data collection. This resulted in multiple retests as well as potentially inaccurate readings collected by the experimenters. In subsequent studies analyzing the firing rate of the thigh musculature, a more reliable footswitch and method of data collection should be utilized for more valid results. This study was also a pilot study used to explore the possibility of a difference in firing order between males in females. Therefore, only four participants were involved in the study. Future studies exploring this topic should use more participants to allow for a better representation of the athletic population. Three standard deviations above of the average voltage of the muscular contraction read from the EMG in a given timeframe was the method of determining a reliable muscle contraction by the researchers. When utilizing the three standard deviations of EMG activity (which is common amongst researchers analyzing EMG activity), it was found that many of the participants' muscle contractions did not meet the criteria thus leaving the researchers without valid information regarding firing order of the thigh musculature. More effective EMG collection methods and larger number of participants are two ways to improving the limitations of this study. The EMG analysis software utilized in this pilot study to analyze the EMG results was new to the researchers. Unfamiliarity with the software may have potentially resulted in errors of the study and data analysis.

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