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

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A Scholarly Project Submitted to the Graduate Faculty of the

Department of Physical Therapy

School of Medicine

University of North Dakota

in partial fulfillment of the requirements for the degree of

Doctor of Physical Therapy

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This Scholarly Project, submitted by Shawn Danielson, Logan Flegel, Nathan Mertens, and Isaiah Schwindt 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 Muscle During Jumping and Landing: Pilot Study

Department Physical Therapy

Degree Doctor of Physical Therapy

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ACKNOWLEDGEMENTS

Thank you to all the participants who gave their time to participate in this research study. Thank you to our advisor, Thomas Mohr, for guiding us in this process and assisting with collection and synthesis of data.

ABSTRACT

Background and Purpose. The purpose of this pilot study was to see if there was a difference in the amount of electromyographic (EMG) activity in the quadriceps (vastus medialis and vastus lateralis) compared to the amount of EMG activity in the hamstrings (biceps femoris and semitendinosus) muscles in active male and female subjects during vertical jumping and landing. In addition, we looked at the amount of knee flexion that occurred shortly after landing from a vertical jump. **Methods.** EMG activity was recorded using a Noraxon† TeleMyo DTS telemetry unit with a sampling rate of 1 kHz. EMG data was recorded during vertical jumping and landing. EMG activity in the quadriceps muscle and hamstring muscles were monitored during the experiment. The subject was also captured on video using the NiNox 125/250 FPS camera system. Subjects consisted of four male and six female athletes in good physical condition with no previous knee pathologies. **Results.** Differences were found in the quadriceps to hamstrings ratio when comparing female to male participants in both single jump (Female 4.31:1, Male 2.41:1) and triple jump landing (Female 3.56:1, Male 2.0:1). Females generally showed higher percent of maximal voluntary contraction in the quadriceps than the males when compared for both jumps. The amount of knee flexion upon landing were similar between genders in both the single and triple jump/landing test. **Conclusion.** The results of this study

showed quadriceps dominance in females as compared to males when landing from a jump. Previous studies have theorized that this level of dominance creates tensile force on the ACL, leading to increased incidence of ACL tears. Strength training focused on hamstring activation with a proper quadriceps to hamstrings ratio should be implemented when preventing ACL injuries especially in the female population. Further research is needed to confirm these conclusions and demonstrate clinical relevance.

CHAPTER 1

Methods

EMG activity was recorded using a Noraxon TeleMyo DTS telemetry unit with a sampling rate of 1 kHz. The EMG data was recorded from the vastus medialis, vastus lateralis (quadriceps), biceps femoris and semitendinosus (hamstrings) muscles using the Noraxon Model 546 DTS EMG sensor system which transmitted the EMG data to a Noraxon Model 580 DTS receiver connected to a laptop computer which stored the collected data. The Noraxon MyoVideo system, using a NiNox 125/250 camera system was used to record the knee motion.

The muscles tested were on the right side on all subjects. Before applying the EMG electrodes the skin was abraded and cleaned. The DTS sensors were attached to skin using double stick tape. The EMG electrodes were placed according to standard placement sites.1,2

A footswitch pad was placed in the right shoe of each subject to detect the times when the subject's foot left the floor and when the subject's foot first touched the floor after landing from the jumps. Before beginning the jump activities, a maximal voluntary contraction (MVC) was elicited from each of the four muscles using a standard manual muscle test position. The MVC was performed to establish a normalization baseline for comparison of the individual subject's EMG activity.

Ten subjects participated in the experiment. Four of the subjects were male and six of the subjects were female. All of the subjects were healthy, active college students with no prior history of knee injuries.

CHAPTER II

Results

In single jump landing, both the male and female participants demonstrated higher levels of quadriceps activity than hamstring activity as measured by percent maximum voluntary contraction (%MVC) (Figure 1). The %MVC of quadriceps activity in both female participants was higher than in males. The vastus medialis demonstrated a slightly greater %MVC contraction than the vastus lateralis (127% vs 126%, respectively) in the female participants. The vastus medialis demonstrated a slightly lower %MVC contraction than the vastus lateralis (61% vs 65%, respectively) in the male participants. The hamstring muscle that showed the lowest %MVC was the semitendinosus in both the male and female participants.

The ratio of the quadriceps to the hamstring muscles for the single jump in males was 2.41:1 as compared to 4.31:1 in females. The male subjects demonstrated similar degrees of knee flexion upon landing, with the lowest subject at 87.5 degrees and the highest at 101 degrees (Figure 3). Female subjects had more variable knee flexion upon landing, with one showing 118 degrees and another 74.6 degrees of knee flexion.

During triple jump landing, female participants demonstrated the greatest EMG activity in the vastus medialis (Figure 2). Once again, the smallest %MVC activity was demonstrated in the semitendinosus for both gender groups. The

ratio of the quadriceps to the hamstring muscles in males was 2.0:1 as compared to 3.56:1 for females. In the triple jump, the females had a higher degree of knee flexion as compared to their results in the single jump, and as compared to males (Figure 3). The female subjects demonstrated 97.3 degrees and 98.5 degrees of maximal knee flexion upon landing from the jumps. The male subjects demonstrated 95.9 degrees and 96.7 degrees of knee flexion upon landing.

Figure 1. Quadriceps and Hamstring Activity During Single Jump Landing.

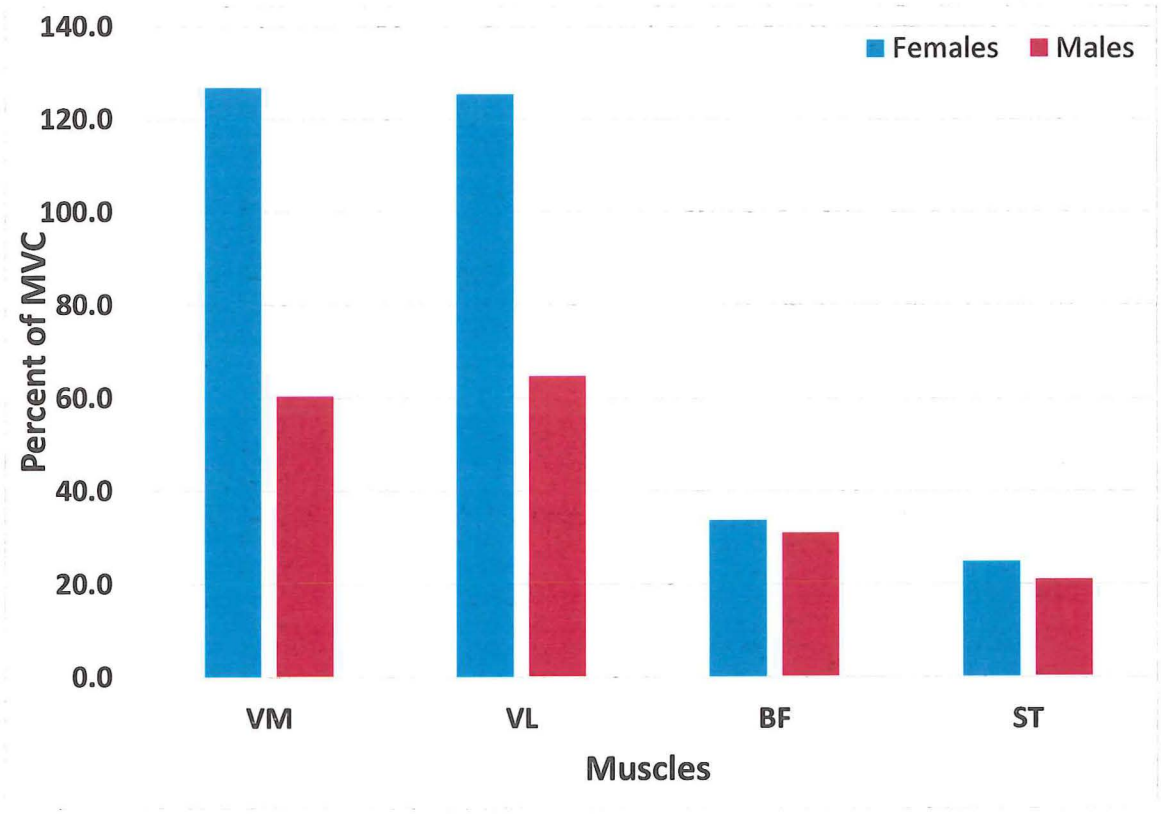


Figure 2. Quadriceps and Hamstring Activity During Triple Jump Landing.

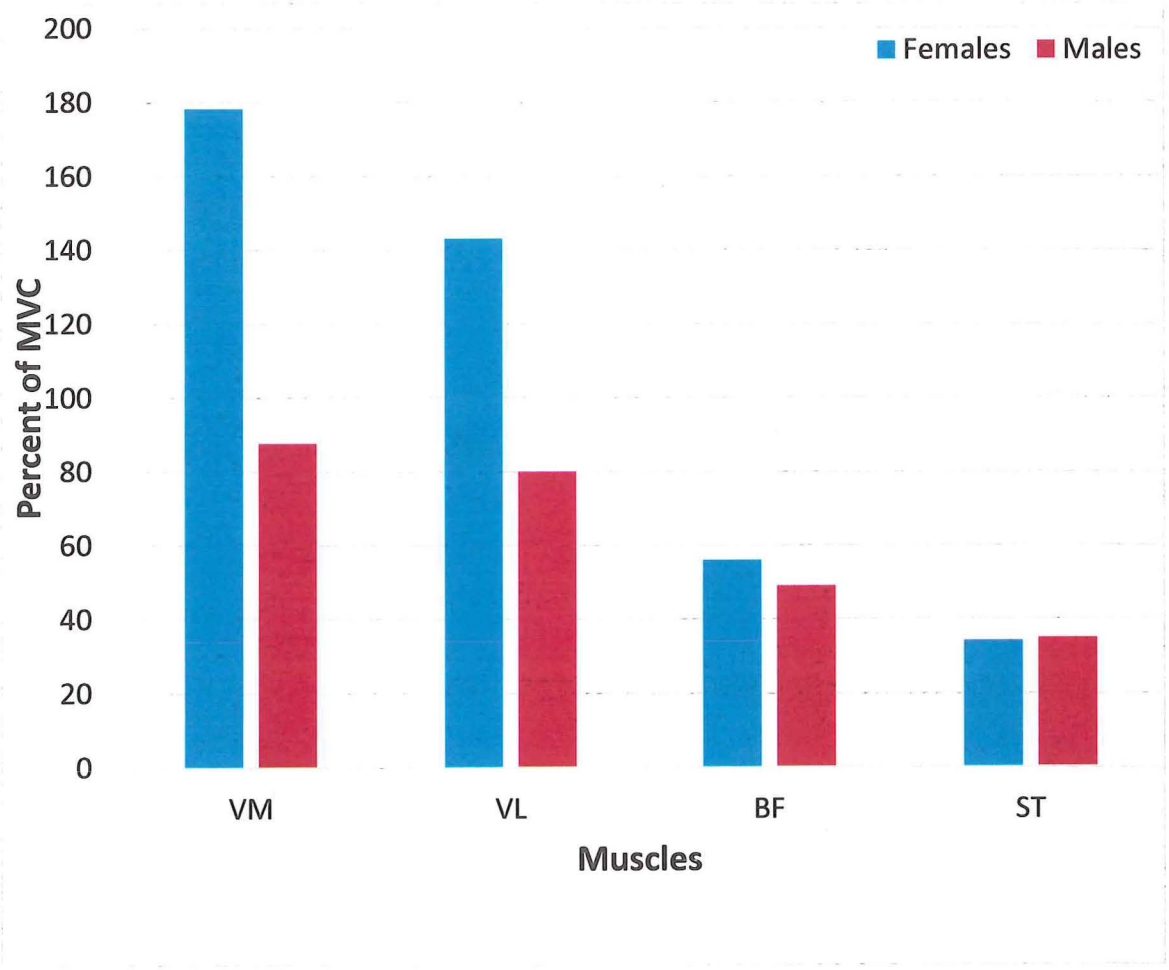
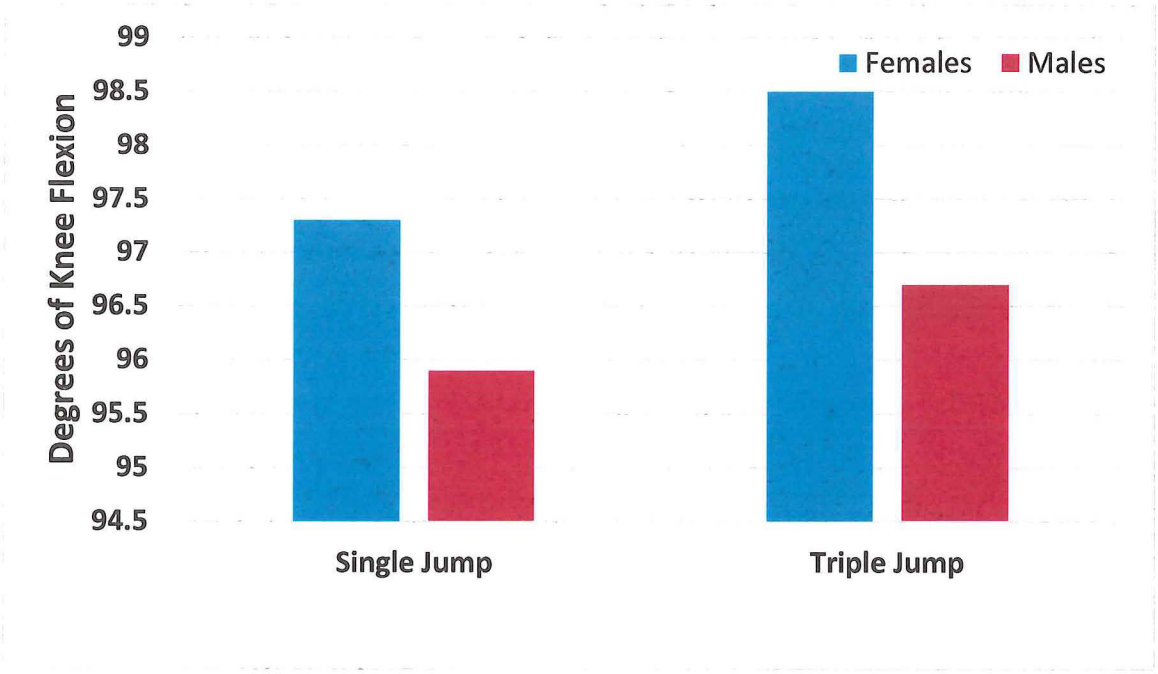


Figure 3. Maximum Knee Flexion During Jumping and Landing.



CHAPTER III

Discussion/Limitations

The results of this study appear to agree with previous studies regarding the quadriceps to hamstring muscles ratio in males versus females during jumping and landing. That is, females tend to use a higher level of muscle contraction in their quadriceps relative to their hamstring muscles than males, during landing from a jump. A literature review found that multiple articles that have analyzed the quadriceps to hamstring muscles ratio between males and females showing differences in quadriceps and hamstring activity between males and females when landing from a jump.[3-5] Ebben et al.[6] found that men demonstrated greater lateral and medial hamstring activation than women during jump landings and cutting. Men also showed greater pre-contact activation of both medial and lateral hamstrings than women. These findings are consistent with the results of our study. Other research has shown knee flexion upon landing from a jump to be negatively correlated with quadriceps dominance in individuals.[2] The dominance of the quadriceps causes a lack of knee flexion which increases the anterior translation of the tibia and increases the tensile force on the ACL upon landing from a jump. This landing strategy may lead to a predisposition for ACL injuries.

Previous studies have examined the value of hamstring training to lower the quadriceps to hamstring muscles ratio when jumping and prevent injury. A recent systematic review found that two legged squats were not effective in improving the quadriceps to hamstring muscles ratio in participants.[7] The same authors found single leg exercises that were performed between 30 and 90 degrees of knee flexion improved the quadriceps to hamstring muscles ratio in participants. It was concluded that single leg exercises are preferred to reduce quadriceps dominance an anterior tensile force on the ACL.

Limitations

There were only ten participants involved in this study to explore the differences in EMG activity between males and females. Future studies should include more participants to allow a better representation with adequate power to allow statistical analysis. The study did not take into account the athletic level of participants, which may result in subject variation.

CHAPTER IV

Conclusions

Prior research has shown that the quadriceps to hamstring muscles 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. Although we did find differences in EMG activity between the male and female participants, this study was a pilot study and our findings were not significant enough to make a generalized statement about the recruitment of the quadriceps versus hamstring muscle groups. However, since this is a pilot study, we recommend further exploration into the activation time and recruitment in addition to the muscle strength between male and females that might account for the differences in EMG activity during jumping and landing.

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

By: Isaiah Schwindt, Logan Flegal, Nathan Mertens, Shawn Danielson

UND SCHOOL OF MEDICINE & HEALTH SCIENCES
THE UNIVERSITY OF NORTH DAKOTA

Abstract

Background and Purpose. The purpose of this pilot study was to see if there was a difference in the amount of electromyographic (EMG) activity in the quadriceps (vastus medialis and vastus lateralis) compared to the amount of EMG activity in the hamstrings (biceps femoris and semitendinosus) muscles in active male and female subjects during vertical jumping and landing. In addition, we looked at the amount of knee flexion that occurred shortly after landing from a vertical jump.

Methods
EMG activity was recorded using a Noraxon† TeleMyo DTS telemetry unit with a sampling rate of 1 kHz. EMG data was recorded during vertical jumping and landing. EMG activity in the quadriceps muscle and hamstring muscles were monitored during the experiment. The subject was also captured on video using the NiNox 125/250 FPS camera system. Subjects consisted of four male and six female athletes in good physical condition with no previous knee pathologies.

Results
Differences were found in the quadriceps to hamstrings ratio when comparing female to male participants in both single jump (Female 4.31:1, Male 2.41:1) and triple jump landing (Female 3.56:1, Male 2.0:1). Females generally showed higher percent of maximal voluntary contraction in the quadriceps than the males when compared for both jumps. The amount of knee flexion upon landing were similar between genders in both the single and triple jump/landing test.

Conclusion
The results of this study showed quadriceps dominance in females as compared to males when landing from a jump. Previous studies have theorized that this level of dominance creates tensile force on the ACL, leading to increased incidence of ACL tears. Strength training focused on hamstring activation with a proper quadriceps to hamstrings ratio should be implemented when preventing ACL injuries especially in the female population. Further research is needed to confirm these conclusions and demonstrate clinical relevance.

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Results

In single jump landing, both the male and female participants demonstrated higher levels of quadriceps activity than hamstring activity as measured by percent maximum voluntary contraction (%MVC) (Figure 1). The %MVC of quadriceps activity in both female participants was higher than in males. The vastus medialis demonstrated a greater %MVC contraction than the vastus lateralis in the female participants. The quadriceps muscle that showed the lowest amount of activation in both males and females was the vastus medialis. The hamstring muscle that showed the lowest %MVC was the semitendinosus. The ratio of the quadriceps to the hamstring muscles for the single jump in males was 2.41:1 as compared to 4.31:1 in females.

The male subjects demonstrated similar degrees of knee flexion upon landing, with the lowest subject at 87.5 degrees and the highest at 101 degrees (Figure 3). Female subjects had more variable knee flexion upon landing, with one showing 118 degrees and another 74.6 degrees of knee flexion.

During triple jump landing, female participants demonstrated the greatest EMG activity in the vastus medialis (Figure 2). Once again, the smallest %MVC activity was demonstrated in the semitendinosus for both gender groups. The ratio of the quadriceps to the hamstring muscles in males was 2.0:1 as compared to 3.56:1 for females. In the triple jump, the females had a higher degree of knee flexion as compared to their results in the single jump, and as compared to males (Figure 3). The female subjects demonstrated 97.3 degrees and 98.5 degrees of maximal knee flexion upon landing from the jumps. The male subjects demonstrated 95.9 degrees and 96.7 degrees of knee flexion upon landing.

Discussion/Limitations

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Previous studies have examined the value of hamstring training to lower the quadriceps to hamstring muscles ratio when jumping and prevent injury. A recent systematic review found that two legged squats were not effective in improving the quadriceps to hamstring muscles ratio in participants.[7] The same authors found single leg exercises that were performed between 30 and 90 degrees of knee flexion to improve the quadriceps to hamstring muscles ratio in participants. It was concluded that single leg exercises are preferred to reduce quadriceps dominance an anterior tensile force on the ACL.

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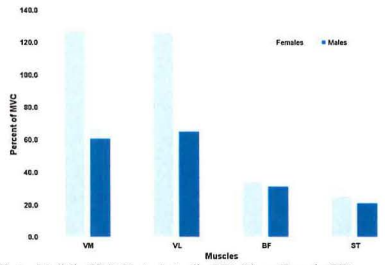
Experiments

Figure 1. Quadriceps and Hamstring Activity During Single Jump Landing.



Vastus Medialis (VM), Vastus Lateralis (VL), Biceps Femoris (BF), Semitendinosus (ST)

Figure 2. Quadriceps and Hamstring Activity During Triple Jump Landing.

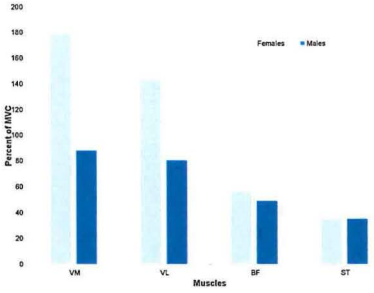
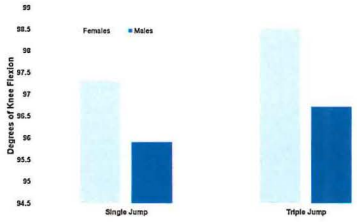


Figure 3. Maximum Knee Flexion During Jumping and Landing.



Conclusions

Prior research has shown that the quadriceps to hamstring muscles 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. Although we did find differences in EMG activity between the male and female participants. Since this study was a pilot study, our findings were not significant enough to make a generalized statement about the recruitment of the quadriceps versus hamstring muscle groups. We recommend further exploration into the activation time and recruitment in addition to the muscle strength between male and females that might account for the differences in EMG activity during jumping and landing.

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