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

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

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Department of Physical Therapy

School of Medicine

University of North Dakota

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Doctor of Physical Therapy

Grand Forks, North Dakota  
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# Electromyographic Activity of Hamstrings and Quadriceps Muscle During Jumping and Landing: Pilot Study

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## Abstract

**Background and Purpose.** The purpose of this pilot study was to see if there was a difference in amount of electromyographic (EMG) activity in the quadriceps (vastus medialis and vastus lateralis) compared to 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 two male and two 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 4.42:1, Male 2.38:1) and triple jump landing (Female 5.46:1, Male 1.90:1). Females generally showed higher percent of maximal voluntary contraction in the quadriceps than the males when compared for both jumps. Remarkable differences in knee flexion upon landing were not found between genders in either 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.

## 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 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 EMG data was analyzed using the Noraxon MR3 Myomuscle software program. The Noraxon Myovideo system, using a NiNox 125/250 camera system was used to record the knee range of motion. The video camera was synced to the EMG data collection. The muscles tested were the right sided vastus lateralis, vastus medialis, biceps femoris and semitendinosus on each subject. Each subject was asked to perform a maximal voluntary contraction (MVC) of the quadriceps and hamstring muscles prior to testing. The maximal voluntary contraction was used to calculate percent of MVC. Three single jumps and three successive jumps were performed by each subject. 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. Graphs were constructed showing the percentage of EMG activity for all the muscles during the jumps and the maximal amount of knee range of motion that occurred during each of the jumps.

## 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 lateralis demonstrated a greater %MVC contraction than the vastus medialis in the female participants. The quadriceps muscle that showed the lowest amount of activation in both males and females was the vastus lateralis. 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 2.38:1 as compared to 4.42:1 in females.

The male subjects demonstrated similar degrees of knee flexion upon landing, with one subject at 95.9 degrees and the other at 99 degrees (Figure 2). Female subjects had more variable knee flexion upon landing, with one showing 109 degrees and the other 74.6 degrees of knee flexion.

During triple jump landing, female participants demonstrated the greatest EMG activity in the vastus medialis (Figure 3). 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 1.9:1 as compared to 5.46:1 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 4). The female subjects demonstrated 103 degrees and 101 degrees of maximal knee flexion upon landing from the jumps. The male subjects demonstrated 95.9 degrees and 90.3 degrees of knee flexion upon landing.

## Discussion/Limitations

The results of this study appears to agree with previous literature regarding the quadriceps to hamstring muscles ratio in males versus females. 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.<sup>1-3</sup> Ebben et al.<sup>4</sup> 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.<sup>2</sup> The dominance of the quadriceps causes a lack of knee flexion caused by dominant quadriceps activity which increase 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 to not be effective in improving the quadriceps to hamstring muscles ratio in participants.<sup>7</sup> 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.

### Limitations

There were only four 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.

## Experiments

Figure 1. Quadriceps and Hamstring Activity During Single Jump Landing

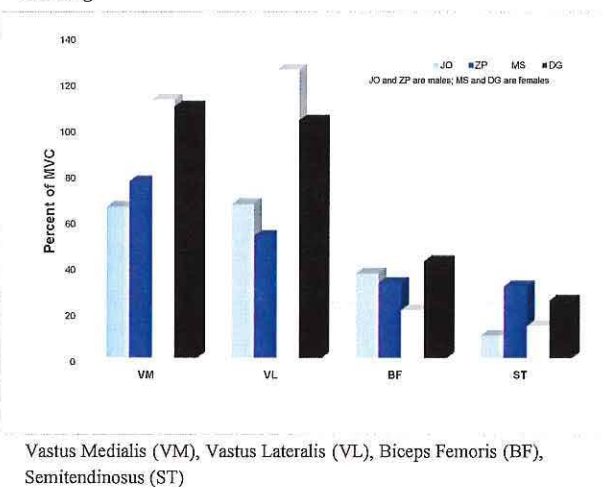
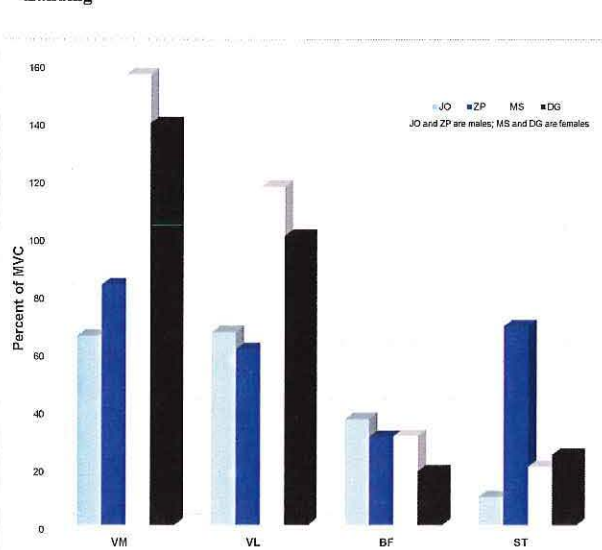


Figure 2. Quadriceps and Hamstring Activity During Triple Jump Landing



## Conclusions

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. 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.

## References

1. Ford KR, Myer GD, Schmitt LC, Uhl TL, Hewett TE. Preferential quadriceps activation in female athletes with incremental increases in landing intensity. *J Appl Biomech.* 2011;27(3):215-222.
2. Walsh M, Boling MC, McGrath M, Blackburn JT, Padua DA. Lower extremity muscle activation and knee flexion during a jump-landing task. *J Athl Train.* 2012 Jul-Aug;47(4):406-13.
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7. Dedinsky R, Baker L, Imbus S, Bowman M, Murray L. Exercises that facilitate optimal hamstring and quadriceps co-activation to help decrease ACL injury risk in health females: A systematic review of the literature. *Int J Sports Phys Ther.* 2017 Feb;12(1):3-15.

This Scholarly Project, submitted by Jayla Greene, Brecca Wahlund, Jay Mittlieder, and Adam Lutz 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.

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(Graduate School Advisor)

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(Chairperson, Physical Therapy)

## PERMISSION

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

**Department** Physical Therapy

**Degree** Doctor of Physical Therapy

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Signature (s)

Gayla Greene  
Kim Clum  
John Z...  
Mr. A...

Date

12/5/18

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## ABSTRACT

**Background and Purpose.** The purpose of this pilot study was to see if there was a difference in amount of electromyographic (EMG) activity in the quadriceps (vastus medialis and vastus lateralis) compared to amount of EMG activity in the hamstrings (biceps femoris and semitendinosus) in active male and female subjects during vertical jumping and landing. In addition, we looked at the amount of knee flexion that occurred in the male and female subjects 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 two quadriceps muscles (vastus medialis and vastus lateralis) and two hamstring muscles (biceps femoris and semitendinosus) were monitored during the experiment. The subject was also captured on video using the NiNox 125/250 FPS camera system. Subjects consisted of two male and two female athletes in good physical condition with no previous knee pathologies.

### Results

Differences were found in the quadriceps to hamstring ratio when comparing female to male participants in both single jump (Female 4.42:1, Male 2.38:1) and triple jump landing (Female 5.46:1, Male 1.90:1). Females generally showed higher percent of maximal voluntary contraction in the quadriceps than the males when compared for both jumps. Remarkable differences in knee flexion upon landing were not found between genders in either 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 hamstring muscles 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 I

### Introduction

Previous research has suggested that female athletes sustain anterior cruciate ligament (ACL) injuries at a higher incidence than male athletes.<sup>1</sup> Ford et al.<sup>1</sup> noted that as the drop height increased there was an increase in the quadriceps muscle activity, but not an increase in hamstring muscle activity. This muscle imbalance has the effect of placing greater strain on the ACL, which predisposes it to injury.

Walsh et al.<sup>2</sup> described the relationship between lower extremity muscle activity and knee flexion angles during a jump landing task. They found that greater activation of the quadriceps and less activation of the hamstrings resulted in a decreased knee flexion angle at landing. Increased activation of the quadriceps versus the hamstrings was hypothesized to be a risk factor for ACL injury.

Bencke et al.<sup>3</sup> reviewed the literature regarding ACL injury risk movements in young female athletes. They reported that young female athletes were at an increased risk for ACL injury during sport activities. They found that clear, gender specific differences in muscle activation and coordination were identified demonstrating elevated quadriceps activity and reduced hamstring activity in young female athletes compared to their male counterparts, suggesting that young female athletes have an increase of an ACL injury.

Research suggests that dominance of the quadriceps (females in particular) relative to the hamstrings increased the risk of an ACL injury.

However, Bencke et al.<sup>3</sup> point out that there is a paucity of studies in adolescent female athletes that looked at muscle activation in non-contact activities in that high risk population. Our review of the literature indicated that there are only a few studies of EMG activity of the knee muscles during jump landing activities, and most were done from a drop landing position. The purpose of our study was to investigate the activity in the quadriceps and hamstring muscles along with the knee flexion angle during a maximal vertical jump from a standing position. We hypothesized that the male participants' quadriceps to hamstring muscles ratio would be higher than the quadriceps to hamstring muscles ratio than the female participants.

## CHAPTER II

### 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 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 EMG data was analyzed using the Noraxon MR3 Myomuscle software program. The Noraxon Myovideo system, using a NiNox 125/250 camera system was used to record the shoulder abduction exercises. The video camera was synced to the EMG data collection.

The muscles tested were the right sided vastus lateralis, vastus medialis, biceps femoris and semitendinosus on each subject. Before applying the EMG electrodes the skin was abraded and cleaned with isopropyl alcohol. Blue Sensor (model M-00-S) surface electrodes were used to pick up the EMG activity. The electrodes were placed on the skin, parallel to the muscle fiber orientation and followed standard, recommended placement sites.<sup>4,5</sup>

#### **Electrode Placement Sites:**

Vastus Medialis – 1/5 distance from medial knee joint line to ASIS, over belly of vastus medialis

Vastus Lateralis – 1/4 distance from lateral knee joint line to ASIS, over belly of vastus lateralis

Biceps Femoris – Midpoint of a line from ischial tuberosity to lateral femoral condyle

Semitendinosus – Midpoint of a line from ischial tuberosity to medial femoral

### **Manual Muscle Test Positions:**

Tested quadriceps in sitting with knee bent to 90 degrees, thigh stabilized and resistance applied at ankle, hold for 5 seconds

Tested hamstrings in sitting with knee bent to 90 degrees, thigh stabilized and resistance applied at ankle, hold for 5 seconds

To allow motion capture, reflective markers were placed on the right greater trochanter, right lateral femoral condyle, right fibular head and right lateral malleolus. The markers were placed to allow motion capture and tracking of right knee flexion during the jumping activities.

The participants were then asked to perform a single vertical jump and a series of three successive vertical jumps. Rest periods were allowed between each jump session. Three single jumps and three successive jumps were performed by each subject. EMG data was collected during jumps from each participant. Using the Noraxon MR3 software, a marker was placed at the beginning and end of each jump record to indicate the time that the foot was on the floor between jumps. 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. In addition, the Noraxon Myovideo software was used to track the knee flexion angle during the entire jump sequence. Graphs were constructed showing the percentage of EMG activity for all the muscles during the jumps and the maximal amount of knee range of motion that occurred during each of the jumps.

## CHAPTER III

### 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 lateralis demonstrated a greater %MVC contraction than the vastus medialis in the female participants. The quadriceps muscle that showed the lowest amount of activation in both males and females was the vastus lateralis. 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 2.38:1 as compared to 4.42:1 in females.

The male subjects demonstrated similar degrees of knee flexion upon landing, with one subject at 95.9 degrees and the other at 99 degrees (Figure 2). Female subjects had more variable knee flexion upon landing, with one showing 109 degrees and the other 74.6 degrees of knee flexion.

During triple jump landing, female participants demonstrated the greatest EMG activity in the vastus medialis (Figure 3). 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 1.9:1 as compared to 5.46:1 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

4). The female subjects demonstrated 103 degrees and 101 degrees of maximum knee flexion upon landing from the jumps. The male subjects demonstrated 95.9 degrees and 90.3 degrees of knee flexion upon landing.

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

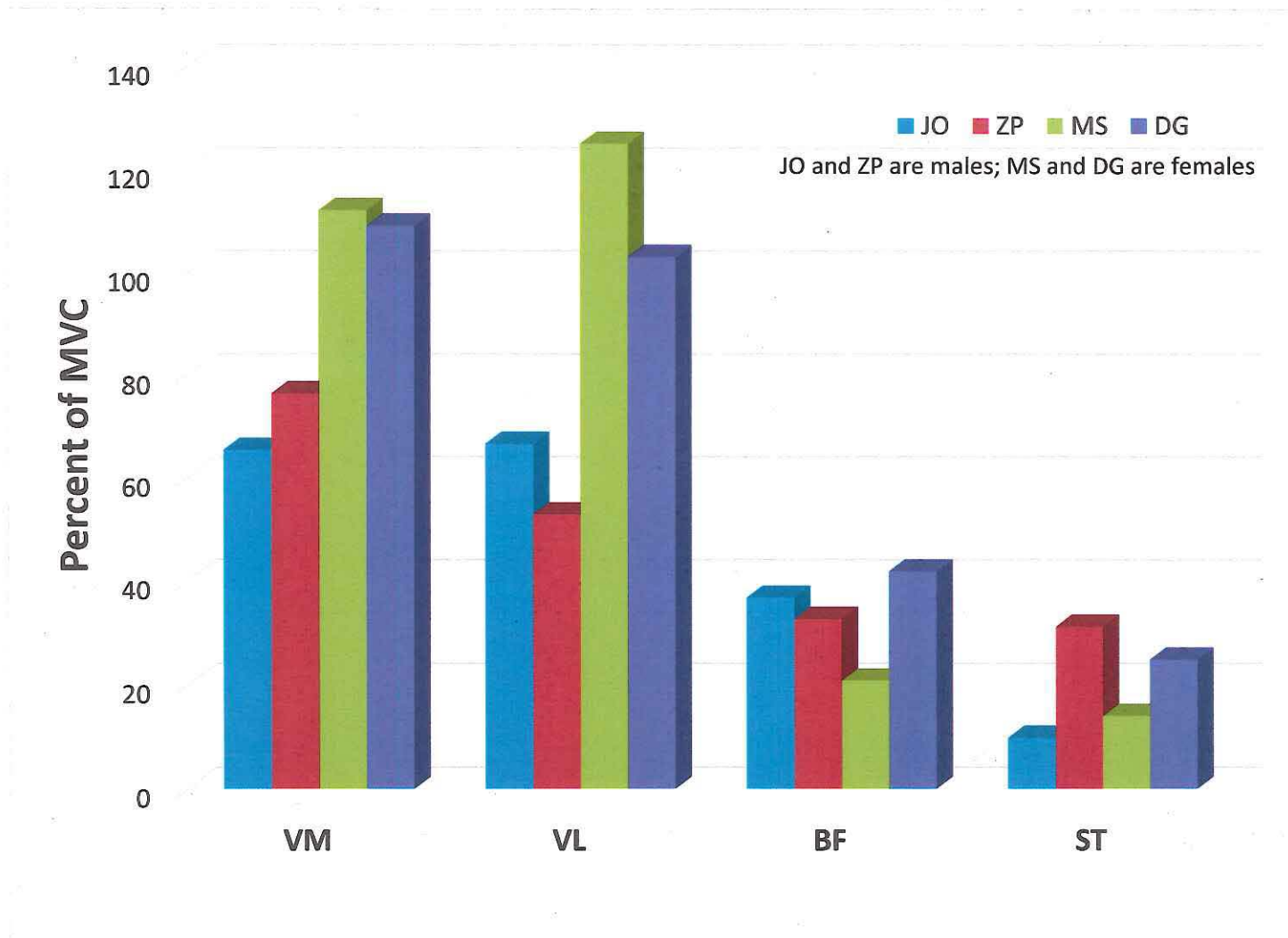




Figure 2. Knee Flexion During Single Jump Landing

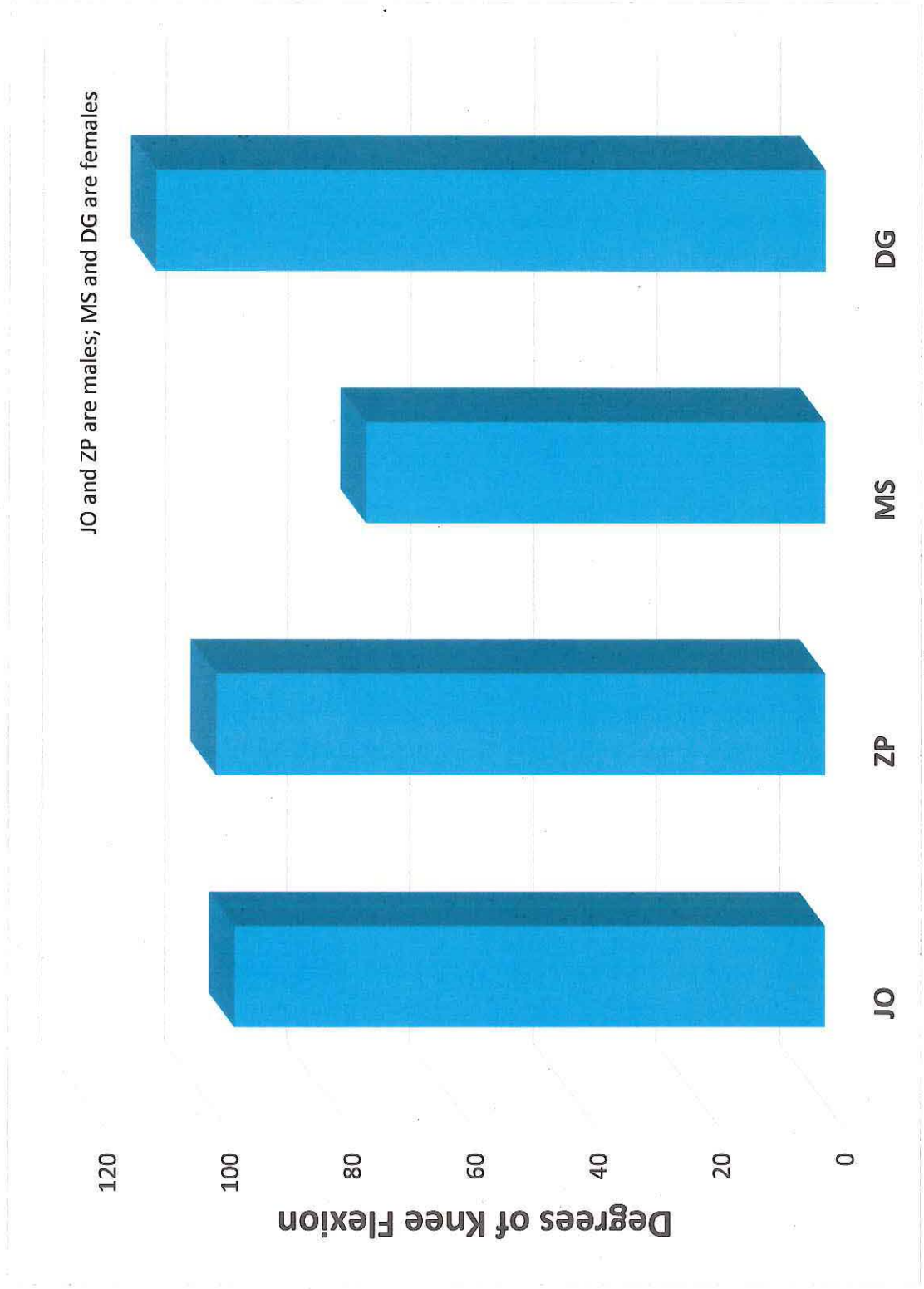


Figure 3. Quadriceps and Hamstring Activity During Triple Jump Landing

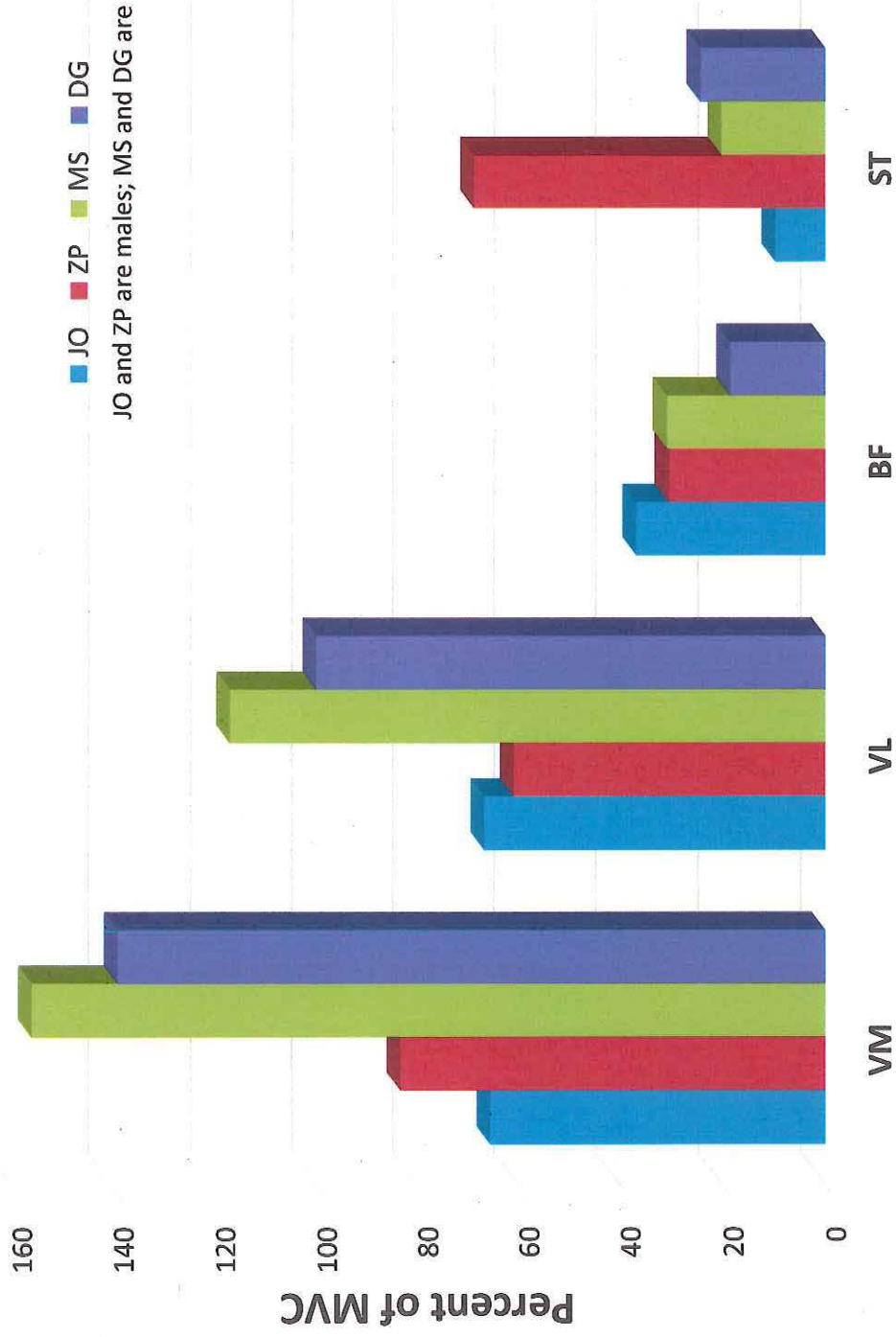
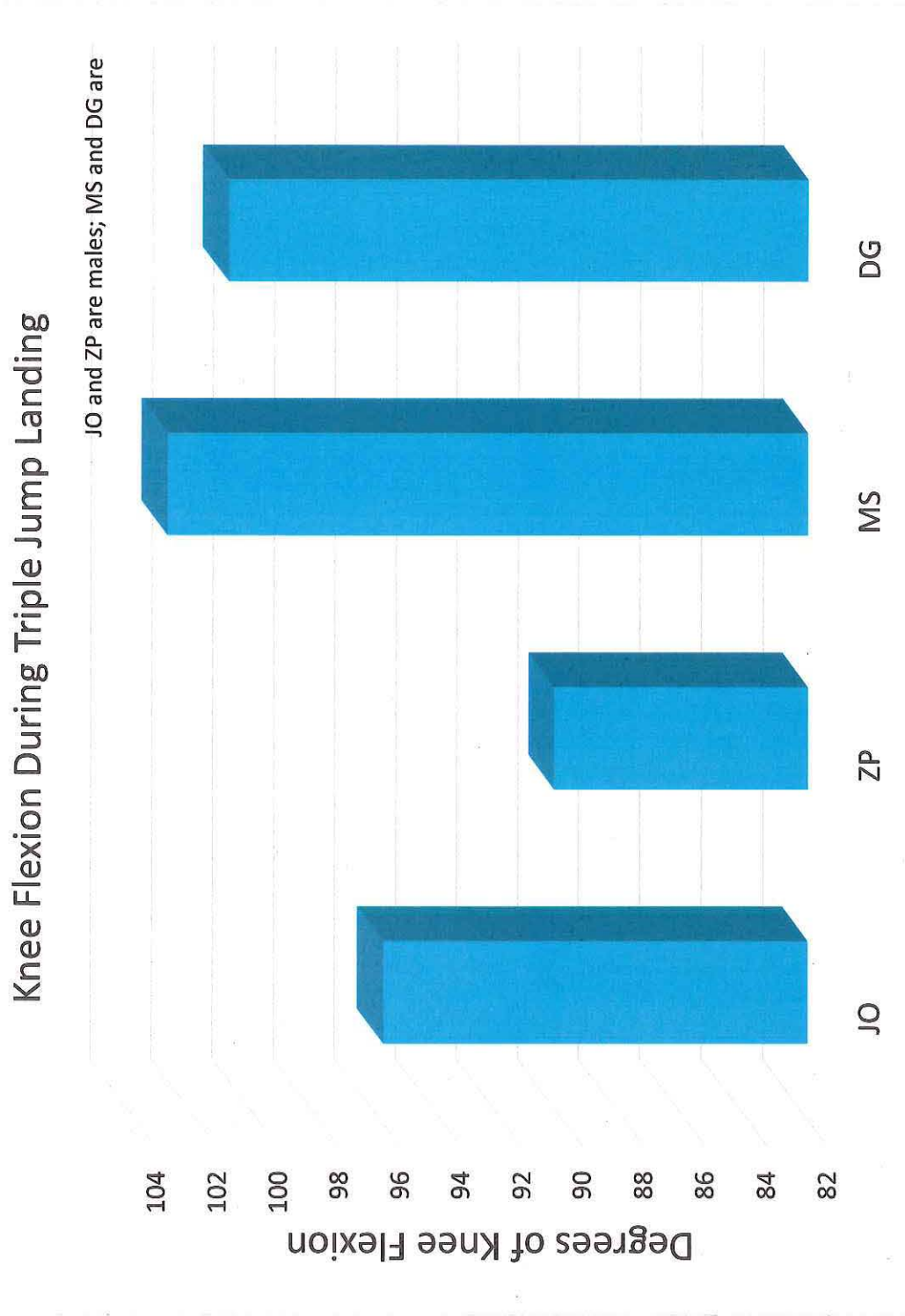


Figure 4. Knee Flexion During Triple Jump Landing



## CHAPTER IV

### Discussion and Limitations

The results of this study appears to agree with previous literature regarding the quadriceps to hamstring muscles ratio in males versus females. 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.<sup>1-3</sup> Ebben et al.<sup>6</sup> 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. Another article found knee flexion upon landing from a jump to be negatively correlated with quadriceps dominance in individuals.<sup>2</sup> They concluded that the dominance of the quadriceps causes a lack of knee flexion and speculated that the reduced knee flexion angle caused by dominant quadriceps activity would increase the tensile force on the ACL upon landing from a jump. Therefore, this type of landing strategies 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 to not be effective in improving the quadriceps to hamstring muscles ratio in participants.<sup>7</sup> 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 could thus be concluded that single leg exercises are preferred to reduce quadriceps dominance and anterior tensile force on the ACL.

### **Limitations**

This pilot study had limitations that must be considered when analyzing the quality of results. There were only four 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. The EMG analysis software utilized in the pilot study to analyze EMG results was new to the researchers with the addition of a new footswitch mechanism. Additional experience with the software, along with a larger subject sample, are ways to overcome the limitations of this study.

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