2018

Neuromuscular changes with static knee loading and drop landings.

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NEUROMUSCULAR CHANGES WITH STATIC KNEE JOINT STRETCHING AND DROP LANDINGS

by

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BS, Millikin University, 2016

A Research Paper

Submitted in Partial Fulfillment of the Requirements for the

Master of Science in Education

Department of Kinesiology

In the Graduate School

Southern Illinois University Carbondale

May 2018

RESEARCH PAPER APPROVAL

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for the Degree of

Master of Science in Education

in the field of Kinesiology

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May 9, 2018

AN ABSTRACT OF THE RESEARCH PROJECT OF

SECILY MOSS, for the Master of Science in Education degree in Kinesiology, presented on May 9th, 2018, at Southern Illinois University Carbondale.

TITLE: NEUROMUSCULAR CHANGES WITH STATIC KNEE LOADING AND DROP LANDINGS

MAJOR PROFESSOR: Dr. Michael Olson

Background: Neuromuscular responses and adaptations associated with loading schemes to the knee joint have been a topic of interest in the realm of biomechanics and researchers have looked at this via drop landings from various box sizes and drop landings after lower extremity fatigue.

Hypothesis/Purpose: The purpose of the study was to assess neuromuscular activity of the muscles surrounding the knee joint before and after static loading to the knee joint capsule during drop landings. It was hypothesized that the knee joint capsule stretch would provide a significant neuromuscular modification during single leg drop landing.

Methods: 20 male and female participants ages 19-26 from SIU participated in 5 successful drop landing task before and after a 10 minute static knee stretch.

Results: There were numerous significant findings with muscle ratio, muscles, and time series with all pre and post drop landings. There were no differences in the gender.

Discussion: Our findings suggest that the muscles of the knee joint during drop landings post static loading that were significant with certain muscle ratios (as described in table 4) and the pre/post condition. Our hypothesis showed that the neuromuscular modification were observed. When looking at the data there was no difference when looking at pre and post conditions, but there was a trend showing that it could become significant. There were differences with muscle ratios pre and post drop landing.

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CHAPTER ONE

INTRODUCTION

Neuromuscular responses and adaptations associated with loading schemes to the knee joint have been a topic of interest in the realm of biomechanics. Researchers have looked at this via drop landings from various box sizes and drop landings after lower extremity fatigue. The premise of this study was to assess neuromuscular response of muscles surrounding the knee joint capsule before and after a static load. This research is extremely important to clinicians that are involved in athletics due to the prevalence of knee injuries, especially to the anterior cruciate ligament (ACL).

Females suffer from more ACL injuries when compared to men (Toscano & Carroll, 2015). This is attributed to women having wider hips thus causing a shear force on the ACL due to increased knee joint angles (Toscano & Carroll, 2015), specifically the quadriceps angle. The greater the angle, the increased risk the person has of injuring their ACL due to valgus forces applied to the knee joint (Kizilgöz, Sivrioğlu, Ulusoy, Aydin, Karayol & Menderes, 2018). The most common form of ACL injury is sustained through a non-contact mechanism (Al-Sultan, AlYousefi, Wtayyanu, Khamseen & Alrasasi, 2017). Females have less leg stiffness when compared to males. Demirbǖken, Yurdalan, Savelberg, and Meijer (2009) looked at various hopping conditions between male and females and found that males had leg stiffness that was 1.5 times higher than women. This was especially true with preferred hopping frequency and hopping with weights on their ankles (Demirbǖken, et al., 2009). When the participants were told to land stiffly there was an increase in peak force on the ACL, as compared to being told to land softly which showed an increase in hip and knee flexion (Laughlin, Weinhandl, Kernozek, Cobb, Keenan, & O’Connor, 2011).

Most injuries that occur in athletes are due to fatigue from changed neuromuscular control. Thus a change will occur in biomechanics in the lower limb therefore creating a greater chance of injury (Lessi & Serrão, 2017). Lessi and Serrão looked at recreational athletes that had undergone ACL reconstruction and wanted to determine how fatigue effects the trunk and pelvis. They found that the anterior cruciate ligament reconstruction (ACLR) group have greater hip adduction which has been correlated with an increase in knee valgus (Hollman, Galardi, Lin, Voth & Whitmarsh, 2014). During this study there was no difference with knee abduction angles however, there were differences with hip adduction. There was a difference in contralateral pelvic dropping with the ACLR group as well. It was speculated that this occurred because of weakness in the hip abductor muscles. However, with the contralateral pelvic drop can cause an increase with external knee rotation, thus causing compression on the medial tibiofemoral compartment of the lower extremity. This can eventually lead to osteoarthritis, which is common after someone undergoes ACL reconstruction (Lessi & Serrão, 2017). In 2008, Kernozek, Torry and Iwasaki looked at gender and lower extremity fatigue, especially with the ACL. It was determined that both genders had increased hip flexion during landing when the lower extremity was fatigued. It was discovered that during landing with and without leg fatigue men landed with knee varus angles and the females landed with valgus angles (Kernozek, Torry, & Iwasaki, 2008). Landing biomechanics was observed in individuals with reconstructed ACLs and compared to healthy individuals where muscle fatigue was induced in both test groups. It was determined the more participants were fatigued the more significant decrease in hip flexion with the ACL reconstruction (ACLR) group was evident. In both ACLR and non ACLR there were significant changes in ankle dorsiflexion, knee rotation, and hip abduction. As the participants became more fatigued there was a significant decrease in knee flexion, increased knee internal rotation, hip adduction and overall leg stiffness. Researchers were able to see biomechanical changes in the knee that had an ACL injury when compared to the non-injured knee (Webster, Santamaria, MCcelland & Feller, 2012). In 2008, Phillips and Van Deursen looked at landing stability in ACL deficient participants compared to individuals with non-injured ACLs. It was discovered that the ACL deficient (ACLD) subjects took longer to slow down and stop when running to balance on the force platform. It was also determined that the ACLD group had an overall slower running speed when compared to the non-ACLD group. The results also showed that the ACLD group took longer to stabilize during the single leg stance (Phillips & Van Deursen, 2008).

Yeadon, King, Forrester, Caldwell and Pain (2010) looked at muscle co-contraction while an elite martial arts athlete performed drop landings from various box heights. Co-contraction was shown to activate the muscles at the knee and hip joints (Yeadon, et al., 2010). In 2014, Cheng, Zhang, Shan and Wang looked at posterior cruciate ligament (PCL) co-activation with knee joint movement. It was determined that co-activation decreased while the knee was placed in extension. The researchers also determined that the PCL demonstrated a posterior displacement within the tibia with both males and females. The researchers determined this is due to the PCL being placed in a static load in the posterior position will increase muscle activation without any help from the antagonist while the knee is placed in both flexion and extension (Cheng, Zhang, Shan & Wang, 2014).

Meardon, Klusendorf, and Kernozek (2016) looked at dynamic posture in runners with and without injuries. It was determined that some deficits of control were observed in dynamic posture. Tests conducted in this study were time to stabilize test (TTS), star exercusion balance test (SEBT), and dynamic posture stability index (DPSI). There were no deficits in reach differences or stabilization time when looking at TTS and SEBT. There were also no differences when looking at postural control between injured and non-injured runners. However, there were differences with ground force reactions with the injured runners having greater variability when looking at the forward hop and lateral hop (Meardon, Klusendorf & Kernozek, 2016).

Mahaki, Mar and Mahaki (2015) looked at the relationships between lower extremity muscle activation and peak vertical, and posterior ground reaction forces while a participant was performing a single drop landing tasks. The researchers had the participant stand on a 30 cm box and drop onto the force platform on their dominant leg and “stick” the landing. This study determined that only the soleus and the tibilas anterior had a positive correlation during the pre-landing phase with peak vertical ground reaction force. There were no significant differences that were found from the various muscles during post landing with peak vertical ground reaction forces (Mahaki, Mar & Mahaki, 2015). In 2011, Fong, Blackburn and Norcross looked at ankle dorsiflexion during range of motion during landing. They discovered that there were correlations with extended-knee dorsiflexion and knee flexion displacement. The knee valgus displacement was determined to be non-significant. It is believed that greater passive dorsiflexion in the ankle is associated with greater knee flexion and thus resulting in smaller ground reaction force landing during landing (Fong, Blackburn & Norcross 2011).

Earp, Newton, Cormie, and Blazevich (2014) looked at loading intensity on muscle tendon unit behaviors while having a maximal knee extensor stretch. It is believed that stiffness in tendons will increase with the rate and magnitude of increased loading due to the viscoelastic properties of tendons. There have been times were tendons become too stiff and will almost perform the roles of a rigid force transducer. It was determined that increasing intensity will cause a decrease in lengthening of the tendon during stretch shortening cycles. It was also determined that muscle tendon unit did change with the increase of external loading in the knee extensions. When the tendon went into an eccentric phase during movement the lengthening decreased (Earp et al. 2014). Walsh (2017) looked at the effects of static and dynamic knee joint muscle stretching. The participants performed hamstring and quadriceps stretches for 90 seconds at a point of mild discomfort. For the dynamic stretching 3 sets of 12 reps were performed at a self-selected pace with a 30 second rest period between each set. The participants were then strapped into a dynamometer to determine lower extremity strength. It was determined that both static and dynamic stretching were both improved with lower extremity strength. When the knee was placed into a 45º the strength was improved with the warm up. Finally, it was determined that static stretching had a decrease in knee extension and flexion with concentric strength (Walsh, 2017). Serefoglu, Sekir, Gű̈r and Akova (2017) looked at static and dynamic stretching of the quadriceps and hamstring muscles with eccentric and concentric isokinetic movements with electromyography antagonist muscles. The static and dynamic stretches that were performed were done 4 times with 30 second holds. Active, static and dynamic stretching were performed and held for 240 seconds. It was determined that static and dynamic stretching did not yield any effects on antagonist muscles (Serefoglu, Sekir, Gű̈r & Akova, 2017). Blackhurst, Peterson, Herzog and Zimmerman (2015) looked at static stretching in comparison with a combination of ballistic and static stretching with the knee performing active range of motion. There are many different types of stretches that can be performed to help increase flexibility. These stretches include static, ballistic, dynamic and proprioceptive neuromuscular facilitation (PNF). The researchers conducted a two week study that combined static and ballistic stretching and compared it to a static stretching group while performing active knee range of motion. The researchers determined that a combination of static and ballistic stretching was just as effective (if not more) than static stretching alone (Blackhurst, Peterson, Herzog & Zimmerman, 2015).

Halonen et al. (2014) looked at static knee loading and deformation of articular cartilage. It was determined that static loading with the meniscus persisted to be practically stationary minus the anterior portion of the lateral meniscus. It would slightly translate anteriorly immediately after contact as compared to the medial meniscus would not move. However the medial meniscus will be more prone to get degenerative changes (Halonen et al., 2014). Static loading in the knee joint with people who have osteoarthritis in the different sections of the meniscus were studied. It was determined that age, body mass index and diagnosis of osteoarthritis were determined to be statistically significant in between the control and test group. When it came to look at the whole knee joint compartment it was determined that it was not statistically significant when the knee joint was being loaded in both groups (Calixto et al. 2015). Kumar, Manal and Rudolph (2012) looked at knee joint loading with gait in both healthy and people with osteoarthritis. It was determined that the osteoarthritis group had a statistically significant space in the medial knee joint that was smaller, a greater knee varus, medial knee laxity, and walking slower than the compare group. This is all due to the loss of articular cartilage within the knee joint. The osteoarthritis group did have a difference in loading within the knee joint in the medial and lower lateral meniscal compartments but it was deemed non-significant. When looking at stance with the osteoarthritis groups in the first half of the stance phase it was statistically significant when looking at medial loading in the osteoarthritis group was almost 250N higher in comparison to the comparison group. However, during the second half of the stance phase it was determined that the osteoarthritis group had knee joint loading that was 350N higher in the lateral and medial compartments. These were determined to not be statistically significant

(Kumar, Manal & Rudolph, 2012). Chu et al. (2003) looked at the effect of ACL creep in the knee joint with knee flexion and extension. The participants received an isometric pull on their tibia for 10 minutes while in flexion and extension before and after the static load was applied. The females received 150 N of pull and the men received 200 N of pull on their tibias. What the researchers determined was the electromyography on the quadriceps had an increase while in extension. The hamstrings did not have any change with muscle co-activation. A trend was noticed in the female group with the knee having an increased extension force after the ACL creep was established. On the flip side, the hamstrings had a trend when the knee was placed into flexion, however, there was no difference in males or females (Chu et al., 2003).

Although numerous studies have been conducted with static loading on the knee, none have looked at the hamstring and quadriceps muscle responses during dynamic activity after the use of static loading. Thus the purpose of this study was to assess neuromuscular activity of the muscles surrounding the knee joint before and after static loading to the knee joint capsule during drop landings. It was hypothesized that the knee joint capsule stretch would provide a significant neuromuscular modification during single leg drop landing.

CHAPTER TWO

METHODS

Participants

Twenty participants were recruited from Southern Illinois University Department of Kinesiology classes. Participants' ranged from 19-26 years of age with the mean age of 21.6 ±2.0. Details of participants are provided in Table 1. The participants were required to read and sign the informed consent prior to participating in the research study. Exclusion criteria were: any injury less than six months, and any lower extremity surgeries. This study was approved by the Human Subjects Committee prior to data collecting.

Table 1. Mean and standard deviations of participant demographics

Sex	Height (meters)	Mass (kg)	# of Subjects	Age
Male	1.78±0.1	78.67±8.1	7	22.57±1.4
Female	1.64±0.1	66.36±14.1	13	21.08±5.7

Equipment

Kinematics:

A 6 camera optoelectic camera system (Oqus 100, Qualysis, Götenborg, Sweden) was used to collect kinematics data (120 Hz). The camera system was calibrated each collection period such that the residuals were below 1.00 mm. The retro-reflective markers were placed bilaterally: acromion processes, posterior superior iliac spine (PSIS), and anterior superior iliac spine (ASIS). Unilateral (right side) marker configurations were: iliac crests, right hip, medial/lateral knee, medial/lateral malleoli, heel, 1st metatarsal-phalangeal joint (MTP), 5th MTP joint. Reflective marker clusters (4 non-colinear) were placed on the right thigh and anterior leg.

Kinetics:

A force platform (AMTI, Watertown, MA, USA) was used to collect the three linear ground reaction forces (GRFs) at landing (1200 Hz). The signals were sent to a USB 2533 12-bit analog digital board (A/D board) and then synchronized with the kinematics data via the Qualisys Track Manager (QTM) software.

Surface Electromyography:

Surface electromyography (EMG) (Motion Labs, Baton Rouge, LA, USA) were used to collect muscle activation patterns. Surface electrodes were placed on the skin at right iliac crest, semimembranosus (SM), biceps femoris long head (BF), vastus lateralis (VL), vastus medialis (VM), and rectus femoris (RF). The electrodes (pre-gelled Ag-AgCl) were placed at an interelectrode distance of 2.0 cm. The collection rate was at 1200 Hz with a bandpass width of 20-500 Hz, common mode rejection ratio of greater than 100 dB and an input resistance 10 mega ohms. The signals were synchronized with the A/D board and QTM software.

Isokinetic Dynamometer

A Biodex system 3 dynamometer (Shirley, NY) was used for the maximal effort trials and the stretching protocol. The Biodex was calibrated before and after the experimental sessions, and was within the manufacture's specifications each time. Primarily, torque data were assessed using this machine.

Protocol

Participants were required to warm up by walking on a treadmill with a self-selected speed for five-ten minutes. After the warm up participants were asked to determine their dominant leg by asking them what leg they would kick a ball. After the warm-up and placement of electrodes and markers, participants performed maximal voluntary isometric contractions (MVIC) in knee flexion and extension. Ramp contractions were performed for five seconds alternating extension and flexion efforts and repeated two more times with 60 seconds of rest between efforts. They were then told to rest for ten minutes while remaining seated. After the 10 min rest, participants were acclimated to the drop-landing protocol. Once acclimated, participants performed 8-10 acceptable drop landings. Landings were repeated if participants were not able to land and maintain balance. Once the participant successfully completed the initial drop landings they were then instructed to sit on the seat if the Biodex machine. The dynamometer axis was aligned with the knee joint center (palpating the lateral femoral epicondyle as a reference). The hip was flexed to 90° while the knee was flexed at 30° and the leg was held in place by the attachment arm of the dynamometer (Chu et al., 2003). An external load was positioned 3.0 cm distal to the femoral epicondyles. A cuff was placed over the skin, while a line tethered to the load was wrapped around the proximal leg. The load was positioned such that the force was perpendicular to the leg. The males received 200 N of pull and the women received 150 N of pull (Chu et al., 2003). The static load was maintained for 10 min. Surface EMG were monitored to ensure a low level of active was maintained during the passive loading protocol. After the passive loading protocol ended, participants immediately performed another 8-10 drop landing trials. They were then allowed to recover on the athletic training table post study.

Data Analysis

Kinematics:

Kinematics and force data were processed using MotionMonitor software (Chicago, IL, USA). Kinematics data were smoothed using a 4^{th} order zero-lag Butterworth Filter at 10 Hz. Kinetics data were low pass filterd with a 4^{th} order zero-lag Butterworth Filter at 60 Hz.

The room coordinate system was established using the right-hand rule (x – anteroposterior, y – mediolateral, z – vertical). Joint angle calculations were based off of the relative position of the thigh and leg to assess knee flexion-extension.

Kinetics:

The vertical GRF was used to assess onset of the landing in drop landings. A 20N threshold level was used to determine the landing of the foot onto the force platform.

Electromyography:

Surface EMG raw signals were full wave rectified and low pass filtered with a digital 4^{th} order zero-lag Butterworth filter at 10 Hz using custom software (Visual Basic for Excel, 2013). Surface EMG signals were normalized to the respective MVIC values.

The means and peaks of the EMG amplitudes of each muscle group were assessed during the landing phase. Time windows of 50 ms duration were established during the landing, such that the 0-50 ms, 51-100 ms, 101-150 ms, and 151-200 ms time periods after initial force platform landing could be analyzed. The periods of 200 ms and 100 ms prior to the initiation of landing were also assessed. All quadriceps muscles were divided against all of the hamstrings.

Statistical Analysis

Statistical Package for Social Sciences (SPSS v.24, Chicago, IL, USA) data analysis was used to calculate the EMG data. In SPSS a repeated measures analysis of variance (ANOVA) with LSD was chosen for the within-subjects comparisons using the best 5 trials of each condition. A between subjects ANOVA was performed using condition (pre/post), sex, and muscle ratios. All of the descriptive statics were chosen to be run with descriptive statistics, estimates of effect size and observed power were also looked at. Alpha was set at $p < 0.05$.

CHAPTER THREE

RESULTS

When looking at average and maximum EMG signals during different times taken at pre and post phases of landing results determined the hypothesis was supported. Outlined below are the results.

Pre and post landing:

Table 2 provides the averages and standard deviations of each time series for pre and post landing. There was no statistical significance when looking at average pre and post landing conditions ($p > 0.922$). There is a trend that is shown with maximum pre and post landing conditions ($p > 0.123$). However, there was some significance when comparing condition to muscle ratios, as well as within trials with both maximum and average EMG values (all <0.000). When looking at average EMG with the time series included it was shown that there was no significance ($p >0.577$).

Time series:

The time series that were looked at were 200-0 ms, 100-0 ms, 0-50 ms, 51-100 ms, 101-150 ms, and 151-200 ms. The average EMG time series was significant ($p <0.000$). Tables 2 highlights all of the differences that were found pre and post condition and muscle with the time series. Table 3 highlights all of the differences that were found with the time series and the muscle ratios with pre and post landing conditions.

Sex comparison:

When comparing males and females with the maximum EMG values there were no differences ($p >0.513$). There was also no significance difference demonstrated for pre and post landing with males and females ($p >0.513$). When looking at average EMG values when comparing males and females, again there was no difference between the groups, as well as when compared to pre and post landing (p >0.888). When looking at average EMG with the time series included again there were no significance between males and females (p >0.966).

Muscle ratio:

There were significant differences when looking at the muscle ratios (p<0.000) and the average EMG ratio values (p <0.000). It was also determined that ratios*condition (p <0.000) was significant. Table 4 provides the information with the muscle ratio compared pre and post landing and which ones were determined to be significant.

Table 2. Pre and Post Mean (±sd) electromyography of average values prior and during landing

	Pre landing					Post landing				
	RF	VL	VM	SM	BF	RF	VL	VM	SM	BF
200-0 ms	0.13±0.1	0.24±0.4*	0.09±0.1	0.17±0.2	0.14±0.3*	0.13±0.1	0.22±0.2	0.07±0.1	0.16±0.2	0.09±0.0*
100-0 ms	0.19±0.2	0.23±0.2	0.13±0.3*	0.18±0.5*	0.15±0.3*	0.18±0.2	0.30±0.3	0.12±0.4*	0.17±0.2	0.12±0.1
0-50 ms	0.37±0.3	0.51±0.4	0.25±0.4*	0.31±0.2	0.16±0.3*	0.34±0.2	0.53±0.4	0.20±0.4*	0.35±0.3	0.13±0.1
51-100 ms	0.55±0.4	0.80±0.5	0.37±0.6*	0.53±0.2	0.25±0.3	0.53±0.3	0.70±0.5	0.28±0.5*	0.59±0.6	0.25±0.3
101-150 ms	0.38±0.3	0.60±0.4	0.24±0.4*	0.40±0.4	0.18±0.2	0.33±0.2	0.47±0.5	0.17±0.3*	0.47±0.5	0.19±0.2
151-200 ms	0.21±0.2	0.39±0.3	0.19±0.4*	0.31±0.1	0.16±0.2	0.21±0.1	0.37±0.3	0.10±0.2*	0.36±0.4	0.12±0.1

*indicates p-value <0.05 between conditions

Table 3. Comparison of muscle groups for average± sd electromyography values

Pre							Post						
	SM/RF	SM/VL	SM/VM	BF/RF	BF/VL	BF/VM		SM/RF	SM/VL	SM/VM	BF/RF	BF/VL	BF/VM
200-0ms	1.53 ±1.7	1.33 ±2.4 *	12.91 ±22.4	1.17 ±2.3 *	0.60 ±0.5	9.46 ±28.7*		1.49 ±1.8	1.20±0.9	1.01±0.8	1.21 ±1.5	1.43 ±1.5	1.86 ±3.4 *
100-0ms	1.21 ±0.9	1.03 ±2.4 *	13.58 ±17.5	1.04 ±1.8 *	0.90 ±2.7 *	9.90 ±27.3*		1.01 ±1.2	0.84±0.6	0.72±0.6	0.84 ±1.2	0.83 ±1.0	1.76 ±3.9 *
0-50ms	1.01 ±0.9	0.94 ±1.6 *	26.29 ±34.0	0.54 ±1.1 *	0.36 ±0.5	9.56 ±22.1*		0.72 ±0.6	12.01 ±18.1	24.78 ±36.0	29.66±53.4	33.60±52.4*	21.88 ±35.5*
51-100ms	1.20 ±1.7	1.06 ±2.5 *	39.33 ±56.4	0.41 ±0.3	0.36 ±0.6 *	12.13 ±15.5		12.74 ±20.8*	0.77±0.5	0.44±0.3	29.66±53.4*	0.60 ±0.5	0.66 ±0.5
101-150ms	1.32 ±1.4	0.87 ±1.3	28.93 ±35.2	0.56 ±0.5	0.43 ±0.5	8.15 ±9.2		0.63 ±0.5	0.62±0.5	0.35±0.3	0.69 ±1.4 *	0.46 ±0.4	0.48 ±0.5
151-200ms	1.71 ±2.1	1.05 ±1.4	20.87 ±31.8	0.79 ±0.7	0.63 ±0.7	6.94 ±7.3		4.71 ±3.9	6.85±6.1	7.80±6.6	17.22±28.8*	11.82±15.7	6.69 ±6.1

*indicates p-value <0.05

Table 4. Muscle co-activation average ±sd electromyography pre and post landing

Pre				Post			
	RF	VL	VM		RF	VL	VM
SM	1.60±2.4	1.78±2.4	2.03±4.5*	SM	2.01±3.2*	2.07±2.9	1.84±2.9*
BF	1.66±2.5	1.77±2.7	1.89±2.9	BF	1.91±2.9	2.07±3.3*	2.01±3.2*

*indicates p-value <0.05 between conditions

CHAPTER FOUR

DISCUSSION

The purpose of the study was to assess neuromuscular activity of the muscles surrounding the knee joint before and after static loading to the knee joint capsule during drop landings. It was hypothesized that the knee joint capsule stretch would provide a significant neuromuscular modification during single leg drop landing. The findings suggest that the muscles of the knee joint during drop landings post static loading were significant with certain muscle ratios (as described in table 4) and the pre/post condition. The hypothesis was supported that the neuromuscular modifications were shown. When looking at the data there were no differences when comparing pre and post conditions, but there was a trend showing that it could become significant. However, there were differences when looking at the pre and post muscle ratios at the hamstring and quadriceps muscles.

Looking at the neuromuscular modifications are important because it was found that most injuries that occur in athletes are due to fatigue from altered neuromuscular control. Thus a change will occur in biomechanics in the lower limb therefore creating a greater chance of injury (Lessi & Serrão, 2017). Lessi and Serrão looked at recreational athletes that had undergone ACL reconstruction and wanted to determine how fatigue effects the trunk and pelvis. They found that the ACLR group had greater hip adduction which was correlated with an increase in knee valgus (Hollman, Galardi, Lin, Voth & Whitmarsh, 2014). During their study there was no difference with knee abduction angles however, there were differences with hip adduction. There was a difference in contralateral pelvic dropping with the ACLR group as well. It is speculated that this occurred because of weakness in the hip abductor muscles. However, with the contralateral pelvic drop can cause an increase with external knee rotation and thus causing compression on the medial tibiofemoral compartment of the lower extremity (Lessi & Serrão, 2017). The findings of the current study correlate with Lessi and Serrão (2017) as it was determined that post static knee stretch was significantly different than pre.

When looking at muscle co-activation in the post condition there were differences especially with RF/SM, VL/BF, VM/BF. This correlates with the 2014 study conducted by Cheng, Zhang, Shan and Wang. They looked at posterior cruciate ligament (PCL) co-activation with knee joint movement in extension while having a static load in placed. It was determined that co-activation decreased while the knee was placed in extension. The researchers determined this is due to the PCL being placed in a static load in the posterior position will increase muscle activation without any help from the antagonist while the knee is placed in both flexion and extension (Cheng, Zhang, Shan & Wang, 2014). When looking at the relative mean activities of the rectus femoris (RF) and vastus medialis (VM) it was determined to be significant. This is showing that post static knee stretch will activate the RF, VM and SM greater than before performing the knee stretch.

There were differences when looking at the various time series when muscles, muscle ratios and with pre/post condition. This is an important finding because it shows which time is the most important with drop landings. There were more significant findings when looking at the muscle ratios, rather than just the muscles. There is not much change when looking at pre and post condition with the muscles and the muscle ratios. With the muscle ratios it was found that pre 0-50 ms was the time that was most significant. This could be because this is where the muscles are just beginning to activate due to "sticking" the landing with the single leg drop land.

There was no significance when looking at sex in any of the data. This is an interesting finding because females are more at risk for a lower extremity injury due their anatomy of the lower extremity being slightly different. Females tend to have wider hips and will then cause a shear force on the ACL due to increased knee joint angle (Toscano & Carroll, 2015). This could be a potential limitation due to numerous number of female participants when compared to the number of male participants.

Kernozek, Terry and Iwasaki (2008) determined that the more the participants were fatigued the greater the participants' hip flexion had during landing. The men landed with a more varus knee angle and the females landed with a more valgus knee angle (Kernozek, Torry, & Iwasaki, 2008) thus causing an increase in shear force on the ACL.

There were some limitations in the study. The first one is we were only able to look at 20 participants, thus limiting our sample size. In the future this study could be conducted again with a bigger sample size, this way the data can be as accurate as possible. Another limitation in the study was the limited age population; a young population that ranged from 19-26 years of age. It would be useful to replicate this study in the future to determine the effects in an older population and to see the possible differences. As stated earlier, another potential limitation would be the number of males and female that were looked at. There were more females than males and that could potentially change the data. The final limitation in this research study would be the placement of the EMG electrodes, although controlled, this may provide differences between participants.

This is the first study that looks at drop landings pre and post static knee stretching. The purpose of the study was to assess neuromuscular activity of the muscles surrounding the knee joint before and after static loading to the knee joint capsule during drop landings. It was hypothesized that the knee joint capsule stretch would provide a significant neuromuscular modification during single leg drop landing. The findings suggest that the muscles of the knee joint during drop landings post static loading that were significant with certain muscle ratios (as described in table 4) and the pre/post condition. The hypothesis showed that the neuromuscular modifications were shown. When looking at the data there was no difference when looking at pre and post conditions, but there was a trend showing that it could become significant. There were differences with muscle ratios pre and post drop landing. However, further research is needed in order to validate the research and to provide a wider population age range to see how the static knee stretch will affect single leg drop landings.

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Research Paper Title:

Neuromuscular changes with static knee joint loading and drop landings.

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