**Loop band placement on the distal-lateral portion of the thigh increases gluteal activation during high intensity squatting in trained subjects.**

By

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A Thesis submitted to the

School of Graduate Studies

In partial fulfillment of the requirements for the degree of

**Master of Science (Kinesiology)**

**School of Human Kinetics and Recreation**

Memorial University of Newfoundland

**August 2016**

St. John's Newfoundland and Labrador

# Abstract

Anecdotal accounts and clinical case studies report improved squatting mechanics when using loop bands as a proprioceptive aid by activating the gluteus muscles. The objectives of this thesis were: 1) to describe how the use of band-loops placed around the distal thighs would affect lower body muscle activation and 2) to examine if their use would have a direct effect on performance. Fifteen resistance-trained males completed a 5 repetition free barbell back squat at 80% of 1 repetition maximum (RM) and a maximal repetition until failure test at 60% of 1RM. This protocol was completed on two separate testing days; 1) loop band placement and 2) control. No differences were found in the number of repetitions to failure test between conditions. The gluteus maximus and gluteus medius showed greater activation during the intervention testing days. Placing a band-loop around the knees may be a used as a strategy to increase the contribution of the gluteal muscles during a squat.

## Acknowledgements

I would first like to thank my supervisor Dr. Duane Button. I never imagined it would be possible for myself to pursue a higher level of education, had Dr. Button not planted this idea within my conscious. Although it hasn't been easy, his knowledge, guidance, patience and downright tough love has made the completion of this degree and thesis possible.

I would like to acknowledge the influence Dr. David Behm had on me as well. He made it possible for me to attend university in Europe, and receive funding to help for this work in order to offset the financial burden of completing a Master's degree. He did all of this with a level of modesty and wisdom I will never forget in my life.

To fellow graduate student, Israel Halperin, I cannot thank you enough. You encouraged me to remain confident and design an experiment that was truly mine and revolved around my interests. You were also there throughout many facets of data acquisition and statistical analysis; I could not have done it without you.

I also had the privilege of working with and gaining the camaraderie of so many other graduate students. My education in this program came from so much more than being in the classroom or lab. Being able to just share a coffee and discuss ideas with the young bright minds within the graduate program was humbling.

I would like to thank all the participants whom took the time to complete a grueling research protocol. It was a pleasure to do research with these highly trained athletes.

Had it not been for the set-up and expertise of Dr. Thamir Alkanani with regard to equipment in the laboratory, the acquisition of my data simply would not have happened in such a timely manner. I cannot thank you enough.

I'd like to thank Thera-band for the use of their products and funding allocation to the school of Human Kinetics and Recreation.

Finally, I'd like to thank my parents. Although you may have been unsure the path I would take in life, you have always supported me. The man I have become is only a product of the unconditional love you've shown me.

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# List of Symbols, Nomenclature or Abbreviations

ACL: Anterior Cruciate Ligament

BF: Bicep Femoris

EMG: Electromyography

FBBS: Free Barbell Back-Squat

GMA: Gluteus Maximus

GME: Gluteus Medius

MVIC: Maximum Voluntary Isometric Contraction

NSCA: National Strength and Conditioning Association

RF: Rectus Femoris

RM: Repetition Maximum

RMS: Root Mean Squared

TBL: Theraband Loops

TMA: Total Muscular Activation

VL: Vastus Lateralis

VM: Vastus Medialis

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# Chapter 1: Review of Literature

## 1.1: Introduction

The squat has an enduring history as an important exercise in the fitness community, rehabilitation, and direct strength training application to performance in sport. The free barbell back squat (FBBS) is performed with an external load placed upon the shoulder and trapezius muscles. It is performed via the triple extension of the hips, knees and ankles, which parallels many movements that occur in daily activity and sport. It is considered a closed kinetic chain exercise, where the force is expressed through the end of the limb while it is fixed to the ground (Escamilla et al. 1998). There are many limitations and considerations which must be taken into account with regard to safety when completing a barbell back squat. Specifically, the activation of the gluteal muscles in order to avoid the adduction of the femur. Femur adduction and subsequent internal rotation can cause medial knee collapse, which is linked to patellofemoral pain syndrome (Geiser et al., 2010) and non-contact anterior cruciate ligament (ACL) injuries (Hewett et al. 2006, Reiman et al. 2009, Powers 2010). Anecdotal accounts and clinical case studies generally report improved squatting mechanics when using loop bands as a proprioceptive aid (Gooyers et al. 2012). The band-loops function as proprioceptive aids because one must activate the gluteal musculature to negate the lateral forces created by the band. The purpose of this review was to: 1) comprehensively describe the free barbell back squat (FBBS) 2) review all current literature and squatting techniques used with band-loops and elastic tubing and 3) discuss the purported influence of band-loops when performing a squat.

## 1.2: Squatting for rehabilitation, performance and sport

Many clinicians and coaches consider the FBBS the cornerstone of any strength and conditioning program for athletes. The most well-known physiological benefits derived from squatting are: 1) increased bone density, 2) increased ligament and tendon strength, leading to greater joint stability, 3) development of large muscle groups composed of the lower back, hips, buttocks and thighs, and 4) greater neuromuscular efficiency (O’Shea 1985). Along with these benefits, when completed correctly the FBBS has been shown to provide a training transfer to biomechanically similar movements requiring a powerful thrust from the hips and thighs; such as jumping for distance or height, all forms of running, throwing, and lifting and pushing with the lower body (Balshaw & Hunter, 2012)

Closed kinetic chain movements have the foot or hand (anchor) fixed to an immobile surface, in contrast open kinetic chain movements have the anchor moving freely. Chao et al. (1996) have shown that closed kinetic chain movements produced less posterior and anterior shear forces than open kinetic chain exercises. Subsequently, compressive forces and co-contraction increased; both of which are considered beneficial for the stabilization of the knee joint. The authors even recommended that closed kinetic chain exercises be employed to strengthen the thigh muscles after injury or ACL reconstruction. Closed chain kinetic exercises appear to increase overall muscle activation, decrease shearing forces and increase stabilization around the knee joint compared to, open chain kinetic movement (Chao et al. 1996). Thus, the FBBS can be emphasized as a means of strengthening the muscles of the knee in rehabilitees after injury or reconstruction of the ACL.

### 1.3: Free barbell-back squat (FBBS) description via National Strength and Conditioning Association (NSCA)

The squat is highly regarded as the single most effective lower body exercise. It has many variations (i.e. front, back and overhead), all of which play a role in developing the quadriceps, gluteus musculature and thigh adductors (Yauz et al. 2015). When the exercise is completed properly, a full back squat will not only strengthen these muscles, it will also help to strengthen the tendons and ligaments, which surround the knee (O'Shea 1985). Although many individuals regard the FBBS as a leg exercise, it also plays a major role in developing the core musculature (Hamlyn et al. 2007). To a large degree this occurs because an individual must have a strong core in order to keep the torso erect and remain stable (Hamlyn et al. 2007), especially if a heavy load is placed on the trapeziuses (McCaw & Melrose, 1999). There is no one optimal method to squatting properly. It is an individualized exercise that will vary based on the trainee's body type, length of the legs and flexibility of the ankles. Coaches will usually instruct trainees to engage or flex their core, which stabilizes the torso and helps to avoid a rounded back (i.e. lower back flexion) (Baechle et al. 2008).

Anatomically the NSCA (2008) lists the gluteus maximus (GMA), semimembranosus, semitendinosus, bicep femoris (BF), vastus lateralis (VL), vastus intermeidus, vastus medialis and the rectus femoris (RF) as the muscles significantly activated during the FBBS. Paoli and colleagues (2009) placed EMG electrodes on 8 superficial thigh muscles: vastus medialis, VL, RF, semitendinosus, BF, GMA, GME, and adductor major and found that activation levels for all of these muscles increased with a corresponding increase in load (0-70% 1RM). This study supports many of the anatomical listings by the NSCA (2008). The FBBS also places increasing load on the erector spinae, effectively strengthening the core musculature (McCaw & Melrose, 1999).

Although the FBBS is individualized, the NSCA (2008) outlines what is considered the ideal squatting technique using a very top down approach. There are multiple variables to consider when performing the squat. The following is a brief description of 8 of those variables. 1) Starting position: stand under the bar so it is in the center of the body, inhale and stand erect with the chest "filled with air." 2) Grip placement: grip the bar with a closed, pronated grip. Closer grips will activate the muscles in the back and help to maintain a rigid and neutral torso. 3) Bar placement: there is usually two ways to place the bar in a FBBS; the high-bar and low-bar. The names of the techniques are related to the placement of the bar on the back. The bar is centered across the shoulders just below the spinous process of the C7 vertebra "high-bar", or further down on the back across the spine of the scapula, "low-bar" (Wretenberg et al. 1996). 4) Head and eye position: head and eyes are positioned forward. This is a natural position; keeping the cervical spine in line with the body helps to maintain bodyweight distribution throughout the squat. Many trainees will look either down or up, compromising their balance and stability (Baechle et al. 2008). 5) Foot position: there are 3 potential stances a trainee may consider using; narrow, medium and wide. Although these stances work the muscles of the thigh to a varying degree, trainees will usually use whichever stance feels comfortable (Baechle et al. 2008). Altering foot stance is also a method often prescribed to isolate muscles during the squat. It is widely believed that increasing stance beyond shoulder width will increase the contribution of the vastus medialis and hip adductors, likewise narrowing stance will increase activation of the vastus lateralis (McCaw et al. 1999). McCaw and colleagues (1999) found no evidence to support this often held belief in the strength training community. Therefore, the stance should feel comfortable with the heels remaining in contact with the floor and toes should be pointed about 30 degrees from neutral. Similar to increasing stance, pointing the toes out (hip external rotation) is often prescribed to increase the recruitment of the hip adductors (Pereira et al. 2010). Although Pereira and colleagues (2010) found hip adductor activation did not significantly change when hip external rotation increased. 6) Abdominals: strong abdominals help maintain torso stability and intra-thoracic pressure. If a trainee has week abdominals this may be a limiting factor in completing a proper FBBS (Baechle et al. 2008). Finally, after the set-up is complete, the trainee will move into the actual squat, first the eccentric phase. 7) The descent: trainees are instructed to i) push their hips back and simultaneously ii) flex the knees, iii) maintain torso angle throughout phase, iv) distribute body weight from the balls of the feet to the heels, v) keep knees behind balls of feet, vi) maintain a slow and controlled eccentric descent, vii) keep shins as vertical as possible by "sitting" into the squat. The eccentric phase will be followed by the concentric phase. 8) The ascent: i) attempt to "drive" feet into the floor, ii) raise hips and shoulders iii) keep chest facing forward by keeping shoulders pulled back, iv) continuing extending hips and knees, v) maintain proper head and eye position, and vi) stand fully erect and back to initial phase before the descent.

How the clinician approaches deficiencies of the squat may depend on individual aspects of each trainee (e.g. body type, limb length). However, the NSCA (2008) has illustrated multiple errors that a trainee might exhibit. 1) Starting positions: trainees may not place their body in the center of the bar and also may not “fill” the body with air (Baechle et al. 2008). These two deficiencies in turn will cause the trainee to become unstable. 2) Grip placement: taking ones hands off the bar during the ascent phase or griping the bar with an open grip. 3) Bar placement: with the high bar placement usually trainees may round the back. With the low-bar placement often times the individual cannot stop the bar from rolling down which places a lot of stress on the wrists and shoulders (Baechle et al. 2008). 4) Head and eye position: tilting the head forward can cause the weight to be shifted forward, usually leading to a rounding of the back. In comparison tilting the head backward will shift too much weight to heels of the feet causing an improper curvature of the spine and stress placed on the neck and back. 5) Foot position: commonly trainees simply will not use different stance variations to find the one that works for them. Another concern is pointing the toes inward, which could cause knee valgus. Knee valgus is a major concern as it causes medial knee displacement, hip adduction and hip internal rotation (Baechle et al. 2008). Knee valgus or as it is commonly called valgus collapse can lead to a plethora of knee injuries (Geiser et al., 2010). 6) Abdominals: if the abdominals are not properly strengthened it can lead to a curvature in the spine and lack of a rigid torso during the squat. 7) The descent: shins not being vertical, a rounding of the back during the descent. 8) The ascent: common mistakes include raising the hips to fast out of the bottom of the squat, usually by using a bouncing motion at the bottom of the eccentric phase (Baechle et al. 2008). Also trainees will commonly shift their weight to their toes causing them to lose their balance forward and or causing valgus collapse (Baechle et al. 2008).

Although the barbell back squat may appear to be a simple exercise, it is in fact a complex movement that has many different aspects. Thus, research studies should use experienced and trained participants when implementing experimentation on FBBS, especially during multi-repetition and heavy loaded FBBS paradigms.

## 1.4: Muscle Activation During Free Barbell Back-Squat Compared to Other Strength Training Modalities

The FBBS is the most widely practiced version of the loaded squat (Gullett et al. 2009) and is generally believed to be superior to other exercises. O'Shea (1985) states "the full squat must be considered the cornerstone exercise, because it quickly stimulates overall strength increases in both men and women". The following section will illustrate why the FBBS is considered the "cornerstone" to a strength and conditioning program by comparing and contrasting this exercise to its most applicable alternatives.

### 1.4.1: Knee Extension Machine and Leg Press

Free weights are generally preferred over machines by strength-trained athletes because they are thought to provide a more unstable training stimulus, requiring greater recruitment of trunk musculature (Schwanbeck et al. 2009).

Wilk and colleagues (1996) found the barbell back squat elicited the highest activation in all muscle groups tested (VL, medial, and lateral hamstrings) when compared to the leg extension machine and leg press. This finding supports the belief that closed kinetic chain exercises are vastly superior to open chain kinetic variants (Escamilla et al. 1998) in terms of muscle activation. Squatting with a free weight demands more neural drive in order to stabilize the load (Wilk et al. 1996). The application of force via levers can attribute to less total muscular activation (TMA) in these exercises when compared to the vertical force against gravity applied from the back squat (Schwanbeck et al. 2009).

### 1.4.2: Smith-Machine Squat

The Smith-Machine squat applies a vertical force against gravity, and has no advantageous lever system, providing a similar movement pattern to the FBBS. However, the barbell itself is stabilized in 2 parallel tracks, allowing a more stable exercise (Schwanbeck et al. 2009).

Schwanbeck and colleagues (2009) compared muscle activation between 8RMs of the Smith-Machine squat and FBBS. Tibialis anterior, gastrocnemius, VM, VL, BF, lumbar erector spinae, and rectus abdominus electromyography (EMG) were simultaneously measured (Schwanbeck et al. 2009). Loads were set relative to each exercise; therefore, different absolute loads were used. The 8RM for Smith-Machine was 14 – 23kgs heavier (Schwanbeck et al. 2009). However, it was found on average the FBBS elicited 43% more activation over all muscles when compared to the Smith-Machine variation. Behm and Anderson (2002) completed a similar study with findings that the FBBS squat elicited greater activation of the trunk muscles, yet the smith-machine squat had higher levels of activation in the knee extensors. This contradiction is likely due to the fact Behm and Anderson (2002) used submaximal loads in contrast to Schwanbeck (2009) whom used an 8RM, which is a more intense training stimulus. Higher activation during the free weight squat may be attributed to the increased role that the knee flexors play in stabilizing and supporting the ankle, knee, and hip joints in a more unstable environment (Behm et al. 2002).

### 1.4.3: Front Squat

The front squat is completed with similar technique as the FBBS, the difference being the load is positioned on the front of the shoulders. The assumption is that because the bar is loaded in this way it causes a different training stimulus than the FBBS. This is plausible as there are technical differences involved during the front squat, these include: 1) positioning the barbell across the anterior deltoids and clavicles 2) having the elbows fully flexed 3) maintaining the upper arm parallel with the floor (Yavuz et al. 2015).

Gullett et al. (2012) tested this commonly held belief by having subjects complete two trials and three repetitions of the front and back squat at 70% of their 1 RM. RF, VL, VM, BF, semitendinosus, and erector spinae EMG was recorded. The authors found no difference in muscle activation between the 2 squat variations. Interestingly, the difference in recorded 1 RM's in their study was 61.8 ±18.6 kg for the back squat and 45.8 ± 14.1 kg for the front squats. This clearly demonstrates trainees can lift much heavier loads during a FBBS.

The front squat is as effective as the back squat in terms of overall muscle activation; however, there is less compressive force (Gullett et al. 2009). Therefore, one could argue the front squat is more effective than the back squat, as it elicits the same activation, yet places less sheering force on the knee (Gullett et al. 2009), an obvious benefit. Regardless of this observation, the front squat is performed less often. (Gullett et al. 2009). The front squat is technically difficult, due to a lack of flexibility in the wrist and elbow joints, therefore many clinicians and trainees are hesitant to program or perform it (Gullett et al. 2009). Although individuals may struggle with the flexibility needed in the FBBS as well, the technical modifications needed are not as vast, making the FBBS a more accessible and thus more practiced variation of the free barbell squat (Gullett et al. 2009).

## 1.5: Free Barbell-Back Squat Considerations

The loaded barbell back squat and its variations are widely used for physical preparation for sport, due to its perceived amount of functionality, the ability of the exercise to overload the muscles of the body, and its perceived level of safety. For this reason, there is a growing body of scientific evidence expressing its efficacy. Many of the studies examined below observed the effect on performance by using squatting variants, technique modifications or perceived external aids.

Achieving a squat when the knees are flexed to 90 degrees (squatting to parallel) is usually the range of motion (ROM) that clinicians will aim for trainees to complete, assuming other standards in regards to form are maintained. This is usually difficult for an individual who is untrained in the squat; they will usually elicit a multitude of the aforementioned deficiencies. The reason this depth of the squat is desired is because individuals will have to activate hip musculature such as the GMA and GME in order to propel themselves upward from this depth of the squat (Caterisano et al. 2002). Thus, by squatting to depth with near maximal loads the GMA and GME will show higher activation.

### 1.5.1: Stance Width and Hip Rotation

There is a commonly held belief that one should squat with a stance width that replicates the specific stance they would use while participating in a specific activity. For example, a bicyclist would a use closer stance to replicate the width of their feet when cycling. However, stance width effects GME and GMA activation.

Paoli et al. (2009) found that the GME muscle activity increased when stance was at 200% hip width during a squat. This finding was only found when participants squatted at their own body weight and 70% 1RM. McCaw and Melrose (1999) completed a similar study but they increased stance width by shoulder width increments during the squats. Surprisingly, they found no changes in quadriceps activation with increased stance during squats at 65% and 75% of the subjects 1 RM. Not surprisingly, both studies showed increases in muscle activation when loads were increased. However, stance width appears to have conflicting results on muscle activation during the squat.

Pereira et al. (2010) compared squatting to parallel when the hip was in a neutral position and when it was rotated anteriorly 30 and 50 degrees. Participants completed a 1 RM in each modified hip position. A positive correlation was found with adductor activity and an increase in hip rotation. All muscle activity was significantly greater in the last 30 degrees of the squat, regardless of hip rotation.

Gullett et al. (2009) demonstrated that stance widths 40% wider than shoulder width, or twice that of hip width seem to increase GMA activation. Likewise, adductor activation increases when the femur is externally rotated. Regardless of stance or hip rotation it appears in the studies covering both, there is a common outcome despite these interventions. Overall muscle activation of the lower body is dictated more so by the external load and squatting depth. As the external load increases and subjects reach the last 30 degrees (deepest phase) of the squat in flexion and extension, muscle activity is significantly greater.

### 1.5.2: Squatting Depths

Clinicians may recommend a range of squat depths for trainees, which they believe could have practical benefits for the trainee's goals. However, it is generally believed that squatting so that the femur is at least parallel to the floor, or deeper, is most effective for improving athletic performance (Caterisano et al. 2002).

Caterisano et al. (2002) tested muscle activation of the quadriceps, hamstrings and GMA while squatting to three depths; "partial", "parallel" and "full" to knee angles of 135, 90 and 45 degrees, respectively, with loads between 0 and 125% of the participants' body weight. GMA muscle activation increased from partial to parallel to full squat depths by 16.9%, 28.0%, and 35.4%, respectively. There were no significant changes in quadriceps muscle activation with increased squat depth. However, the same loads were used at all depths. An individual's 1RM for a partial squat, is potentially going to be much greater than the 1 RM for the full squat. If a trainee uses the same load, it may be a moderately to high load for the full squat, but would be a light load for the partial squat in the same individual. This could be solved if relative 1 RM testing had been done for all three depths, effectively establishing an appropriate relative load for each test, which would overcome a caveat in Caterisano's (2002) study as participants squatted a load between 0-125% of their body weight, and they used the same weight at all depths of the squat.

Isear and colleagues (1997) completed a study to observe EMG activity through multiple arcs of the squat. The arcs of motion in which they tested included: 0-30[degrees], 30-60[degrees], 60-90[degrees], a brief pause, 90-60[degrees], 60-30[degrees], 30-0 [degrees]. The aim of this study was to 1) describe the amount of quadriceps and hamstring co-contraction and 2) determine muscle recruitment patterns of the GMA, hamstrings, quadriceps, and gastrocnemius during an unloaded squat. The majority of studies in this field tend to focus primarily on the interaction of the quadriceps and hamstrings, but the GMA has been shown to be increasingly active as hip flexion increases (Isear et al. 1997). Thus, when an individual completes a squat to 90 degrees', the activation of the GMA may have functional significance. They found that GMA activation was greatest during the 90-60 [degrees] arc. After the hold period, subsequent propulsion during the concentric phase the GMA EMG elicited a jump from approximately 5 % activation to 17 %. Isear and colleagues (1997) tested muscle activation while using an unloaded squat. As reported above, as the squat load increases so too does muscle activation, thus the potential does exist to see an exponential increase in activation proportional to the load placed on the trainee during different arc phases of the squat.

#### 1.5.3: High vs. Low Bar Placement

Wretenberg et al. (1996) compared high and low bar squats when squatting to parallel and full depths. This study used subjects with competitive powerlifting backgrounds and strength trainees. TMA was not significantly impacted between the use of a high or low bar set up in both populations used. However, the power-lifter group showed greater over all muscle activation, which was likely due to the fact that they lift much heavier absolute loads (65% heavier 1 RMs). The most notable outcome from this study was that the hip moment of force was almost double when using the low bar placement compared to high bar. Wretenberg and colleagues (1996) recommend using the low bar when knee health is of concern and the high bar technique if overloading the hip is of concern, as the moments of both joints are more evenly disrupted when using the high bar technique.

Overall, if an individual's aim is to activate the muscles of the hip and lower limb they should perform heavy loaded FBBS to a depth that is considered parallel or below. It appears stance; hip rotation and bar placement does not have significant impact on muscle activation.

## 1.6: Importance of Gluteus Activation

A long history of data illustrates the important role of the GMA and GME in athletic endeavors (Delp, et al. 1999, Gottschalk et al. 1989, Lyons et al. 1983). The GMA is a powerful hip extensor and lateral rotator (Delp, et al. 1999). It is often used to accelerate the body upward and forward from a position of hip flexion ranging from 45° to 60° (Delp, et al. 1999). The GME stabilizes the femur and pelvis during weight-bearing activities with the greatest GME activation observed during the stance phase of gait (Gottschalk et al. 1989, Lyons et al. 1983). This demonstrates the importance of the muscle with regard to medial knee collapse, as its activation works to maintain the femur in a biomechanically correct position during squatting. It has been shown that a strong relationship exists between hip dysfunction and knee pathology (Powers, 2010; Reiman, et al. 2009). Ireland, Willson, Ballantyne, and Davis (2003) revealed that females with patellofemoral pain syndrome (PFPS) demonstrated 26% less hip abductor and 36% less hip lateral rotation strength than controls. Powers (2003) theorized that hip abductor and lateral rotator weakness can lead to knee valgus, hip adduction, and hip internal rotation, a position that can place undue stress on lower extremity joints. Correcting the hip strength deficits improves lower extremity pain in runners (Ferber et al. 2011). Several ways in which an individual could activate the GMA and GME and prevent some of aforementioned issues would be to perform exercises with elastic tubing or loop bands.

## 1.7: Leg Exercises with Elastic Tubing

Elastic bands offer variable resistance throughout a range of motion and have long been used for rehabilitation purposes. More recently the use of elastic bands has found a niche in many strength-training programs (Stevenson 2010). The following will give an overview of how elastic bands are used in a conventional rehabilitation setting and as a means to enhance the stretch shortening cycle in athletes completing the FBBS. It is important to understand their current use by clinicians as we propose a new use for the band-loop; increasing hip muscular activation in trained subjects.

### 1.7.1: Elastic Tubing in Rehabilitation

Elastic bands offer variable resistance throughout a range of motion. The use of elastic tubing has been usually associated with rehabilitation. For example, an objective for clinicians when strengthening the quadriceps after anterior cruciate ligament reconstruction, is to avoid stress directed on the ACL graft. Schulthies et al. (1998) hypothesized completing exercises with elastic tubing attached to the uninjured leg would increase co-contraction of the contralateral (injured) leg and subsequently strengthen the quadriceps while applying insignificant shearing forces to the injured leg and thus ACL. Four relatively simple exercises were used: 1) crossover, 2) reverse crossover, 3) back pull and 4) front pull they found that the activation of the uninjured leg ranged from 25% - 50% MVIC, and hamstring: quadriceps co-contraction ranged from 60% - 137%. The bands force was standardized to 20% of the participants bodyweight, thus the levels of activation were very high when the relative force is considered. The authors suggested that the exercises they employed would be useful in a rehabilitation setting. These closed kinetic chain exercises help to increase joint compression, enhancing joint stability and thus will help to protect the ACL graft (Schulthies et al. 1998). Likewise, closed kinetic chain exercises are more likely to produce cocontraction of the hamstring muscles, which also decreases anterior shearing forces (Schulthies et al. 1998). The FBBS would provide similar benefits in a rehabilitation setting and the use of the band could help to stabilize the pelvis. Thus, if programmed correctly this training modality has the potential to be helpful in a rehabilitation setting.

**1.7.2: Hip Strengthening**

Youdas et al. (2014) used the same exercise, intervention and protocol as Schulthies and colleagues (1988), the difference being the population was healthy, and EMG data were collected from both legs. Also Youdas and colleagues (2014) collected EMG from the GMA and GME only, as strengthening these muscles are an objective of clinicians with patients whom suffer from a multitude of musculoskeletal disorders. Youdas (2014) and colleagues found the stance limb to only have greater GME activity in one (front pull) of the four exercises used. Activation was higher in the GME and GMA in the movement limb in all other exercises. The authors suggest that there is no therapeutic benefit for the stance limb when the contralateral leg is attached to the resistance bands. This is contrary to findings found by Schulthies et al. (1988). Youdas (2014) stated this based on the peak EMG amplitude failure to reach the 50% threshold, which is considered necessary for strength gains in a healthy population (Andersen et al. 2006). Hence, if weight bearing tolerance is not a concern there is no benefit to the GME or GMA on the stance limb via resisting sagittal- and frontal-plane hip movements on the moving limbs. However, these findings may not apply to an injured population of subjects used in Schulthies (1998) experiment.

### 1.7.3: Elastic Tubing and Variable Resistance Training.

In rehabilitation, bands are characterized as portable, offer light resistance, and versatility. When strength training they are usually thicker (increasing resistance) and are used for variable resistance training (VRT). VRT accommodates the strength curve of extension-type exercises thus, resistance on the band is increased as the hip and knee joints extend (Stevenson 2010). Stevenson (2010) attached the bands on each side of the bar and anchored them to the ground, while having participants complete 55% 1RM in the FBBS, the bands added 20% of the force of the subjects 1RM. They found that peak velocity in the eccentric phase and rate of force development (RFD) in the concentric phase increased with the use of the bands. The authors speculated that practitioners who concern themselves with increasing RFD should incorporate this in their training protocol.

## 1.8: Squatting with band-loops

Band-loops are a continuous loop of elastic that provides progressive resistance as they are stretched. They usually come in multiple resistance levels, which allows clinicians to choose a band that provides an appropriate amount of resistance for their chosen exercise. Band-loops can be used for countless exercises; the only limitation is the imagination of the clinician or trainee. They are usually wrapped around the thighs or shanks and used for a wide variety of lower body exercises with the aim to increase strength or balance. One of the most notable exercises is the lateral walk, anecdotal reports consider this an effective way to activate the gluteal muscles before exercise or sport. The GMA and GME must be active when the femur is abducted from the body. Therefore, when the band is placed around the ankles or knees, the stance limb anchors the band and as the femur abducts the resistance from the band-loop becomes greater, thus increasing the contribution from the gluteal muscles to continue the abduction of the non-stance limb. Band-loops are generally considered to be effective both in a rehabilitation setting and as an effective way to prime the body for vigorous activity in trained athletes.

### 1.8.1: Band-loops; Lateral Thigh Placement

To the authors knowledge, there is only one study that examined the effects of a band-loop on squat technique and performance. In a study by Gooyers et al. (2012) participants performed a body weighted squat and jumping exercises with and without a band-loop placed around the distal portion of the thighs. Gooyers and colleagues (2012) hypothesized that a band-loop wrapped around the distal thighs might encourage trainees to control internal rotation of the femur and subsequent medial collapse of the knees. No verbal or visual aid was given during the exercises because Cook et al. (1999) theorized that bands would invoke a proprioceptive response, placing less emphasis on these commonly used aids by clinicians. Gooyers et al. (2012) hypothesized frontal knee plane kinematics and kinetics would be different when a band-loop was used. Their study was an attempt to assess the biomechanical impact of the bands, thus no EMG were collected. They found that placement of resistance bands around the distal thighs failed to promote neutral knee alignment during squatting and jumping exercises. Results from this study did not support the contention that a band-loop would help to maintain knee width when squatting and jumping. Rather, the stiffest band elicited an exaggerated medial collapse of the knees during the ascent phase of the countermovement jump. This outcome was uniform across all participants, regardless of gender.

The countermovement jump is a fast and explosive movement; the feet leave the ground for a brief period of time. Without having the feet anchored to the ground, the potential for medial knee collapse will greatly increase with an external force applied to the outside of the knees. This is not an ideal way to assess the effect of the band-loop. Furthermore, the effect the band-loop had, with bodyweight squatting was not as hypothesized, as there was no change in medial displacement of the knee. This could have been due to the clinical practice of the researchers, the untrained participants, or both. Interestingly, Gooyers et al. (2012) stated that “Future research should examine the activation of the hip and thigh musculature to further explore the influence of band-loops on altering dynamic neuromuscular control of lower extremity alignment during squatting and jumping tasks”. The researchers also discussed the potential need for a task or performance goal, which may lead to more favorable results. A highly trained population may also help to avoid some of the caveats faced by Gooyers and his Colleagues.

### 1.8.2: Biomechanical Influence

One must attempt to keep their torso upright and ridgid when squatting (NSCA). If a trainee can activate their hips to a greater extent this stabilizes the pelvis and allows for greater upper trunk control. Aberrant movements of the pelvis and trunk can influence the movements acting on the knee. During dynamic tasks, excessive trunk motions in the frontal and sagittal plane may reflect muscular adjustments to accommodate hip muscle weakness and lack of pelvic control or a combination of both (Powers 2010). Thus, the muscles that maintain a level pelvis (hip abductors) play an important role during dynamic movements. An argument can be made that dynamic trunk stability cannot exist without pelvic stability. Although the trunk musculature (ie, abdominals, transverse abdominis, obliques, multifidi, erector spinae) play an integral role in stabilizing the spine, these muscles would not be able to compensate for poor pelvis control (Powers 2010).

Powers (2010) makes a compelling argument that present evidence to support the contention that impairments at the hip may adversely impact tibiofemoral and patellofemoral mechanics. However, it is also clear that mechanistic studies and randomized controlled trials are needed before recommendations can be made. Powers (2010) hypothesized that a biomechanical argument can be made for the incorporation of two general principles into the design of an intervention program to address proximal impairments related to knee injury: (1) pelvis and trunk stability and (2) dynamic hip control. The use of a band-loop could help correct both of these problems, especially if a band-loop could be used as a tool to increase GMA and GME activation during a dynamic movement such as a squat.

With increased pelvis control directly effecting the stability of the trunk and band-loops believed to increase pelvis control, it would seem possible that band-loops could increase the efficiency in which a trainee completes FBBS. A band-loop may allow the participant to keep their torso more upright, making this biomechanically advantageous. Thus, less energy will be expended during a submaximal squat repetition subsequently allowing an individual to complete a greater number of repetitions.

### 1.9: Conclusion

Present literature suggests that: 1) the FBBS is the most widely used version of the free barbell back squat and arguably the most effective lower body exercise, 2) as a closed kinetic chain exercise it is viable not only for strength training but in a rehabilitation setting also, 3) current research using elastic bands and band-loops have been confined to a rehabilitation setting or their potential use to increase RDF in a trained population (with band use external to the body), 4) activating and strengthening the GMA and GME is vital to optimize athletic performance and avoid knee dysfunction and 5) band-loop placement on the thigh does not impact the biomechanics of the squat or oblige trainees to avoid medial knee collapse.

To the author's knowledge, no study has been completed to examine the effects of a band-loop placed around the distal thighs during a squat to determine its effect on muscle activation of lower body muscles during a squat. Furthermore, what affect would the band-loop have on a direct performance outcome (maximal repetition squat) at a high intensity (60% 1 RM). The next chapter is a study completed by the author to determine the effect of a band-loop on muscle activation (especially the gluteal muscles) during a high intensity squatting protocol, and overall squat performance to failure in trained athletes.

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## Chapter 2: Co-authorship Statement

My contribution to this thesis is outlined below:

i) I recruited all participants and analyzed all data collected for this thesis.

ii) With the help of fellow master's student, Mr. Israel Halperin, I collected all experimental data and completed all statistical analysis for this thesis.

iii) I prepared the manuscript and thesis with the help and guidance of my supervisor, Dr. Duane Button.

iv) Dr. Button provided constructive feedback on the manuscript and Thesis.

# Chapter 3: Loop band placement on the distal-lateral portion of the thigh increases gluteal activation during high intensity squatting in trained subjects.

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Running Head: Loop bands increase lower body EMG.

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## 3.1: Abstract

**Context**: No published studies have compared muscle activation levels during a free barbell back squat (FFBS) while having Theraband loops (TBL) across the distal, lateral portion of the thighs.

**Objective:** To quantify total muscular activation (TMA) change amongst the Gluteus Medius (GME), Gluteus Maximus (GMA), Vastus Lateralis (VL), and Biceps Femoris (BF) during a free barbell back squat with, and without the use of TBL.

**Design:** Two-way repeated measures ANOVA tests were used to determine normalized EMG differences during a 5RM test (2 conditions [Control and Band-loop] x first, third, and fifth repetition) and 60% of 1RM test to failure (2 conditions x first, middle, and last repetition) for tested muscles and for each type of muscle contraction (Concentric and Eccentric). A paired *t*-test was used to examine differences between conditions for the number of repetitions to failure in the 60% of 1RM test to failure.

**Setting:** University Laboratory

**Patients or Other Participants:** Fifteen resistance-trained males (23.6±3.5yrs) participated.

**Interventions:** Subjects performed a randomized cross over design separated by 24-48 hours. Participants performed 5 repetitions of a barbell back squat at 80% of their 1 RM test followed by a repetitions to failure at 60% of their 1RM test with (experimental) and without a loop band (control) placed around their thighs.

**Main Outcome Measures:** EMG of the vastus lateralis (VL), biceps femoris (BF), gluteus medius (GM) and gluteus maximus (GMA) during the 5RM test and repetitions to failure at 60% of 1RM.

**Results:** No differences were found in the number of repetitions to failure test between conditions ($P= 0.171$). Similarly, no differences were found between conditions in EMG activity of the quadriceps and hamstrings during the 5RM test, as well as the repetitions to failure test in the concentric and eccentric contractions ($P\geq 0.210$). In contrast, the gluteus medius demonstrated greater EMG activity in the band-loop day during the 5RM test, and repetitions to failure test in the concentric and eccentric contractions ($P\leq 0.046$). Likewise, the gluteus maximus showed higher EMG activity in the band-loop day during the 5RM and the repetitions to failure tests in the concentric and eccentric contractions ($P\leq 0.037$).

**Conclusion:** Placing a band around the knees may be a used as a strategy to increase the contribution of these muscles during medium and heavy squat training among trained individuals.

**3.2: Keywords:** squat, resistance trained, electromyography.

### 3.3: Introduction

The free barbell back squat (FBBS) is considered the most widely practiced version of the loaded squat (Gullett et al. 2009). The National Strength and Conditioning Association (NSCA) consider it to potentially be the single most effective lower body exercise. Therefore, clinicians are continually searching for technical or external aids to help increase squatting efficiency. Therband Loops (TBL) or elastic tubing modalities wrapped around the distal-lateral thighs have been purported to aid trainees in the avoidance of medial knee collapse. Femur adduction and subsequent internal rotation can cause medial knee collapse, which is linked to patellofemoral pain syndrome (Geiser et al. 2010) and non-contact ACL injuries (Hewett et al. 2006; Reiman et al. 2009; Powers, 2010). Aside from the TBL biomechanical influence on frontal knee plane mechanics, it may also play a role in directly increasing total muscular activation (TMA) of the lower body, most notably the muscles of the posterior pelvic region.

Clinicians usually will recommend most trainees attempt to squat such that the femur is either parallel to the floor or to an angle 'below' parallel (i.e. a deeper squat). One reason for this is that the gluteal muscles are more activate at the bottom phase of the squat and must become increasingly active in order to stabilize at the bottom of a squat and for the subsequent propulsion needed for the ascent from this position (Isear et. al. 1997). Likewise, the gluteal muscles help to stabilize the pelvis and allow for a more upright torso (Powers 2010), which is believed to increase squatting safety and efficacy. Therefore, it is usually a goal of most practitioners to re-emphasize the use of the gluteal muscles.

Gooyers et al (2012) hypothesized the use of loop bands across the distal-lateral thighs would act as a proprioceptive aid, encouraging trainees to abduct the femur and avoid subsequent medial knee collapse. However, the TBL failed to promote neutral knee alignment during squatting and jumping exercises. These findings were contradictory to expectations based on clinical (Cook et al. 1998) and anecdotal reports. Gooyers (2012) recommended that future research should focus on activation of the thigh and hip musculature to further explore the influence of the bands on altering dynamic neuromuscular control of the lower body during squatting tasks.

Therefore, the purpose of this investigation was to examine the impact of the use of TBL around the distal-lateral portion of the thigh, on thigh and posterior hip total muscular activation (TMA). Another objective was to observe any direct squatting performance outcome, which may occur when the intervention is in place. Based on work done by Gooyers and colleagues (2012) we hypothesize an increase in activation of the GMA and GME, when the loop-band is applied. Theraband loops and elastic tubing modalities have a well-documented history in rehabilitation. This investigation differs from others completed when using this intervention, most notably subjects completed the FBBS at a high intensity (80% and 60% 1 RM) and were chosen from a trained population.

## 3.4: Methods

### 3.4.1: Subjects

Fifteen (age 23.7 ± 3.5, years; height 180 ± 8.3 cm; weight 86.1 ± 10.2, kg) male participants whom had 6.2 ± 4.6 years of back squat experience volunteered for the study. Participants were verbally informed of all procedures, and if willing, signed a written consent form. Subjects were instructed to not smoke, drink alcohol, or exercise at least 6 h prior to testing and to not consume food or caffeinated beverages for at least 2 h prior to testing. The Memorial University of Newfoundland Interdisciplinary Committee on Ethics in Human Research approved this study (ICEHR #20141327-HK) and was in accordance with the Tri-Council guideline in Canada with full disclosure of potential risks to participants.

#### 3.4.2: Experimental Design

Participants were required to visit to the laboratory on 3 occasions: introductory, control and experimental condition. During the introductory session participants were given a verbal explanation on what to expect during the study, and also were given a consent form to read and sign. Participants' age, height, weight and years' experience doing FBBS were recorded. An electronic goniometer was positioned on the lateral axis of the knee to ensure the knee reached a minimum of 90 degrees. Once the 90-degree squat was determined variable risers were placed to this height to act as a guide to ensure participants achieved this depth with each repetition. Subjects were told to touch and not sit on the risers. Tape was placed on the floor, tracing the outer edge of the feet to control for foot positioning between sessions (Figure 1). Verbal commands by the investigator were used to instruct each participant to descend and ascend. A metronome set to 50 beats per minute (BPM) was used to control for tempo during descent and ascent (1.2/1.2/1.2/1.2). In order to find each individual's 3 repetition maximum (RM) they were allowed to warm-up with as much weight and as many sets as needed. This was done to accommodate the training status of each individual. The 3RM was used to give a predictive 1RM, which was used to calculate each individuals 80% maximum for the 5RM test, and 60% for the maximum repetition test. See Figure 2 for an example of a FBBS performed during the experiment.

For the control and intervention sessions participants completed maximum voluntary contractions (MVC) at the beginning of each session in order to normalize muscle activation during each test. The 5RM and 60% RM to failure tests were completed during both conditions. The only difference between each condition was the band-loop was placed around the distal portion of the thighs during the experimental condition (Figure 3). The band was placed approximately 3-5 centimetres above the anterior superior patellar.

#### 3.4.3: Protocol during Control and experimental conditions

Upon arriving to the lab subjects were prepared for EMG (see below). Participants were asked to perform 2 isometric contractions for each muscle group to ensure the electrodes and instrumentation were working properly. Tensor bandages were wrapped around both thighs to ensure that electrodes would stay in place and to ease the discomfort of wearing the band-loop. Participants then completed a non-specific, submaximal warm up on a stationary bike at 70 RPM with one 1 KP resistance for 5-minutes. Participants completed an exercise specific warm-up, consisting of one set with a 20-kilogram bar, then 2 sets of squats with a self-selected load and number of repetitions that were standardized between each session. This strategy was chosen to accommodate the varying training status of participants and to increase the ecological validity of this study. Upon completion of the last warm-up set, subjects were given 5 minutes of rest before completing the 5 RM test. After another 5-minute rest period, participants completed a 60% 1RM to failure test.

### 3.4.4: Band-loops

The Theraband Band-loops provide a progressive amount of resistance as they are stretched. Two exact same bands were used in this investigation. Bands were alternated in use during each intervention session. Before the study commenced, both bands were pre-stretched to twenty-five centimeters for two hours. Both bands were attached to a load cell after every third session of use and stretched to 60 centimeters. Throughout the duration of the experiment, force created by the bands ranged from 10.27 – 12.47 kilograms when stretched 60 centimeters.

### 3.4.5: Electromyography (EMG)

Skin preparation for all electrodes included hair removal via reusable razors, dead epithelial cell removal via abrasive sandpaper, and cleansing with an isopropyl alcohol swab. Indelible ink outlines were traced around the surface electrodes to ensure accurate repeated electrode placement between trails. Bipolar surface electromyography electrodes were used to measure all EMG signals**.** Two surface EMG recording electrodes (Meditrace Pellet Ag/AgCl electrodes, disc shape, and 10 mm in diameter, Graphic Controls Ltd., Buffalo, NY) were placed 2 cm apart on the dominant leg vastus lateralis (VL), biceps femoris (BF), gluteus medius (GME) and gluteus maximus (GMA) mid-muscle bellies, with a ground electrode placed on the fibular head. Tape was applied to the electrodes and leads to ensure optimal surface contact for the duration of the testing. All EMG activity was sampled at 2000 Hz, with a Blackman 61 dB band-pass filter between 10 and 500 Hz, amplified (bi-polar differential amplifier, input impedance = 2 Mf, common mode rejection ratio [110 dB min (50/60 Hz), gain 1000, and analog to digitally converted (12 bit) and stored on a personal computer for further analysis (Dell Inspiron 6000). A commercially available software program (AcqKnowledge 4.1, Biopac Systems Inc., Holliston, MA) was used to analyze the digitally converted analog data.

Participants performed two, 4-second MVC for the knee extensors, knee flexors, hip extensors and hip abductors in order to determine maximum EMG levels for the VL, BF, GME and GMA, respectively. VL, BF, GME and GMA EMG were measured during each MVC so EMG activity during the two squat protocols could be normalized to MVC EMG for each respective muscle. For all MVC's, participants were instructed to contract as hard and as fast as possible and were given strong verbal encouragement. RMS EMG of all muscles was measured for 1 s duration from 2-3 s during the 4 s MVC. Knee extension MVC: Subjects were seated in a specially designed chair (Technical Services, Memorial University, St. John's, NL, Canada) with the hips secured at $90^0$. Bilateral shoulder straps linked with waist and groin straps ensured minimal body translation. A foam-padded strap was placed around the dominant leg at the ankle. Participants performed the MVC by contracting the limb against the strap. A high-tension wire secured the strap and isometric force was measured with a Wheatstone bridge configuration strain gauge (Omega Engineering Inc., Don Mills, ON). Differential voltage from the strain gauge, was amplified, converted (Biopac Systems Inc. DA 100 and analog to digital (A/D) converter MP100WSW; Holliston, MA) and monitored on a computer. Peak isometric force was calculated from the knee extension MVC and the mean

RMS EMG of the VL was analyzed over a one second duration following the peak MVC. The other MVCs were performed via 1) knee flexion: from a standing position, participants stood with their back towards an immovable object. Subjects performed the MVC by pushing their dominant leg against the immovable object. Hip flexion abduction: subjects were positioned horizontally on a bench, on the contralateral side of electrode placement. The investigator applied pressure with their hands so as to immobilize the thigh. Subjects attempted to abduct the leg in an attempt to push the investigator away. Hip flexion: participants were in a prone position and the investigator applied pressure to the posterior portion of the thigh, keeping the anterior portion of the thigh from lifting off the ground. Participants were told to contract their gluteus maximus as they push the investigator away.

### 3.4.6: Criterion Variables

#### 3.4.6.1: EMG during the squat

To measure the amount of muscle activation during the squat protocols, mean RMS EMG of the VL, BF, GME and GMA was analyzed over a burst of EMG activity (lasting approximately 500ms in duration). Figure 4 shows raw EMG traces for each of the four muscles from one individual during a 5 RM test. The first, third and fifth repetitions were chosen for the 5 RM test and the first, middle and last repetition were chosen for the 60% RM reps to failure test for all muscle EMG analysis in the control and experimental conditions. The EMG signal was first smoothed with a band pass filter with a low frequency cut off of 10 HZ and a high frequency cut-off of 500 HZ. Root mean square was derived from all signals with a time interval of 30 milliseconds. The highest peak to peak (P-P) of each input voltage was found manually for both eccentric and concentric phases in each repetition. The mean RMS EMG from 250 ms pre- and post-P-P value was used for comparison.

#### 3.4.6.2: Maximum Repetitions

During the 60 % repetition maximum test, the amount of repetitions completed during the intervention versus the control session was seen as an acute, direct performance outcome of using the band-loop.

### 3.4.7: Statistical Analysis

All statistical analyses were performed via SPSS (SPSS 18.0 for Macintosh, IBM Corporation, Armonk, New York, USA). A paired *t*-test was used to examine if a significant difference between conditions was found in the number of repetitions to failure in the 60% of 1RM test to failure. A two-way repeated measures ANOVA test (2 conditions (Control and band-loop) were conducted to determine normalized EMG differences in the 5RM test (first, third, and fifth repetition) and the 60% of 1RM test to failure (first, middle, and last repetition) for the four individually tested muscles (VL, BF, GMA and GME) and for each type of muscle contraction (concentric and eccentric). Paired *t*-tests were used to decompose significant interactions between muscles tested and a post hoc Bonferroni was used to compare means if main effects were found. Significance was set at $p < 0.05$. Cohen's *d* effect sizes (ES) (1988) were also calculated to compare the differences between conditions. All data are reported as means ± SD.

## 3.5: Results

### 3.5.1: Repetitions

No significant difference was found in the number of repetitions to failure in the 60% of 1RM test between conditions (*p*= 0.171; Control day: 20.4 ± 4.7, Loop band day: 21.4 ± 6).

### 3.5.2: EMG during the 5RM squat

A main effect for repetitions was found for VL EMG during the concentric phase in which repetition 1 was significantly lower than repetition 5 across conditions (*p* = 0.008; ES = 0.39; 10%) (Figure 5A). However, no significant interaction (*p* = 0.126) or main effects for conditions (p = 0.936) were found.

A main effect for repetitions was found for VL EMG during the eccentric phase in which repetition 1 was significantly lower than repetition 5 across conditions (*p* = 0.050; ES = 0.40; 10%) (Figure 5B). No significant interactions (*p* = 0.856) or main effect for conditions (*p* = 0.282) were found.

A main effect for repetitions was found for BF EMG during the concentric phase with repetition 1 being lower than repetition 5 across conditions (*p* = 0.021; ES = 0.85; 22%) (Figure 5C). No significant interactions (*p* = 0.362), main effects for condition (*p* = 0.702) or repetitions (*p* = 0.071) were found (Figure 5D).

A significant interaction was found for GME EMG activity during the concentric phase (*p* = 0.046). Particularly, the EMG magnitude was greater during the band-loop in repetitions 3 (*p* = 0.040; ES = 0.66; 18%) and 5 (*p* = 0.048; ES = 0.67; 16%) (Figure 5E). Additionally, a main effect for repetitions was found in which repetition 1 was significantly greater than 5 across conditions ($p < 0.001$; ES = 0.67; 14%) (Figure 5E). A significant interaction was found for GME EMG activity during the eccentric phase. The EMG magnitude was higher during the band-loop only in repetition 3 ($p = 0.011$; ES = 0.96; 13%) (Figure 5F). Additionally, a main effect for repetitions was found in which repetition 1 was significantly lower than repetition 5 across conditions ($p < 0.016$; ES = 0.67; 14%) (Figure 5F).

A significant interaction was found for GMA in which EMG activity during the concentric phase was greater in the loop-day conditions in repetitions 1 ($p = 0.001$; ES = 0.81; 22%) and 3 ($p = 0.002$; ES =1.14; 32%) (Figure 5G). In addition, a main effect for repetitions was found where repetition 1 was lower than repetition 5 across conditions ($p = 0.021$; ES = 0.72; 19%) (Figure 5G). A significant interaction was found for GMA during the eccentric phase in which greater EMG amplitude was found in the band-loop only in repetition 1 ($p = 0.019$; ES = 0.80; 11%) (Figure 5H). Also, a main effect for repetitions was found with repetition 1 being lower than repetition 5 across conditions ($p = 0.001$; ES = 0.33; 5%) (Figure 5H).

### 3.5.3: EMG during squat to failure at 60% of 1RM

A main effect for repetitions was found for VL EMG during the concentric phase in which the first repetition was significantly lower than the last repetition across conditions ($p < 0.001$; ES = 1.05;24%) (Figure 6A). However, no significant interactions ($p = 0.548$) or main effect for conditions ($p = 0.638$) were found. Similarly, a main effect for repetitions was found for quadriceps EMG during the eccentric phase in which the first repetition was significantly lower than the last repetition across conditions ($p = 0.049$;

ES = 0.62; 16%) (Figure 6B). No significant interactions ($p$ = 0.856) or main effect for conditions ($p$ = 0.282) were found.

A main effect for repetitions was found for BF EMG during the concentric phase were the first repetition was significantly lower than the last repetition across conditions ($p$ = 0.006; ES = 0.80;21%) (Figure 6C). During the eccentric phase there were no significant interactions ($p$ = 0.873), main effect for conditions ($p$ = 0.941) or repetitions ($p$ = 0.143) were found (Figure 6D).

A main effect for repetitions was found for GME EMG activity during the concentric phase in which the first repetition was significantly lower than the last repetition across conditions ($p$ < 0.001; ES = 1.14;23%) (Figure 6E). No significant interactions ($p$ = 0.128), main effects for conditions ($p$ = 0.068) or repetitions were found. Likewise, a main effect for repetitions was found for GME EMG activity during the eccentric phase in which the first repetition was significantly lower than the last repetition across conditions ($p$ < 0.001; ES = 0.84;11%) (Figure 6F). No significant interactions ($p$= 0.204) or main effect for conditions ($p$= 0.071) were found.

A significant interaction was found for GMA in which EMG activity during the concentric phase was greater in the band-loop in first repetition ($p$ = 0.001; ES = 0.97; 21%) (Figure 6G). In addition, a main effect for repetitions was found where the first repetition was lower than the last repetition across conditions ($p$ = 0.001; ES = 1.34; 35%) (Figure 6G). A significant main effect for conditions was found for GMA during the eccentric phase in which greater EMG amplitude was found in the band-loop compared to the control ($p$ = 0.009; ES = 0.83; 12%) (Figure 6H). Also, a main effect for repetitions was found in which the first repetition was lower than the last repetition across conditions ($p$ = 0.001; ES = 1.26; 18%) (Figure 6H).

### 3.6: Discussion

Placement of Theraband Loops (TBL) around the distal lateral aspect of the thighs significantly increased activation levels of the gluteal muscles (Both GME and GMA) during both the concentric and eccentric phases of the squat. The increased level of activation of these muscles was observed in both the 5 repetition at 80% of 1RM and repetition until failure at 60% of 1 RM tests. Thus in agreement with our hypothesis the use of the TBL with trained subjects increased muscular activation levels of the gluteal musculature. During the 5RM test the GME showed significant activation increases during repetitions 3 (18%) and 5 (16%) of the concentric phase, and only during repetition 3 (13%) of the eccentric phase when the band-loop was applied. Likewise, the GMA showed significant EMG increases at repetition 1 and 3 of the concentric phase, and greater activation during repetition 1 of the eccentric phase when the band-loop was applied. The 60% percent until failure test showed no interactions with the intervention and its effect on the EMG of the GME. However, the GMA was more active during repetition 1 (21%) of the concentric phase, and across all (12%) repetitions during the eccentric phase. It appears that during the higher intensity squatting protocol, both the GMA and GME elicited higher levels of EMG. Yet the GMA showed a uniform increase in EMG during the eccentric phase of the 60% RM squat until failure, and the GME was unchanged. It seems the GME plays more of a roll in stabilizing the pelvis and avoiding medial knee collapse at higher intensities, this increase could be explained by the intensity increase itself or perhaps the need of the GME to activate to a greater extent if the GMA has been activated to its maximal functional capacity. The GMA on the other hand was never maximally activated, and not the limiting factor during the repetition to failure test, thus it was the sole contributor in avoiding internal rotation of the hip during this test.

There was no significant increase in repetitions completed during the 60% RM test with the TBL applied. Therefore, although there was an increase in muscle activation, there was no direct benefit for increasing squat repetitions. However, on average the number of repetitions completed by participants increased by 1 on band-loop days. Although this was not statistically significant, coaches and trainees in a real-world setting may want to incorporate this aid to experiment if it helps athletes increase their repetition totals.

VL and BF muscles showed no change in activation levels when the band loop was applied. We hypothesized increased activation of the gluteal muscles from the basis the band would oblige the hip abductors to activate to a greater extent to resist the lateral forces created by the band-loop. However, testing the quadriceps and hamstrings was of importance as Gooyers (2012) hypothesized that frontal knee plane mechanics were unchanged in their study because unpublished findings within their lab indicated that the band-loops may have elicited greater activity in the lateral thigh muscles (e.g. VL) during squatting movements without influencing activation of the hip abductors and external rotators (i.e. gluteal muscles). However, the results from our study do not support this contention in a trained population, as the VL did not show a significant change in muscular activation when the bands were applied, yet the gluteal muscles were significantly more active.

Holistically speaking all muscle sites tested showed a common trend: muscle activation increased from the first, median to last repetitions, except the eccentric activation of the hamstring during both the 80% 5 RM and 60% repetition until failure tests. This illustrates that muscles activation increases with repetition number.

The use of TBL in the manner above is commonly a method used by coaches and clinicians to coerce the activation of the hip muscles in order to enhance lower body awareness and control frontal knee plane position (Gooyers et al. 2012). This proposed awareness would help to decrease the likelihood of medial knee collapse, and subsequent chronic or acute knee injuries. Although Gooyers and colleagues (2012) found no evidence that the use of the TBL controlled frontal knee plane mechanics, our findings supported the contention that gluteal activation was increased with the use of the bands in a trained population, whom completed FBBS at a high intensity.

Participants self-reported the TBL in this experiment were highly forceful, and the majority of participants were apprehensive in their use during their first sets of testing. After pilot testing, we decided to use tensor wraps in order to decrease the discomfort felt by the bands. These bands also changed in resistance over the course of the study ranging from 10.27 – 12.47 kilograms over a 60 cm stretch. We do not believe this had a significant impact on the results of the study, however this could potentially be avoided in future studies by using a new TBL for each session. It also should be noted placement of the TBL proved difficult to standardize on subjects, as the band would not stay flattened against the subjects' thighs and would naturally follow the path of least resistance on the subject's legs.

Gooyers and colleagues (2012) collected no EMG during their experiment and used an untrained population. It is possible that our participants already activated their hip muscles to a great degree because of their experience in the FBBS, this activation was potentially further compounded by the use of the heavy resistance based TBL used. Further research should focus on the use of different levels of resistance bands in an untrained population, at a lower intensity of squatting. When using untrained participants, it may be necessary to enact coaching tools such as verbal or visual feedback. Rucci and Tomporowski (2010) recently showed that the performance of Olympic lifting styles (hang-clean) was significantly increased when there was a combination of verbal and visual cues used by clinicians. Therefore, further research could focus on what would be the optimal way to use verbal, visual and proprioceptive aids (ie.TBL) to positively impact training.

### 3.7: Practical Implications

Coaches tend to focus on strengthening the hips of athletes whom are involved in a wide range of athletic endeavors, as it is generally believed the hip musculature play an important role with regard to bettering ones' overall performance (Delp, et al. 1999, Gottschalk et al. 1989, Lyons et al. 1983). The GMA accelerates the body upward and forward from a state of hip flexion (Delp et al. 1999); the GME stabilizes the pelvis and femur during weight bearing activities (Gottschalk et al. 1989, Lyons et al. 1983). It has also been shown that a strong relationship has been identified between hip dysfunction and knee pathology (Powers, 2010; Reiman, et al. 2009). Therefore, it is generally agreed upon that activating the hips to a greater extent can work in dual purpose of increasing athletic performance and also correcting dysfunction of the lower extremities. Coaches and trainees' who program high intensity squat training should use the TBL in order to activate the hip musculature to a greater degree.

Although the individuals who participated in the study were trained and injury free, it is likely any benefits acquired by the use of this intervention would transfer to new trainees and rehabilitees. More research should be completed in these fields, with untrained and injured subjects. Likewise, tension ratings (ie. low, medium, high) of TBL and how they may optimize clinical outcome must be considered. Although other training cues, exercises, and modalities have been studied for their ability to alter frontal plane knee mechanics during squatting and jumping exercises (Hewett et al. 2002, Mandelbaum et al. 2005, Myer et al. 2006). The acute response to the use of TBL training has not been quantified. Additionally, previous research has yet to identify how the stiffness of a resistance band is related to the magnitude of this response, if at all.

### 3.7: Conclusions

The present findings suggest that use of the band-loops around the distal lateral portion of the thigh causes: 1) an increased activation of the GMA and GME, 2) no change in hamstring (BF) or quadriceps (VL) EMG and 3) no direct performance advantage. The study aimed to better understand the affect of wearing the resistance band around the distal thighs in a trained population when squatting at a high intensity, given its widespread use and purported benefits of this training modality as a prophylactic aid. Our findings supported positive anecdotal and clinical reports, as the gluteal muscles were significantly more active, leading to the assumption that this increased contribution of these muscles would decrease the likelihood of femur internal rotation and subsequent medial collapse of the knee joint. Future efforts to examine the impact of band-loop should focus on: 1) biomechanical change on frontal knee plane mechanics in a trained population during high intensity squatting and 2) the affect of the band-loop on the FBBS at lower intensities in recreationally trained athletes both from a biomechanical and muscular activation prospective. Participants within this population could potentially have the greatest amount of change in their squatting technique, as trained athletes have practiced, and thus have refined the squat to a greater degree.

### 3.8: References


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## 3.9 Figure Legends

### 3.9.1: Figure 1. Control for hip rotation.

Tape placed at the anterior and lateral aspects of the foot and marked for each individual participant. Participants were instructed to adjust their stance to this angle width during each testing session.

### 3.9.2: Figure 2. Experimental set-up, posterior view.

Placement of variable risers controlled for FBBS depth. All testing was completed within a closed squatting station with safety bars set to applicable heights for each participant.

### 3.9.3: Figure 3. Experimental set-up, anterior view.

Placement of band and tensor bandage, EMG connected to the right thigh in order to avoid discomfort and keep electrodes in place.

### 3.9.4: Figure 4. 80% 1RM, Raw Data Figure.

Raw EMG data of the VL, BF, GMA, GME. E represents the eccentric phase, hollow bar represents the holding phase at the terminal ROM, and C represents the concentric phase. X axis is time in seconds (s), Y axis is EMG output in millivolts (mV).

### 3.9.5: Figure 5. 80% 1RM, 5 Repetition Test.

Average concentric EMG of first, median and last repetitions of the VL(A), BF (C), GME (E), GMA (G); Average eccentric EMG of first, median and last repetitions of the VL(B), BF (D), GME (F), GMA (H). * Represents significant difference between groups, # represents significant main effect for repetition number at $p < 0.05$. Data represents mean ± SD.

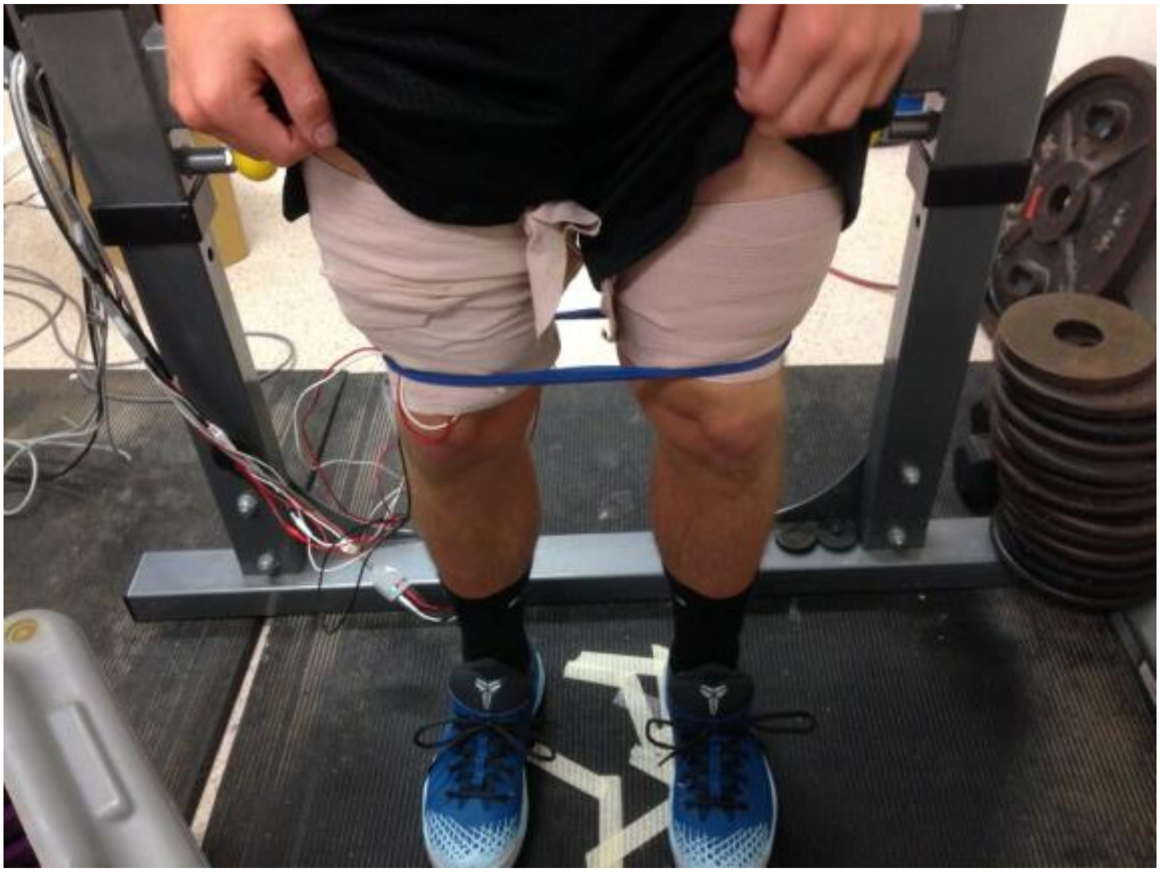
### 3.9.6: Figure 6. 60% 1 RM, Maximum Repetitions Test.

A) Average concentric EMG of first, median and last repetitions of the VL(A), BF (C), GME (E), GMA (G); B) Average eccentric EMG of first, median and last repetitions of the VL(B), BF (D), GME (F), GMA (H). * Represents significant difference between groups, # represents significant main effect for repetition number and ¥ represents significant main effect for group at $p < 0.05$. Data represents mean ± SD.

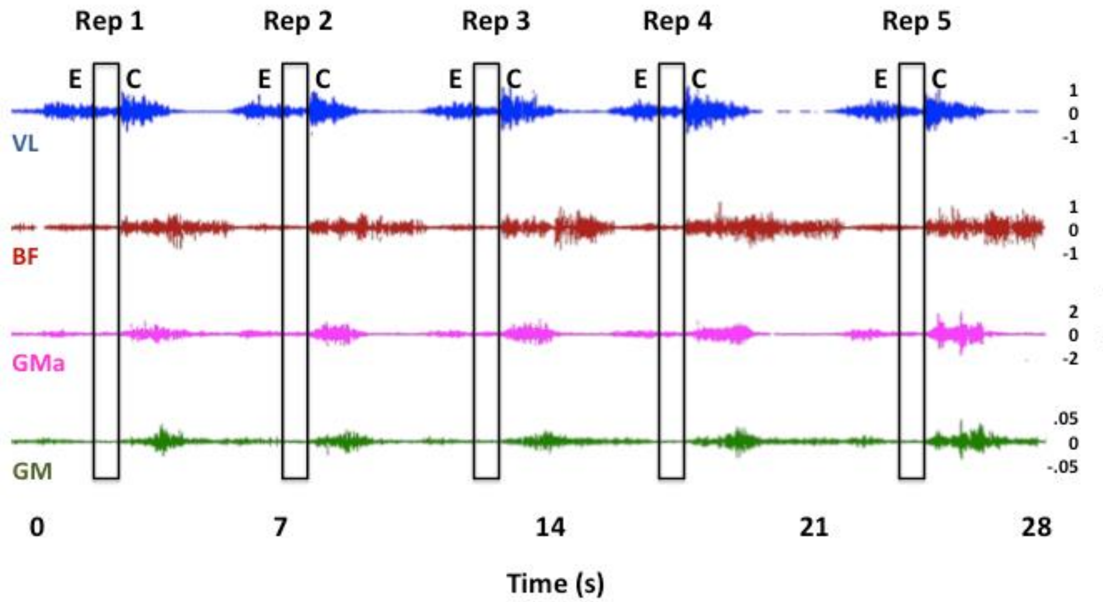
**3.9.1: Figure 1.**

**3.9.2: Figure 2.**

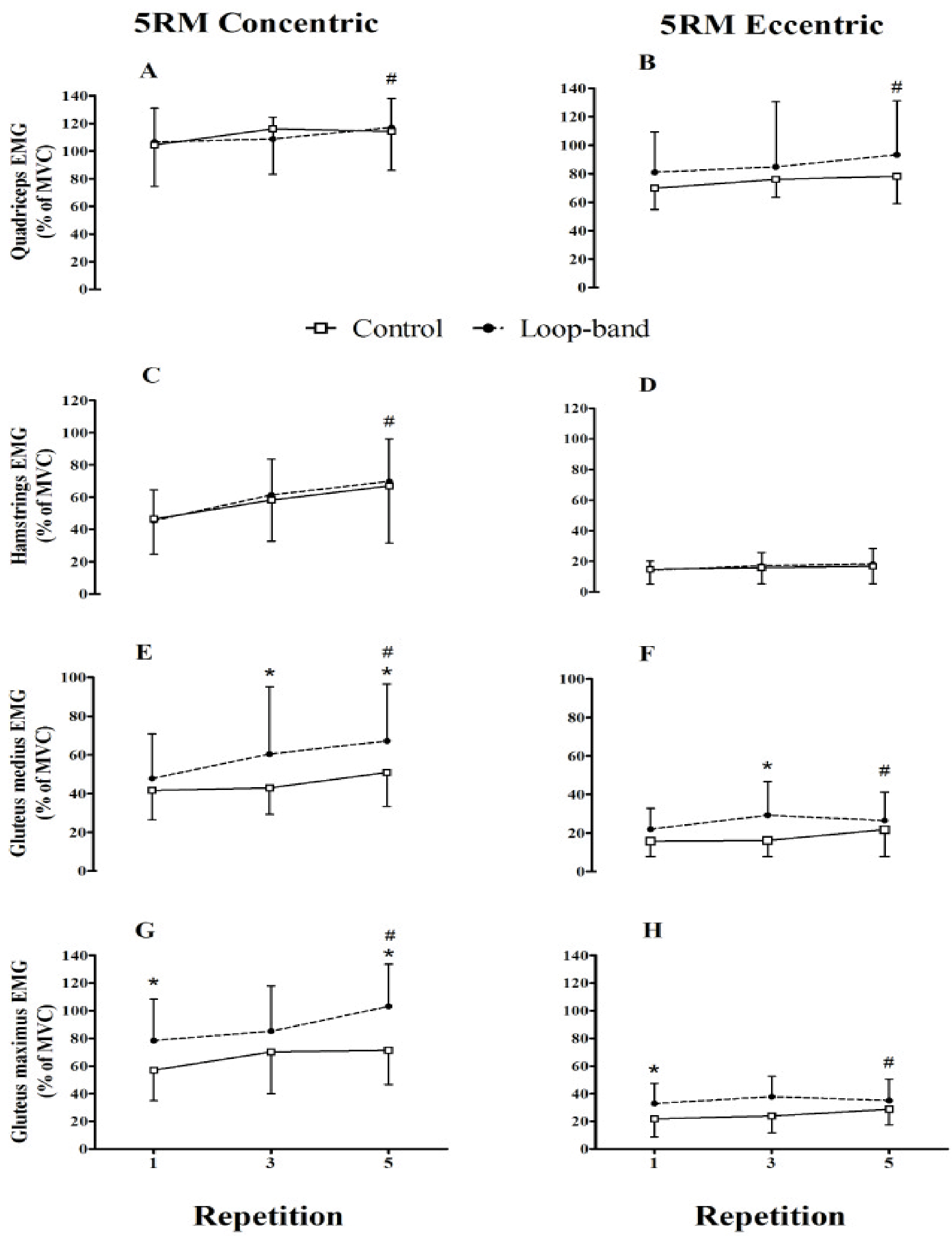
**3.9.3: Figure 3.**



**3.9.4: Figure 4.**

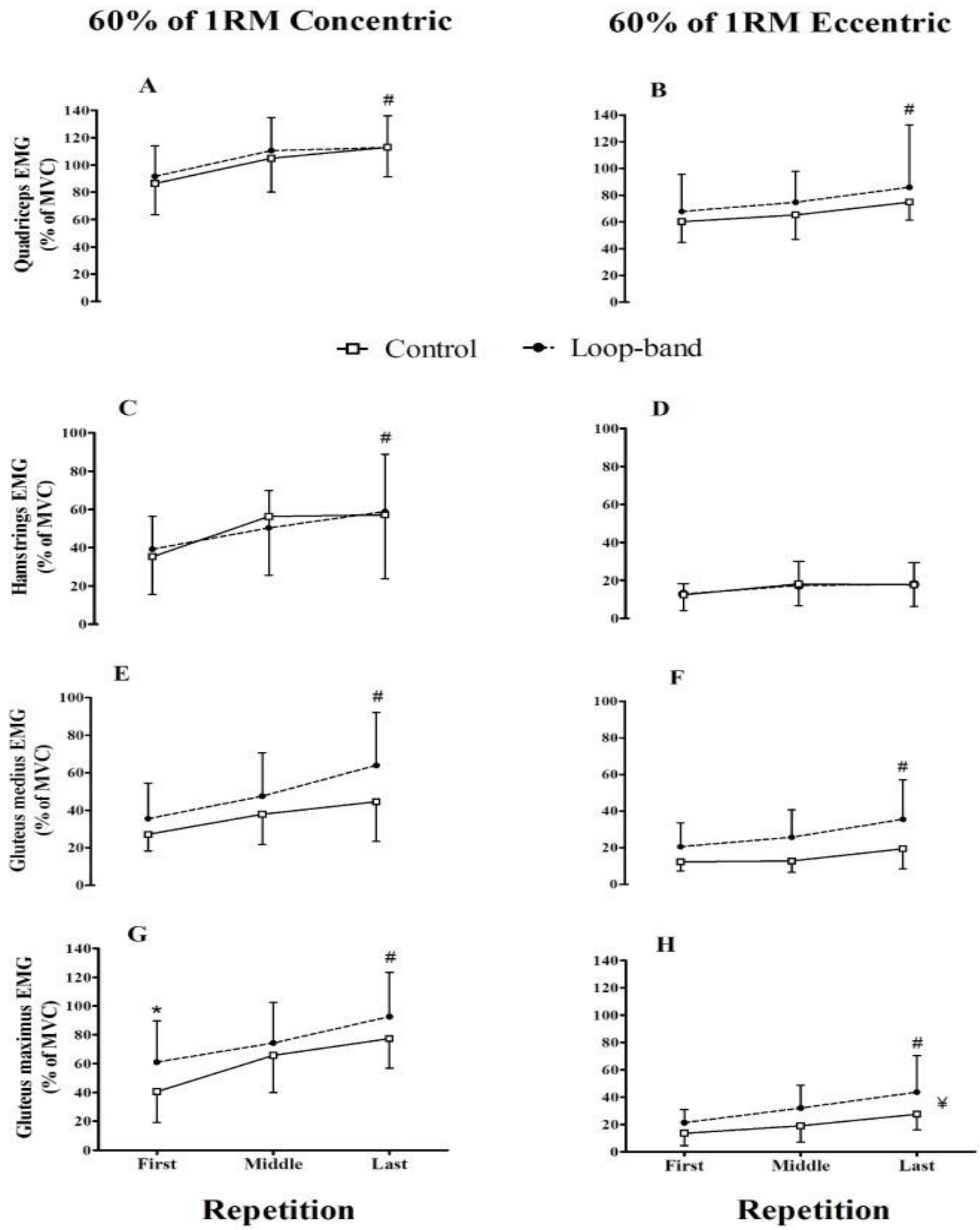

Rep 1
Rep 2
Rep 3
Rep 4
Rep 5
E
C
VL
BF
GMa
GM
1
0
-1
2
-2
.05
-.05
EMG (mV)
0
7
14
21
28
Time (s)

**3.9.5: Figure 5.**



5RM Concentric
5RM Eccentric
A
B
C
D
E
F
G
H
Quadriceps EMG (% of MVC)
Hamstrings EMG (% of MVC)
Gluteus medius EMG (% of MVC)
Gluteus maximus EMG (% of MVC)
Control
Loop-band
Repetition
Repetition

### 3.9.6: Figure 6.



60% of 1RM Concentric
60% of 1RM Eccentric
A
B
Quadriceps EMG (% of MVC)
Control
Loop-band
C
D
Hamstrings EMG (% of MVC)
E
F
Gluteus medius EMG (% of MVC)
G
H
Gluteus maximus EMG (% of MVC)
First
Middle
Last
Repetition

## Appendix A: Free and Informed Consent

**Informed Consent Form**

Title: Physiological mechanisms involved when using a TheraBand Loop (Theraband®) when squat training.

Researcher(s): Kyle Spracklin, Israel Halperin and Dr. Duane Button

School of Human Kinetics and Recreation, MUN

kyle.spracklin@mun.ca, Israel_Halperin@hotmail.com, dbutton@mun.ca

You are invited to take part in a research project entitled "Physiological mechanisms involved when using a TheraBand Loop (Theraband®) when squat training."

This form is part of the process of informed consent. It should give you the basic idea of what the research is about and what your participation will involve. It also describes your right to withdraw from the study any time during data collection and have your data deleted, also you can request to have said data deleted up to and including June 1st 2014. In order to decide whether you wish to participate in this research study, you should understand enough about its risks and benefits to be able to make an informed decision. This is the informed consent process. Take time to read this carefully and to understand the information given to you. Please contact the researcher, Kyle Spracklin, if you have any questions about the study or for more information not included here before you consent.

It is entirely up to you to decide whether to take part in this research. If you choose not to take part in this research or if you decide to withdraw from the research once it has started, there will be no negative consequences for you, now or in the future.

**Introduction**

As part of my Master's thesis, I am conducting research under the supervision of Dr. Duane Button. This research is aimed at gaining a better understanding of how applying force to the distal portion of the thighs can help to increase squatting performance.

Anecdotal evidence from trainers and exercise specialists have demonstrated that using the theraband loop can increase the efficiency in which first time trainees can complete a squatting movement. This study will work to quantify the physiological reasons behind this increase in squatting efficiency*. The squat is widely considered the single best exercise to develop the lower body musculature. Therefore, this research could help determine whether or not using the theraband loop would be an effective training aid to help either experienced or first time trainees complete the squat properly.

**Efficiency defined as: Increased lateral force displacement, Increased activation of hip musculature (Gluteus Maximus and Gluteus Medias),*

**Purpose of study:**

At this time no investigation has been completed which looks at the mechanisms involved which appear to increase the efficiency of the squat. The study hopes to determine these mechanisms and if indeed squatting performance is improved. It is believed, the use of the Theraband Loop could potentially cause an increase in the activation of the hip musculature, increasing efficiency and range of motion of a trainee's squat.

**What you will do in this study:**

You will be asked to attend the lab on two separate occasions; the first occasion will involve familiarizing you with the testing protocol, as well as filling out a simple questionnaire. The experiment will be explained to you, and you will be given the consent form to read. You can ask questions about the study before consenting to taking part. The questionnaires called the *Physical Activity Readiness Questionnaire* (*PAR-Q), which will assess your physical activity levels.*

You will go through the same routine on both testing days.

Upon arriving to the laboratory you will be prepared for recording muscle activity. This is done using a procedure known as electromyography (EMG). In order to record muscle activity with this technique, small sticky electrodes will be attached to the Quadriceps, Hamstrings and Gluteus musculature. There will be a total of 4 electrodes placed on each muscle with a fifth, needed to ensure signal quality, being placed on the boney part of the knee. Preparation for the electrode placement will include removal of hair with a razor, the use of sandpaper for removal of dead skin, and the rubbing of an alcohol swab over the shaven skin to clean the surface.

You will then complete a warm up on a stationary bike. The intensity will be low; the exertion will be similar to that of a fast paced walked.

We will then have to determine the maximum voluntary contraction (MVC) of the 4 muscles. This will mean you will flex and extend the knee and abduct the leg forcefully in order for researchers to determine the maximum force output of each muscle.

After the preperation is complete you will complete 5 sets of a squat. 1 as a warm up, 2 with 10% of your body weight added as a load and two at just your body weight. The loaded version of the squat will be done via the “goblet” technique, which means holding the weight out in front of you, just below the chin. The only difference being that on one testing day you will have a band around the distal portion of your thighs, as this is our intervention.

If you are in a trained population you will complete a 3 repetition maximum (3 RM) and a repetition maximum of 100% of your body weight. This will be completed using a barbell back squat, other parameters of the above protocol will remain the same.

**Length of time:**

Participation in this study will require you to come to a lab located in the School of Human Kinetics and Recreation at Memorial for two testing sessions. The total time commitment will be approximately ~2 hours (each session lasting approximately 60 minutes). These testing sessions will be completed on different days, separated by a minimum of 48 hours.

**Withdrawal from the study:**

You will be free to withdraw from this study at any point. To do so you simply need to inform the researchers and you will be free to leave. Any data collected up to this point will not be used in the study and will be destroyed. Furthermore, even if you are a student in one of Dr. Button's classes, withdrawing from the study at any stage would not impact you, your grades or standing with the Human Kinetics and Recreation department. Along with the ability to withdrawal from the study at any time, you can also request the removal of the data collected from you, any time before June 1st 2014

**Possible benefits:**

The main benefits you may experience from participation in this study is that you will be exposed to the laboratory environment and have the opportunity to experience first-hand the techniques commonly used to assess human muscle function. You will also contribute to expand the body of knowledge regarding exercise. This band intervention could become an everyday training and rehabilitation technique.

**Possible risks:**

There are several minor risks associated with participating in this study:

1) You will have electrodes placed on the front and back of your legs and gluteal muscles. These electrodes have an adhesive that has a tendency to leave a red

mark on your skin. This mark is temporary (usually fades within 1-2 days) and is not generally associated with any discomfort or itching.

2) Performing maximal muscle contractions might lead to slight delayed onset muscle soreness which is a common occurrence from intense training, it in no way will result in any permanent harm to the muscles.

**Confidentiality vs. Anonymity**

There is a difference between confidentiality and anonymity: Confidentiality is ensuring that identities of participants are accessible only to those authorized to have access. Anonymity is a result of not disclosing participant's identifying characteristics (such as name or description of physical appearance).

**Confidentiality and Storage of Data:**

*a.* Results of this study will be reported in written (scientific article) and spoken (local and national conferences and lectures). For both forms of communication, only group average data will be presented. In cases where individual data needs to be communicated, it will be done in such a manner that your confidentiality will be protected (i.e. data will be presented as coming from a representative subject).

*b*. All data and information collected during this study will be kept for a minimum of 5 years in accordance with Memorial's policy on integrity on scholarly research. Computer files will be stored on a password-protected computer and paper records will be kept in a locked filing cabinet in a secure location.

**Anonymity:**

Your participation in this study will not be made known to anyone except researchers who are directly involved in this study. Your identity will not be used in any publications or report without your explicit permission.

**Recording of Data:**

There will be video recordings made during testing. However, the face will not be shown and the video will remain confidential.

**Reporting of Results:**

Results of this study will be reported in written (scientific article) and spoken (local and national conferences and lectures) communications. Generally, all results will be presented as group averages. In cases where individual data needs to be communicated it will be done in such a manner that your confidentiality will be protected (i.e. data will be presented as coming from a representative subject). Upon completion of this investigation the thesis report will be available publically in the QE II library.

**Sharing of Results with Participants:**

Following completion of this study please feel free to ask any specific questions you may have about the activities you were just asked to partake in. Also if you wish to receive a brief summary of the results then please indicate this when asked at the end of the form.

**Questions:**

You are welcome to ask questions at any time during your participation in this research. If you would like more information about this study, please contact: Kyle Spracklin (kyle.spracklin@mun.ca) or Dr. Duane Button (dbutton@mun.ca).

The proposal for this research has been reviewed by the Interdisciplinary Committee on Ethics in Human Research and found to be in compliance with Memorial University's ethics policy. If you have ethical concerns about the research (such as the way you have been treated or your rights as a participant), you may contact the Chairperson of the ICEHR at icehr@mun.ca or by telephone at 709-864-2861.

**Consent:**

Your signature on this form means that:

- You have read the information about the research.
- You have been able to ask questions about this study.
- You are satisfied with the answers to all your questions.
- You understand what the study is about and what you will be doing.
- You understand that you are free to withdraw from the study at any time during data collection, without having to give a reason, and that doing so will not affect you now or in the future. However, the data cannot be removed once submitted to as a thesis or to publication in scientific journal. However, if you do wish to have your data removed before publication this request must be made by June 1st 2014.
- You understand that any data collected from you up to the point of your withdrawal will be destroyed.

If you sign this form, you do not give up your legal rights and do not release the researchers from their professional responsibilities.

**Your signature:**

I have read what this study is about and understood the risks and benefits. I have had adequate time to think about this and had the opportunity to ask questions and my questions have been answered.

☐ I agree to allow video recording to occur during this session, and all subsequent sessions

while involved in this investigation.

☐ I agree to participate in the research project understanding the risks and contributions of my participation, that my participation is voluntary, and that I may end my participation at any time.

☐ I wish to receive a summary of the results of this study Please provide an e-mail address where this summary can be sent: ________________________________________

A copy of this Informed Consent Form has been given to me for my records.

________________________________ ________________________________

Signature of participant Date

**Researcher's Signature:**

I have explained this study to the best of my ability. I invited questions and gave answers. I believe that the participant fully understands what is involved in being in the study, any potential risks of the study and that he or she has freely chosen to be in the study.

Signature of Principal Investigator

Date