Abduction Strength Deficiency: How Common, How Early and How Amendable?

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Abstract

Gluteus medius strength deficiency has been linked to various injuries of the lower limb (Fairclough et al., 2007, Bullock-Saxton et al., 1993, Powers et al., 2003, Williams and Cohen, 2009). However there is limited information in the literature about the prevalence of this condition among healthy individuals. When observing peoples' walking patterns, it is common to see excess side to side movement indicative of abduction strength deficiencies. However the conventional dynamometry strength testing generally show normal results despite the person having an abnormal gait pattern and the conventional exercise used to treat this condition is not yet proven to be effective. A recently published study on Australian Rules footballers suggested that hip abduction weakness does occur in healthy people when a previously unpublished test was used. It uncovered the weakness and using the same position as an exercise was capable of correcting it (Osborne et al., 2012b). The current study investigated the testing position against conventional testing positions and the exercise against conventional exercises. This study also investigated the possibility of growth spurt related hip abduction strength deficiency in high school aged males.

Three studies were used to investigate the new testing position and exercise. An observational study among 101 healthy adults was completed to investigate the prevalence of hip abduction strength deficiency and compare the new hip abduction testing position to conventional hip abduction testing positions. An interventional study was completed to investigate the effects of the new abduction exercise against a conventional abduction exercise and an adduction exercise as controls. This study involved three 1st XV rugby teams with a intervention period of two months. The third study was also an observational study involving 105 high school students. This study investigated the prevalence of abduction strength deficiency in relation to growth spurts among high school aged males.

In the study involving healthy adults, it was found that people tested the weakest in the new testing position. When the new hip abduction exercise was compared to conventional hip abduction exercises and an addcution exercise as a control, there were no significant strength improvements. The third study also found no hip abduction strength deifciency realted to growth among high school aged males.

The recently published testing position may be a useful tool in uncovering hip abduction strength deficiency but as an exercise it did not produce any significant strength gains. Although a recently published study on Australian Rules Footballers suggested that hip abduction strength deficiency may occur due to growth (Osborne et al., 2012b), this study suggested there were no growth related hip abduction strength deficiency.

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List of Abbreviations

GMed	Gluteus medius muscle
AddE	Adductor exercise described in Holmich's study on footballers (Holmich et al., 1999).
GME	Hip abduction exercise described in Osborne's study on Australian Rules Footballers (Osborne et al., 2012b)
Clam1	The Clam 1 exercise described in Boren's electromyographic study of gluteal exercises (Boren et al., 2011)
SLAb	Supine lying abduction testing position mentioned in Holmich's hand held dynamometry reliability study (Thorborg et al., 2010)
SLAd	Supine lying adduction testing position mentioned in Holmich's hand held dynamometry reliability study (Thorborg et al., 2010)
AFL	Australian Rules Footballer League
MRC	Medical Research Council

Chapter 1

1 Introduction

1.1 Background and Objectives

When the strength hip abduction is inadequate, injuries are more likely to occur (Fairclough et al., 2007, Bullock-Saxton et al., 1993, Powers et al., 2003, Williams and Cohen, 2009). Weakness of Hip abduction has been linked to various injuries such as patello-femoral pain syndrome (Powers et al., 2003), ilio-tibial band syndrome (Fairclough et al., 2007), greater trochanteric pain syndrome (Williams and Cohen, 2009), anterior cruciate ligament rupture (Zeller et al., 2003) as well as low back pain (Bullock-Saxton et al., 1993). There were no publications reporting strength deficiencies among the healthy population but it is common to see that even when observing the healthy population, many people have excess side-to-side movement in their gait patterns, a feature which could indicate abduction strength deficiency. A study on elite Australian Rules Football players showed that abduction strength deficiencies exist not only in healthy individuals but also elite junior athletes (Osborne et al., 2012b).

Several muscles are involved with hip abduction. Gluteus medius (GMed) originates from the iliac crest and inserts into the greater trochanter of the femur. Its function is to abduct, and externally rotate the hip giving it a major role in both forward-backwards and lateral locomotion. Other abductors include the gluteus maximus, which originate from the posterior aspect of the ilica crest and inserts at the proximal part of the femur (Lyons et al., 1983) and tensor fascia lata which originates from the underside portion of the iliac crest and inserts into the fascia lata (Gottschalk et al., 1989).

GMed is primarily assessed indirectly by the observation of the Trendelenburg's sign and Trendelenburg gait. It is also assessed directly by hand-held dynamometry. In terms of dynamometry, GMed is currently assessed by a person's ability to perform pure abduction (SLAb (Figure 16 and 17)) against resistance as well as performing the clam against resistance (Clam1 (Figure 15) (as taught at University of Otago Schools of Medicine and Physiotherapy respectively). However these tests often return normal results despite the person having excess side to side movement in their walking pattern. The aforementioned study on Australian Rules Footballers used a new testing position which uncovered hip abduction strength deficiency among healthy individuals (Osborne et al., 2012b). The drawback was that the study did not test the players using the traditional hip abduction techniques and one of the questions the current study intended to answer is how well the new position compares with conventional GMed dynamometry testing.

To reverse hip abduction strength deficiency, exercise prescription is the main form of treatment. There are various exercises but the exercise most commonly taught and prescribed by physiotherapists is the Clam1 mentioned in Boren's study (Boren et al., 2011) however, there have been no studies on its efficacy and part of this project will study Clam1. Boren's EMG studies indicate that the Clam1 exercise has more gluteus maximus recruitment rather than GMed (Boren et al., 2011). The main interest of this study will be on the hip abduction exercise (GME) described in the Australian Rules Footballers study (Osborne et al., 2012b). In this study it was shown that significant strength gains can be accomplished by an unsupervised home programme however this study did not compare the exercise to a control group, We will compare this exercise to the Clam1 in Boren's electromyography study (Boren et al., 2011) and an adductor exercise (AddE) which was published in the Lancet (Holmich et al., 1999) as a control. To test this hypothesis, this study recruited three 1st XV rugby teams from three different schools. Their hip strengths were tested, they were then prescribed 1 of the 3 exercise programmes and their strength was tested again 1 month and then 2 months after exercise.

The study on the Australian Rules Footballers also suggested that hip abduction strength deficiency develops during adolescence as a result of their growth spurts and this project will also address that hypothesis. The final part of this project was to test the hip strength of the students from all high school years (NZ year 9 to year 13). Although growth spurts result inoverall muscle mass and strength increases (Rauch et al., 2004), it is common to see rapidly growing children with excess side to side movement in their gait. We speculate that it is because the strength of the hip abductors does not keep up with the demands of the rapid growth in height leaving them with ongoing strength deficiencies.

1.1.1. Indications for Current Project

Although GMed deficiency had been associated with injuries of the lower limb there were limited publications on strength deficiencies among the healthy population. This study aimed to investigate the prevalence of GMed strength deficiency among the healthy population of adults and adolescents based on previously set parameters. This study also investigated the effectiveness of the GME. The Australian Rules Footballers study did highlight significant strength gains with in two months (Osborne et al., 2012b). However the aforementioned study did not compare the exercise to controls and this sdudy compared the GME exercise to a common exercised prescribed to strengthen the GMed and another exercise prescribed to strengthen another muscle group.

1.2 Aims

1.2.1 Pilot Study

This project aimed to answer several questions. The first of which is how the recently published testing position (GME (Figure 20)) compares to conventional testing positions (Clam1 (Figure 15)) and SLAb (Figure 16 and 17)) among the healthy adult population. To study the adduction/abduction ratios we will also use the SLAd (Figure 18 and 19). In addition we will also aim to find the prevalence of gluteus medius weakness among the healthy adult population.

1.2.2 Intervention Study

An intervention study was done to compare the GME against the Clam1 and AddE (control). We also used this study to help determine the prevalence of gluteus medius strength deficiencies among the high school age group. We will also be able to compare ratios of the different strength tests in this age group and compare to previous data and to determine whether this ratio changes with strengthening.

1.2.3 Growth Study

The last part of the project investigated the possibility of growth spurt related hip abduction strength deficiency. The participants were high school aged males. We investigated whether weakness developed as the adolescent grew.

Chapter 2

2 Literature Review

2.1 Anatomy of GMed

The gluteus medius is a fan shaped muscle, which originates from the iliac crest and inserts into the greater trochanter via a strong tendon although the exact insertion site is controversial (Flack et al., 2012). Although traditionally classified as a hip abductor, it also has major role in external rotation of the hip, which gives it an important role in the stabilisation of the lower limb during gait (Boling et al., 2006, Gottschalk et al., 1989, O'Sullivan et al., 2010, Flack et al., 2012).

2.2 Anatomy of Other Hip Abductors

Aside from GMed, other hip abductors include the gluteus maximus, gluteus minimus and tensor fascia latae (Lyons et al., 1983, Gottschalk et al., 1989).

Gluteus maximus originates from the posterior portion of the iliac crest, the sacrum and the coccyx and attatches to the proximal part of the femur as well as the ilio-tibial tract (Lieberman et al., 2006). Like GMed, it was a role in lateral hip stability in loading (Lyons et al., 1983). Gluteus minimus originates from anterior superior iliac spine and the posterior superior iliac spine and attatches distally to the greater trochanter. It also assists as a hip stabiliser (Gottschalk et al., 1989). Tensor fascia latae originates from the anterior underside of the iliac crest and inserts into the fascia latae (Evans, 1979). According to Gottschalk, the tensor fascia latae is the major hip abductor (Gottschalk et al., 1989).

2.3 Clinical Importance of the Hip Abductors

Strength deficiency of hip abductors has been associated with various injuries. When the hip lacks external rotation, it will result in a person having genus valgus (proximal part of knee bent inwards while the distal aspect bent outwards). Powers proposed that as a result of this, the patella would be pulled more laterally with respect to the knee joint and this leads to patello-femoral pain syndrome (Powers, 2003). It was found in a study involving female athletes that those who had patello-femoral pain syndrome had weaker hip abduction strength when performing side-lying abduction with the dynamometer placed at the knee as well as weaker external rotation (subject sitting with dynamometer placed at knee (Leetun et al., 2004, Niemuth et al., 2005). Brindle also showed that people with anterior knee pain had delayed activation in their gluteus medius instead of the mismatch between vastus medialis oblique and vastus lateralis which is what people initially thought (Brindle et al., 2003).

Also, as a result of reduced hip abduction, it is hypothesised to lead to increased pressure via friction or compression between the ilio-tibial band and the lateral aspect of the femur. This may lead to an increased risk of ilio-tibial band syndrome, which is common among runners (Fairclough et al., 2007, Noble, 1980, Fredericson et al., 2000). It has also been shown that the re-strengthening of weak abductors could help with symptom relief in those with ilio-tibial band syndrome (Fredericson et al., 2000). Fredericson et al (2000) also mentioned that those with abduction strength in the lowest quartile were more likely to be injured. It has also been hypothesised that because females have weaker hip control, their quadriceps play the predominant role in landing resulting in increased pressure on the ACL. This leads to an increased risk of non-contact anterior cruciate ligament (ACL) rupture (Zeller et al., 2003). In a study by Williams and Cohen (2009), it was found that a significant proportion of those who had greater trochanteric pain syndrome also had some sort of pathology associated with their gluteus medius.

Gluteus medius strength deficiency is not restricted to lower limb injuries. It has also been associated with injuries of the lower back (Bullock-Saxton et al., 1993, Nelson-Wong et al., 2008).

2.4 Testing Hip Abduction

2.4.1 Trendelenburg's Sign/ Single Stance Test

One way to assess hip abduction strength deficiency is by the Trendelenburg's sign (Figure 1). The Trendelenburg's sign was a test originally used before the era of x-rays and a positive result was associated with pathology such as neurological disorders affecting the hip musculature, dislocation of the hip joint, subluxating hips and arthritis of the hip joint (Hardcastle and Nade, 1985).

The test involves standing on one leg where the hip is flexed at 30 degrees and the knee bent so that the foot clears the ground. The subject must also hold it for 30 seconds. In normal circumstances, the pelvis on the unsupported side will raise to shift the weight towards the supporting leg and hold it there for thirty seconds. However, only someone with a Medical Research Council (MRC) strength grade of five is capable of that. People with an MRC lower than five will usually have a positive Trendelenburg sign (Hardcastle and Nade, 1985), which may leads to Trendelenburg gait and the various injuries mentioned previously.

Recently, the original Trendelenburg's test was modified and had to follow a more stringent criteria. In this case, the back and pelvis cannot deviate and the upper limb cannot make compensatory adjustments. The hip is flexed at 60 degrees and the position is held for 30 seconds. The study also suggests that the test is moderately reliable between testers as long as the examiner observes from directly behind the subject (Tidstrand and Horneij, 2009) (Figure 2).

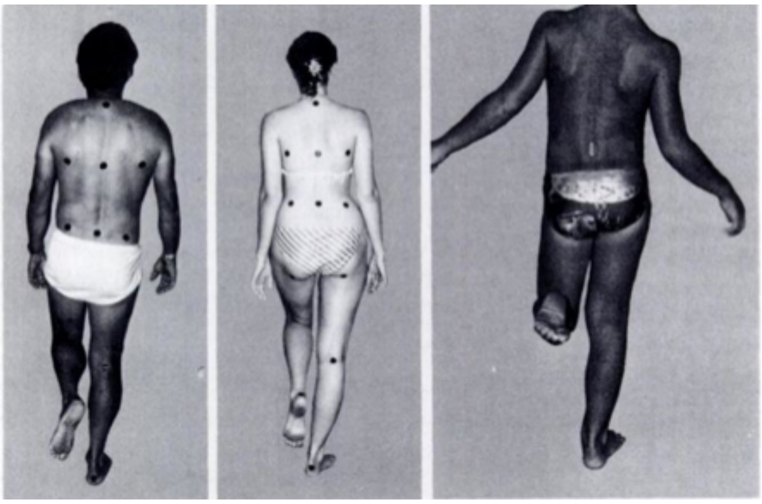


Figure 1. Photo showing negative Trendelenburg sign (left and middle) and a positive Trendelenburg sign (right) (Hardcastle and Nade, 1985)

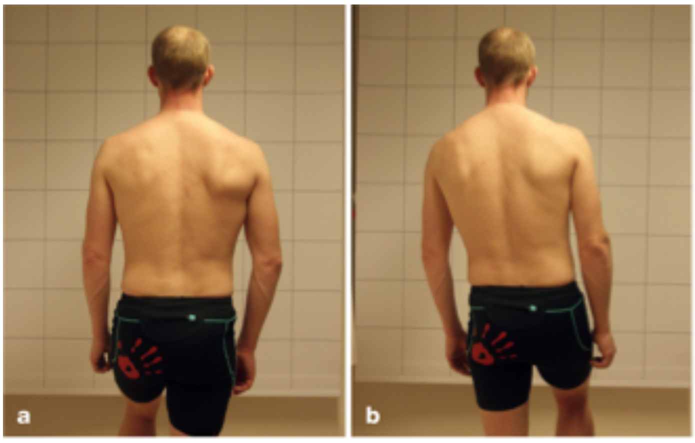


Figure 2. Photo showing a negative Trendelenburg sign (left) and a positive Trendelenburg sign (right) (Tidstrand and Horneij, 2009)

2.4.2 Abduction Testing Positions and MRC Scoring System for Strength

The most common way to test hip abduction strength is by side-lying abduction or supine abduction with the dynamometer placed at the ankle (Thorborg et al., 2009). A recently AFL study demonstrated a new way of assessing hip abduction strength which utilises a position similar to the recovery position and measures the strength of the participant pushing his knee up against resistance (Osborne et al., 2012b). The Clam1 position has also been used as a testing position to assess hip abduction strength (Willy and Davis, 2011).

In the clinical setting, strength is graded by the MRC score. The scoring system is from 0 to 5. Normal strength is given a score of 5, active strength against gravity and resistance is given a score of 4, active movement against gravity is given a score of 3, active movement with gravity eliminated is given a score of 2, flicker or trace of contraction is given a score of 1 and no contraction is given a score of 0 (John, 1984). Hardcastle and Nade (1985) noted that an MRC grade of 4 in abduction strength would lead to a positive Trendelenburg's sign however it was difficult to quantify MRC strength grade of 4 when using hand-held dynamometry. The AFL study recently published used a cut off between MRC grade 5 and MRC grade 4 as 130N of force with the assumption that an average person should be able to abduct with 130N during gait (Osborne et al., 2012b).

2.4.3 Hand Held Dynamometry

Strength testing with the use of the dynamometer is also used. One example is pure abduction with the dynamometer placed at the ankle (Thorborg et al., 2009, Willy and Davis, 2011) although some others place the dynamometer at the knee (Leetun et al., 2004, Niemuth et al., 2005). Another method is where the participant takes the Clam1 position and pushes against dynamometer which is placed at the knee (Willy and Davis, 2011).

The use of the hand held dynamometer is reliable with the same tester. When subjects were tested and re-tested after a week the figures were consistent between the two tests (Thorborg et al., 2009). However when the testers are switched, then the reliability comes into question (Bunker et al., 1997). Based on that study, all the testing will be performed by the same person.

2.4.3.1 Make vs Break Test

There are two ways to perform manual strength testing. A break test is when the examiner pushes against the subject's limb (who is exerting maximal force) until the subject's strength is overcome and a make test is when the examiner holds the dynamometer steady and allows the subject to exert maximal force (Bohannon, 1988, Burns et al., 2005). In general, because the examiner has to overcome the subject's force in the break test, the force values are greater than the same strength test performed using the make procedure (Burns et al., 2005, Bohannon, 1988). In terms of reliability they are both equally reliable provided the examiner has enough strength to perform both (Bohannon, 1988, Burns et al., 2005) however because the SLAb and SLAd tests in the current study were instrumented, break tests could not be performed and therefore in order to maintain consistency, the other tests (Clam1/GME) had to be be make test. Make tests are also easier in that it requires less physical strength from the examiner.

2.4.4 Electromyography

Other investigations of the hip musculature include electromyography. This method is used to gain insight into neural control of the musculoskeletal system (Boling et al., 2006, O'Sullivan et al., 2010). It can consist of surface electrodes (O'Sullivan et al., 2010) or fine needle electrodes (Philippon et al., 2011). It is also commonly used to assess the activation of various muscle groups in various rehabilitation exercises (Philippon et al., 2011). The drawback of surface electrodes is that it has some issues with crosstalk (O'Sullivan et al., 2010) and, although it is moderately accurate, it tends to be preferential towards the muscles closer to the surface. Also, it can be quite difficult to standardise the maximal voluntary isometric contraction (MVIC) with a specific movement as it leads to issues where some exercises have more than 100% of the MVIC (Boren et al., 2011). As a result of the limitations mentioned above, there are major inter-tester disparities of MVIC percentage form the same exercise (Boren et al., 2011, Reiman et al., 2012).

2.4.5 Gait Analysis

Gait analysis can also be used to assess Trendelenburg gait and gluteus medius deficiency (Willy and Davis, 2011). However, the process is complicated and the reliability of this type of analysis was inadequate (Eastlack et al., 1991). Modern camera-assisted analysis have high reliability (Ugbolue et al., 2013) but the method would be difficult to perform in a variety of locations and large numbers of participants which were required for the current study.

2.5 Clinical Application- Treatment

2.5.1 Rehabilitation/ Re-Strengthening

There are currently numerous exercises used to strengthen the hip abductors. Below are various examples of the most effective and common exercises in terms of MVIC-normalised EMG amplitudes of GMed and GMax. Below is a simple line graph (Figure 3) of the MVIC for common gluteus medius exercises and a brief description of each one (Boren et al., 2011).

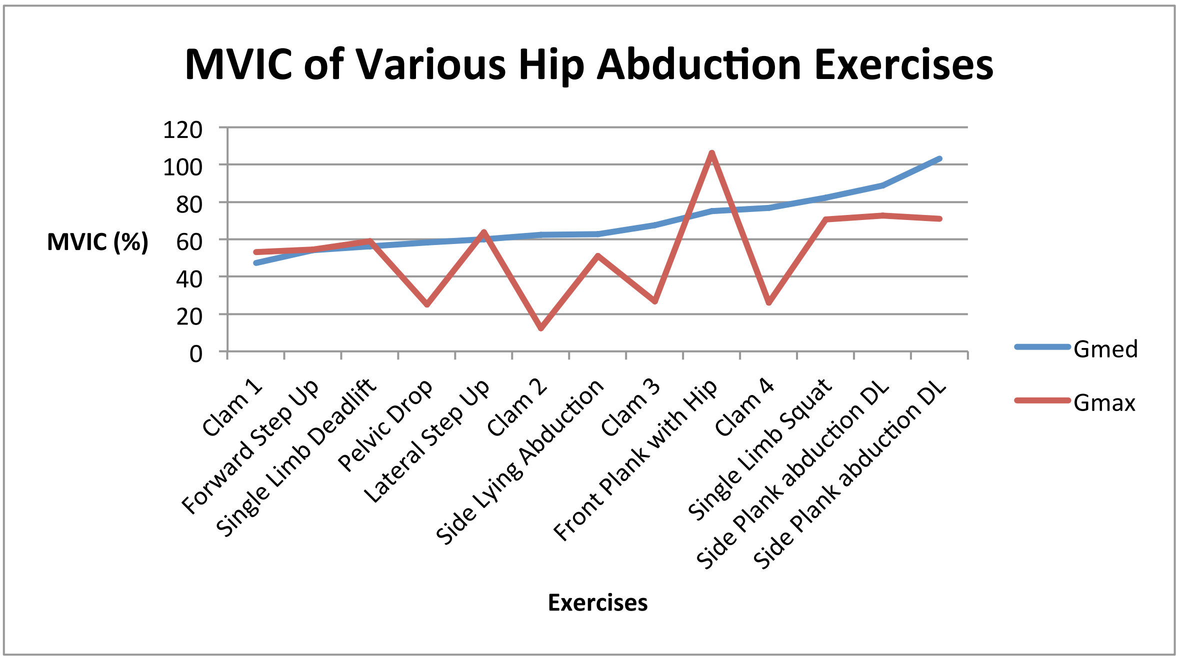


Figure 3. Graph showing the normalised EMG amplitudes of various abduction exercises in relation to gluteus medius and gluteus maximus (Boren et al., 2011)

To perform the pelvic drop (Figure 4), a platform of roughly 5cm in height is needed. The participant's non-test leg stands at the edge of the platform while the test leg is freely hanging. Then the participant is asked to lower the test leg's heel so that if touches the ground. Then the participant must raise the heel of the test leg up to the level of the platform while keeping the knees and hip extended (Philippon et al., 2011), (Boren et al., 2011).

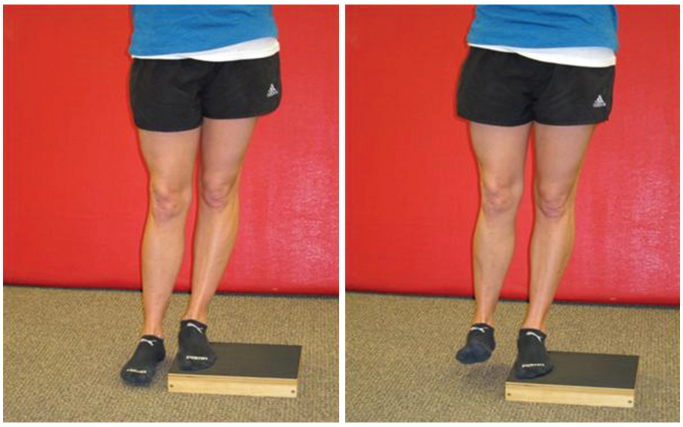


Figure 4. Photo showing the pelvic drop (Boren et al., 2011)

To perform the hip clam (Clam1), the subject gets into a side-lying position with the hips and knees flexed at 45 degrees. The subject then goes on to perform hip abduction and external rotation (Philippon et al., 2011). And although other angles can be used, the principle stays the same. The current study is interested in this exercise despite the fact that that activates gluteus medius by 45% of the MVIC(Boren et al., 2011) because it is an exercise commonly used to strengthen the gluteus medius in the community. There are also variations for this exercise. One of them is where the subject lifting the foot up while the knees stay together (Clam2 from Boren et al) while the other one includes the subject lifting the whole lower limb off the ground (Clam3 from Boren et al). The last variation includes the non active limb flexed at 45 degrees at the hip and knee while the active leg is neutral at the hip but flexed 90 degrees at the knee (Clam4 from Boren et al) (Figure 5).

Figure 5. Photo showing the hip clam with Clam1 (top left), Clam2 (top right), Clam3 (bottom left) and Clam4 (bottom right).

To perform the side-lying hip abduction (Figure 6), the subject lies on his/her side. The back must be neutral. The subject is then asked to lift the leg about 30 degrees and then bring it back to the original position. Usually in this exercise, the top leg straight and the bottom leg bent to prevent body rotation. The person then lifts the top leg off the ground as usual (Boren et al., 2011). Side lying hip abduction can also be performed against the wall. The subject assumes the position for a regular side-lying hip abduction but with the back against the wall. The subject lifts his/her leg as usual with the difference being that he/she presses the heel against the wall and applying constant pressure by means of hip extension (Philippon et al., 2011).

Figure 6. **Photo demostrating the side lying abduction (Boren et al., 2011)**

To perform the side plank with abduction (Figure 7), the subject is side lying with the elbow and arm lifting the upper body off the ground. The subject then lifts the hip off the ground so that the hip and back are in neutral position. While the subject is maintaining that position, the patient then performs the side lying hip abduction (Boren et al., 2011).

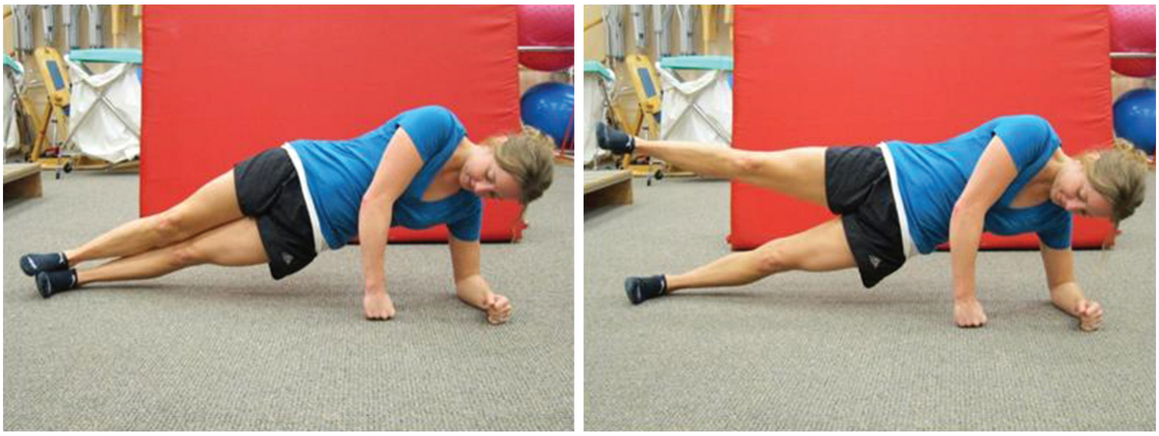


Figure 7. **Photo demonstrating the side plank with abduction (Boren et al., 2011)**

To perform the single limb squat (Figure 8), the subject stands on the active leg and lowers the buttock until it touches the chair behind him/her. The subject then raises him/herself with the active leg to get back to the original position (Boren et al., 2011).

Figure 8. Photo demonstrating the single limb squat (Boren et al., 2011)

To perform the front plank with hip extension (Figure 9), the subject starts in the prone position on his/her elbows in plank with trunk, hips and knees in neutral alignment. The subject then lifts the active leg off the ground, flexes the knee and then extends the hip bringing the heel towards the ceiling. After which the subject will bring the active limb back to the starting position (Boren et al., 2011).

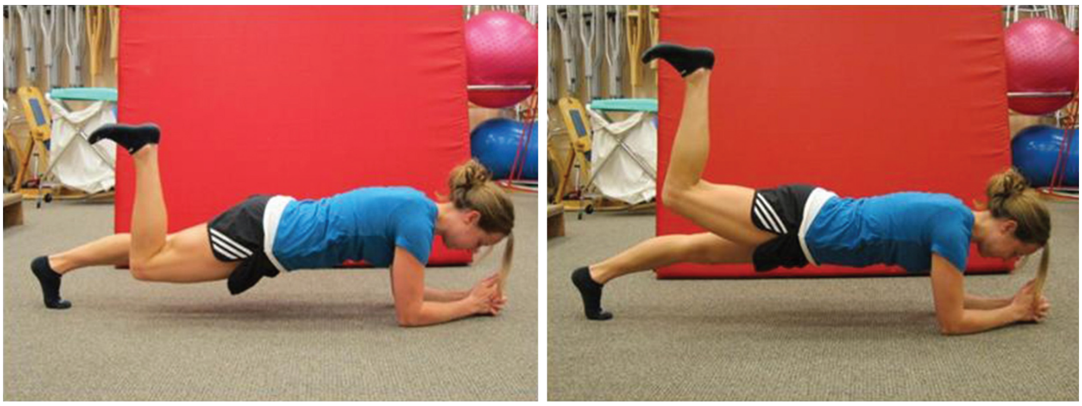


Figure 9. Photo demonstrating the front plank with hip extension (Boren et al., 2011)

To perform the lateral step up (Figure 10), the subject stands on the edge of platform and squats slowly so that the heel of the other limb touches the ground. The subject then returns to the starting position by pushing with the dominant leg (Boren et al., 2011).

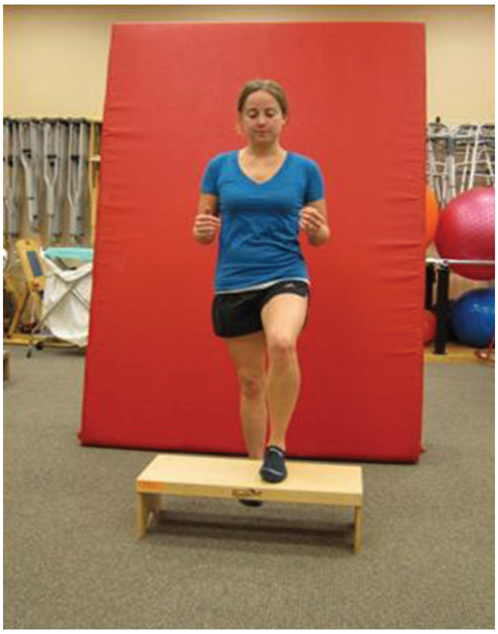
Figure 10. **Photo showing the lateral step up (Boren et al., 2011)**

To perform the single limb deadlift (Figure 11), the subject stands on one leg and slowly flexes the hip with the back straight until he/she can touch the floor with the opposite hand. After which the subject returns to the original position (Boren et al., 2011).

Figure 11. **Photo showing the single limb deadlift (Boren et al., 2011)**

To perform the forward step up (Figure 12), the subject starts with both feet on the ground and then proceeds to step forwards up a platform and then step down to the starting position. After which the subject will repeat the exercise with the other limb (Boren et al., 2011).

Figure 12. Photo showing the forward step up (Boren et al., 2011)



The exercise this project is interested in (GME) is the one described in a article published (Figure 13 and Figure 14). In that paper, the participants have benefited from strength gains of over 80% in a period of two months. However, there were no control group so one part of this project is to compare the exercise against controls.

Figure 13. Photo demonstrating the GME (Osborne et al., 2012b)

Figure 14. Photo demonstrating the GME (Osborne et al., 2012b)

2.5.2 Other Comparison Exercises

In order to investigate the Clam1 and GME, a control group is needed. Since we are testing adduction strength along with SLAb, Clam1 and GME, an adductor exercise shown to be effective for relieving groin pain will be used (Holmich et al., 1999). The adductor exercise is not the main concern of this study but the results can be compared to existing literature.

2.6 Adductor-Abductor Ratios and Left-Right Ratio

2.6.1 Adductor-Abductor Ratio

Eccentric abduction and adduction is important for a variety of sports and is an important indicator of groin related injuries (Thorborg et al., 2010, Nicholas and Tyler, 2002). It was found that injured players had lower adduction strength compared to their abduction strength (Nicholas and Tyler, 2002, Tyler et al., 2001) and it is recommended that for injury prevention and rehabilitation, players should not have more than 10% difference between abduction and adduction (Nicholas and Tyler, 2002). However, it is a claim and 10% difference may be beyond the limits of hand-held dynamometry. Furthermore, there are different ways to measure abduction and adduction, which complicates this measurement so depending on which combination of abduction/adduction test the examiners use, there will be a different result.

2.6.2 Left-Right Ratio

In terms of side to side differences, Thorborg et al (2010) found that the dominant leg/non dominant leg ratio were not significantly different for non-athletic individuals although elite players in certain sports such as soccer can change it. Again we will compare the side-to-side ratios with the current literature. Bender mentioned that in terms of abduction, those with more than 10% disparity between left and right are more likely to be injured (Bender et al., 1964). However, this study was based on a military cohort who underwent very rigorous physical activity and it was based on knee flexion and extension, which had more margin of error because the knee joint's movements are more limited compared to the hip joint. Osborne et al (2012) used 25% because setting the target at 10% disparity would be difficult given the reliability of dynamometry testing for the positions used in the current study and that having left/right disparities of greater than 25% would be more significant clinically.

2.7 Growth Related Strength Issues

In general, when children undergo growth spurts, both their bone and muscle develop rapidly (Rauch et al., 2004). However it is common to observe that when adolescents grow rapidly in height, they start to exhibit excess side-to-side movements in their gait. We speculate that this could be due to the hip abductors not meeting the demands of the rapid growth in height despite an overall increase in hip musculature. Alternatively, these observations could simply be due to the "swagger" gait associated with increased confidence of males during puberty (Rowe et al., 2004).

In this study we will sample boys from all high school years in the positions: Clam1 (Figure 15), SLAb (Figure 16 and 17), SLAd (Figure 18 and 19) and GME (Figure 20).

Chapter 3

3 Pilot Study

3.1 Introduction

When observing the gait pattern of healthy people, it is common to see excess side-to-side movement due to abduction strength deficiency. Landing from this type of gait has been associated with injuries of the back (Nelson-Wong et al., 2008), thigh (Fairclough et al., 2007) as well as the knees (Brindle et al., 2003). However, current strength testing using hand-held dynamometry has been insensitive at exposing this deficiency. A recently published paper (Osborne et al., 2012b) has suggested that a new testing position can uncover hip abduction strength deficiencies in people who would otherwise be tested normal via current strength testing methods despite having abnormal gait.

3.2 Aim

The aim of this pilot study is to compare the GME testing position against Clam1 and SLAb when assessing the strength of the muscles acting on the hip joint. The secondary aim is to establish the community norms for hip strength in the different positions and left-right/abduction/adduction ratios.

3.3 Methods

3.3.1 Ethics and Recruitment

This study was approved by The Department of Medicine, Dunedin School of Medicine, University of Otago. Participants must be healthy at the time of testing and were excluded if they were undergoing treatment for any lower limb injuries (appendix B).

Participants were recruited by word-of-mouth and the tests were conducted in a variety of settings from living rooms to offices. The participants were then asked to give written consent by signing the category B consent form (appendix B). In terms of personal information, the data taken from the participant was their initials, self reported height and weight and date of birth.

For statistical analysis informed consent had been obtained by the participants before undergoing the strength testing. The data was analysed by a statistician and the programme used was StataCorp, Stata Statistical Software: Release 12. College Station, TX: StataCorp LP2011. The model used was the 'Applied Mixed Models in Medicine; 2nd edition' (Brown, 2006).

3.3.2 Strength Testing

To test the hip strength, a hand held dynamometer was used (Commander Muscle Tester, JTech). Participants were then strength tested in four different ways on each limb: Clam1 (Figure 15), SLAb Figure 16 and 17), SLAd (Figure 18 and 19) and GME (Figure 20). In the Clam1 position, the participant was side lying with both the hips and the knees bent at 45˚. In terms of the arms, the inferior arm was fully extended and abducted so that the head rested on it while the inferior arm was simply placed on the floor in front of the participant. The dynamometer was placed at the level of the knee while the participant was asked to perform a make test. The GME was similar to the clam except that in the arms, the superior hand was placed on the inferior arm approximately where the biceps brachii muscle was and the elbow was placed on the ground. The difference in the leg position is that the inferior leg remained straight while the superior leg was bent with its foot wrapped around the back of the inferior leg at the knee position. The examiner then adjusted the knee so that the spine was straight. Like the clam, the participants was asked to perform the make test. For the SlAb and SLAd, the participant lying was supine with the non-test leg bent and the dynamometer placed just distal the medial malleolus for SLAd and just proximal the lateral malleolus for SLAb. In both the tests, a strap was wrapped around the dynamometer like a sling with the examiner standing on the free parts of the strap. The tension was adjusted so that the force was below the threshold for the dynamometer before it starts recording but high enough so that the dynamometer remained still. The participant was then instructed to perform the make test like the other two test.

Figure 15. **Photo demonstrating hip strength testing in the Clam1 position**

Figure 16. Photo demonstrating hip strength testing in the SLAb position.

Figure 17. Photo demonstrating hip strength testing in the SLAb position.

Figure 18. **Photo demonstrating hip strength testing in the SLAd position.**

Figure 19. **Photo demonstrating hip strenth testing in SLAd position.**

Figure 20. Photo demonstrating hip strength testing in the GME position.

The sequence of the tests was arranged in a quasi-randomised order (Appendix A) to maximize muscle recovery time as well as efficiency. To achieve both those outcomes, eight different sequences were used and participants were randomly assigned to one of them. The participant would complete the assigned sequence once and then repeat the sequence for added reliability.

3.3.3 Analysis

In terms of strength deficiency, the paramater for hip abduction strength deficiency was based from the AFL study previously mentioned where the strength of (130N) was used (Osborne et al., 2012b). For side-to-side difference, we used both the 10% cut-off from the Military Cadet study (Bender et al., 1964) as well as the 25% cut-off from the AFL study (Osborne et al., 2012b).

All statistical analysis was adjusted for the continuous variables such as age, height, gender, weight and BMI. Also the SLAb and SLAd tests were conducted with the dynamometer at the ankle while the Clam1 and GME were conducted with the dynamometer placed at knee level. To account for this, the figures from the SLAb and SLAd were divided by 0.55 because the human leg's average ratio is 0.55 thigh and 0.45 leg (Strecker et al., 1997).

3.4 Results

3.4.1 Demographics

Table 1. Illustrating the demographics of the study population.

	Male (n=56)	Female (n=45)
Age	25 (SD 9)	28 (SD 10)
Height	1.75m (SD 0.06)	1.63m (SD 0.06)
Weight	72kg (SD 11)	59kg (SD 9)
BMI	23.4 (SD 3.1)	22.2 (SD 2.6)

3.4.2 Raw Mean Strength Findings

Table 2. Outlining the average strength readings of the females.

	Left	Right
GME	100N (SD 35.4)	99N (SD 32.4)
SLAb	134N (SD 50.4)	137N (SD 42.6)
SLAd	135N (SD 41.6)	134N (SD 42.4)
Clam1	211N (SD 59.4)	205N (SD 58.7)

Table 3. Outlining the mean strength readings of the males in the study.

	Left	Right
GME	171N (SD 55.6)	173N (SD 57.9)
SLAb	184N (SD 59.0)	197N (SD 59.9)
SLAd	214N (SD 76.1)	216N (SD 71.1)
Clam1	309N (SD 75.3)	306N (SD 68.9)

3.4.3 Strength Deficiency and Strength Discrepancies Between Sides

When analysing the females with parameters used by previous studies, 37 (82%) of the participants had a GME reading lower than 130N on the left limb (Figure 21) and 37 (82%) of the participants had a GME lower than 130N on the right leg. In terms of left/right strength disparities greater than 10%, there were 36 participants (80%) from GME with a mean of 22.6% (SD 8.4), 27 participants (60%) from SLAb with a mean of 22.9% (SD 10.2), 17 participants (38%) from SLAd with a mean of 20.4% (SD 8.2) and 19 participants (42%) from Clam1 with a mean of 21.7 (SD 12.1). It was also noted that all women who participated had GME strength under 130N and/or side-to-side difference greater than 10% in at least one of the testing positions. When considering 25% disparity as the target, there were 10 (22%) participants from GME with a mean of 33.5% (SD 5.7), 9 (20%) from SLAb with a mean of 34.8% (SD 8.0), 5 (11%) from SLAd with a mean of 30.8% (SD 5.9) and 5 (11%) from Clam1 with a mean of 39.2 (SD 9.3). It was also noted that 42 (93%) of the participants had either GME weaker than 130N or left-right disparity greater than 25% in at least one of the tests.

When analysing the males using parameters based from previous studies, 15 (27%) of the participants had GME strength lower than 130N on the left side and 13 (23%) of the participants had GME strength lower than 130N on the right side (Figure 22). In terms of having a left-right ratio disparity greater than 10%, there were 30 participants (54%) from GME with an average of 27.3% (SD 14.3), 33 participants (59%) from SLAb with an average of 20.1% (SD 8.9), 28 participants (50%) from SLAd with an average of 20.4% (SD 7.7) and 23 participants (41%) from Clam1 with an average of 20.6% (SD 10.1). It was also noted that only one participant had both a GME strength of over 130N and have left-right disparities of less than 10% in all the tests. Going by the 25% cut off used in the Osborne study, there were 14 (25%) from GME with a mean of 38.6% (SD 13.1), 6 (11%) from SLAb with a mean of 34.8% (SD 7.4), 7 (13%) from SLAd with a mean of 31.1 (SD 5.4) and 4 from Clam1 with a mean of 40.5% (SD 6.5). It was also noted that 33 (59%) had either GME strength less than 130N or left-right disparity greater than 25% in one of the strength tests.

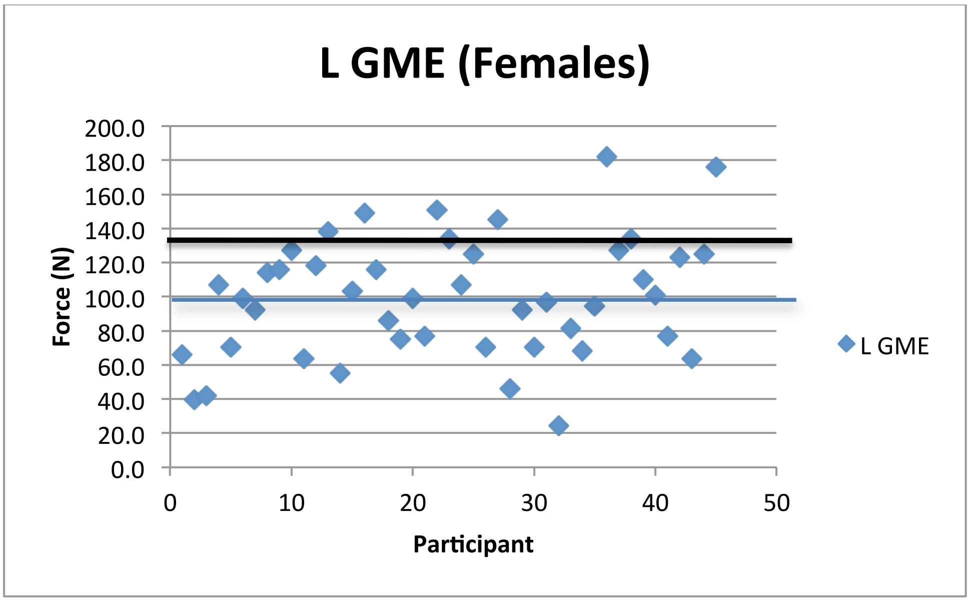


Figure 21. Graph showing the strength tests of the left leg in the GME position (Blue line is the mean). The cut off for strength deficiency was the 130N used in the AFL study(Osborne et al., 2012a) (black line).

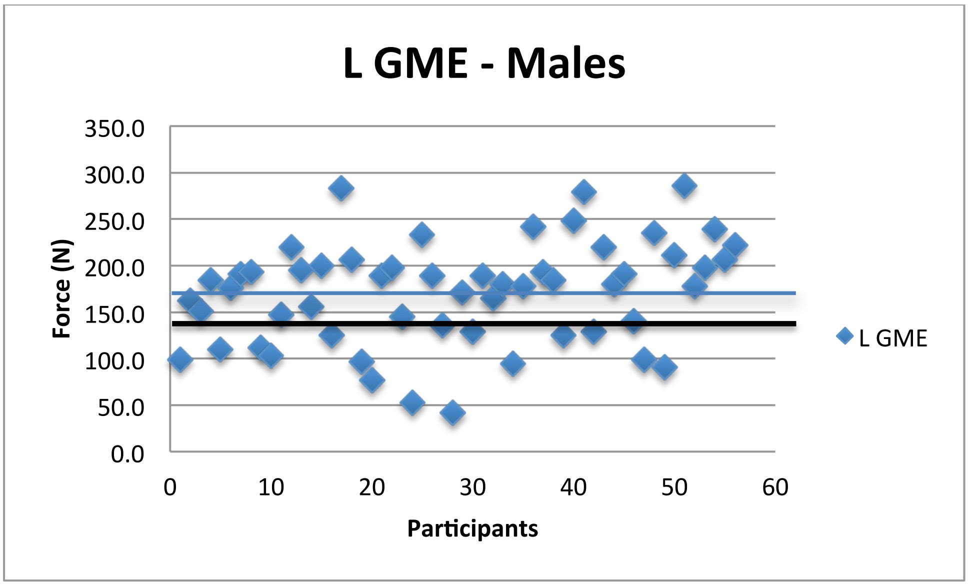


Figure 22. Showing the strength tests of the left leg in the GME position (blue line is the mean). The cut off for strength deficiency was the 130N based the AFL study (Osborne et al., 2012a)(black line).

3.4.4 Statistical Analysis

3.4.4.1 Relationship Between the Different Tests

The strength of one position can predict the strength in another position. In terms of SLAb, an increase in its strength can be predicted by an increase in SLAd (p<0.001) and Clam1 (p=0.004) but not GME (p>0.05). In terms of SLAd, an increase in its strength can be predicted by an increase in SLAb (p<0.001), Clam1 (p=0.014) and GME (p=0.020). An increase in Clam1 strength can be predicted by SLAb (p=0.010), SLAd (p=0.004) and GME (p<0.001). For the GME, an increased strength can be predicted by an increase in SLAd (p=0.024) and Clam1 (p<0.001) but not SLAb (p>0.05).

3.4.4.2 Comparison Between Strength Tests

When the three abduction strength tests were compared, people were the strongest in Clam1 position followd by the SLAb position with GME being the testing position where participants tested the weakest._Compared to SLAb the strength of Clam1 is on average 98N greater (97.5 (95% CI: 91.2, 103.9)) and the GME is on average 26N lower (-26.0 (-32.4, -19.7)). Compared to the GME, the clam is on average 124N stronger (123.6 (117.2,129.9).

3.4.4.3 Strength Correlation with Demographics

Strength is correlated with gender, age, BMI, weight and height. When comparing the genders, the strength of the males was on average 47.2N greater than females (47.2 (22.4,72.1)). As participants become older the strength decreased at a rate of 1.5 (-2.4, -0.5) per year. For each BMI increase of 1, strength was increased by 5.9N (2.7,9.0). For every 1cm increase in height, the strength increased by 1.4N (0.008,2.72) although the correlations with height were borderline significant (p=0.049). There are no associations between which leg was used (left or right) and strength.

3.4.4.4 Ratios of Left-Right, Abduction-Adduction and the Ratio Between Different Abduction Tests

In terms of the abduction/adduction ratio the mean ratio between all the differing exercises were calculated (Table 3.1). When comparing the three abduction tests to the SLAd, the GME/SLAd ratio is 0.794 (SD 0.197), the Clam1/SLAd ratio is 1.546 (SD 0.324) and the SLAb/SLAd ratio is 0.946 (SD 0.126). In terms of the GME position, the mean GME/SLAb ratio was 0.858 (SD 0.239) and the mean GME/Clam1 ratio was 0.523 (SD 0.107) (Table 4). When the left/right ratio was analysed in terms of percent strength, the left side was 0.82% higher than the right side and it was not statistically significant.

Table 4. Showing the all the ratios between the different tests.

Variable	Mean	Std. Dev.	Min	Max
Add/Abd	1.090	0.151	0.779	1.609
Add/Clam	0.684	0.142	0.425	1.066
Add/Gmed	1.364	0.341	0.718	2.453
Abd/Add	0.946	0.126	0.642	1.328
Abd/Clam	0.637	0.124	0.400	0.976
Abd/Gmed	1.287	0.374	0.592	2.501
Clam/Add	1.546	0.324	0.939	2.351
Clam/Abd	1.661	0.342	1.035	2.598
Clam/Gmed	2.049	0.552	1.347	5.240
Gmed/Add	0.794	0.197	0.409	1.443
Gmed/Abd	0.858	0.239	0.408	1.691
Gmed/Clam	0.523	0.107	0.205	0.778

3.5 Discussion

3.5.1 Abduction Strength Deficiency

The pilot study found that half of the study population had abduction strength deficiency (<130N, 37 females and 15 males) when measured by the testing position described in the AFL study. This finding correlates with the previous finding where a third of healthy individuals have underlying abduction strength deficiency (Osborne et al., 2012b). This may explain the observation that it is common to observe people with excess side-to-side movement during gait suggesting hip abduction strength deficiency. It could be argued that despite these people a deficient in GME abduction strength test it is not pathological however one finding was that having a weaker GME correlates with greater strength difference between the sides, which is reported to be related to increased risk of injury (Bender et al., 1964, Fredericson et al., 2000). When comparing the genders, females did have lower strength tests. This supports and may explain why they need to use their quadriceps to compensate for weaker hip control and are more likely to suffer non-contact anterior cruciate ligament ruptres (Zeller et al., 2003).

3.5.2 Ratios

In terms of the ratios, there was insignificant difference between left and right as well as the SLAb/SLAd ratio. This correlates well with the study done by Thorborg (Thorborg et al., 2010). In that study, he noted that one of his limitations was small sample size (Thorborg et al., 2010). However, this study with 45 females and 56 males strengthens his conclusions that there were little side to side difference and that the abduction adduction ratio is relatively even (Thorborg et al., 2010). From this study, we also concluded that because the SLAb/SLAd ratio is less than 10% different among normal individuals that it is the best to use for abduction/adduction ratio testing. Although depending how it is measured and which abduction/adduction position used, there will be a different norm and different cut-off.

However it was interesting to note that despite having no left-right strength asymmetry on the whole, a significant proportion of the participants had more than 10% difference in left-right strength. A similar case was seen in the Australian Rules footballers study although a 25% mark was used due to accuracy limitations (Osborne et al., 2012b). Fredericson and Bender mentioned that a left-right disparity of more than 10% leads to increased risk of injury (Bender et al., 1964, Fredericson et al., 2000) and the findings of this study poses the question of whether a significant proportion of the healthy population is at risk of injury if participating in physical activity, whether the 10% strength disparity is beyond the accuracy of hand-held dynamometry, whether the 25% from the Australian Rules footballers study (Osborne et al., 2012b) should be used and whether having left-right strength disparities has no injury risk at all?

When the 25% cut off was used, a smaller proportion was found. The Australian Rules footballers study found 40% of its players had left-right disparities over 25% while this study only had about 20%. This could suggest that elite-athletes are more likely to have left-right disparities than the average population and are perhaps more at risk of injury, assuming Fredericson's statement is correct. Of course, it could be due to the smaller sample size of the Aussie Rules footballers study. However, there are still a significant proportion of participants with either a GME strength under 130N or left-right disparity of greater than 25% and these findings suggest that to avoid risk of injury, it is important to condition the lower limb for adequate abduction strength and decrease the strength disparities between the left and right.

3.5.3 Comparison of the Testing Positions

When comparing the testing position, the Clam1 is the strongest while the GME is the weakest. The reason Clam1 is the strongest could be due to higher input of gluteus maximus and relatively lower input of gluteus medius (Boren et al., 2011) as well as input from the other limb as it is in the same plane as the active leg. A similar issue could be said about the SLAb although not to the extent as Clam1 (Boren et al., 2011) Gottschalk et al (1989) also suggested that SLAb may have a significant input from the tensor fascia latae although this has not been proven by fine needle EMG. We speculate that the high gluteus maximus involvement may be a reason why people can have normal strength in the Clam1 and SLAb testing positions and still have excess side-to-side movement in their gait. We also speculate because people were the weakest in GME it may have a good chance to uncover GMed strength deficiency among those with normal Clam1 and SLAb strength but with excess side-to-side movement in their gait. There is also a chance that GME may have the highest GMed involvement although this has yet to be proven with EMG and it is an area where future studies can investigate.

3.5.4 Relationship Between the Different Strength Tests

The findings showed that being greater in strength of one position seem to correlate well with an increased strength of another position except for GME and SLAb. This means that if one position is strengthened, another may also be strengthened. We speculated that because people tested the weakest in the GME position they may develop the largest strength gains in all testing positions. Using SLAd as an exercise may also allow for greater strength in all testing positions. These aspects were further investigated in the 1st XV study where each team was prescribed a different exercise between the AddE, GME and Clam1.

3.5.5 Limitations

Hardcastle and Nade (1985) mentioned that an MRC strength grading lower than 5 would lead to a positive Trendelenburg sign and an aspect that was difficult was how to extrapolate an MRC grade lower than 5 to an objective reading in Newtons. We based the cut-off at 130N from the AFL study which was the strength of the examiner's index finger with the assumption that a large muscle group such as gluteus medius should be able to overcome the strength of a finger (Osborne et al., 2012b). Although it provided an objective parameter it was difficult to extrapolate beyond the young elite athletes in the AFL study however this parameter was used in the absense of other objective clinical tests.

Although we did find many participants with strength lower than 130N, another limitation was that due time constraints, the functional aspects such as balance were not tested. We could expect to find that those with weaker strength in the GME position would perform poorer than those who were stronger and it would be good to investigate that in the future.

Another issue came when the participants were too strong. In the Clam1 position, when a participant was able to produce an excess of 400N it was very hard for the examiner to resist. So it was another reason why the make test was a sensible decision as it would be too difficult to perform the break test. For the SLAd and SLAb, if the surface was slippery or the examiner's footwear lacked grip, the participant can drag the examiner while performing the strength test making it more difficult. As a result, it would be recommended that the examiner wore appropriate footwear for the SLAb/SLAd tests in the intervention and growth study.

Another minor limitation was handheld dynamometry. Although it does provide objective readings in Newton and is reliable (Thorborg et al., 2009). The positioning, physique, enthusiasm of examiner and participant, strength and technique of the examiner and participant can generate some inaccuracies in the data. However as long as the examiner is the same for all the tests, all the data were still reliably used for analysis.

The clothing may also have an impact on the accuracy of the data. Some participants with footwear with more proximal covering made it difficult for the examiner to find the location to place the dynamometer in the SLAb/SLAd testing positions as well as dampening the force transfer from foot to the dynamometer.

The last issue was that due to convenience and the assumption that healthy adults' height and weight do not change significantly over time, self reported data on height and weight was used. However, it is commonly found that people tend to overestimate their height and underestimate their weight (Spencer et al., 2002) and therefore the main study involved the actual measurement of the height and weight. Adolescence height and weight is more likely to vary between tests as well due to rapid growth during puberty (Rauch et al., 2004) hence the height and weight must be up to date.

For the intervention and growth study, four new aspects were be implemented. First, a clamping device was used to instrument the GME and Clam1 test (Figure 27). We hoped to remove the errors associated with the examiner out of the equation as all the examiner needs to do is to stand on the platform while the participant pushes on the dynamometer held by the cast (Figure 28 and 29). Second the examiner must wear shoes with adequate grip such as sneakers or other exercise shoes to avoid being dragged along the ground while testing SLAb and SLAd. The third change is that the participant must remove his/her footwear so it will be easier to locate and place the dynamometer on the anatomical landmarks. We also measured height and weight and included ethnicity as part of the basic demographic data for the main study.

3.6 Conclusion

The pilot study found that hip abduction strength deficiency was very common among healthy individuals when using the new testing position used in the AFL study (Osborne et al., 2012b). It also suggested that the GME position is a testing method which can potentially uncover hip abduction strength deficiencies in people who otherwise would be strong in other abduction tests and has potential as a clinical tool to measure abduction strength.

The pilot study also found that although the study population did not have statistically significant strength difference between the sides it was common to see indivuduals with greater than 25% strength difference between the sides. This has clinical significance as strength difference between the sides have correlations with lower limb injuries (Fredericson et al., 2000, Bender et al., 1964).

Chapter 4

4 Intervention Study

4.1 Introduction

To correct hip abduction strength deficiency an abduction exercise is usually prescribed. An Australian Rules footballers study recently showed that the GME exercise is capable of producing significant strength gains (Osborne et al., 2012b). However that study lacked controls so we will compare it with the Clam1 which is common exercise taught by the University of Otago, School of Physiotherapy and School of Medicine and an adductor exercise from a soccer study (Holmich et al., 1999) as a control.

4.2 Aims

The primary aim of this part of the study was to compare the effect of the GME exercise to the commonly taught Clam1 exercise and the AddE exercise which was the control. Other aims included comparing the strength readings and ratios in this group and compare it with the data from the pilot study and similar studies in the literature.

4.3 Procedures

4.3.1 Recruitment

This study was approved by the Human Ethics Committee of the University of Otago (number 12/107) and has the support from the Ngāi Tahu Research Consultation Committee (appendix E). Permission to undertake this study has been approved by the headmaster and the 1st XV coach of the respective schools. Signed consent was obtained from participants and additional parents/caregiver consents were obtained from younger children.

The participants were recruited from three local high schools in Dunedin. The particular groups recruited were the 1st XV rugby teams from 'John McGlashan's College, Dunedin', 'King's High School, Dunedin' and 'Taieri College, Dunedin'. All teams were briefed prior to the commencement of the study.

The inclusion criteria were:

-Males who were enrolled at the three high schools who were

-healthy and had no medical conditions stopping them from participating in physical education classes and/or sport.

-Represented the 1st XV rugby team for their respective school.

The exclusion criteria were:

- those with known medical conditions that affect the hip.

- current groin pain,
- current back pain and
- any other injury preventing them from performing the strength tests.
- -Those who did not compete in the 1st XV rugby team for their respective schools.

All students had their basic demographics recorded. This included date of birth, ethnicity, weight and height. The examiner also used the height and weight to calculate the BMI and the date of birth to determine the participant's age at the time of testing. They were then strength tested by a hand held dynamometer (Commander muscle tester, jtech). The testing positions were the same one used in the pilot study. To reduce the error associated with hand-held dynamometry, a clamping device was introduced for the two side lying positions (Figures 23-25). However, after approximately a dozen tests it was found that the clamping device introduced more inaccuracies so the clamping device was withdrawn and the remainder of the tests were performed using the hand-held method. Like the pilot study (Figure 15-20), the students were tested in four different positions on each hip twice.

Figure 23. Photo showing the clamping device for the GME and Clam1 testing positions

Figure 24. Photo demonstrating the use of the clamping device for the Clam1 position.

Figure 25. Photo demonstrating the use of the clamping device for the GME position.

The tests were performed in a quasi-randomised order to maximise rest time between the tests and to minimise the time taken to perform the tests (Appendix A). This also reduced the bias associated with using the same testing sequence.

In the AFL study, there were no controls (Osborne et al., 2012b) and a power calculation done on that study determined that if a study was done with controls we needed at least 8 participants in each group to see a statistically significant result with 80% certainty. In terms of the number of participants for the intervention study: 20 participants from King's High School consented to participate, 24 participants from John McGlashan College consented to participate and 17 participants from Taieri College consented to participate. There are significantly more participants than the power calculation recommended but non-compliance and withdrawals from the study are possible so the excess number of participants can compensate for that possibility.

After the initial baseline testing, the First XV teams were then instructed to a different hip conditioning/strengthening exercise. All the exercises are used in rehabilitation of sports injuries of the hip and each exercise also acts as a control group for the other two. Two of the exercises are currently used to strengthen the hip abduction muscles. One is the Clam1 (Philippon et al., 2011, Boren et al., 2011), which is commonly prescribed to strengthen hip abduction. The second exercise is the GME which is shown to increase strength significantly (Osborne et al., 2012b). The last exercise is the AddE which was used to treat groin pain (Holmich et al., 1999). This exercise was used as a control group as it doesn't actively target the hip abductors but is still an exercise which will benefit overall hip strength (Holmich et al., 1999). The Clam1 was prescribed to John McGlashan College's 1st XV team, the GME was prescribed to Taieri College's 1st XV and the AddE exercise was prescribed to King's High School.

Testing was repeated after 1 month from when the exercise was taught. The testing methods were the same as the initial baseline testing except the height and weight measurement were excluded. The examiner also enquired the students about how they were coping in terms of the exercise and encouraged them to keep going for the remainder of the study. The final testing was conducted two months after the teaching of the exercise. Again the testing methods were the same as the initial baseline testing and unlike the half way testing, the height and weight were measured. While testing the students, the examiner did not have access to any previous data so the examiner cannot encourage or discourage the effort of the participants in order to alter the results to the examiners' liking.

4.3.2 Exercises

The Clam1 was performed with the person side-lying and with both hips and knees bent at approximately 45˚. In terms of the upper limb, the inferior arm was fully extended and abducted so the head rests on it. The superior arm was simply placed on the floor in front. One repetition involved the participant lifting the knee off the ground (while the feet are still together) and back to the original position (Figure 5-top left picture). The GME was similar to the clam except the inferior leg (while side-lying) remained straight and the superior arm is placed on the inferior arm at the level of the biceps and then the elbow is placed on the ground much like the GME testing position (Figure 13 and 14). One repetition involved the participant lifting his knee off the floor and back down on the ground. For the AddE exercise, the participant starts off lying supine. There are two aspects to this. For the first one, a ball that is roughly the size of a football is then placed between the ankles while the lower limb is straight. The participant then squeezes the ball between his ankles for 30 seconds and then relaxes which constitutes one repetition (Figure 30). During the second part, the participant is still supine with the knees bent. The participant then places the ball between his knees and squeezes it for 30 seconds and then relaxes which results in one repetition (Figure 31).

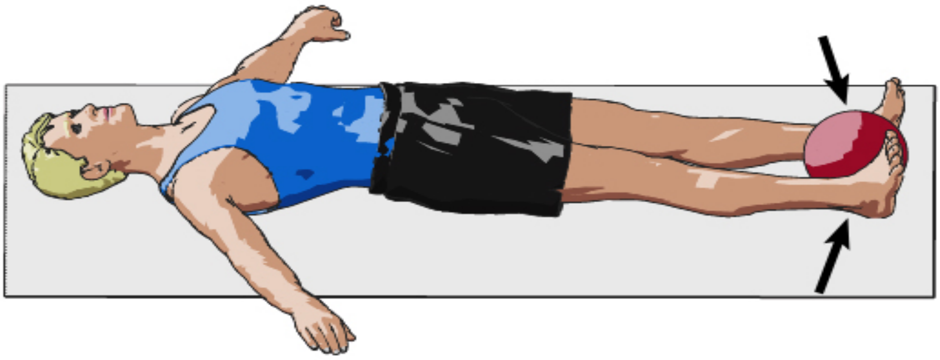


Figure 26. Picture demonstrating the adductor squeeze at the ankle level (Exerset, 2012)

Figure 27. Photo demonstrating the adductor squeeze performed at knee level (Advisor, 2008)

For the Clam1 exercise, the students were instructed to perform 100 repetitions on each leg per day. In an attempt to make the exercise prescription convinient, time of the day did not matter and the students were allowed split the 100 repetitions into however many sets they choose as long as they reach 100 repetitions per day i.e. the student can perform 100 repetitions in a single set or 5 sets of 20 repetitions etc. For the GME, the instructions were the same as with the clam in that the participant must perform 100 repetitions each leg per day in any number of sets and at any time of the day. For the adductor exercise, the participant is asked to perform 10 repetitions at the ankle and 10 repetitions at the knee per day – each repetition being 30 sec.

4.3.3 Statistical Analysis

For comparison purposes, the strength tests where the dynamometer was placed at the ankle (SLAb and SLAd) had their figures divided by 0.55 because the thigh to leg ratio is on average 55:45 (Strecker et al., 1997).

For the analysis itself, a few methods were used including Bonferroni method, Bartlett's test, ML regression and LR test. Bonferroni's method and Bartlett's test was used to compare the groups in terms of their demographics, linear regression and LR test were used to compare the left-right strength difference, Bartlett's test was also used to compare the overall strength between the three groups. To see the changes in strength, LR test and linear regression was used.

4.4 Results

4.4.1 Baseline

4.4.1.1 Basic Demographics Comparison

Table 5. Outlining the mean demographics of the intervention study.

	AddE group	Clam1 group	GME group
Age	17 (SD 1.0)	17 (SD 0.7)	17 (SD 0.6)
Height	1.75m (0.06)	1.80m (0.06)	1.77m (0.07)
Weight	82kg (SD 12.4)	82kg (SD 10.3)	70kg (SD 9.3)
BMI	27 (SD 4.0)	25 (SD 2.4)	22 (SD 2.5)

When comparing the three groups it was found that the boys from the AddE group and the Clam1 group had similar weight however the boys from the GME group were significantly lighter ($p<0.05$). When the height was compared, it was found that the boys from AddE group were shorter ($p<0.05$). There were no significant differences when the age was compared.

4.4.1.2 Looking at the Overall Strength

The first analysis was to determine the mean strength readings of all participants from all three groups. This set of data was taken from 61 participants however one of the participants had a sling around his arm and was unable to be tested on GME and Clam1 on the left side. It was found that the mean strength for GME was 207N (SD 55) for the right and 202N (SD 50) for the left. In terms of SLAb, the mean strength was 222N (SD 52) for the right and 205N (SD 49) for the left. In terms of SLAd the mean strength was 223N (SD 47) for the right and 228N (SD 51) for the left. For Clam1 the mean strength reading was 314N (SD 70) for the right and 315N (SD 69) for the left. This gives an overall average of 214N (SD 51) for SLAb, 226N (SD 49) for SLAd, 314N (SD 69) for Clam1 and 204N (SD 53) for GME.

4.4.1.3 Comparing the Strength of the Three Groups

The second analysis was to determine the strength readings of the three groups in isolation. The average readings obtained included both left and right legs. For the AddE group, there were 20 participants hence the average was derived from 40 figures with the exception of left GME and left Clam1 where one of the participants had a sling and was unable to be tested in those positions hence there were 39 figures. The mean strength readings in the AddE group were 191N (SD 52) for GME, 215N (SD 45) for SLAb, 222N (SD 53) for SLAd and 292N (SD 71) for Clam1. For the Clam1 group, there were 24 participants so the mean was obtained from 48 figures. The mean strength readings in the Clam1 group were 226N (SD 55) for GME, 228N (SD 52) for SLAb, 240N (SD 43) for SLAd and 347N (SD 60) for Clam1. For the GME group, there were 17 participants so the mean was obtained from 34 figures. The mean strength readings for the GME group were 193N (SD 51) for SLAb, 209N (SD 48) for SLAd, 294N (SD 63) for Clam1 and 190N (SD 40) for GME (Table 6).

When comparing the strength between the participants of the three schools, it was found that there were no significant differences between the participants' strength in any of the testing positions.

4.4.1.4 Strength in Relation to Demographics

When analysing the relationship between demographics and strength readings, it was found that right SLAb strength was correlated with height and weight ($p<0.05$) but not age or BMI, right SLAd was correlated with weight and BMI ($p<0.05$) but not with age or height, right Clam1 was correlated with weight and BMI ($p<0.05$) but not with age or height and right GME was not correlated with any of the demographics. When analysing the left limb, it was found that the SLAb strength correlated with height and weight ($p<0.05$) but not age or BMI, SLAd correlates with height, weight and BMI ($p<0.05$) but not age and GME correlates with weight and BMI ($p<0.05$) but not height or age.

4.4.1.5 Analysis on Strength Difference Between Sides

When analysing side-to-side strength differences al all the participants, it was found that the left side was stronger than the right side in SLAb ($p<0.05$). However, no significant side-to-side differences were found in the other testing positions. It was also found that strength in one exercise was highly correlated with the strength in another exercise.

4.4.1.6 AddE group: Strength Deficiency and Left:Right Ratios

When analysing the AddE group's data based on previously used parameters, no participants had a GME reading weaker than 130N on the left and 2 (33%) participants had a GME reading weaker than 130N on the right side. However, only the participants who were not tested with the clamp was used (6/20) because it was established that the clamp introduced further inaccuracies but given that the clamp underreported the strength readings we can assume that if they had higher strength than 130N with the clamp, then they would surely have a strength higher than 130N without the clamp we can consider the rest of the group to have GME strength higher than 130N because their results were higher than 130N despite being tested with the clamp. In this case we can conclude that only 2/20 (10%) had GME strength lower than 130N. In terms of left-right strength disparities greater than 10%, there were 4/6 (67%) participants from the GME position with a mean of 18.5% (SD 6.9), 13 (65%) participants from SLAb with a mean of 18.8% (SD 5.5), 13 (65%) from SLAd with a mean of 21.3% (SD 7.8) and 4/6 participants from Clam1 with a mean of 14.0% (SD 1.8). Only 1 participant had the GME strength higher than 130N as well as being symmetrical however his GME and Clam was not included because he was tested with the clamp.

When 25% left-right disparity cut off was used, there were 2 (10%) from SLAb with a mean of 28% (SD 1.4) and 3 (15%) from SLAd with a mean of 30.5% (SD 5.1). It was also noted that there were 6 (30%) participants who either had GME weaker than 130N or more than 25% left-right disparity in either SLAb or SLAd. GME and Clam1 were not included due to the effects of the clamping device.

4.4.1.7 Clam1 Group: Strength Deficiency and Left:Right Ratio

When analysing the Clam1 group's data based on previously used parameters, 1 (4%) person had GME strength lower than 130N on the left side and none on the right side. In terms of left-right disparities greater than 10%, there were 14 (61%) from GME with a mean of 25.5% (SD 18.7), 14 (58%) from SLAb with a mean of 17.7% (SD 7.2), 9 (38%) from SLAd with a mean of 17.2% (SD 9.3) and 10 (43%) from Clam1 with a mean of 16.6% (SD 4.7). It was also noted that all the participants either had a GME under 130N for left-right disparity greater than 10% in at least one of the testing positions.

When the 25% left-right disparity was used there were 4 (17%) participants from GME with a mean of 34.5% (SD 6.8), 1 (4%) participant from SLAb who had a disparity of 39% and 1(4%) from SLAd with a disparity of 40%. It was also noted that 6 of the participants had either GME weaker than 130N or a left-right disparity greater than 25% in one of the positions.

4.4.1.8 GME Group: Strength Deficiency and Left:Right Ratio

Upon observation of the GME group's data based on previously used parameters, there was 1 (6%) participant with a GME lower than 130N on the left leg and 1 participant with a GME lower than 130N on the right leg. In terms of left-right strength disparities greater than 10%, there were 9 (53%) from GME with a mean of 18.3% (SD 4.4), 12 (71%) from SLAb with a mean of 18.8% (SD 7.8), 10 (59%) from SLAd with a mean of 21.3% (SD 7.8) and 6 (35%) from Clam1 with a mean of 14% (SD 1.8). It was noted that all except 2 of the participants either had s GME strength under 130N and/or left-right disparity of greater than 10% on at least 1 of the strength tests.

If the 25% cut off was used, there were 5 (29%) participants form SLAb with an average of 31.2% (SD 3.5) and 2 (12%) from SLAd with an average of 29% (SD 2.8). It was also noted that 8 participants either had a GME weaker than 130N or more than 25% left-right disparity in one of the positions.

4.4.2 Halfway and Final Testing

4.4.2.1 Complications

During the halfway testing of the study, two participants from the AddE group withdrew. One of them no longer had commitment to the team and the other suffered an injury preventing him from participating. During the final testing of the study, another participant withdrew from the study due to injury. One participant from the GME group started this experiment during the halfway testing so the third set of data was not obtained from him and as a result the number of remaining participants was 16.

4.4.2.2 Halfway Mean Strength Readings

When analysing the three groups from the halfway testing, the mean readings for the AddE group were 220N (SD 44) for GME, 226N (SD 46) for SLAb, 255N (SD 56) for SLAd and 355N (SD 70) for Clam1. The mean readings for the Clam1 group were 239N (SD 61) for GME, 230N (SD 47) for SLAb, 257N (SD 56) for SLAd and 360N (SD 74) for Clam1. The mean readings for the GME group were 179N (SD 49) for the GME, 211N (SD 60) for SLAb, 237N (SD 64) for SLAd and 320N (SD 80) for Clam1.

4.4.2.3 Final Mean Strength Readings

When analysing the three groups from the final testing, the mean readings for the AddE group were 261N (SD 47) for GME, 276N (SD 54) for SLAb, 315N (SD 71) for SLAd and 434N (SD 57) for Clam1. The mean strength readings for the Clam1 group were 250N (SD51) for GME, 273N (SD 56) for SLAb, 293N (SD 59) for SLAd and 415N (SD 71) for Clam1. The mean strength readings for the GME group were 192N (SD 56) for GME, 224N (SD 50) for SLAb, 232N (SD 58) for SLAd and 335N (SD 80) for Clam1.

Table 6. Showing the strength tests of the three groups at baseline, 1 month and 2 months.

Test Position	AddE			Clam1			GME		
	Baseline	1 Month	2 Month	Baseline	1 Month	2 Month	Baseline	1 Month	2 Month
GME	191N (SD 52)	220N (SD 44)	261 (SD 47)	226N (SD 55)	239N (SD 61)	250 (SD 51)	190N (SD 40)	179 (SD 49)*	192 (SD 56)*
SLAb	215N (SD 45)	226N (SD 46)	276 (SD 54)	228N (SD 51)	230 (SD 47)	273 (SD 56)	193N (SD 51)	211 (SD 60)	224 (SD 50)
SLAd	222N (SD 53)	255N (SD 56)	315 (SD 71)*	249N (SD 43)	257 (SD 56)	293 (SD 59)	209N (SD 48)	237 (SD 64)	232 (SD 58)
Clam1	292N (SD 71)	355N (SD 70)*	434 (SD 57)*	347N (SD 60)	360 (SD 74)	415 (SD 71)	294N (SD 63)	320 (SD 80)	335 (SD 80)

4.4.3 Statistical Analysis

4.4.3.1 AddE Group Strength Gains

When analysing the AddE group, it was found that there was a significant increase in strength in the SLAd position after 2 months ($p=0.014$) (Figure 28) and there was a significant increase in the Clam1 position on both 1 month after and 2 months after ($p<0.001$ on both occasions) (Figure 29) (Table 6). However, there was no evidence of an increase in GME or SLAb.

4.4.3.2 Clam1 Group Strength Gains

When analysing the Clam1 group, it was found that there were no significant increases in strength in any of the strength tests (Figure 30) (Table 6).

4.4.3.3 GME Group Strength Gains

When analysing GME, it was found that there was a significant decrease in strength the first month followed by a significant increase in strength after the second month ($p=0.015$ and $p=0.019$ respectively) (Figure 31) (Table 6).

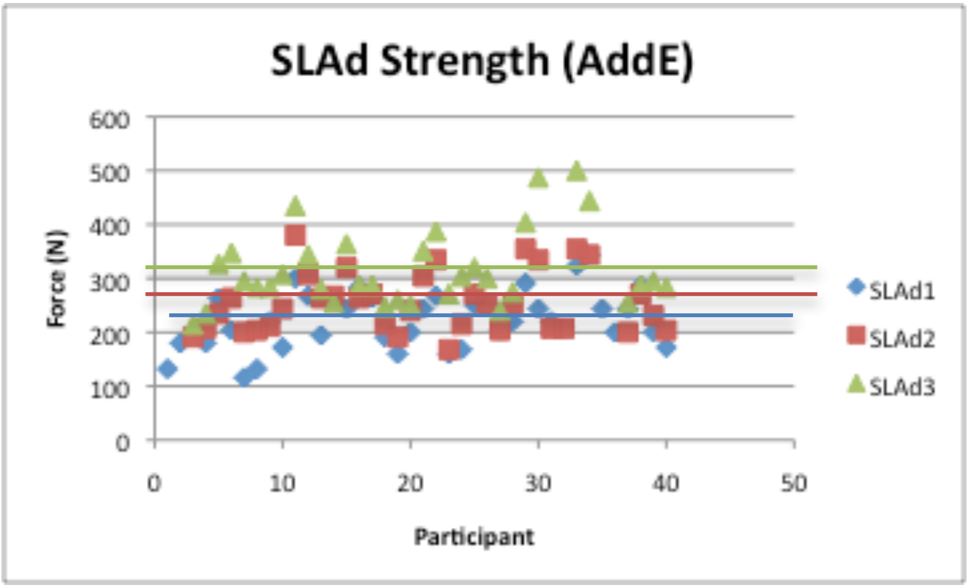


Figure 28. Showing the strength of SLAd for the AddE group. Each participant has 2 values (left and right), AddE1 was the baseline results, AddE2 was the halfway results and AddE3 was the final results. The horizontal lines represent the means (colour matched with the time of testing).

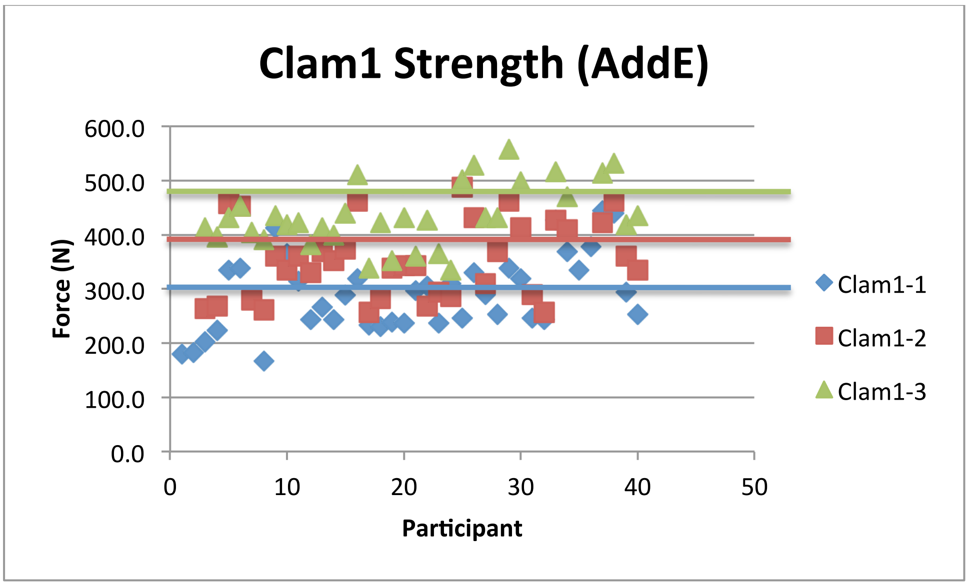


Figure 29. Showing the strength of Clam1 for the AddE group. Each participant has 2 values (left and right), Clam1-1 was the baseline results, Clam1-2 was the halfway results and Clam1-3 was the final results. The horizontal lines represent the means (colour matched with the time of testing).

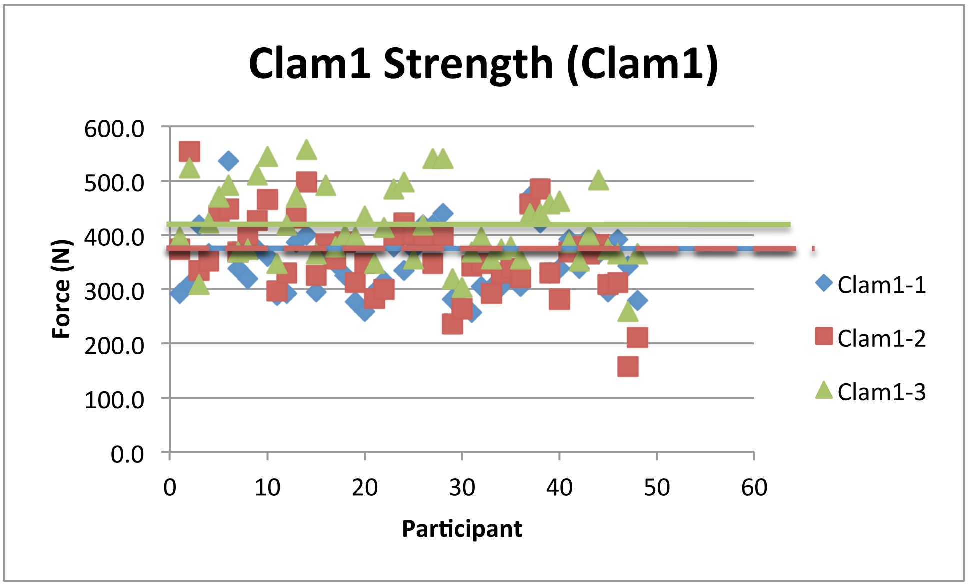


Figure 30. Showing the strength of Clam1 for the Clam1 group. Each participant has 2 values (left and right), Clam1-1 was the baseline results, Clam1-2 was the halfway results and Clam1-3 was the final results. The horizontal lines represent the means (colour matched with the time of testing).

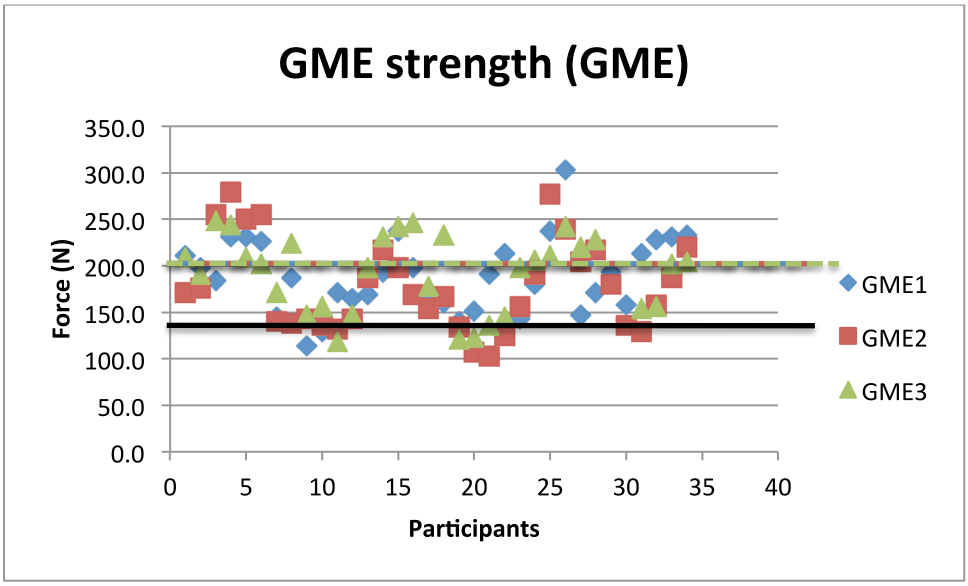


Figure 31. Showing the strength of GME for the GME group. Each participant has 2 values (left and right), GME1 was the baseline results, GME2 was the halfway results and GME3 was the final results. The horizontal lines represent the means (colour matched with the time of testing). Black line represents the cut-off for strength deficiency.

4.5 Discussion

4.5.1 Comparison of Exercises

4.5.1.1 AddE Group

In terms of the AddE group, the participants benefited from strength gains in the SLAd position compared with the other groups. It correlated well with the footballers study where the participants experienced symptom relief from their groin pain after doing the AddE exercise (Holmich et al., 1999). The surprising finding with the AddE group was that they also gained significant improvement in the Clam1 position when compared to the two groups who were prescribed abduction exercises. This was surprising given that AddE is an exercise prescribed to strengthen the adductors. A possible reason is that when one side of the hip joint is strengthened, the antagonist may spontaneously strengthen to compensate while the person is performing his/her daily activities. This also supports the previous analyses of this project where strength in one position predicts the strength of another but this takes it further in suggesting that an increase in strength in one positions will result in increase of another. An argument against this finding was that the boys grew and became stronger but the other groups did not become stronger in the same time frame and the AddE boys did not gain significant height and weight during the study so the factors of growth cannot influence the strength of the participants. The clamp was removed during baseline testing so it may influence the first follow up but certainly not the second. However, the SLAb and GME strength did not increase as a result of strengthening the adductors and maybe it is because the SLAb and GME are not the antagonists of the SLAd strength and maybe the SLAb/SLAd is not a good ratio to use.

4.5.1.2 Clam1 Group

The Clam1 group did not benefit from any strength gains. The reason could be that as both the pilot study and the baseline testing showed the participants are already strong in the Clam1 position so it is unlikely that they will receive any strength gains. Given the previous EMG studies (Boren et al., 2011) and the studies in this project there are multiple indications that Clam1 is not likely to uncover any strength deficiencies nor be used to as an effective exercise so the question is whether the Clam1 exercise should still be taught and prescribed to strengthen the abductors.

4.5.1.3 GME Group

The GME group did not benefit from any strength gains either. This is in contrast to the AFL study where the participants received significant strength gains (Osborne et al., 2012b). A possible reason was that the original school intended for the GME group withdrew from the study and a new team was needed to be recruited for the GME group. The new GME group was also recruited when the rugby season was close to finishing which may affect motivation and compliance. However although the GME group may be disadvantaged is some way the study can only conclude that the GME exercise did not produce significant strength gains when compared to the Clam1 exercise and the control exercise.

4.5.2 Analysis of Baseline Testing

4.5.2.1 Prevalence of Strength Deficiencies and >25% Side-to-Side Difference

In terms of strength deficiencies using the GME, very few were found to be weak according to the 130N cut off used in the AFL study (Osborne et al., 2012b). This finding suggested the opposite of the AFL study and that even when their parameter was used, strength deficiency was uncommon.

On the whole the strength of the boys were even on both sides. There are indications that SLAb strengths are uneven and that the boys are more likely to become uneven with SLAb as they grow (growth study) but when all factors are adjusted, it had minimal effect so either there were some issues with the testing or we may need to further investigate the cause. The study did find a small proportion of players with a left-right strength disparity of greater than 25%. However it was less than the proportion found in the pilot study and the Australian Rules Footballers study. In the pilot study we did raise the possibility that athletes may be predisposed to side-to-side difference and this study with recreational athletes may support that statement. Even in the high school study there were much less people with left-right disparities greater than 25% so it suggests that left-right disparities is greater in elite athletes and shows the importance of conditioning when participating in high level sport.

4.5.2.2 Strength in Correlation with Aspects of Growth

One of the findings was that the different strength correlated with different aspects of growth such as height, weight, age and BMI. For example, the left GME correlates with weight and BMI while the right GME doesn't correlate with anything and the same goes for SLAd and Clam1 where the right side's strength correlates with one aspect but the other side had no correlation. A possibility may be due to the effect of growth spurts where the strength fails to keep up while the boys grew however the numbers of participants were low and this set of data lacked variety in height, weight and age.

4.5.2.3 Comparison of the Three Groups

When the three groups are compared with each other, it was found that the participants of the GME group were significantly lighter than the other two groups, the AddE group was significantly shorter than the other two groups but the age was similar between the three groups. There were also no significant baseline strength differences between the schools. Because it was found that weight was the most important determinant in strength (growth study) the AddE and Clam1 group are comparable but the GME group may lag behind in terms of strength gains although their baseline strength are equal so we can conclude that all three groups are equal at the start.

4.6 Conclusion

The AddE exercise not only improves symptoms in groin pain (Holmich et al., 1999) but also strengthens the adductors and abduction but only in the Clam1 position.

Despite being commonly prescribed to strengthen the hip abductors, Clam1 exercise failed to strengthen the hip abductors in all three hip abduction test positions used in this study.

There is discrepancy between this study and the AFL study where the boys benefited from significant abduction strength gains from the GME exercise.

Chapter 5

5 Growth Study

5.1 Introduction

As children grow, their musculoskeletal system undergoes rapid development (Rauch et al., 2004). However as they rapidly grow rapidly in height during their growth spurt it is common to see excess side-to-side movement in their gait. We speculate that it is because their abduction strength is unable to keep up with the demands of the rapidly increasing height.

5.2 Aim

In this part of the project we will sample boys from all high school years and test their hip strength using GME, SLAb, SLAd and Clam1. We hope to show that as the boys get older their strength improvements in the GME position lags behind the other strength tests.

5.3 Methods

5.3.1 Recruitment and Testing

Like the intervention study, this study was approved by the Human Ethics Committee of the University of Otago (number 12/107) and has the support from the Ngāi Tahu Research Consultation Committee (appendix E). Approval was obtained from staff and participants of John McGlashan College, Dunedin. Signed consents were obtained from participants and additional parent/caregiver consents were obtained from children under the age of 16.

The participants were recruited from John McGlashan College, Dunedin as well as the baseline data from participants of the 1st XV study who were not tested using the clamping device. Prior to the study all the potential participants were all briefed at an assembly. The age ranges of the participants were New Zealand year 9 to year 13, which constitutes of ages from a minimum of 13 and maximum of 18. At least 20 were drawn from each school year in our range. The participants had to be healthy with no injuries or medical conditions capable of hindering their ability to perform the strength tests.

The inclusion criteria were:

-We recruited males who were enrolled at John McGlashan College who were

-healthy and had no medical conditions stopping them from participating in physical education classes and/or sport.

-From years 9-13 (minimum of 20 from each school year).

The exclusion criteria were:

- those with known medical conditions that affect the hip.

- current groin pain,
- current back pain and
- any other injury preventing them from performing the strength tests.

All the participants then had their basic demographics recorded. This included the date of birth, height, weight, ethnicity and date of testing. From this, the examiner also calculated the BMI from the weight and height as well as their age at the time of testing.

The participants then had their hip strength tested using the same method as the pilot study and the intervention study.

5.3.2 Statistical Analysis

How height, weight and age influenced each of the strength tests was analysed by Pearson's Correlation. To investigate how the individual strength tests changed with respect to the parameters linear regression was used. For comparison purposes, the strength tests where the dynamometer was placed at the ankle (SLAb and SLAd) had their figures divided by 0.55 because the thigh to leg ratio is on average 55:45 (Strecker et al., 1997).

5.4 Results

5.4.1 Demographics

In terms of the sample twenty participants were year 9 with a mean age of 13.7 (SD 0.5), mean height of 1.66m (SD 0.09), mean weight of 58.0kg (SD 9.7) and mean BMI of 21.0 (SD 2.8). Twenty participants were year 10 with mean age of 14.5 (SD 0.5), a mean height of 1.71m (SD 0.07), a mean weight of 61.7kg (SD 9.5) and a mean BMI of 21.1 (SD 2.4). Twenty participants were year 11 with a mean age of 15.3 (SD 0.6), a mean height of 1.77m (SD 0.06), a mean weight of 77.4kg (SD 15.8) and a mean BMI of 24.5 (SD 4.3). Twenty-five participants were year 12 with a mean age of 16.1 (SD 0.3), a mean height of 1.76m (SD 0.07), a mean weight of 73.9kg (SD 11.1) and a mean BMI of 23.7 (SD 3.0). Twenty participants were year 13 with a mean age of 17.2 (SD 0.5), a mean height of 1.79m (SD 0.06), a mean weight of 79.6kg (SD 11.4) and a mean BMI of 24.9 (SD 2.9) (Table 7).

Table 7. Showing the mean demographics of the growth study

	Year 9	Year 10	Year 11	Year 12	Year 13
Age	13.7 (SD 0.5)	14.5 (SD 0.5)	15.3 (SD 0.6)	16.1 (SD 0.3)	17.2 (SD 0.5)
Height	1.66m (SD 0.09)	1.71m (SD 0.07)	1.77m (SD 0.06)	1.76m (SD 0.07)	1.79 (SD 0.06)
Weight	58.0kg (SD 9.7)	61.7kg (SD 9.5)	77.4kg (SD 15.8)	73.9 (SD 11.1)	79.6 (SD 11.4)
BMI	21.0 (SD 2.8)	21.1 (SD 2.4)	24.5 (SD 4.3)	23.7 (SD 3.0)	24.9 (SD 2.9)

5.4.2 Mean Strength Findings

Table 8. Showing the mean strength tests from years 9-13 in the growth study.

	School Year									
	9		10		11		12		13	
	Left	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**	**Left**	**Right**
GME	144.7	154.9	173.4	165.4	196.1	213.0	189.6	203.6	223.9	222.3
	41.3	44.8	46.2	48.1	52.1	51.9	47.4	56.2	65.4	64.8
SLAb	102.7	96.6	110.3	111.6	116.6	127.5	111.2	115.6	119.1	133.4
	25.1	38.8	24.3	28.6	26.9	27.2	36.2	31.4	32.9	32.2
SLAd	110.9	116.4	113.8	120.3	130.6	132.4	118.8	119.8	128.7	126.3
	31.7	35.7	20.2	24.2	24.1	28.2	26.9	29.9	29.9	27.0
Clam1	232.2	238.1	247.1	253.3	337.7	337.4	326.3	321.6	348.0	350.5
	67.8	71.6	62.6	67.1	70.8	75.2	88.2	81.6	80.1	80.4

5.4.3 Ratios

In terms of left-right ratio disparities greater than 25%, there were 15 (14%) participants from GME with a mean of 35.7% (SD 8.0), 14 (13%) from SLAb with a mean of 33.9% (SD 6.6), 9 (9%) from SLAd with a mean of 29% (SD 1.7) and 3 (3%) from Clam1 with a mean of 37% (SD 4.6).

5.4.4 Statistical Analysis

5.4.4.1 Strength in Relation to Demographics

When the Pearson Correlation was used, it was found that as the boys became heavier, they got stronger in all testing positions. As the boys became taller, they got stronger in all testing positions. Lastly, as the boys got older, they got stronger in all testing positions. When the linear regression was used, it was found that the SLAd became stronger as the boys became heavier, the SLAb got stronger as the boys became heavier, the Clam1 became stronger as the boys became heavier and older and the GME became stronger as the boys became heavier and older. When all factors were adjusted, weight was the most significant determinant of strength.

5.4.4.2 Left:Right Strength Discrepancies Associated with Growth

When investigating side-to-side difference with Pearson Correlation, it was found that as the as the boys became taller, they became more lop-sided in the SLAb position. In terms of weight, it was found that as the boys became heavier they became more lop-sided in the SLAb position. It was also found that as the boys became older, they became more lop-sided in the SLAb position. However when a linear regression analysis was performed, it was found that when all factors were controlled for there were no changes in side-to-side difference as they boys became taller, heavier or older.

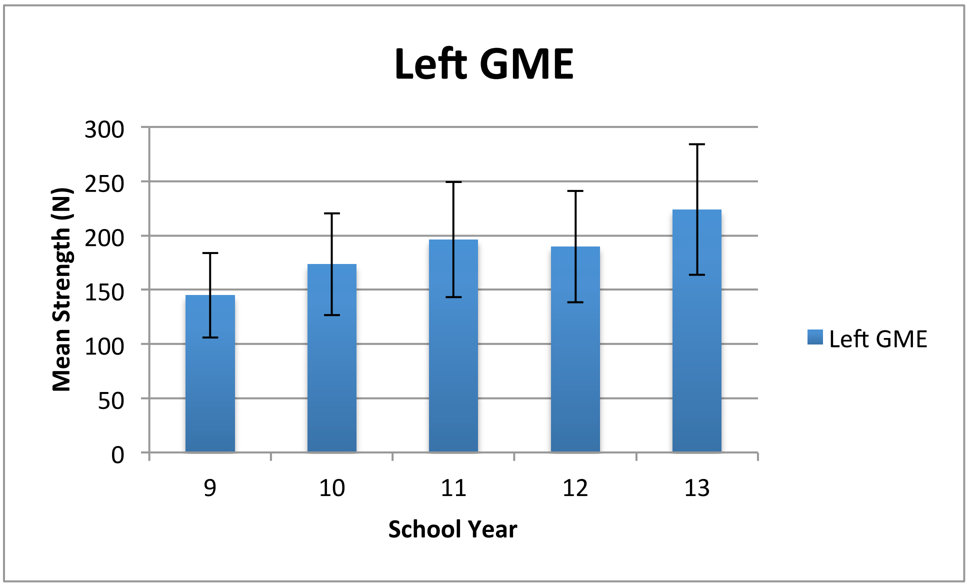


Figure 32. Figure showing the mean GME strength of the school years with standard deviation.

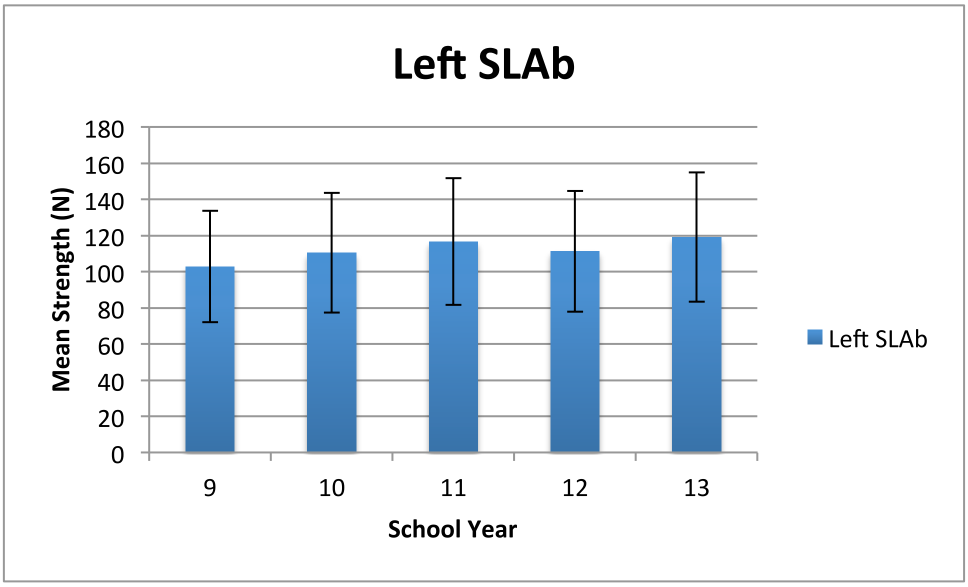


Figure 33. Figure showing the mean SLAb strength of the school years with standard deviation.

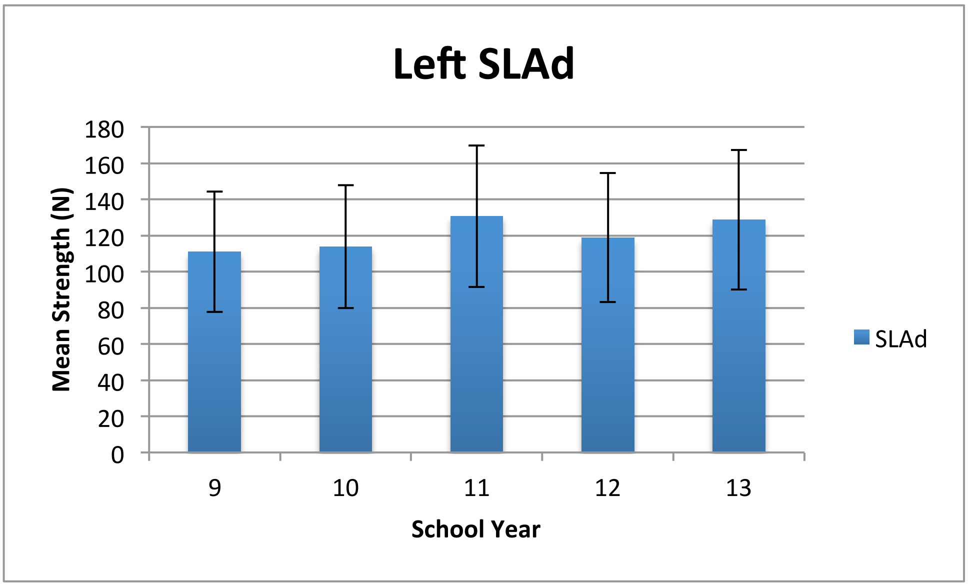


Figure 34. Figure showing the mean SLAd strengths of the school years with standard deviation.

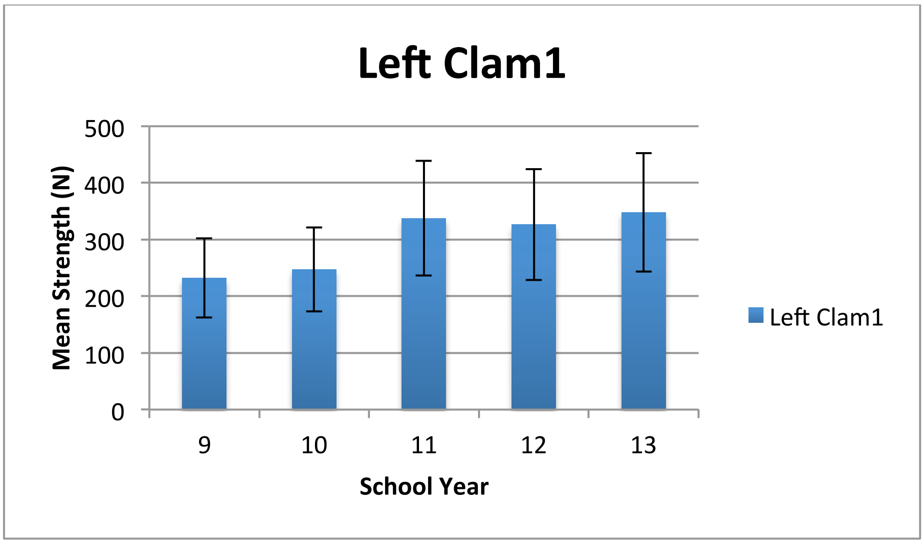


Figure 35. Figure showing the mean Clam1 strength of the school years with standard deviation.

5.5 Discussion

5.5.1 Determinants of Strength

It was found that the strength depended mostly on weight. This can be explained by the reasoning that if a person is heavier, they require more strength to support that weight while walking. This is also supported by the rapid increases in muscle mass associated with puberty (Rauch et al., 2004) contributing to the weight and hence strength increases.

5.5.2 Growth Related Strength Deficiency

In terms of strength deficiencies, the 130N cut-off could not be used because the participants in this study were younger and lighter so it would be assumed that they were weaker and the parameter used for older boys and adults could not be applied. Looking at the data on the whole, the strength of GME did not lag behind the strength increases of other positions. A possible explanation of the observed excess side-to-side gait pattern could be due to the “swagger associated” with increases in confidence during puberty (Rowe et al., 2004) rather than strength deficiencies. However the question is that if these boys continued to walk in this way after they stop growing, could it lead to strength deficiencies as an adult like the observations seen from the pilot study?

5.5.3 Strength Difference Between Sides

In terms of side-to-side differences it was seen that an increase in height, weight or age resulted in an increased incidence of lopsidedness in the SLAb position however when all the factors were adjusted for there were no significant associations with growth and lopsidedness. This could either be due to experimental issues, which associated lop-sidedness with each of the parameters but not when all factors are adjusted for or there may be a correlation with increase lopsidedness but this study lacked the number required.

Chapter 6

6 Overall Conclusion

6.1 Summary

From the pilot study it was found that hip abduction strength deficiencies were common among the healthy population when tested in the GME position. This finding correlated with the AFL study where 1/3 of healthy elite athletes were also found to have abduction strength deficiencies (Osborne et al., 2012b) which may explain the common observation of excess side-to-side movement when people walk. The other finding was that it was common to see side-to-side strength difference of greater than 25% between the sides. Both these findings indicate that abduction strength deficiencies are not only seen in the injured population (Fredericson et al., 2000) but also in the healthy population. Because abduction strength deficiency is linked with injury, (Fredericson et al., 2000, Brindle et al., 2003, Powers, 2003, Ireland et al., 2003) the findings suggests that abduction strengthening exercises should be prescribed not only for rehabilitation purposes among the injured but also for conditioning purposes among the healthy population who exercise.

Although we hypothesised that participants would receive the most amount of benefit from the GME exercise however this was not the case in this study which was contrary to the AFL study where participants benefited from significant strength gains (Osborne et al., 2012b). In this study, the participants did not benefit from the Clam1 exercise either. This may also be due to lack of adherence similar to the GME group. The surprising finding was that along with the expected increase in adduction strength the AddE exercise also increased the abduction strength the Clam1 position.

Because of abduction strength deficiencies found in the adolescence (Osborne et al., 2012b), the abduction strength deficiencies found in the pilot study and the general observation of Trendelenburg gait patterns among teenagers undergoing growth spurts, it was hypothesised that the hip abduction strength cannot keep up with the rapidly growing height during a growth spurt. However it in the growth study it was found that there were no growth spurt related strength deficiencies with the abductors. The strength in all testing positions increased as height, age and weight increased with the main determining factor being the weight.

6.2 Limitations and Future Directions

One difficulty was to extrapolate a subjective MRC strength grading of 4 into an objective number. We the AFL study's 130N (Osborne et al., 2012b) with the assumption that a muscle as important as the gluteus medius in terms of gait should be able to overcome 130N while holding the body during stance phase. The other aspect was that although there were many found to be deficient in the GME position there were no testing to see if lack of strength correlated with lack of function. It would be ideal if future studies could show that lack in GME strength correlated with poorer functional tests such as balance. Because of ethical constraints, only healthy individual participated in this project and another criticism to this project was the strength deficiency in the GME position shown in the pilot study were not pathological therefore it would be ideal to obtain some data from injured individuals alongside the healthy individuals to obtain an overview of the level of GME strength in injured people. This way there is a group to compare the pilot study population to in order to show that their underlying weakness was pathological.

Another aspect, as mentioned previously was the clamp, which affected Clam1 and GME positions. It was initially introduced to instrument the testing thereby removing the inaccuracies associated with the examiner. However, it was found to introduce more inaccuracies because it was easy for the dynamometer to be knocked off its cast and took less than 300N for the participant to lift the examiner off the ground (without the clamp, the examiner can handle 400-500N) which meant that the clamping device understated the actual strength of the participants as can be seen as the AddE group had significantly improved strength readings in the Clam1 position during the halfway testing compared to the Clam1 and GME group had minimal improvements despite being prescribed the exercises which were intended to strengthen the abductors. The clamp was also difficult to set up and when under time pressure, it was easy to make a mistake with the set up and made it easy for the examiner to tire. Fortunately the clamp was removed at baseline so only the first follow-up was affected.

Another shortcoming mentioned previously was that our intended school for GME withdrew and as a result we needed a replacement. Because of the withdrawal and late recruitment, this study also suffered from recruiting the team while the season was ending making it harder for players to stay motivated with the exercise prescription and also made it difficult to recruit the players who were not attending the high school which meant our sample size was smaller than originally intended.

In terms of exercise prescription, there was a lack of supervision. The participants were taught and then they performed the exercise under supervision during the teaching session and then they were left on their own to do the exercise at home. As a result of this, it was not possible to achieve continued supervision of the participants. Furthermore, there were participants who were unable to attend the teaching session so they either performed the exercise incorrectly or they did not perform it. It was found on the halfway testing that a few boys from AddE group did not perform the exercise because they were away during the teaching session. Surprisingly the AddE group benefited from the most strength gains suggesting the effectiveness of the AddE exercise. There was also one GME boy who performed the exercise incorrectly because he missed the teaching session and was taught wrongly by his peers who presumably also performed the exercise incorrectly. Due to lack of supervision, adherence could also be a potential issue. Although all attempts were made to encourage the participants to perform the exercise, there was no way to guarantee the participant actually did full number of repetitions every day. Because this study works with adolescence, lack of adherence may be very likely (Jacobson et al., 1990, Modi and Quittner, 2006, Martin et al., 2000). However, the experimental group consists of fit individuals which are one of the positive predictors for adherence (Martin et al., 2000).

The study could also benefit from a larger sample size. Although we tested many participants in total, we felt that the numbers in each group were small. The 1st XV teams average at about 20 participants and the growth study only had 20 from each year level with a variation is ages across the school years. As a result it made it difficult to compare the groups in both studies and we feel that there may be stronger conclusions had the sample sizes had been larger.

Minor limitations included those associated with hand-held dynamometry. The dynamometer's maximum reading was 556N so anyone who produced more force would have his strength underestimated. While the examiner tried his best to hold the dynamometer steady, if the participants produce force forces over 500N, it is capable of moving the examiner's hand in the Clam1 position and is the force of the SLAb and SLAd is greater than 200N, then it is capable drag the examiner across the floor during the SLAb and SLAd strength tests. This is worse when the surface is slippery such as linoelum. It seems that the new test is most reliable at obtaining consistent figures. There were some issues with clothing as tighter legwear made it difficult to get into position and that socks can make it slippery for the support leg in the SLAd and SLAb positions.

In terms of future improvements adherence and supervision certainly needs to improve. A future study could utilise physical education classes where students perform the exercises during the PE class in addition to what they have to do at home. It has been suggested that class exercise programmes combined with home exercise it better than home based exercise alone in terms of adherence (McCarthy et al., 2004). This also has the advantage of having more people because a PE class in a city school should have at least 20 to 30 people and there are multiple PE classes per school. If students perform the exercise during PE class, it allows for better supervision hence the investigator can have more certainty about the correct performance of the exercise and a certain level of adherence rather than teaching it once and then letting the students do it on their own at home, where there were people who stated they did not perform the exercise and people who were discovered to perform the exercise incorrectly during follow-up. PE classes also mean that the students will be in PE gear, which is ideal because the clothing should be comfortable enough to get into the testing positions without the hindrance of tight trousers.

Given the findings of strength testing aspect of this project, it would be interesting to do an EMG study on the GME exercise and compare it to the Clam1 and AddE in terms of gluteus medius, gluteus maximus and tensor fascia lata recruitment. EMG is different to dynamometry and will allow us to look at these exercises from a different angle. Looking at the findings of the pilot study and the figures produced from the strength testing, we hypothesise that GME would have a high MVIC for gluteus medius and would really like to investigate to see if that is the case. Left-right disparity and abduction-adduction ratio could also be an interesting aspect to investigate further. It has been speculated that abduction/adduction and left-right strength disparities contribute to an increased risk of injury (Fredericson et al., 2000, Bender et al., 1964) however we wonder if that is true considering that it was a common finding in the pilot study. Does maintaining an even abduction/adduction and left-right ratio prevent injury?

Although gluteus medius strength deficiency was found to be common, there are criticisms about whether this weakness was considered pathological. In the future, would be good to look at functional balance test to see if there are any correlation between weakness in the GME position and poorer balance as impaired balance leads to increased risk of falls (Granacher et al., 2013). It would also be ideal to have injured people tested to have a comparison group for the healthy population.

6.3 Conclusions

-GME is potentially a good clinical tool at uncovering hip abduction strength deficiencies.

-Hip strength deficiencies are common in the healthy population when using previously published parameters.

-There are no strength difference between sides on the whole. However it is very common to see people with greater than 25% between the sides.

-The AddE is a good exercise for increasing adductor strength and also interestingly increases the strength of the antagonist muscle groups.

-Clam1 and GME exercise did not strengthen the hip abductors in this study.

- Growth related strength deficiencies have not been detected in this study.

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8 Appendix

8.1 Appendix A: The sequence of the strength tests arranged in their quasi-randomized order.

1	2	3	4	5	6	7	8
GME L:	Clam1 L:	Clam1 L:	GME L:	GME R:	Clam1 R:	Clam1 R:	GME R:
SLAb R:	SLAb R:	SLAb R:	SLAb R:	SLAb L:	SLAb L:	SLAb L:	SLAb L:
SLAd R:	SLAd R:	SLAd R:	SLAd R:	SLAd L:	SLAd L:	SLAd L:	SLAd L:
Clam1 L:	GME L:	GME L:	Clam1 L:	Clam1 R:	GME R:	GME R:	Clam1 R:
Clam1 R:	Clam1 R:	GME R:	GME R:	Clam1 L:	Clam1 L:	GME L:	GME L:
SLAd L:	SLAd L:	SLAd L:	SLAd L:	SLAd R:	SLAd R:	SLAd R:	SLAd R:
SLAb L:	SLAb L:	SLAb L:	SLAb L:	SLAb R:	SLAb R:	SLAb R:	SLAb R:
GME R:	GME R:	Clam1 R:	Clam1 R:	GME L:	GME L:	Clam1 L:	Clam1 L:
GME L:	Clam1 L:	Clam1 L:	GME L:	GME R:	Clam1 R:	Clam1 R:	GME R:
SLAb R:	SLAb R:	SLAb R:	SLAb R:	SLAb L:	SLAb L:	SLAb L:	SLAb L:
SLAd R:	SLAd R:	SLAd R:	SLAd R:	SLAd L:	SLAd L:	SLAd L:	SLAd L:
Clam1 L:	GME L:	GME L:	Clam1 L:	Clam1 R:	GME R:	GME R:	Clam1 R:
Clam1 R:	Clam1 R:	GME R:	GME R:	Clam1 L:	Clam1 L:	GME L:	GME L:
SLAd L:	SLAd L:	SLAd L:	SLAd L:	SLAd R:	SLAd R:	SLAd R:	SLAd R:
SLAb L:	SLAb L:	SLAb L:	SLAb L:	SLAb R:	SLAb R:	SLAb R:	SLAb R:
GME R:	GME R:	Clam1 R:	Clam1 R:	GME L:	GME L:	Clam1 L:	Clam1 L:

8.2 Appendix B: Category B Ethical Approval for the pilot study

Form Updated: February 2011

HUMAN ETHICS APPLICATION: CATEGORY B

(Departmental Approval)

1. **University of Otago staff member responsible for project:**
   Dr Hamish Osborne

2. **Department:** Dept Medicine, Dunedin School of Medicine

3. **Contact details of staff member responsible:**

   Department of Medicine, University of Otago, PO Box 913, Dunedin 9054, New Zealand

   Office: +64 3 474 0999 internal: 8556

   Fax +64 3 474 7641

   Skype: ncsm06

   hamish.osborne@otago.ac.nz

4. **Title of project:** How common is hip strength deficiency in the general community?

5. **Indicate type of project and names of other investigators and students**:

   Staff Research ☐ **Names** Dr Hamish Osborne

   Student Research ☐ **Names** Shumou Chen

   Level of Study (e.g. PhD, Masters, Hons) BMedSc(Hons)

   External Research/ ☐ **Names**

1

Collaboration

Institute/Company

6. When will recruitment and data collection commence? Immediately

When will data collection be completed? After 100 subjects have been tested

7. Brief description <u>in lay terms</u> of the aim of the project, and outline of research questions.

When walking down the street it is common to see men and women who are otherwise healthy with normal hips to have excess side-to-side movement. Landing patterns from this gait type have been associated with various injuries of the lower back, hip as well as the knees however current strength testing is insensitive at exposing this hip strength deficiency. A paper written by Dr Hamish Osborne and recently accepted for publication has suggested that a new testing position can uncover hip strength deficiency in these otherwise normal people with excess sideways movement in their gait who would have previously tested as normal despite their gait pattern being abnormal. This hip strength is part of what the wider community calls core strength.

This experiment is a pilot study with the main aim to define the technique of hand held dynamometry to assess strength of muscles around the hip in different positions. From this a large scale study can be accurately powered to achieve an outcome. As a secondary aim data will be gathered to develop a database to determine the community norms for hip strength in several different positions.

8. Brief description of the method

The experiment will include hip strength testing using a hand held dynamometer in 4 different positions on both sides. The best of three readings will be recorded as well as date of birth, gender, height and weight.

The data will be compared to normative data in the literature. The experimental subjects will be healthy adults over 18 years of age. Exclusion criteria will include those who have known problems with their hips.

9. **Please disclose and discuss any potential problems**: (For example: medical/legal problems, issues with disclosure, conflict of interest, etc)

N/A

Applicant's Signature**:** ....

(Principal Applicant: as specified in Question 1, Must ***not*** *be in the name of a student)*

Signature of *Head of Department: ....

Name of Signatory (please print): ……………………………………………….

Date: 07/02/2012....................................

Departmental approval: *I have read this application and believe it to be scientifically and ethically sound. I approve the research design. The Research proposed in this application is compatible with the University of Otago policies and I give my consent for the application to be forwarded to the University of Otago Human Ethics Committee.*

[Reference Number *as allocated upon approval by the Ethics Committee*]
[*Date*]

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

How common is hip strength deficiency?

INFORMATION SHEET FOR PARTICIPANTS

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

When walking down the street it is common to see men and women who are otherwise healthy with normal hips to have excess movement. Landing patterns from this gait type have been associated with various injuries of the lower back, hip as well as the knees however current strength testing is insensitive at exposing this hip strength deficiency. This hip strength is part of what the wider community calls core strength.

This experiment is a pilot study with the main aim to define the technique of hand held strength testing to assess strength of muscles around the hip in different positions. From this a large scale study can be accurately planned. As a secondary aim data will be gathered to develop a database to determine the community norms for hip strength in several different positions.

What Type of Participants are being sought?

We are looking for healthy participants over the age of 18 with no known history of hip problems.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to have your hip strength tested in 4 different positions. It involves you pushing as hard as you can against a hand held strength testing machine for about 3 seconds. This will be done 3 times on each limb with the best result of the three recorded

The procedure shouldn't take more than 10 minutes of your time and we will be quite flexible in terms of suiting your time schedule.

There are no known health risks associated with this procedure aside from feeling a bit tired after the experiment.

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Your name, age, gender, weight, height and your strength readings will be recorded. The information will be kept strictly confidential between you, the BMedSc(Hons) student involved (Michael Chen) and his supervisor (Dr Hamish Osborne).

The data collected will be securely stored in such a way that only those mentioned above will be able to gain access to it. At the end of the project any personal information will be destroyed immediately except that, as required by the University's research policy, any raw data on which the results of the project depend will be retained in secure storage for five years, after which it will be destroyed.

The completed research will be published in a way in which you cannot be identified. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity. As the participant, you will also be given a copy of the raw data.

This proposal has been reviewed and approved by the Department of Medicine, University of Otago.

Can Participants Change their Mind and Withdraw from the Project?

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact:

Dr Hamish Osborne

Department of Medicine

University Telephone Number: 03 474 0999 ext 8556

Email Address: hamish.osborne@otago.ac.nz

The Department of Medicine has approved this study. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479-8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

How common is Gluteus Medius deficiency?

CONSENT FORM FOR
PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that: -

1. My participation in the project is entirely voluntary;

2. I am free to withdraw from the project at any time without any disadvantage;

3. Personal identifying information will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. There are no known health risks apart from slight fatigue upon physical exertion.

5. The results of the project may be published and available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

....
(Signature of participant) (Date)

Participants needed for research study involving core strength.

When walking down the street it is common to see men and women who are otherwise healthy with normal hips to have excess side to side movement of their bodies.

Landing patterns from this gait type have been associated with various injuries of the lower back, hip as well as the knees.

Current strength testing is insensitive at exposing this hip strength deficiency.

The aim of this study is to use a new strength testing technique thought to be sensitive to the weakness that leads to the excess side to side movement

We are looking for healthy individuals over the age of 18 to have their hip strength tested. It will take no more than 10 minutes and will be reasonably flexible to your time schedule.

There are no known health risks aside from a bit of fatigue from physical exertion.

For more information please feel free to contact:

Dr Hamish Osborne (Supervisor)
Department of Sports and Exercise Medicine
Department of Medicine
Phone: 03 474 0999 ext 8556
Email: hamish.osborne@otago.ac.nz

[**This project has been reviewed and approved by the Department of Medicine, University of Otago**]

Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz	Hip Strength Testing (Michael Chen) chesh844@student.otago.ac.nz

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8.3 Appendix C: Category A Ethics application form

Application Form for ethical consideration of research and teaching proposals involving human participants

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

HUMAN ETHICS APPLICATION: CATEGORY a

1. **University of Otago staff member responsible for project:** Dr Hamish Osborne

2. **Department:** Department of Medicine, Dunedin School of Medicine

3. **Contact details of staff member responsible:** Department of Medicine, University of Otago, PO Box 913, Dunedin 9054, New Zealand | office: +64 3 474 0999 internal: 8556 | fax +64 3 474 7641 | skype: ncsm06

4. **Title of project:** Hip Strength Weakness in Adolesents – how common, what magnitude and how easy to fix is it?

5. **Indicate type of project and names of other investigators and students**:

Staff Research	☐	**Names**	Dr Hamish Osborne
Student Research	☐	**Names**	Shumou (Michael) Chen
Level of Study (e.g. PhD, Masters, Hons)			BMedSc(Hons)
External Research/ Collaboration	☐	**Names**	
Institute/Company			

6. Is this a repeated class teaching activity?

NO

If YES, and this application is to continue a previously approved repeated class teaching activity, please provide Reference Number:

7. Fast-Track procedure

Do you request fast-track consideration? *(See 'Filling Out Your Human Ethics Application')*

NO

If YES, please state specific reasons:-

8. When will recruitment and data collection commence?

As soon as ethics approval obtained

When will data collection be completed?

Approximately 2 months from completion of initial data collection

9. Funding of project.

Is the project to be funded by an external grant?

NO

If YES, please specify who is funding the project:

If commercial use will be made of the data, will potential participants be made aware of this before they agree to participate? If not, please explain:

10. Brief description <u>in lay terms</u> of the purpose of the project (approx. 75 words)**:**

Walking down the street it can be observed that many people walk with gait patterns that can be attributed to weakness of buttock muscles. This can also be observed on a sporting field. This buttock weakness has not been reported in the literature. The main purpose of this study is to see whether these weaknesses are common in the adolescent community (when it is thought that this weakness starts to occur related to growth spurts), and whether it can be easily corrected.

11. Aim of project, including the research questions the project is intended to answer:

There are several aims.

1. Relative to age/size does buttock weakness develop in the adolescent community as the children grow?
2. How common are these strength deficiencies observed, is it related to age or size, and are they easy to correct?
3. Is one exercise better than another to correct this weakness?

12. Researcher or instructor experience and qualifications in this research area:

The main researcher has an article in press showing that in an elite group of under age footballers that these buttock strength deficiencies are both common and easy to correct. He has worked with elite junior sport as medical director for a decade as team doctor, works with a professional rugby team and is in private practice as a Sports Physician.

13. Participants

13**(a) Population from which participants are drawn:** The participants will be drawn from three local high schools. The students will be drawn largely from two groups within the schools; physical education students and the rugby First 15 squads.

13**(b) Specify inclusion and exclusion criteria:**

Inclusion criteria: Boys currently enrolled at the three high schools

Currently no medical conditions stopping them from participating in school physical education and sport.

Exclusion Criteria: Known medical conditions affecting the hip.

Current groin pain.

Current back pain

Any other injury preventing them from performing the strength tests.

13**(c) Estimated number of participants:** 215

13**(d) Age range of participants:** High school age

13**(e) Method of recruitment:** The high schools will select classes to be enrolled along with the first 15 rugby squads. i.e. groups of convenience.

13**(f) Please specify any payment or reward to be offered:** Nil

14. Methods and Procedures:

The students and their parents will sign consent forms prior to the start of the study.

All students will have basic demographics recorded – age, ethnicity, weight and height. They will then be strength tested using a hand held dynamometer (strength testing device) that will actually be held in place by either a brace or strap to reduce the error inherent in hand held strength testing. Each student will have 4 strength tests performed on each hip twice. This will be performed in a quasi randomised order so as to maximise rest time between similar tests but minimise time taken to perform the test and reduce bias from the same order being repeated each time.

Approximately 30 boys from each year at high school will be tested from one school. 25 boys from three high schools First 15 rugby squads will also be tested.

The First 15 Rugby squads at each school will then be instructed in a particular exercise. There are three different exercises – one for each school. Each is used in rehabilitation of sporting injuries around the hip. Each exercise acts as a control group for the other two. Two different buttock strengthening exericses will be used and another exercise that does not strengthen the buttock at all, essentially a placebo exercise but it has in itself been published in the Lancet as an exercise for hip rehabilitation. The exercise technique will be checked one week later to ensure correct performance of the exercise. The strength tests will be repeated at one month from the start of the study and again at two months when weight and height will again be recorded.

15. Compliance with The Privacy Act 1993 and the Health Information Privacy Code 1994 imposes strict requirements concerning the collection, use and disclosure of personal information. These questions allow the Committee to assess compliance.

15(a) Are you collecting and storing personal information directly from the individual concerned that could identify the individual?

No

15(b) Are you collecting information about individuals from another source? Please explain: No

15(c) Collecting Personal Information:

- Will you be collecting personal information?

  NO

- Will you be informing participants of the purpose for which you are collecting the information and the uses you propose to make of it?

  YES

- Will you be informing participants who will receive the information?

  YES

- Will you inform participants of the consequences, if any, of not supplying the information?

  YES

- Will you inform the participants of their rights of access to and correction of personal information?

  YES

Where the answer is YES, please make sure the information is available in the Information Sheet for Participants.

If you are NOT informing them of the points above, please explain why:

15(d) Please outline your data storage and security procedures.

The data will be collected directly by the researcher. This will be entered into a statistical database. A copy of this database will be stored on a second computer and back-up hard drive within the Department of Medicine. The computers used are password protected and the back-up data locked away in accordance with University of Otago Policy. All data will be held in the office of Dr Osborne in the Department of Medicine in Dunedin. Data obtained as a result of the research will be retained for at least 5 years in secure storage. Any personal information held on the participants [such as names] will be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

15(e) Who will have access to personal information, under what conditions, and subject to what safeguards?

Only the named researchers involved in the collection and analysis of the data will have access.

Will participants have access to the information they have provided?

The results of the research will be made available to participants on completion of the study and a brief summary of the data sent to each school.

15(f) Do you intend to publish any personal information they have provided?

NO

If YES, please specify in what form you intend to do this?

15(g) Do you propose to collect demographic information to describe your sample? For example: gender, age, ethnicity, education level, etc.

Yes, age, gender, height, weight and ethnicity information will be collected.

15 (h) Have you, or do you propose to undertake Māori consultation? Please choose one of the options below, and delete the options that do not apply:

YES. This will be submitted for the May 6th meeting

16. Does the research or teaching project involve any form of deception?

NO

If yes, please explain all debriefing procedures:

17. Please disclose and discuss any potential problems:

- The researchers are clearly identified to the participants and contact details are presented on the Information Sheet.
- There are no perceived potential problems or conflicts of interest associated with this project.

18. Applicant's Signature: ....

[Principal Applicant: as specified in Question 1]

Date: ....

19. Departmental approval: *I have read this application and believe it to be scientifically and ethically sound. I approve the research design. The Research proposed in this application is compatible with the University of Otago policies and I give my consent for the application to be forwarded to the University of Otago Human Ethics Committee with my recommendation that it be approved.*

Signature of *Head of Department: ....

Name of Signatory (please print): …………………………………………………

Date: ....

[Reference Number *as allocated upon approval by the Ethics Committee*]
[*Date*]

Hip strength weakness, how common is it and does it start to develop in adolescence?

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

Walking down the street it can be observed that many people walk with gait patterns that can be attributed to weakness of buttock muscles. This can also be observed on a sporting field. This buttock weakness has not been reported in the medical literature. The main purpose of this study is to see whether these weaknesses are common in the adolescents (when it is thought that this weakness starts to occur related to growth spurts).

This project is being undertaken as part of the requirements for the Bachelor of Medical Science with Honours Degree

What Type of Participants are being sought?

We are looking to enrol high school aged boys from each year of high school who are otherwise fit to participate in school physical education and sports programs who don't have any underlying problems with their hips. We are looking to enrol 30 boys from each high school year.

Each participant will be given the results of their tests at the time of the measurements being taken and the school will be given a summary of the group results.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to provide your date of birth and ethnicity, have your weight and height measured and then the muscles around each hip measured in 4 different positions twice during the same period of testing. The strength will be measured using a hand held strength testing machine held in place with straps. It will take about 10 minutes to do this testing. This will be done during school hours. As a result of the tests there might be some minor soreness in the muscles tested like you might get after going for a run when you haven't been for a few weeks. This will not require any treatment.

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Once collected the data will be analysed to whether there is weakness in one or other hip muscle compared to other boys of the same age and size. It would be envisaged that this work in an abbreviated form will be published in a medical journal and in a larger format will form the basis of a Thesis for the Bachelor of Medical Science with Honours.

The only identifying information collected will be names and these will be removed from the database once data collection is complete.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. Data obtained as a result of the research will be retained for at least 5 years in secure storage. Any personal information held on the participants [such as names] will be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

The results of the project will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact:-

Dr Hamish Osborne

Department of Medicine, Dunedin School of Medicine

University Telephone Number:- 4747007 ext 8556

Email Address: Hamish.Osborne@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it and does it start to develop in adolescence?

CONSENT FORM FOR
PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;

2. I am free to withdraw from the project at any time without any disadvantage;

3. Personal identifying information [*e.g. your name*] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. You might have some slight muscle soreness after the test that won't need any special treatment.

5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

....
(Signature of participant) (Date)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

UNIVERSITY of OTAGO
SAPERE AUDE
Te Whare Wānanga o Otāgo
NEW ZEALAND

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it and does it start to develop in adolescence?

CONSENT FORM FOR
PARENTS/GUARDIANS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My child's participation in the project is entirely voluntary;

2. I am free to withdraw my child from the project at any time without any disadvantage;

3. Personal identifying information [*e.g. names*] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. Your child might have some mild soreness in their muscles after the test

5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my child's anonymity.

I agree for my child to take part in this project.

....
(Signature of parent/guardian) (Date)

....
(Name of child)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it and does it start to develop in adolescence?

CONSENT FORM FOR CHILD PARTICIPANTS

I have been told about this study and understand what it is about. All my questions have been answered in a way that makes sense.

I know that:

1. Participation in this study is voluntary, which means that I do not have to take part if I don't want to and nothing will happen to me. I can also stop taking part at any time and don't have to give a reason.

2. Anytime I want to stop, that's okay.

3. If I have any worries or if I have any other questions, then I can talk about these with Michael Chen or Dr Hamish Osborne

4. The paper and computer file with my answers will only be seen by the researcher and the people he is working with. They will keep whatever I say private.

5. The researchers will write up the results from this study for their University work. The results may also be written up in journals and talked about at conferences. My name will not be on anything the researchers write up about this study.

I agree to take part in the study.

....
Signed Date

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

[Reference Number *as allocated upon approval by the Ethics Committee*]
[*Date*]

Hip strength weakness, how common is it in young sportsmen and how easy is it to fix?

Thank you for showing an interest in this project. Please read this information sheet carefully before deciding whether or not to participate. If you decide to participate we thank you. If you decide not to take part there will be no disadvantage to you and we thank you for considering our request.

What is the Aim of the Project?

It has been observed that weakness around the hips is common but not yet proven scientifically. This study aims to see whether these weaknesses occur in young sportsmen. We anticipate finding weaknesses and so the second part of the study is to give you a strengthening exercise commonly given as part of a hip rehabilitation program You will do this regularly for two months and we will then retest you to see how good the exercise is at correcting the weakness.

This project is being undertaken as part of the requirements for the Bachelor of Medical Science with Honours Degree

What Type of Participants are being sought?

We are looking to enrol boys in the First 15 Rugby squad who are otherwise fit to participate in school physical education and sports programs who don't have any underlying problems with their hips.

Each participant will be given the results of their tests at the time of the measurements being taken and the school will be given a summary of the group results.

What will Participants be Asked to Do?

Should you agree to take part in this project, you will be asked to provide your date of birth and ethnicity, have your weight and height measured and then the muscles around each hip measured in 4 different positions twice during the same period of testing. The strength will be measured using a hand held strength testing machine held in place with straps. It will take about 10 minutes to do this testing. This will be done during school hours. As a result of the tests there might be some minor soreness in the muscles tested like you might get after going for a run when you haven't been for a few weeks. This will not require any treatment.

You will then be given one exercise to perform. You will be carefully taught how to do this. you will be told how many times the exercise is to be done each day. After one week we will check that your exercise technique is correct still.

Your strength will be retested one month after the start of the study and again at the end of the study, two months from when it started. Your weight and height will be measured again at the end.

Please be aware that you may decide not to take part in the project without any disadvantage to yourself of any kind.

What Data or Information will be Collected and What Use will be Made of it?

Once collected the data will be analysed to whether there is weakness in one or other hip muscle compared to other boys of the same age and size. We will also be looking at how large the strength gains are. It would be envisaged that this work in an abbreviated form will be published in a medical journal and in a larger format will form the basis of a Thesis for the Bachelor of Medical Science with Honours.

The only identifying information collected will be names and these will be removed from the database once data collection is complete.

The data collected will be securely stored in such a way that only those mentioned below will be able to gain access to it. Data obtained as a result of the research will be retained for at least 5 years in secure storage. Any personal information held on the participants [such as names] will be destroyed at the completion of the research even though the data derived from the research will, in most cases, be kept for much longer or possibly indefinitely.

The results of the project will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve your anonymity.

You may withdraw from participation in the project at any time and without any disadvantage to yourself of any kind.

What if Participants have any Questions?

If you have any questions about our project, either now or in the future, please feel free to contact:-

Dr Hamish Osborne

Department of Medicine, Dunedin School of Medicine

University Telephone Number:- 4747007 ext 8556

Email Address: Hamish.Osborne@otago.ac.nz

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it in young sportsmen and how easy is it to fix?

CONSENT FORM FOR
PARTICIPANTS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My participation in the project is entirely voluntary;
2. I am free to withdraw from the project at any time without any disadvantage;
3. Personal identifying information [*e.g. your name*] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;
4. You might have some slight muscle soreness after the test that won't need any special treatment.
5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my anonymity.

I agree to take part in this project.

....
(Signature of participant) (Date)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

UNIVERSITY of OTAGO
SAPERE AUDE
Te Whare Wānanga o Otāgo
NEW ZEALAND

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it in young sportsmen and how easy is it to fix?

CONSENT FORM FOR
PARENTS/GUARDIANS

I have read the Information Sheet concerning this project and understand what it is about. All my questions have been answered to my satisfaction. I understand that I am free to request further information at any stage.

I know that:-

1. My child's participation in the project is entirely voluntary;

2. I am free to withdraw my child from the project at any time without any disadvantage;

3. Personal identifying information [*e.g. names*] will be destroyed at the conclusion of the project but any raw data on which the results of the project depend will be retained in secure storage for at least five years;

4. Your child might have some mild soreness in their muscles after the test;

5. The results of the project may be published and will be available in the University of Otago Library (Dunedin, New Zealand) but every attempt will be made to preserve my child's anonymity.

I agree for my child to take part in this project.

....
(Signature of parent/guardian) (Date)

....
(Name of child)

This study has been approved by the University of Otago Human Ethics Committee. If you have any concerns about the ethical conduct of the research you may contact the Committee through the Human Ethics Committee Administrator (ph 03 479 8256). Any issues you raise will be treated in confidence and investigated and you will be informed of the outcome.

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

[Reference Number *as allocated upon approval by the Ethics Committee*]
[Date]

Hip strength weakness, how common is it in young sportsmen and how easy is it to fix?

CONSENT FORM FOR CHILD PARTICIPANTS

I have been told about this study and understand what it is about. All my questions have been answered in a way that makes sense.

I know that:

1. Participation in this study is voluntary, which means that I do not have to take part if I don't want to and nothing will happen to me. I can also stop taking part at any time and don't have to give a reason.

2. Anytime I want to stop, that's okay.

3. If I have any worries or if I have any other questions, then I can talk about these with Michael Chen or Dr Hamish Osborne

4. The paper and computer file with my answers will only be seen by the researcher and the people he is working with. They will keep whatever I say private.

5. The researchers will write up the results from this study for their University work. The results may also be written up in journals and talked about at conferences. My name will not be on anything the researchers write up about this study.

I agree to take part in the study.

....
Signed Date

Application Form for ethical consideration of research and teaching proposals involving human participants

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IMPORTANT NOTES FOR APPLICANTS

- Please detach this page of notes before making the copies to be forwarded to the University of Otago Human Ethics Committee.

- Proposals submitted to the Committee will normally only be considered if they are submitted in typed or word-processed format.

- If being used in electronic form the various sections of this application form should be expanded or contracted to suit the length of the information to be entered. **It is helpful if applicants use a font different to the default font on the electronic application form (Times 12 point) as this helps to distinguish the applicant's entries from the standard headings and guideline notes which appear throughout the application form. Please do not use all capital letters or italics.**

- Please use language which is, as far as possible, free from jargon and is comprehensible to lay-people, or children if applicable. Please ensure your Consent Form, Information Sheet and Advertisement have been carefully proof-read, the institution as a whole is likely to be judged by them.

- Please send **sixteen copies (double-sided and stapled)** of the completed application, **plus the original**, to Gary Witte, Manager, Academic Committees (Extension 8256) e-mail: gary.witte@otago.ac.nz

Final Checklist

Please check-:-

- ☐ **Applicant** - that the application is in the name of a University staff member and not, for example, the student researcher
- ☐ **Font** - that a font has been used which is different to that used for the information and guidance already provided in the template by the University of Otago Human Ethics Committee
- ☐ **Signatures** - that the appropriate signatures are in sections 18 and 19.
- ☐ **Page Numbers** – that each additional page follows the page numbering from the application.
- ☐ **Data storage and disposal**
  - ■ that section 15(d) state clearly the details of the secure storage of the data (normally within a University Department) and who will be responsible for the eventual disposal of the data (which must normally be kept for at least 5 years. An appropriate member of the University staff should normally be responsible for the eventual disposal of data - not a student researcher.)
  - ■ that if the data is to be stored other than within a University Department a detailed justification for this is given
- ☐ **Questionnaires** - that any questionnaire and/or survey to be used in the project is attached to the application
- ☐ **Information Sheet / Consent Form** - that these are attached and
  - ■ that the language and style used is appropriate to the age and knowledge of the likely readers;
  - ■ that no personal home contact details for a student researcher are included (unless a detailed justification for this is included in the main application);
  - ■ that both forms conclude (in anticipation of approval) with the statement "This project has been reviewed and approved by the University of Otago Human Ethics Committee";
  - ■ that they have been carefully proof-read;
- ☐ **Stapled as one document** - that all components of each copy of the application are stapled together with one staple (**16 copies** are needed in total)

8.4 Appendix D: Category A Ethics approval letter

UNIVERSITY of OTAGO
Te Whare Wānanga o Otāgo
NEW ZEALAND

12/107

Academic Services
Manager, Academic Committees, Mr Gary Witte

9 May 2012

Dr H Osborne
Dunedin School of Medicine
Division of Health Sciences

Dear Dr Osborne,

I am again writing to you concerning your proposal entitled "**Hip Strength Weakness in Adolescents - how common, what magnitude and how easy to fix is it?**", Ethics Committee reference number **12/107**.

Thank you for your email clarifying when the intervention procedures will be used. We are grateful for evidence of Maori consultation.

On the basis of this response, I am pleased to confirm that the proposal now has full ethical approval to proceed.

Approval is for up to three years from the date of this letter. If this project has not been completed within three years from the date of this letter, re-approval must be requested. If the nature, consent, location, procedures or personnel of your approved application change, please advise me in writing.

Yours sincerely,

Gary Witte

Mr Gary Witte
Manager, Academic Committees
Tel: 479 8256
Email: gary.witte@otago.ac.nz

c.c. Dr J B Adams Dean Dunedin School of Medicine

8.5 Appendix E: Ngai Tahu Research Consulation Committee approval

NGĀI TAHU RESEARCH CONSULTATION COMMITTEE

TE KOMITI RAKAHAU KI KĀI TAHU

15/05/2012 - 27
Tuesday, 15 May 2012

Dr Osborne
Medicine
Dunedin

Tēnā koe Dr Osborne

Title: Hip Strength Weakness in Adolescents - how common, what magnitude and how easy to fix is it?

The Ngāi Tahu Research Consultation Committee (The Committee) met on Tuesday, 15 May 2012 to discuss your research proposition.

By way of introduction, this response from the Committee is provided as part of the Memorandum of Understanding between Te Rūnanga o Ngāi Tahu and the University. In the statement of principles of the memorandum, it states "Ngāi Tahu acknowledges that the consultation process outlined in this policy provides no power of veto by Ngāi Tahu to research undertaken at the University of Otago". As such, this response is not "approval" or "mandate" for the research, rather it is a mandated response from a Ngāi Tahu appointed committee. This process is part of a number of requirements for researchers to undertake and does not cover other issues relating to ethics, including methodology; they are separate requirements with other committees, for example the Human Ethics Committee, etc.

Within the context of the Policy for Research Consultation with Māori, the Committee base consultation on that defined by Justice McGechan:

> *"Consultation does not mean negotiation or agreement. It means: setting out a proposal not fully decided upon; adequately informing a party about relevant information upon which the proposal is based; listening to what the others have to say with an open mind (in that there is room to be persuaded against the proposal); undertaking that task in a genuine and not cosmetic manner. Reaching a decision that may or may not alter the original proposal."*

The Committee considers the research to be of importance to Māori health.

As this study involves human participants, the Committee strongly encourage that ethnicity data be collected as part of the research project. That is the questions on self-identified ethnicity and descent, these questions are contained in the 2006 census.

The Committee suggests dissemination of the research findings to Māori health organisations regarding this study.

The Ngai Tahu Research Consultation Committee has membership from:

Te Rūnunga o Ōtākou Incorporated
Kāti Huirapa Rūnaka ki Puketeraki
Te Rūnanga o Moeraki

NGĀI TAHU RESEARCH CONSULTATION COMMITTEE

TE KOMITI RAKAHAU KI KĀI TAHU

We wish you every success in your research and the Committee also requests a copy of the research findings.

This letter of suggestion, recommendation and advice is current for an 18 month period from Tuesday, 15 May 2012 to 15 November 2013.

The recommendations and suggestions above are provided on your proposal submitted through the consultation website process. These recommendations and suggestions do not necessarily relate to ethical issues with the research, including methodology. Other committees may also provide feedback in these areas.

Nāhaku noa, nā

pp NTRCC

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