The influence of ‘American’ and ‘Russian’ kettlebell swings on glenohumeral positioning

Liam Paterson Jones

Declaration

Name of candidate: LIAM PATERSON JONES

This research thesis entitled 'The influence of ‘American’ and ‘Russian’ kettlebell swings on glenohumeral positioning, is submitted in partial fulfilment for the requirements for the Unitec degree of Master of Osteopathy.

Principal Supervisor: Rob Moran

CANDIDATE’S DECLARATION

I confirm that:

- This thesis represents my own work;
- The contribution of supervisors and others to this work was consistent with the Unitec Regulations and Policies.
- Research for this work has been conducted in accordance with the Unitec Research Ethics Committee Policy and Procedures, and has fulfilled any requirements set for this project by the Unitec Research Ethics Committee.
  Research Ethics Committee Approval Number: 2016-1064.

Candidate Signature: .................................................. Date: 22 March 2019

Student number: 1366332
Acknowledgements

I would like to thank my supervisors Rob Moran and Megan McEwen for all their help and guidance throughout this research project.

In addition, I would also like to thank Scott Allen and Wesley Verhoeff for their help and input into this project and the participants who participated in this study.

I would also like to express my gratitude to my family and friends who have supported and encouraged me through this project.
ABSTRACT

The influence of ‘American’ and ‘Russian’ kettlebell swings on glenohumeral positioning: A randomised, controlled, cross-over experimental design.

BACKGROUND: Shoulders are one of the most common sites for pain and/or dysfunction among athletes especially with overhead exercise. With increasing interest in bootcamp and CrossFit® style exercise has come an increase in the numbers of people participating in this style of exercise. One popular exercise is the kettlebell swing. The kettlebell swing can be done either overhead also called the American swing or to shoulder height called the Russian swing. To date, no research has been undertaken on the change in the positioning of the humeral head on the glenoid fossa when comparing overhead to shoulder height kettlebell swings.

AIM: To explore the relationship between overhead (American) and shoulder height (Russian) kettlebell swings and changes in humeral head positioning.

METHODS: Two separate studies were undertaken. Firstly, a group study of 8 participants and, secondly three case studies were undertaken. In both studies participants had both shoulders scanned using ultrasound imaging both before and after a fatiguing exercise protocol. Measures taken by ultrasound were; subacromial distance, coracoacromial ligament length, coracohumeral distance and coracoacromial ligament to humeral head distance.

The exercise protocol consisted of 3 sets of 20 Russian kettlebell swings or 3 sets of 15 American kettlebell swings. Participants were assigned a kettlebell weight based on the finding of a mid-thigh pull assessment of full body strength. Participants then returned after one week to be crossed over into the other swing style group. In the case studies the sets of swings were increased from 3 to 5 to increase the level of fatigue.

RESULTS: One participant in the group study became injured between the data collection sessions, unrelated to the study, and was unable to complete the fatiguing exercise protocol. Both the data from the group study and the case studies showed no change pre- to post-exercise, in any of the ultrasound measures; subacromial distance, coracoacromial ligament length, coracohumeral distance and coracoacromial ligament to humeral head distance.

CONCLUSION: Neither study showed changes in glenohumeral positioning (in the measured dimensions) between pre and post-exercise. Measurement of the coracoacromial ligament to the humeral head may be a useful measure of glenohumeral positioning, due to its clarity and ease of measurement using ultrasound and it is recommended that further investigation into this measure be undertaken. The mid-thigh pull was a useful tool in measuring full body strength and may be useful in prescribing kettlebell weights in future studies.

Keywords: Overhead exercise, shoulder fatigue, kettlebell
Table of Contents

Chapter 1: Literature Review ........................................................................................................ 11
1 Introduction ............................................................................................................................... 11
2 Prevalence of shoulder injury ................................................................................................. 11
3 Shoulder Joint .......................................................................................................................... 12
   3.1 Glenohumeral joint .............................................................................................................. 12
   3.2 Variations in shoulder anatomy ......................................................................................... 13
   3.3 Physiology of shoulder impingement .................................................................................. 14
   3.4 Impact of thoracic spine position of the glenohumeral joint .............................................. 15
   3.5 Impact of overhead exercise on glenohumeral joint ......................................................... 16
4 Measures of glenohumeral positioning ................................................................................... 17
   4.1 Subacromial distance ......................................................................................................... 18
   4.2 Coracoacromial ligament .................................................................................................. 19
   4.3 Coracohumeral distance .................................................................................................... 20
   4.4 Detection of changes in glenohumeral joint ..................................................................... 21
      4.4.1 Ultrasound .................................................................................................................. 21
5 Whole body strength introduction ........................................................................................... 22
   5.1 Whole body strength .......................................................................................................... 22
   5.2 Dynamic maximal strength ............................................................................................... 22
   5.3 Estimating 1-rep max from reps-to-failure ....................................................................... 23
   5.4 Isometric maximal strength .............................................................................................. 23
   5.5 Implications on research ................................................................................................... 24
6 Overhead exercise and the kettlebell ..................................................................................... 24
   6.1 Kettlebells as an exercise tool ......................................................................................... 24
References ...................................................................................................................................... 27

Chapter 2: Group Study ............................................................................................................. 35
1 Methods ...................................................................................................................................... 35
   1.1 Design and ethics .............................................................................................................. 35
   1.2 Variables ............................................................................................................................ 36
   1.3 Recruitment ..................................................................................................................... 40
   1.4 Sample size calculation ................................................................................................... 40
   1.5 Participants and screening ............................................................................................... 40
      1.5.1 Participants ................................................................................................................ 40
      1.5.2 Sonographer .............................................................................................................. 40
   1.6 Testing procedures .......................................................................................................... 41
      1.6.1 Session 1 – Familiarisation and descriptive measure collection ............................. 41
      1.6.2 Session 1 - Measure of thoracic mobility ............................................................... 42
      1.6.3 Session 2 and 3 - Warm-up ..................................................................................... 44
      1.6.4 Session 2 and 3 - Participant Allocation ................................................................. 44
List of Figures

Figure 1: Illustrating differences in kettlebell Swings.

Figure 2: American vs Russian kettlebell swings.

Figure 3: Diagram showing participant allocation.

Figure 4: Coracoacromial ligament length and humeral head to coracoid process distance pre- and post-exercise separated by left and right and swing style.

Figure 5: Subacromial distance pre- and post-exercise separated by left and right and swing style.

Figure 6: Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style.

Figure 7: Coracoacromial ligament length and humeral head to coracoid process.

Figure 8: Subacromial distance pre- and post-exercise separated by left and right and swing style.

Figure 9: Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style.

Figure 10: Coracoacromial ligament length and humeral head to coracoid process distance pre- and post-exercise separated by left and right and swing style.

Figure 11: Subacromial distance pre- and post-exercise separated by left and right and swing style.

Figure 12: Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style.
**Figure 13:** Coracoacromial ligament length and humeral head to coracoid process distance pre- and post-exercise separated by left and right and swing style.

**Figure 14:** Subacromial distance pre- and post-exercise separated by left and right and swing style.

**Figure 15:** Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style.
List of Tables

**Table 1:** Kettlebell assignment table.

**Table 2:** Showing MDC calculations for subacromial distance using Maenhouts (2012) study

**Table 3:** Showing demographic data for participants

**Table 4:** Participant A descriptive characteristics

**Table 5:** Participant A mid-thigh pull

**Table 6:** Secondary Ultrasound Findings

**Table 7:** Participant B descriptive characteristics

**Table 8:** Participant B mid-thigh pull

**Table 9:** Secondary Ultrasound Findings

**Table 10:** Participant C descriptive characteristics

**Table 11:** Participant C mid-thigh pull

**Table 12:** Secondary Ultrasound Findings
**Introduction to Thesis**

In recent years there has been an increasing number of people participating in CrossFit® and other functional fitness strength and conditioning approaches such as ‘boot camp’ (Hak, Hodzovic, & Hickey, 2013). With this increase in participation comes an increased risk of injury. One of the most common sites of pain or dysfunction in athletes generally is that of the shoulder (Pribicevic, 2012), and one of the activities that is a common cause of shoulder pain is that of overhead sport or exercise (Pribicevic, 2012). Overhead exercise is an exercise or sport in which a participant moves an object above shoulder height, such as kettlebell swings and shoulder press or sports like volleyball. To date there has been little research into the area of overhead exercise, and no research into the position of the humerus on the glenoid fossa in overhead exercise when compared with shoulder height exercise. Which may be a contributing factor to shoulder impingement. An exercise that can be done both overhead and at shoulder height is that of the kettlebell swing (Tsatsouline, 2006). The swing exercise is a double-handed swing where the end position can be varied between overhead and shoulder height. This thesis reports two studies investigating the relationship between the kettlebell swing performed both overhead, and to shoulder height and whether this exercise impacts the positioning of the humeral head on the glenoid fossa.

**Structure of Thesis**

Chapter 1 – Literature Review

In this section background literature relevant to the thesis will be reviewed and a case will be built for the purpose of this thesis.

Chapter 2 – Group Study

This chapter contains a randomised, controlled, cross-over experiment to investigate the effect of overhead and shoulder height exercise of glenohumeral position.

Chapter 3 – Case Series

In this chapter three case studies are investigated, and weaknesses that were identified during the course of the group study are addressed.
Chapter 1

Literature Review

1 Introduction

Overhead sports are those involving movements of the arm above shoulder height such as tennis, volleyball, and badminton and also includes exercises such as shoulder press or American kettlebell swings. These sports and exercises place a large amount of mechanical stress and strain through the shoulder joint while moving through rapid changes in direction of movement. Many athletes participating in overhead sports present with pain at some point in their careers, and rotator cuff injuries or shoulder impingements are the most common source of pain (Blevins, 1997; Wilk et al., 2009). Therefore, investigation into the risk factors that different types of sport and exercise place on the shoulder is essential in enabling both athletes and coaches to perform and prescribe exercises and movements that enable goals to be achieved while not exposing the athlete to unnecessary or undue risk.

This literature review has four aims: firstly, it describes the prevalence of shoulder injury, shoulder joint structure and anatomy and the physiology of shoulder impingement along with factors that may influence impingement. Secondly, it describes how the glenohumeral joints position may be measured with as well as other ultrasound measures that may potentially be used to detect position such as subacromial distance, the coracoacromial ligament, and the coracohumeral distance. Thirdly, as overhead exercise routines use prescribed weights based on strength this review discusses whole body strength and the pros and cons of various ways in which this may be measured. Finally, it discusses the use and growing interest in the kettlebell and its associated exercises.

Overall this review aims to build a rationale for investigation into the way overhead exercise impacts the glenohumeral joint. As well as identifying the role that fatigue may play as a risk factor for shoulder impingement and potential ways of measuring glenohumeral position change within individuals.

2 Prevalence of shoulder injury

The shoulder joint is one of the most common sites for injury, a systematic review of the prevalence and incidence of all forms shoulder pain the in the general population found that
there was a 7 – 66.7 % prevalence for lifetime shoulder pain (Luime et al., 2004). With point or 1 – month prevalence, increasing age was associated with increasing prevalence of shoulder pain (Luime et al., 2004). Injuries involving the shoulder joint are common in athletes (Bedi, 2011), with the most common pathologies being rotator cuff muscle irritations, tear or impingement, shoulder joint instability or dislocation and acromioclavicular joint sprains. Forty percent of high school volley ball players (Frisch et al., 2017), 52 % of surf lifesavers (Carter, Marshall, & Abbott, 2015) and 50% of American football players (Kaplan, Flanigan, Norwig, Jost, & Bradley, 2005) have experienced shoulder pain or injury. The shoulder joint appears to be susceptible to injury because it is a highly mobile and complex joint and must maintain an optimal relationship between mobility and stability (Bowen & Warren, 1991). Overhead athletes are particularly susceptible to shoulder injury (Wilk et al., 2009) because the balance between stability and mobility is frequently compromised, where the shoulder must be lax enough to allow for a great range of motion but also stable enough to prevent injury and subluxation. The glenohumeral joint is complex in that there are many directions in which the humeral head can move and therefore compromise movement. This can occur through creating an imbalance via muscular tension and weakness in antagonistic musculature, impingement through superior migration of the humeral head or movement compromise due to improper positioning of the shoulder joint via the shoulder girdle.

It has yet to be thoroughly investigated which overhead exercises in a strength and conditioning training environment may increase the risk of shoulder injury and how this increased risk presents biomechanically. While it has been established that overhead exercises put individuals at greater risk of injury, the specific exercise types that create greater risk and what cause this increase in injury risk and the mechanisms by which this occurs have not been properly established.

3.0 Shoulder Joint
This section examines shoulder anatomy and variations, as well as shoulder impingement and risk factors, it also examines the impact that overhead exercise has on the glenohumeral joint.

3.1 Glenohumeral joint
The glenohumeral joint is a complex structure that has many passive and dynamic forces acting on it, such as tension from non-contractile structures such as ligaments and joint capsule, and contractile forces applied by muscle contraction. These forces are required to allow for both mobility and stability of the joint (Bowen & Warren, 1991). The glenohumeral joint has six degrees of movement - three rotations and three translations (Bassett, Browne, Morrey, & An, 1990). The orientation of the humeral head on the glenoid as per the six degrees of movement previously mentioned (glenohumeral positioning) can impact its ability to function. If the head of the humerus is held in any direction (i.e. superiorly, inferiorly, anteriorly or posteriorly) this may impact the ability of the humerus to perform full range of motion without negatively impacting other structures and increasing risk of tissue compromise or injury. For example, if held superiorly thus decreasing the subacromial distance this may potentially limit the amount of arm abduction that can occur without entrapping subacromial structures.

### 3.2 Variations in shoulder anatomy

Variations of morphology within the shoulder joint are typically found around the acromion process. According to Bigliani et al (1991) there are three different presentations of the slope of the acromial process; flat 13%, curved 57% or hooked 30%, with curved being the anatomical “normal” and both curved and hooked predisposing individuals to subacromial impingement or rotator cuff tears by creating abnormal contact between the acromion and the soft tissues of the subacromial distance. In a study of 111 patients diagnosed with impingement syndrome by a xylocaine subacromial injection test and 191 healthy patients, patients with a hook-shaped acromion had 6.2 times the risk of those without (Tangtrakulwanich, 2012). In contrast to Bigliani et al (1991) study of 750 dry bone scapular and 80 cadaver shoulders (Edelson, 1995) hooking of the acromion was not found in subjects under the age of 30 (Edelson, 1995). In a similar study (Prescher, 2000), no presentations of hooked acromion were found with 10.2% being flat and 89.8% being curved, leading the authors to conclude that hooked acromions were a miss-interpretation of acromial spurs. Another variation within the acromion is os acromiale where the triangular tip of the acromion has failed to properly fuse, this occurs in 7 – 15% of people (Prescher, 2000). Variation in the shape of the acromion has been linked to an increase in the prevalence of shoulder injury or pain specifically supraspinatus tears (Nyffeler & Meyer, 2017). Nyffeler and Meyer (2017) also investigated the link between glenoid shape and shoulder pathology theorising that the patho-mechanism is the compression of the supraspinatus between the
humeral head and acromion process, but concluded that the impact of glenoid inclination on shoulder pathology is less clear, although there may be a link between reduction of the gliding mechanism between the tendon and the bone and an increase in the risk for articular side tears. Therefore, morphological differences need to be considered in patients with shoulder pain and appropriate adaptations made to exercise and training to decrease the risk of shoulder injury, although the practicality of assessing these differences would be hard to justify as the associated cost and exposure to ionising radiation would outweigh the benefits.

3.3 Physiology of Shoulder Impingement

Shoulder impingement is a painful condition first described by orthopaedic surgeon Charles S. Neer in 1983 (Neer, 1983) and most commonly occurs when the supraspinatus tendon becomes ‘entrapped’ between the coracoacromial arch and the head of the humerus. This entrapment typically occurs when the arm approaches 90 degrees of abduction (Koester, George, & Kuhn, 2005). Currently shoulder impingement is diagnosed via physical examination using orthopaedic tests and confirmed via ultrasound (Kromer, Tautenhahn, De Bie, Staal, & Bastiaenen, 2009) although a lack of uniformity in testing procedures has prompted a reassessment in both the testing and labelling of shoulder pain (Schellingerhout, Verhagen, Thomas, & Koes, 2008). There are several risk factors associated with impingement including the subacromial distance being narrowed by acromion shape, bony spurs on the inferior side of the acromion process, degenerative changes of the glenohumeral joint, or soft tissue thickening of the subacromial bursa with or without an increase in fluid or supraspinatus atrophy (Barrett, O’Keeffe, O’Sullivan, Lewis, & McCreesh, 2016). There can also be functional narrowing due to dysfunction in rotator cuff muscles, dysfunctional scapulothoracic movement patterns or faulty scapular positioning with overhead movement (Barrett, et. al, 2016)

Chopp and Dickerson (2012) investigated the contributions that both superior migration of the humeral head and scapular reorientation had on subacromial distance. Subacromial distance was measured using geometric simulation analysis at 0, 45 and 90 degrees of abduction. Chopp and Dickerson (2012) found that scapular position was of secondary importance to humeral head migration in relation to the impact on subacromial distance. Chopp and Dickerson (2012) go on to conclude that future research should focus on situations known to induce rotator cuff fatigue, such as overhead work.
Dysfunctional rotator cuff musculature has been identified as an important risk factor for people with sub-acromial impingement, along with weakness which is often associated with atrophy which is a risk factor for developing rotator cuff tears (Allen & Warner, 1995). When the rotator cuff muscles become dysfunctional or weak this can lead to a decrease in the stabilizing and depressing effect they have on the humeral head, therefore, leading to a reduction in subacromial distance via superior migration of the humeral head potentially entrapping the soft tissues of the subacromial distance. As theorised by Halder et al., (2001) and generally accepted (Levangie & Norkin, 2005) an increase in superior translation resulting from rotator cuff weakness could lead to a decrease in the sub-acromial distance during elevation of the arm and thus increase mechanical compression of the sub-acromial contents. These findings suggest that the positioning of the humeral head on the glenoid fossa is of importance in allowing the proper biomechanical function of the glenohumeral joint through its ranges of motion especially abduction.

3.4 Impact of thoracic spine position on the glenohumeral joint.

Position and mobility of the thoracic spine has also been shown to directly impact glenohumeral function and motion (Kebaetse, McClure, & Pratt, 1999; Peat, Culham, & Wilk, 2009). Kebaetse et al (1999) showed that a small increase in thoracic spine flexion can lead to unfavourable scapular positioning including elevated and anteriorly tilted scapula resulted in less upward rotation and posterior tilt during glenohumeral elevation, therefore, potentially reducing full range of motion or increasing risk of injury. Similarly, Peat et al (2009) also found that increases in thoracic spine flexion were associated with a decreased elevation of the glenohumeral joint and a decrease in the amount of force generated at 90 degrees in scapular plane abduction. Because the mobility of the thoracic spine can influence the positioning of the glenohumeral joint, it is important that studies of the glenohumeral mechanics account for thoracic spine mobility in either the study design, statistical analysis or both.

In clinical therapy relating to painful shoulder function, the thoracic spine is considered to be an important component of treatment (Barrett et al., 2016; Boyles et al., 2009; Kebaetse et al., 1999) due to its role in glenohumeral positioning. As investigated by Boyles et al., (2009) in 56 patients with shoulder impingement syndrome, post thoracic spine manipulation there was a statistically significant decrease in self-reported pain and disability measures at 48 hour follow up. This is hypothesised as being due to the increase in posterior rotation of the
scapula created by an increase in thoracic extension. A systematic review of studies investigating the effect of thoracic spine manipulation on shoulder pain found that that the majority of patients 76-100% experienced a reduction in pain after thoracic spine treatment (Peek, Miller, & Heneghan, 2015). This has led to manual therapy targeting the thoracic spine mobility as part of a treatment plan when a patient presents with shoulder pain.

3.5 Impact of overhead exercise on glenohumeral joint

During overhead activity, the shoulder acts to ‘funnel’ forces from the arm into the trunk of the body (Wilk et al., 2009). This makes the shoulder susceptible to injury as it transmits high loads and forces through a particularly mobile and intrinsically unstable joint. Surprisingly, there appears to be no consensus regarding intrinsic risk factors for shoulder injury in overhead athletes (Maenhout et al., 2012). Maenhout (2012) suggested that these discrepancies’ may be due to the differing requirements on the shoulder depending on the activity or exercise being performed.

Risk factors identified for shoulder impingement by Frost & Andersen (1999) include overhead and intensive work using the shoulder. In a systematic review of the literature Van Rijn, Huisstede, Koes, & Burdorf (2010) also identified lifting upward of 20 kilograms more than 10 times a day, repetitive shoulder or hand/ wrist motion for at least 2 hours a day and work involving the hand above shoulder level increased the risk of developing shoulder impingement syndrome. When compared with a popular work out routine featuring a standard kettlebell workout there are areas that overlap with risk factors for impingement syndrome such as overhead work, heavy weight above 20kg and repetition of movement. Carpenter, Blasier and Pellizzon (1998) investigated the effect of muscle fatigue on awareness of shoulder joint position in 20 volunteers with no shoulder abnormalities. The main finding from this research was that proprioception decreases with muscular fatigue with more movement of the arm needed after a fatiguing exercise protocol for participants to detect motion at the shoulder joint, with 0.92 degrees of external rotation needed pre-exercise and 1.59 degrees needed to detect motion post-exercise. In discussing their findings Carpenter et al. (1998) theorise that this decrease in proprioceptive sense with muscle fatigue may impact on fatigue-related shoulder dysfunction and decreased athletic performance with fatigue. The authors did not look at the internal structure of the shoulder and how this may be affected by fatigue.
Research by Ebaugh, McClure, & Karduna, (2006) found that fatiguing the shoulder girdle resulting in either humeral migration or scapular reorientation also produces altered movement patterns in both the glenohumeral and scapulothoracic joints. While Ebaugh et al. (2006) findings were statistically significant, the authors reported that the magnitude of these differences were small and their clinical importance not known. Unfortunately, this study only investigated the differences in movement and focused on the changes in muscle activation using electromyography (EMG). They did not look at changes in glenohumeral positioning during movement within the glenohumeral joint and were unable to say what importance the changes they found had. Maenhout et. al. (2015) studied changes in subacromial and scapular position after fatiguing overhead exercise. This study used 29 healthy recreational overhead athletes consisting of; 14 men and 15 women with a mean age of 22 years of age, participants too part in a variety of overhead sport including volleyball (n=20), tennis (n=2), water polo (n=3), squash (n=3) and badminton (n=1). Participants were put through a fatiguing shoulder exercise consisting of moving from internal to external rotation and scanned via ultrasound pre- and post-exercise. The main finding was that subacromial distance increased when actively held at 45 or 60 degrees of abduction in overhead athletes. Maenhout et al. (2015) theorise that this is an impingement sparing mechanism whereby the humerus becomes more inferiorly translated with fatigue, therefore, creating a greater subacromial distance and reducing the likelihood of impingement or entrapment in the subacromial distance, although it is unclear if this mechanism occurs in inexperienced individuals participating in overhead activity. Secondarily, they also established that sonography was a valid tool for measuring subacromial distance pre-and post-exercise with the humerus actively held in position.

To date, there appears to be no research investigating the position of the humeral head on the glenoid fossa in relation to different forms of overhead exercise or overhead compared with non-overhead exercise, and it has yet to be established which measures of glenohumeral positioning are best used to assess this.

4 Measures of glenohumeral positioning
Traditionally measures of glenohumeral positioning use the subacromial distance as the standard measure for detecting change (Graichen et al., 2005; Maenhout, Van Eessel, Van Dyck, Vanraes, & Cools, 2012; Maenhout et al., 2015, 2012). This section aims to review that measure and introduce other potential indices used to assess the position of the humerus
on the glenoid fossa such as the distance of the humeral head from the midpoint of the coracohumeral ligament and from the coracoid process.

### 4.1 Sub-acromial distance

The sub-acromial distance is the most common index of humeral head positioning in literature. It is commonly used to identify people at risk of shoulder impingement. This distance is defined by the humeral head inferiorly, the anterior edge and under surface of the anterior third of the acromion, coracoacromial ligament and the acromioclavicular. Joint tissues which also occupy this distance include the supraspinatus tendon, subacromial bursa, long head of the biceps brachii tendon and the shoulder joint capsule. Maenhout et al., (2012) assessed the subacromial distance and compared measures between the dominant and the non-dominant shoulder. They also compared the differences between elite and recreational athletes and how this distance changes at different angles of abduction. Maenhout et al (2012) used ultrasound imaging to measure the subacromial distance at 0, 45 and 60 degrees of abduction. They found that sub-acromial distance reduces as the arm is abducted and is the same on the dominant and non-dominant sides. However, the reduction is less in elite athletes during the first 45 degrees when compared with recreational athletes. A major limitation of this study that was identified was the range of sports disciplines included between elite athletes (handball) and recreational athletes (volleyball, water polo, squash, and badminton) which they state may have been responsible for the differences between the two groups. The lack of a standardized measuring posture may also have impacted the results. Maenhout et al (2012) also identify that sonographic measurements of the sub-acromial distance can be impacted by posture and muscle activity. Further to this, it is suggested that future research should use a stricter protocol for ultrasound measurement as there is potential for variations in the way ultrasound is applied to impact the resulting measurements. It is also suggested that future research on shoulder fatigue induced by overhead exercise would be of interest and that other measures should be taken to further identify the positioning of the humeral head not just in relation to the acromion. Maenhout et al. (2015) investigated the impact of fatigue on the shoulder joint. Fatigue was created by holding an aluminium tube with a loose granular mass contained inside, repeatedly moving this from external to internal rotation with both elbow and shoulder held at 90 degrees abduction until the participants gave a rating over 14 of 20 on the Borg rating scale of perceived fatigue (Borg, 1998). When the findings of this 2015 study are compared with Maenhout et al. (2012) study the results are
similar in that as abduction is increased the subacromial distance is decrease but when compared pre- and post-exercise relative to the starting distance the distance has increased.

### 4.2 Coracoacromial ligament

As the coracoacromial ligament creates part of the roof of the coracoacromial arch the length and thickness of this ligament has been implicated as a possible cause of rotator cuff pathology (Soslowsky, An, Johnston, & Carpenter, 1994). It has also been shown that this ligament is responsible for some inferior restraint of the movement of the humeral head (Lee, Liau, Cheng, Tan, & Shih, 2003). Lee et al. (2003) demonstrated the role of rotator cuff muscles in the restraint of the humeral head, finding that the rotator cuff muscles were able to reduce the superior migration of the humeral head. Research by Dietrich et al., (2016) examined the coracoacromial ligament in asymptomatic and symptomatic participants with shoulder impingement diagnosed by experienced shoulder surgeons to investigate what role the coracoacromial ligament may play in impingement. Two radiologists obtained and analysed ultrasound images of the coracoacromial ligament along the longitudinal axis. The authors found that the mean ± standard deviation (SD) length of the ligament in asymptomatic participants was 30.6 ± 2.4 mm compared with 30.4 ± 3.6 mm in participants with impingement, showing no statistical difference. The influence of long-term physical activity on ligaments has been researched by Tipton, Matthes, Maynard, & Carey (1975) showing that long term repetitive exercise creates an increase in ligamentous strength and long term disuse creates a decrease in ligamentous strength. However, the effects of short term or immediate exercise on ligaments has not been thoroughly investigated with the hypothesis being that with short term or a single session of normal exercise there will be no change to the structure of the ligament (Laurent, 2018).

The coracoacromial ligament to humeral head distance is another measure analogous to the subacromial distance but has the advantage of being fully examinable using ultrasound imaging. The acromion is a bony structure, therefore only the measurement from the superior aspect to the humeral head can be seen on sonography because sound waves do not penetrate bone (Howell, 2012). Therefore, the measurement does not take the thickness or morphology of the underside of the acromion into consideration, leading to potentially undetected factors that may impinge on the subacromial distance such as bony growth or thickening of the under
side of the acromial process. While plain film x-ray can be used to detect these features it also has the added cost and exposure to ionising radiation (Ostlere & Marmery, 2007).

4.3 Coracohumeral distance

The coracoid process may cause anterior impingement if the coracohumeral distance is decreased. The distance from the coracoid process to the humeral head must be sufficient to accommodate the articular cartilage of the humerus, subscapularis tendon, subscapularis bursa and rotator cuff tissue (Neer, Satterlee, Dalsey, & Flatow, 1992). This distance can be used to assess for sub coracoid impingement where the coracoid process impinges the subscapularis tendon on the greater trochanter of the humeral head (Kragh Jr., Doukas, & Basamania, 2004). Gerber (1987) demonstrated using computerised tomography (CT) in an anatomic study of 47 normal shoulders that the mean ± SD distance between medially rotated humeral head and the coracoid is 8.6 ± 1.31 mm with forward flexion combined with medial rotation reducing the coracohumeral distance to 6.7 ± 1.11 mm. When the coracohumeral distance measured less than 6mm it was considered to be indicative of sub coracoid stenosis. A more recent study of asymptomatic adult males has shown that normal coracohumeral distance measured using ultrasounds is between 9mm to 11mm (Giaroli, Major, Lemley, & Lee, 2006) while in symptomatic patients this measure is reduced to 5.5mm or less (Okoro, Reddy, & Pimpelnarkar, 2009). When the coracoid to humeral head distance is reduced to less than 5mm it is strongly associated with subscapularis tendinosis and tears (Richards, Burkhart, & Campbell, 2005). When measured using ultrasound the coracohumeral distance to humeral head measurement has been shown to be a reliable assessment of the humeral head in relation to the coracoid process and may, therefore, be used to assess the changes in the humeral head positioning (Richards et al., 2005). It has also been established that the coracohumeral distance is best undertaken in internal rotation although this appears to not be commonly done for reasons that are unclear (Richards et al., 2005). Sub coracoid impingement has been found together with subacromial impingement in 35% of patients presenting with chronic shoulder pain (Misirlioglu et al., 2012). In the majority of studies that investigate the sub coracoid distance or the subacromial distance ultrasound imagery is used as the primary tool as it provides a low cost easily accessible form of assessment but it is worth investigating other measures that may provide similar and additional information to these measurements about the shoulder joint positioning.
4.4 Detection of changes in glenohumeral joint

In addition to plain film x-ray, both ultrasound and magnetic resonance imaging (MRI) have been widely used for examination of the shoulder joint. Traditionally ultrasound imaging has been used to help diagnose and make management decisions for people with shoulder pain related to rotator cuff disorders. Whereas MRI is the primary diagnostic tool if bony, ligamentous or cartilage changes are suspected (De Jesus, Parker, Frangos, & Nazarian, 2009). Due to the expense associated with access to MRI ultrasound is typically used for initial assessment, before further investigation using MRI as required.

4.4.1 Ultrasound

Ultrasound is a cost-effective and safe way of examining patients with no exposure to ionising radiation and can be used in place of plain film x-ray noting that its benefits include higher resolution, possibility of dynamic examination, easier comparison to the opposing limb and can be used on patients with surgically implanted metal (Howell, 2012). Research by (Ostlere & Marmery, 2007) has shown that the sensitivity and specificity of ultrasound equal those of MRI when assessing patients with shoulder pain. Research by Azzoni, Cabitza, & Parrini (2004) established that sonographic measurement of the subacromial distance shows both precision and accuracy of measurements when compared with MRI. Ultrasound has been well established in its use for diagnosis and examination of the shoulder joint (Daenen, Houben, Bauduin, Lu, & Meulemans, 2007), and along with being firmly established in assessment for shoulder impingement (De Candia, Doratiotto, Pelizzo, Paschina, & Bazzocchi, 2002) It is often used to assess whether the shoulder is impinged and what structures are involved in the impingement. Currently, there appears to be no research into the positioning of the humerus in the glenoid fossa using multiple surrounding structures as measurements and looking at whether these measurements change during exercise.

Apart from studies reporting the coracoid to humeral head distance (Kragh Jr. et al., 2004; Okoro et al., 2009; Richards et al., 2005; Tracy, Trella, Nazarian, Tuohy, & Williams, 2010) there is little research into changes in distances between structures of the shoulder, such as the narrowing of the subacromial distance, and at what distance a measurement might be considered abnormal. The amount of clinically significant change has yet to be established. Currently, while ultrasound imaging can be used to detect and measure changes in the shoulder its main use in diagnosis is observation of inflammation, thickening bursa, assessment of tendon integrity and other pathological changes after a patient presents with
pain (Daenen et al., 2007). Currently the majority of research has used ultrasound to assess the subacromial space and this has shown good reliability but currently there is no research into the use of ultrasound to measure the position of the humeral head on the glenoid fossa in relation to other surrounding structures.

5 Whole Body Strength Introduction

Studies that address the changing position of the humeral head on the glenoid use a fatiguing protocol (Iida, Kaneko, Aoki, & Shibata, 2014; Maenhout et al., 2012; Maenhout et al., 2015; Teyhen, Miller, Middag, & Kane, 2008) and as such require participants to have their strength assessed to ensure that a similar level of fatigue is reached between participants the following section reviews some of the issues that occur when assess participants whole body strength.

5.1 Whole Body Strength

Strength and power are important components of athletic performance and are used to assess level of athletic development. A number of different tests can be used in conjunction to highlight an athletes strengths and weaknesses and be used to tailor training to best suit individuals specific needs (Abernethy, Wilson, & Logan, 1995). Strength is usually analysed using one of two techniques - either dynamic maximal strength or isometric maximal strength.

5.2 Dynamic maximal strength

Analysis of maximal strength is typically undertaken by establishing 1 repetition maximum (1RM) testing, and this is considered the gold standard (Levinger et al., 2009). One repetition maximum is defined as ‘the maximum mass a participant can move through the applicable range of motion for a single repetition’ (Brzycki, 1993). Testing of 1RM has been used to quantify the current level of strength and therefore enable tracking over time, evaluation of training programmes, or assessment of strength imbalances. Testing of 1RM can be used to individually measure the strength of a single muscle or movement or can be used to approximate an individual’s overall strength. The major benefits of 1RM testing are its ability to offer an inexpensive, convenient and time efficient test that is suitable for large numbers of people (Brzycki, 1993). However, safety does become a major concern when lifters perform at maximal load. An inordinate and unreasonable amount of stress can be placed on muscles, bones, and tissues (McGuigan, Winchester, & Erickson, 2006). 1RM also tends to increase
blood pressure beyond what is usual with submaximal weights. There is also a risk of tissue
damage with improper form as it can be a highly specialized skill that requires a specific
technique (Beckham et al., 2013).

5.3 Estimating 1RM from Repetitions-to-failure
To decrease the risks related with one-rep max testing there is a movement towards
estimating 1RM from a repetitions-to-failure technique whereby the participant completes as
many reps as possible with a lower weight and their one-rep max is calculated from the result
(Brzycki, 1993). Generally, there has been a good relationship between the estimated 1RM
from repetitions-to-failure and the actual 1RM with findings similar in each method
(Levinger et al., 2009; Reynolds, Gordon, & Robergs, 2006).

5.4 Isometric maximal strength
Isometric strength is a comparable measure to 1RM and can be used to assess a participants
maximal strength, while similar to 1RM testing the participants strength is measured using a
fixed setup where the participant exerts maximal strength against a fixed point using a sensor
or force plate to measure the maximal exertion (Caldwell et al., 1974). By using this
technique, the risk of injury is reduced as there is no moving weight and by using force
sensors the maximal strength can be accurately recorded to any degree of specificity
compared with 1RM usually measured in increments determined by the availability of
specific weight plates. The mid-thigh pull and squat are the most common measures of
isometric maximal strength and are used as general measures of whole body strength
(McGuigan et al., 2006). Previous research had also demonstrated the importance of
isometric maximal strength in a number of athletic disciplines (Stone et al., 2004). The mid-
thigh pull has been shown to have a close relationship with dynamic maximal deadlift
(McGuigan & Winchester, 2008). The limitations of using isometric strength testing are; its
expense, lack of portability due to size and setup required and lack of availability to a wider
population due to the specific equipment required.

5.5 Implications for research
As research into fatigue requires that participants whole body strength be assessed to ensure
for individuals strength variations are controlled for and therefore a comparable level of
fatigue reached between participants a method needs to be used that can safely, promptly and
accurately measure the strength of each participant. Therefore, using a mid-thigh pull set up
ensures a quick, safe, accurate and prompt measure of strength providing that the mid-thigh pull set up instruments can be obtained and set up prior to the start of data collection.

6 Overhead exercise and the kettlebell

In previous research changes in the shoulder joint have been investigated with fatiguing exercise protocols (Maenhout et al., 2015, 2012) but there is currently no research that investigates a similar exercise done both overhead and at shoulder height and whether overhead exercise has a greater impact on glenohumeral positioning than that of shoulder height activity. An exercise needs to be used that has similar motion but can be done either overhead or to shoulder height, one such exercise is that of the kettlebell swing.

6.1 Kettlebells as an exercise tool

Within sport and exercise training there is a growing movement towards boot camp and group focused training among these is CrossFit®. CrossFit® originally founded by Greg Glassman is a fitness regimen which incorporates elements from multiple different fitness modalities such as high-intensity interval training, weightlifting, powerlifting, gymnastics, calisthenics and other exercises. A staple exercise tool within CrossFit® is the kettlebell mainly used for the kettlebell swing. Since 2001, kettlebells have become increasingly popular in the West and have become a favourite of functional fitness uses such as in CrossFit®, as well as in ‘boot-camp’ and other popular forms of functional fitness training (Liebenson, 2011)

The kettlebell is a cast iron weight consisting of a metal ball with a handle. They were originally developed in Russia in the 1700s and used in agriculture as a balance for weighing the crops. Since the 1940s kettlebells have been used throughout Europe for competition and sport and have been used by Eastern European military as part of physical training. The weight of a kettlebell is traditionally measured in ‘pood’, one pood being equal to approximately 16 kg. Traditionally kettlebells come in multiples of one pood such as 1.5 pood being 24kg, and 2 pood 32 kg (Tsatsouline, 2006). There are two main double-handed swing styles using the kettlebell. The traditional or ‘Russian’ swing involves swinging the kettlebell to shoulder height, whereas the newer ‘American’ swing involves swinging overhead (see Figure 1).
Figure 1 illustrating differences in Kettlebell Swings
‘American’ (left) swung overhead to a fully vertical end-point, while the ‘Russian’ (right) swung to finish at shoulder height.

Although there have been no studies on the injury risk between the two swings there is ongoing debate, often evident in blogs and other forums, about the merits and risks of both swings (Lind, 2016). There are a number of arguments against the overhead or American style swing but the main argument related to injury is that swinging a kettlebell overhead with two hands puts the participant at an increased risk of injury by forcing hyperextension in the thoracic spine because having the hands close together limits shoulder mobility increasing the load through the acromioclavicular joint (Mitchell, Johnson, Coates, Riemann, & Krajewski, 2016). As there has been no research into the differences between these two swings in terms of biomechanics there is little empirical data to inform decisions about selection of swing style based on the potential impact these exercises have on shoulder function.

There appears to be no previous studies investigating changes in subacromial measures in response to overhead strength training exercises, and almost certainly none investigating subacromial distance in association with kettlebell exercise. Therefore, this study intends to use ultrasound to observe changes in glenohumeral positioning following kettlebell swings in the American kettlebell swing (overhead movement) compared to the Russian kettlebell swing (below shoulder height movement). The distance from the humerus to surrounding structures including the acromion, coracoid process and coracoacromial ligament will be measured. Due to the difference in the movements and the work done per “swing” the total
amount of work done will need to be controlled for as will the differences in participants overall strength.

The findings of this study could be of value in identifying risk factors for shoulder impingement including the role of exercise selection when using the kettlebell.
References


Dietrich, T. J., Jonczy, M., Buck, F. M., Sutter, R., Puskas, G. J., & Pfirrmann, C. W. A. (2016). Ultrasound of the coracoacromial ligament in asymptomatic volunteers and


Teyhen, D. S., Miller, J. M., Middag, T. R., & Kane, E. J. (2008). Rotator cuff fatigue and


Chapter 2
Randomised, controlled, cross-over experiment to investigate the effect of overhead and shoulder height exercise of glenohumeral position.

1 Methods

1.1 Design and Ethics
The study was a randomised and controlled, crossover experimental design (see Figure 3). Using ultrasound imaging with repeated measures (Pre- and post-exercise) of the subacromial distance (acromion process to humeral head), mid-point of the coracoacromial ligament to humeral head, humerus to coracoid process at 90 degrees internal rotation and coracoacromial ligament length. These measures were compared pre and post exercise between two different kettlebell swing styles (Figure 1), American (overhead) and Russian (shoulder height). The procedures and conditions of the study were approved by the Unitec Research Ethics Committee (UREC 2016-2064), and all participants gave written informed consent (see Appendix B).
1.2 Variables

Dependant variables:

1. Subacromial distance measured from shortest distance from tip of acromion to humeral head,

2. Coracoacromial ligament length measured from closest point of ligament attachment between coracoid and acromion,
3 Sub-coracoacromial ligament distance measured from midpoint of coracoacromial ligament to humerus,

4 Humeral head to coracoid process,
Independent variables including movement standards:

1 Russian kettlebell swing
   Start position is standing with knees bent no more than 20 degrees, maintaining slight flex in elbow, hip thrust and swing bell up. At the bottom, the wrists must touch the thighs and the bell must pass behind the heels
   End position: Arms locked out straight, the handle of the KB above shoulder level

2 American kettlebell swing
   Start position is standing with knees bent no more than 20 degrees, maintaining slight flex in elbow, hip thrust and swing bell up. At the bottom, the wrists must touch the thighs and the bell must pass behind the heels
   End position: Arms locked out straight, ears visible behind the arms

Figure 2 Russian (Left) and American (right) kettlebell swings end point comparison.
Figure 3. Diagram showing participant allocation

**Assessed for Eligibility (n = 14)**

- **Excluded (n = 6)**
  - Did not meet inclusion/Exclusion criteria (n = 4)
  - Declined to participate (n = 2)

**Block Randomised (n = 8)**

**Allocated to Russian Swings style (n = 4)**

**Allocated to American swing style (n = 4)**

**Warm up**
- 2 x 10 dislocates
- 2 x 10 body weight squats
- 2 x 10 bodyweight lunges
- 3 x 10 American kettlebell swings with 6kg kettlebell

**Ultrasound scan**
- Coracoacromial ligament length
- Humeral head to coracoid process
- Sub acromial distance
- Coracoacromial ligament to humeral head

**Exercise (Either)**
- 3 x 10 Russian swings
- 3 x 14 American Swings

**Ultrasounds scanning protocol repeated**

**1 week wash out and participants crossed over to alternate swings style, and repeated testing**
1.3 Recruitment
A convenience sample of participants were recruited using publicly distributed flyers (See Appendix C), email marketing targeting students, and word-of-mouth. Potential participants were targeted amongst those attending local gymnasiums by posting notices in gyms. Participants who responded to advertising were then contacted through phone or email and were assessed for eligibility, and provided with an information sheet (See Appendix D).

1.4 Sample Size Calculation
Based on a search of the literature, there appear to be no previous studies that have investigated the influence of kettlebell swings on subacromial space measures, therefore there is no data from which to estimate an effect size between swing styles which means a statistical approach to estimate sample size using power calculations is challenging. Therefore, to remain within the scope constraints of a 90 credit thesis investigation, a target sample of 12 participants will be recruited using (non-randomised) convenience sampling. This target is based primarily on the time taken for data collection.

A priori power calculation using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007) indicated that a sample of 10 participants would enable, at a power of 80%, and alpha of 0.05, the detection of an effect size \( d > 1 \) for a difference in subacromial distance between groups.

1.5 Participants and Screening

1.5.1 Participants
Participants were screened before they were enrolled into the study. Participants were asked to complete a demographic questionnaire (Table 3). Eligibility criteria were: (1) Participants were required to be male to control for gender differences in the subacromial distance (Heiko Graichen et al., 2001), (2) aged 20-35 years, (3) have at least 1 year of strength and conditioning experience, (4) have a self-reported deadlift of between 1.6 and 2 times their bodyweight. The deadlift criterion, was used to try to have participants as similar in respect to experience and strength as reasonably possible. (5) Participants also needed to be familiar with the use of kettlebells to ensure safety and proper form while completing the required exercises.
Participants were excluded if they (1) reported having been diagnosed with shoulder pathology (including thoracic spine, sternoclavicular and acromioclavicular joints), (2) if they
had received shoulder surgery or experienced upper-limb trauma, (3) if they participated in single-sided dominant sports such as tennis or (4) if they had regularly participated in preventative shoulder maintenance programmes.

1.5.2 Sonographer
A registered sonographer with a special interest in musculoskeletal sonography and 20 years of clinical experience was recruited to undertake all ultrasound measurements. The sonographer was blinded to the style of swings being performed by each participant. The ultrasound machine used was a GE LOGIQ e portable ultrasound machine using the musculoskeletal pre-settings and using a L5-12 linear transducer.

1.6 Testing Procedures

1.6.1 Session 1 – Familiarisation and descriptive measure collection
Participants attended a familiarisation session prior to the main study to ensure familiarity with required procedures for the study and to collect demographic data. Participants were instructed to maintain their normal work-out routine prior to attending the familiarisation session and data collections sessions. Each participant completed a consent form and had measures of; age, height, weight (Sanitas Digital, SBG17) and thoracic mobility (See session 1 – measure of thoracic mobility) recorded. Participants underwent a maximum isometric strength assessment using a mid-thigh pull setup (Kawamori et al., 2006). The isometric mid-thigh pull is well established (Beckham et al., 2013) as a valid index of maximum strength and is widely used in the strength and conditioning literature (McGuigan, Newton, Winchester, & Nelson, 2010; McGuigan & Winchester, 2008). The maximal isometric strength as established from the mid-thigh pull was then used to prescribe a kettlebell weight either 16kg, 20kg or 24kgs, the prescribed weight was between 6 and 7% of maximal isometric strength (See table 1). These weights and percentages of maximal isometric strength were used as kettlebells are typically available in standard increments of 4kgs and therefore 6-7% aligns with the available kettlebell weights. By assigning kettlebells based on 6-7% of isometric maximal strength this allowed for differences between strength of participants to be controlled for and equates to participants doing a similar level of work for both swing styles despite the difference in kettlebell elevation between the swings. As the total amount of work done, and therefore level of fatigue reached, is dependent on swing style, participants were video recorded completing both an American and Russian kettlebell
so that their swing path length could be analysed using video analysis software (Kinovea version 0.8.15.), to determine the path length of the kettlebell. Then using the formula Work = force\*distance the total amount of work could be calculated for each individual participant, and the number of repetitions of American swings was scaled as to closely approximate the total work done for the Russian swing.

1.6.2 Session 1 - Measure of thoracic mobility
Thoracic mobility can impact the position of the shoulder girdle and therefore the potential ranges of motion achieved by the shoulder (Kebaetse et al., 1999). As the thoracic spine extends the shoulder complex rotates posteriorly allowing the humerus to reach greater ranges of abduction and flexion (Kebaetse et al., 1999). Therefore, thoracic mobility was assessed as a covariate, as it may change the positioning of the shoulder and change the glenohumeral distances being recorded. Using the tape measure method or modified Schober method (Littlewood & May, 2007) described by Furness et al (2015) which consists of measuring from the spinous process of T1 to T12 in full spinal extension and then measuring the same distance in full flexion and recording the difference in distance between the two measurements, participants’ thoracic mobility was assessed pre-exercise to monitor whether greater thoracic mobility may influence changes in glenohumeral positioning.
Table 1. Kettlebell assignment table. Selection of kettlebell based isometric maximum strength from mid-thigh pull. The kettlebell prescribed is between ~6 to ~7% of the maximum isometric strength (as indicated in the shaded cells). Example: A participant maximum mid-thigh pull of between 2300 – 2700N, would correspond to the 16kg kettlebell \((160N/2300N)*100 = 6.96\%

<table>
<thead>
<tr>
<th>Mid-thigh Pull (N)</th>
<th>16kg</th>
<th>20kg</th>
<th>24kg</th>
<th>28kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>2300</td>
<td>6.96</td>
<td>8.70</td>
<td>10.43</td>
<td>12.17</td>
</tr>
<tr>
<td>2400</td>
<td>6.67</td>
<td>8.33</td>
<td>10.00</td>
<td>11.67</td>
</tr>
<tr>
<td>2500</td>
<td>6.40</td>
<td>8.00</td>
<td>9.60</td>
<td>11.20</td>
</tr>
<tr>
<td>2600</td>
<td>6.15</td>
<td>7.69</td>
<td>9.23</td>
<td>10.77</td>
</tr>
<tr>
<td>2700</td>
<td>5.93</td>
<td>7.41</td>
<td>8.89</td>
<td>10.37</td>
</tr>
<tr>
<td>2800</td>
<td>5.71</td>
<td>7.14</td>
<td>8.57</td>
<td>10.00</td>
</tr>
<tr>
<td>2900</td>
<td>5.52</td>
<td>6.90</td>
<td>8.28</td>
<td>9.66</td>
</tr>
<tr>
<td>3000</td>
<td>5.33</td>
<td>6.67</td>
<td>8.00</td>
<td>9.33</td>
</tr>
<tr>
<td>3100</td>
<td>5.16</td>
<td>6.45</td>
<td>7.74</td>
<td>9.03</td>
</tr>
<tr>
<td>3200</td>
<td>5.00</td>
<td>6.25</td>
<td>7.50</td>
<td>8.75</td>
</tr>
<tr>
<td>3300</td>
<td>4.85</td>
<td>6.06</td>
<td>7.27</td>
<td>8.48</td>
</tr>
<tr>
<td>3400</td>
<td>4.71</td>
<td>5.88</td>
<td>7.06</td>
<td>8.24</td>
</tr>
<tr>
<td>3500</td>
<td>4.57</td>
<td>5.71</td>
<td>6.86</td>
<td>8.00</td>
</tr>
<tr>
<td>3600</td>
<td>4.44</td>
<td>5.56</td>
<td>6.67</td>
<td>7.78</td>
</tr>
<tr>
<td>3700</td>
<td>4.32</td>
<td>5.41</td>
<td>6.49</td>
<td>7.57</td>
</tr>
<tr>
<td>3800</td>
<td>4.21</td>
<td>5.26</td>
<td>6.32</td>
<td>7.37</td>
</tr>
<tr>
<td>3900</td>
<td>4.10</td>
<td>5.13</td>
<td>6.15</td>
<td>7.18</td>
</tr>
</tbody>
</table>
1.6.3 Session 2 and 3 - Warm-up
Participants were guided through a warm-up of four different exercises consisting of 2 sets of 10 repetitions (“2 x 10”) overhead shoulder stretches (wide grip shoulder dislocations), 2 x 10 body weight squats, 2 x 10 bodyweight lunges and 3 x 10 American kettlebell swings using a 6kg kettlebell. Participants were observed for safe form during these exercises.

1.6.4 Session 2 and 3 – Participant Allocation
Participants were randomly allocated using block randomisation consisting of two blocks of four participants each (http://random.org) for the order in which they undertook either Russian swing or American swing.

1.6.5 Session 2 and 3 – Ultrasound protocol
Each participant was scanned after completing their warm-up (before the allocated swing prescription) and immediately after completion of the exercise. All ultrasound scans were conducted in a separate, but adjacent room from where the warm-up and exercise routines were completed. During ultrasound scanning, participant posture and angle of arm abduction were standardised and corrected before scanning to control for postural effect of glenohumeral joint positioning and to ensure posture and position was maintained throughout the procedure. Participants were standing throughout the procedure and had both shoulders scanned with the right shoulder scanned first. Measures were taken using the calliper function of the ultrasound machine for the coracoacromial ligament length, humeral head to coracoid process distance at 90 degrees internal rotation, subacromial distance and midpoint of the coracoacromial ligament to humeral head distance. The coracoacromial ligament to humeral head distance was measured at 0°, 45° and 60° of abduction (Maenhout et al., 2012). The subacromial distance was measured at 0° and 45° of abduction because the landmarks on the head of the humerus rotated under the acromial process at 60° abduction making it unobservable on ultrasound. The angles of abduction were measured with the arm both passively supported using wooden blocks and also actively held (Maenhout et al., 2012). The angle at which the arm was positioned was monitored continuously during the measures using a digital inclinometer (Baseline Evaluation Instruments Model: 12-1057). All distances were measured in millimetres and the sonographer was asked to report any incidental pathological findings unreported by participants prior to recruitment (ie inflamed bursa, bursal bunching, acromioclavicular joint damage or tendinopathy) to identify potential
confounding factors that may have influenced the subacromial distance or surrounding structures by increasing or decreasing the measured size.

1.6.6 Session 2 and 3 – Kettlebell exercise

After the first scanning session participants performed either 3 sets of 20 repetitions of Russian kettlebell swings or, depending on random allocation, 3 x 14 American swings with 1-minute rest between each set. A researcher was present at all times to ensure adherence to the protocol. The participants were scanned again approximately 20 seconds following the final exercise set using the same procedures as undertaken prior to the exercise. Participants returned one week later to complete the same routine using the alternate style of kettlebell swing. During this week participants were asked to maintain the same exercise routine as they had prior to the first session.

1.7 Data Analysis

In order to interpret pre-post distances of acromial humeral distance an operational definition for the Minimum Detectable Change (MDC) was calculated using the standard error of measurement (SEM) reported by Maenhout et al (2012). The MDC was calculated using MDC at 90% =1.65 * 1.41 * SEM (Wu et al, 2011) at angles of 0 and 45 degrees of abduction (See table 2).

<table>
<thead>
<tr>
<th>Angle of abduction</th>
<th>SEM (mm) (Maenhout, 2012)</th>
<th>MDC at 90% (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0.54</td>
<td>1.49</td>
</tr>
<tr>
<td>45</td>
<td>0.87</td>
<td>2.02</td>
</tr>
</tbody>
</table>

In the absence of published research reporting the SEM or MDC for ultrasound-based measures of the sub coracoacromial ligament distance, humeral head to coracoid process at 90 degrees internal rotation and coracoacromial ligament length, the MDC for these parameters were operationally defined as being the same as that for the subacromial distance. The rationale for this was that they are similar in magnitude, anatomical location and are measured using the same sonographic techniques.
Raw data was tabulated into spreadsheets then individually graphed for each measure (coracoacromial ligament length, humeral head to coracoid process, subacromial distance at 0 and 45 degrees and sub coracoacromial ligament distance at 0, 45 and 60-degrees abduction). Graph points of pre- and post-exercise were separated by left and right, and by swing style. The mean change for each dependant variable was then calculated and this compared with the MDC (as above) to interpret measurable change. The small sample precluded inferential statistics.
2 Results

2.1 Participants
Fourteen people responded to advertising and volunteered to participate in the study, of which 8 people satisfied the inclusion criteria. All subjects who met the inclusion criteria provided informed consent (See Appendix B) to the procedures of the study. After completing video analysis assessment of swing path length all participants were prescribed the same ratio of American to Russian kettlebell sings with 15 and 20 respectively. Of the 8 eligible participants one became injured between the first and second testing sessions and was unable to raise his arm above shoulder height. The injury was unrelated to the study but the participant was unable to complete the second testing session, therefore there are no post-exercise (Russian swing) data points for this participant. Of the 8 participants, 6 had non-symptomatic secondary findings on ultrasound (See Table 3).
<table>
<thead>
<tr>
<th>Participant ID</th>
<th>Age (years)</th>
<th>Weight (kg)</th>
<th>Height (cm)</th>
<th>Years’ Experience</th>
<th>Body Fat %</th>
<th>Max MTP (N)</th>
<th>Assigned Kettlebell Weight (Kg)</th>
<th>Ratio of American to Russian Swings (Am/Rus)</th>
<th>Secondary Ultrasound Findings</th>
<th>Thoracic Spine Extension to Flexion (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30</td>
<td>101</td>
<td>186</td>
<td>3</td>
<td>13.8</td>
<td>3654</td>
<td>24</td>
<td>15/20</td>
<td>No Findings</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>20</td>
<td>80.4</td>
<td>176</td>
<td>3</td>
<td>6.2</td>
<td>3667</td>
<td>24</td>
<td>15/20</td>
<td>(L) Thickened bursa (R) Bursal Bunching on Abduction</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>85.2</td>
<td>185</td>
<td>2</td>
<td>18.3</td>
<td>3623</td>
<td>24</td>
<td>15/20</td>
<td>(R) Thickened Bursa</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>21</td>
<td>67.9</td>
<td>170</td>
<td>3</td>
<td>12.2</td>
<td>2777</td>
<td>16</td>
<td>15/20</td>
<td>(L) increase bursal size</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>21</td>
<td>87.3</td>
<td>186</td>
<td>2</td>
<td>9.4</td>
<td>3324</td>
<td>20</td>
<td>15/20</td>
<td>(R) Bursal thickening (L) Fluid in bursa</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>81.1</td>
<td>180</td>
<td>3</td>
<td>19</td>
<td>2742</td>
<td>16</td>
<td>15/20</td>
<td>(L) Fluid in bursa</td>
<td>6</td>
</tr>
<tr>
<td>7</td>
<td>27</td>
<td>63.7</td>
<td>172</td>
<td>2</td>
<td>15</td>
<td>2421</td>
<td>16</td>
<td>15/20</td>
<td>(R) Fluid in bursa</td>
<td>5</td>
</tr>
<tr>
<td>8</td>
<td>30</td>
<td>67.4</td>
<td>176</td>
<td>3</td>
<td>9</td>
<td>2676</td>
<td>16</td>
<td>15/20</td>
<td>No Findings</td>
<td>6</td>
</tr>
<tr>
<td>Mean</td>
<td>25</td>
<td>79.3</td>
<td>179</td>
<td>2.6</td>
<td>12.9</td>
<td>3110</td>
<td>15/20</td>
<td>5.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Abbreviations; kg – kilograms, cm – centimetres, N – Newtons, Am – American, Rus - Russian
Figure 4 - Coracoacromial ligament length and humeral head to coracoid process distance pre- and post-exercise separated by left and right and swing style. Panel A - Coracoacromial ligament length. Panel B - Humeral head to coracoid process. Mean change of all participants calculated below data points.
Figure 5 – Subacromial distance pre- and post-exercise separated by left and right and swing style. Panel A – Subacromial distance, pre and post exercise at 0 degrees passive abduction. Panel B Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Mean change of all participants calculated below data points.
Figure 6 – Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style. Panel A – Sub coracoacromial ligament distance, pre and post exercise at 0 degrees passive abduction. Panel B Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Mean change of all participants calculated below data points.
2.2 Overhead and shoulder height fatiguing exercises effects on humeral head positioning.
As illustrated in Figures 1, 2 and 3 all measured pre to post-exercise changes were less than the MDC of 1.49mm at 0 degrees of abduction and 2.02mm and 45 degrees of abduction, therefore with either swing style there is no detectible change in any of the variables measured. 60 degrees of abduction was unable to be measured due to anatomical limitations.

2.3 Relationship between thoracic spine mobility and subacromial distance
As there were no observed changes in any dependent variables between pre and post exercise the relationship between thoracic spine mobility and subacromial distance could not be evaluated.
3 Discussion

3.1 Overview and statement of principal findings
All pre-post-exercise changes fall within the limits defined as minimum detectible. Therefore, the results show that there were no detectable differences in subacromial distance, coracoacromial ligament length, the coracoid process to humeral head distance and mid-point in the coracoacromial ligament to humeral head in shoulder height kettlebell swings when compared to overhead kettlebell swings. Therefore, the secondary potential proposed relationship between fatiguing overhead exercise and thoracic spine mobility was not able to be investigated.

3.2 Discussion of findings in context to wider literature
While this study found no changes in measures between kettlebell swing style or left and right arm, previous research investigating the effect of fatigue on the subacromial distance has reported pre to post-exercise change in subacromial distance (Maenhout, Dhooge, Van Herzeele, Palmans, & Cools, 2015). This study is the only study to quantify a level of detectable change (MDC) whereas previous studies have reported data without identifying a level at which the change in distances can be classified as detectable (Maenhout, Van Eessel, Van Dyck, Vanraes, & Cools, 2012; Maenhout, Dhooge, Van Herzeele, Palmans, & Cools, 2015). Maenhout, et. al. (2013) investigated the acromial humeral distance of overhead and recreational athletes at 0, 45, and 60 degrees of abduction where as this thesis only looked at 0 and 45 degrees of abduction as the bony landmarks on the humerus rotated under the acromion process and were no longer visible on ultrasound. The differences between the findings of this thesis and the Maenhout et.al. (2013) study which did detect change in the subacromial distance are most likely due to this study’s classification of MDC as well as the potential landmarks used to measure the distances at the higher degrees of abduction, along with the differences in population and scanning methods which were not stated in previous studies.

3.3 Strengths
This study used a variety of methods to assess participants and took a number of measures to assess the impact that they may have on the results including mid-thigh pull, thoracic spine mobility and body fat analysis. When this study is compared to other similar research (Ebaugh, McClure, & Karduna, 2006; Maenhout et al., 2012; Maenhout et al., 2015) this is
the only known study to use both Mid-thigh pull as a measure of overall participant strength and thoracic spine mobility measures to determine their potential effect on overhead exercise. Furthermore, this study highlighted the potential use of both of these as effective tools to measure and report participant overall strength and thoracic spine flexibility.

3.3.1 Mid-thigh pull
This is the only study known that has used mid-thigh pull to assess total body strength and then use a percentage of maximal strength to assign a kettlebell weight. In routine training, a kettlebell user would select a kettlebell weight based on personal preference and self-assessed strength (Liebenson, 2011) but by using MTP to assess participants total strength and scale this to assign a kettlebell this ensured that all participants were fatigued to a similar level. Other studies have based kettlebell selection off of ‘typical recommendations for novice kettlebell training’ i.e. 8 kg for women and 12 for men (Jay et al., 2011) or based off participant weight (Lake & Lauder, 2012). By using MTP instead of a weighted deadlift as a measure of total strength this enabled participants strength to be measured with greater precision and eliminated the need to test and retest to find the participants one rep max and therefore removed the potential reduction of maximal strength by fatigue building up while trying to establish the participants total strength. This also aimed to keep the participants as homogenous as possible and to identify factors that may potentially confound results.

3.3.2 Thoracic spine mobility.
Previous research has demonstrated that thoracic spine mobility has an impact on glenohumeral and shoulder positioning (Kebaetse et al., 1999) and therefore may affect participants ability to obtain end of range abduction. This study assessed participants thoracic mobility by measuring the range between full extension and full flexion. Due to the results of this study, it cannot be concluded that thoracic spine mobility impacted on either shoulder height or overhead exercises impact on the glenohumeral joint. Although all participants thoracic spine mobility was similar suggesting a comparable amount of mobility between participants.

3.4 Weaknesses
There are two weaknesses within this study that may have influenced the findings, firstly the ultrasound scans were recorded in millimetres and secondly, the level of fatigue that the participants reached may not have been enough to create changes in the glenohumeral joint.

3.4.1 Ultrasound scan recording
The ultrasound scans were measured in millimetres due to experimenter error in recording, therefore if the amount of change was less than $\pm 0.5$ mm this would not be detectible on the ultrasound scans. In further studies it would be useful to record measurements to the precision available for the ultrasound machine used (i.e. 0.0). By comparison to other studies such as Maenhout et. al. (2013), they used measurements down to 0.01 mm, therefore to enable comparison with other similar studies the measures need to be of a comparable size.

3.4.2 Level of fatigue
A further weakness is participants were asked to perform 3 sets of exercise (kettlebell swings). It has not been established in the literature if this level of exercise was enough to produce changes detectible on ultrasound in the shoulder joint. This number of sets was used as it is what is often assigned in a gym or kettlebell work out setting. It would be useful for the level of exercise to be increased so that if minor changes had occurred in the glenohumeral position these may be exaggerated by an increased level of fatigue in the shoulder. Therefore, future studies may either want to look at increasing either the number of reps or the number of sets done or both.

3.5 Limitations
This study was designed so that the participants were as similar as possible so that factors such as level of exercise experience, gender or age did not affect the results by having participants whose results were not comparable. While this reduces the possibility of other influences such as age or gender differences (Maenhout et al., 2015) on the results it does limit the applicability of the findings to other groups of people outside of the target population these include females (Maenhout et al., 2015), older or younger people or people with either a lot of previous experience or very little experience (Azzoni et al., 2004). Further, this study only measured the variables once per scan instead of taking the mean measure from 3 individual scans as is traditionally done. This was due to time constraints and amount of data collected, as repeated measuring of variables would vastly increase the time taken. Therefore, the time from the cessation of exercise to scanning would be lengthened.
potentially affecting the later scans in the process as the musculature would have more time to recover from the fatiguing exercise.

3.6 Future implications
This study was an investigation into changes in humeral head positioning within the shoulder joint with overhead kettlebell swings (American swings) compared with shoulder height (Russian) kettlebell swings. The study was intended to give a broad view of change that may occur in the subacromial distance, the coracoacromial ligament, the coracoacromial distance and the distance from the coracoacromial ligament to the humeral head. As this study was not intended to give a definitive answer to whether or not there was a link between overhead kettlebell swings and shoulder dysfunction or impingement further research need to be done to determine if there is a causative effect from overhead exercise. This study demonstrated a design and controls that may be applied to future similar work. It has demonstrated a way of controlling for differences between two kettlebell swing styles, a way of prescribing a kettlebell weight based off of full body strength using mid-thigh pull and using video analysis to calculate kettlebell path to ensure the ratio of work done between swing styles is kept similar. This study uses multiple variables in assessing the positioning of the glenohumeral joint. In particular, it would be interesting to conduct further research into the comparison between the well-established measure of subacromial distance and the measure of sub coracoacromial ligament distance that this study used. There is potential for the sub coracoacromial ligament distance to be used as a measure where the subacromial distance cannot be used such as at angles on abduction greater than 60 degrees or where there is either pathology or bony abnormally surrounding the acromion.

3.7 Further work and unanswered questions
As identified above as weaknesses further research should be conducted using a greater level of shoulder fatigue and more accurate sonographic measuring. It has also been demonstrated that it appears to be useful to allow for visibility of individual participants results so it is recommended that future research use a similar approach.
References


Female Overhead Athletes. Clinical Journal of Sport Medicine, 1. https://doi.org/10.1097/JSM.0b013e31825b6995


Chapter 3

Case studies

1 Introduction
A number of weaknesses were identified in the study described in Chapter 2. Therefore, Chapter 3 presents a series of case studies intended to address those weaknesses and take a more in-depth look into participants characteristic such as types of exercise, time spent exercising per day/week and exercise history. Two main points of weakness identified in the previous study were; Firstly, failing to record the distance measured to two decimal points, i.e. to 0.01 mm. Secondly, due to there being no detectible change in the results from the previous study, the level of work done by each participant will be increase. This will be done by increasing the number of swings completed. The aim of this increase in work load is to increase the level of fatigue the participants reached before commencing the second ultrasound scan, potentially increasing any changes in the glenohumeral positioning that may be occurring below the detectable limit.
2 Methods
The methods applied in each case study are the same as those detailed in Chapter 2, except for changes to the exercise protocol, and the ultrasound measures as described below. The procedures and conditions of the study were approved by the Unitec Ethics Committee (UREC 2016-2064), and all participants gave written informed consent (see Appendix B).

2.1 Exercise Protocol
The warm up participants conducted was the same as outlined in the previous chapter. The exercise dose was increased from 3 sets to 5 sets of either 20 Russian swings or 14 American swings but maintaining the same number of repetitions per set. The purpose of this was to examine whether a greater amount of fatigue would create a more pronounced post-exercise change in glenohumeral position.

2.2 Ultrasound imaging measurement protocol
The ultrasound scans were conducted by the same sonographer, following the same procedures as the Chapter 2 study, but the precision of recording of measurements was increased from 1mm to 0.01mm.
3 Case 1 Presentation

Participant A (PA), was a 21-year-old male, full-time tertiary student. PA had been participating in CrossFit involving kettlebell training for the last 18 months, with a typical schedule of 6 times a week for 2-3 hours duration per session. PA also does a once weekly high-intensity interval training (HIIT) session consisting of short sprints (100m) interspersed with recovery jogging (300m). PA had previous experience participating in social squash once a week during secondary schooling which he stopped 4 years ago. PA had an undiagnosed “irritation” in his left shoulder 6 years ago, which resolved after a few weeks and has had no ongoing problems since.

3.1 Results

The following tables present the participants descriptive characteristics, mid-thigh pull results and any secondary ultrasound findings.

Table 4. Participant A descriptive characteristics

<table>
<thead>
<tr>
<th>Age</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Left or right hand dominant</th>
<th>Body fat based on skinfolds (%)</th>
<th>Thoracic spine in extension from T1 to T12 (cm)</th>
<th>Thoracic spine in flexion from T1 to T12 (cm)</th>
<th>Difference Flexion to Extension (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>186</td>
<td>87.3</td>
<td>Right</td>
<td>9.4%</td>
<td>38</td>
<td>42</td>
<td>4</td>
</tr>
</tbody>
</table>

Table 5 Participant A mid-thigh pull

<table>
<thead>
<tr>
<th>PA weight on force plate (N)</th>
<th>Mid-thigh pull attempt 1 (N)</th>
<th>Mid-thigh pull attempt 2 (N)</th>
<th>Mid-thigh pull attempt 3 (N)</th>
<th>Assigned kettlebell weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>845</td>
<td>3324</td>
<td>3171</td>
<td>3238</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 6 Secondary Ultrasound Findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Left Shoulder</th>
<th>Right Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid in subacromial bursa</td>
<td></td>
<td>Fluid in subacromial bursa</td>
</tr>
</tbody>
</table>
All measurements in coracoacromial ligament length (Figure 7), humeral head to coracoid process distance (Figure 7), subacromial distance (Figure 9) and coracoacromial ligament to humeral head distance (Figure 9) are below the MDC of 1.49mm at 0 degrees abduction and 2.02mm and 45 degrees abduction, as established in Chapter 2. Therefore, it was concluded that there is no change in any of the recorded measurements.
Figure 7 - Coracoacromial ligament length and humeral head to coracoid process distance pre- and post-exercise separated by left and right and swing style. Panel A - Coracoacromial ligament length. Panel B - Humeral head to coracoid process. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PA is calculated below data points.
Figure 8 – Subacromial distance pre- and post-exercise separated by left and right and swing style. Panel A – Subacromial distance, pre and post exercise at 0 degrees passive abduction. Panel B Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PA is calculated below data points.
Figure 9 – Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style. Panel A – Sub coracoacromial ligament distance, pre and post exercise at 0 degrees passive abduction. Panel B Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PA is calculated below data points.
4 Case 2 Presentation

Participant B (PB), was a 20-year-old male, full-time tertiary student. PB had been participating in CrossFit involving kettlebell training for the last 4 years, with a typical schedule of 5 times a week for 2-3 hours duration per session, using kettlebell swings in at least two of his weekly sessions. PB also participates in running for fitness of variable intensity and frequency, usually twice weekly for approximately 30 minutes. PB had an undiagnosed left shoulder injury four years prior to data collection which did not stop him training but caused slight pain on movement, it resolved after 2 months and has not reoccurred since this time.

4.1 Results

The following tables present the participants descriptive characteristics, mid-thigh pull results and any secondary ultrasound findings.

Table 7. Participant B descriptive characteristics

<table>
<thead>
<tr>
<th>Age (cm)</th>
<th>Height (kg)</th>
<th>Weight (kg)</th>
<th>Left or right hand dominant</th>
<th>Body fat based on skin folds (%)</th>
<th>Thoracic spine in extension from T1 to T12 (cm)</th>
<th>Thoracic spine in flexion from T1 to T12 (cm)</th>
<th>Difference Flexion to Extension (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>176</td>
<td>80.4</td>
<td>Right</td>
<td>6.2%</td>
<td>34</td>
<td>49</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 8 Participant B mid-thigh pull

<table>
<thead>
<tr>
<th>PB weight on force plate (N)</th>
<th>Mid-thigh pull attempt 1 (N)</th>
<th>Mid-thigh pull attempt 2 (N)</th>
<th>Mid-thigh pull attempt 3 (N)</th>
<th>Assigned kettlebell weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>786</td>
<td>3667</td>
<td>3582</td>
<td>3436</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 9 Secondary ultrasound findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Left Shoulder</th>
<th>Right Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>No secondary ultrasound findings</td>
<td></td>
<td>Slightly enlarged subacromial bursa</td>
</tr>
</tbody>
</table>
All measurements in coracoacromial ligament length (Figure 10), humeral head to coracoid process distance (Figure 10), subacromial distance (Figure 11) and coracoacromial ligament to humeral head distance (Figure 12) are below the MDC of 1.49mm at 0 degrees abduction and 2.02mm and 45 degrees abduction, as established in Chapter 2. Therefore, it was concluded that there is no change in any of the recorded measurements.
Figure 10

Panel A - Coracoacromial ligament length. Panel B - Humeral head to coracoid process.

Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PB is calculated below data points.
Figure 11 – Subacromial distance pre- and post-exercise separated by left and right and swing style. Panel A – Subacromial distance, pre and post exercise at 0 degrees passive abduction. Panel B Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PB is calculated below data points.
Figure 12 – Sub coracoacromial ligament distance pre- and post-exercise separated by left and right and swing style. Panel A – Sub coracoacromial ligament distance, pre and post exercise at 0 degrees passive abduction. Panel B - Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PB is calculated below data points.
5 Case 3 Presentation

Participant C (PC), was a 21-year-old male, full-time tertiary student. PC had been participating in CrossFit involving kettlebell training for the last 2 years, 3 times a week for 2-3 hours duration per session. PC had previous experience participating socially in both judo (7 years) and rugby (4 years) participating in each 1 – 2 times per week. PC dislocated his right shoulder 6 years ago and it was reset and resolved without complication and he reported no recurrent dislocation or other issues.

5.1 Results

The following tables present the participants descriptive characteristics, mid-thigh pull results and any secondary ultrasound findings.

Table 10. Participant C descriptive characteristics

<table>
<thead>
<tr>
<th>Age (cm)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Left or right hand dominant</th>
<th>Body fat based off skin folds (%)</th>
<th>Thoracic spine in extension from T1 to T12 (cm)</th>
<th>Thoracic spine in flexion from T1 to T12 (cm)</th>
<th>Difference Flexion to Extension (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>21</td>
<td>170</td>
<td>67.9</td>
<td>Right</td>
<td>12.2%</td>
<td>32</td>
<td>37</td>
<td>5</td>
</tr>
</tbody>
</table>

Table 11 Participant C mid-thigh pull

<table>
<thead>
<tr>
<th>PC weight on force plate (N)</th>
<th>Mid-thigh pull attempt 1 (N)</th>
<th>Mid-thigh pull attempt 2 (N)</th>
<th>Mid-thigh pull attempt 3 (N)</th>
<th>Assigned kettlebell weight (Kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>662</td>
<td>2402</td>
<td>2649</td>
<td>2777</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 12 Secondary Ultrasound Findings

<table>
<thead>
<tr>
<th>Findings</th>
<th>Left Shoulder</th>
<th>Right Shoulder</th>
</tr>
</thead>
<tbody>
<tr>
<td>Findings</td>
<td>Fluid in subacromial bursa</td>
<td>Fluid in subacromial bursa</td>
</tr>
</tbody>
</table>

All measurements in coracoacromial ligament length (Figure 13), humeral head to coracoid process distance (Figure 13), subacromial distance (Figure 14) and coracoacromial ligament
to humeral head distance (Figure 15) are below the MDC of 1.49mm at 0 degrees abduction and 2.02mm and 45 degrees abduction, as established in Chapter 2. Therefore, it was concluded that there is no change in any of the recorded measurements.
Figure 13
Panel A - Coracoacromial ligament length. Panel B - Humeral head to coracoid process.
Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PC is calculated below data points.
Figure 14 – **Subacromial distance** pre- and post-exercise separated by left and right and swing style. Panel A – Subacromial distance, pre and post exercise at 0 degrees passive abduction. Panel B - Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PC is calculated below data points.
**Figure 15 – Sub coracoacromial ligament distance** pre- and post-exercise separated by left and right and swing style. Panel A – Sub coracoacromial ligament distance, pre and post exercise at 0 degrees passive abduction. Panel B - Subacromial distance, pre and post exercise at 45 degrees passive abduction. Panel C - Subacromial distance, pre and post exercise at 45 degrees active abduction. Figure shows pre to post-exercise (closed circle to open circle) changes in measured distances, separated by left and right shoulder and American and Russian kettlebell swings. The value of mean change of PC is calculated below data points.
Summary of results
In all of the case studies the differences in subacromial distance, coracoacromial ligament length, the coracoid process to humeral head distance and mid-point in the coracoacromial ligament to humeral head fall within the MDC. Therefore, this means that there were no detectible changes in any of the measurements.
7 Discussion
In addition to the main issues already discussed in Chapter 1 this section addresses issues specific to the case studies.

7.1 Overview and statement of principal findings
All pre- post-exercise changes fell within the limits defined as minimum detectible (MDC). Therefore, the results show that there were no detectable differences in shoulder height kettlebell swings when compared to overhead kettlebell swings in any of the case studies.

7.2 Comparison with group data from Chapter 2
When the study from Chapter 2 is compared with the case studies from Chapter 3 they have the same overall results. As the two highlighted weaknesses of the initial study were addressed in the case series it can now be said with more certainty that there were no detectible findings in subacromial distance, coracoacromial ligament length, the coracoid process to humeral head distance and mid-point in the coracoacromial ligament to the humeral head in ether Chapter 2 or Chapter 3. By increasing the level of exercise done and the resulting level of fatigue it was hypothesised that this would exaggerate any minor changes in glenohumeral positioning that occurred in the subacromial distance, coracoacromial ligament length, the coracoid process to humeral head distance and mid-point in the coracoacromial ligament to the humeral head found in Chapter 2. But as can be seen this was not the case and the volume of exercise did not impact the findings. As with the increase in the precision of the ultrasound measurements taken the ultrasound did not detect any increase in changes and the overall results were the same.

7.3 Considerations for future studies.
Future studies that are conducted in the area of fatiguing overhead exercise and its effects on glenohumeral positioning could look at other means of measuring the glenohumeral positioning as outlined in this study. Using ultrasound around the bony structures of the shoulder joint such as the acromion proved difficult to take measurements, especially as the arm moved into greater amounts of abduction. This limited the measurements that could be taken above 60 degrees. As this study highlighted a comparable measure to that of the subacromial distance is that of the
sub coracoacromial ligament distance. Further research into this distance and at greater angles of abduction may provide another useful tool in glenohumeral position measurement.
Appendix A

Liam Jones
10 Dallow Place
Glenmore
Auckland

21.9.16

Kia ora Liam,

Your file number for this application: 2016-1064
Title: The influence of 'American' and 'Russian' kettlebell swings on subacromial space: A randomised, controlled, cross-over experimental design.

Your application for ethics approval has been reviewed by the Unitec Research Ethics Committee (UREC) and has been approved for the following period:

Start date: 20.10.16
Finish date: 20.10.17

Please note that:

1. The above dates must be referred to on the information AND consent forms given to all participants.

2. You must inform UREC, in advance, of any ethically-relevant deviation in the project. This may require additional approval.

You may now commence your research according to the protocols approved by UREC. We wish you every success with your project.

Yours sincerely,

[Signature]

Nigel Adams
Deputy Chair, UREC

cc: Rob Moran
    Cynthia Almeida
Appendix B

Participant Consent Form

Research Project Title:
The influence of ‘American’ and ‘Russian’ kettlebell swings on subacromial space: A randomised controlled, cross-over experimental design.

I have had the research project explained to me and I have read and understand the information sheet given to me.

I understand that:
- I don’t have to be part of this research project should I chose not to participate and may withdraw at any time.
- I have the right to withdraw my results up until 24 hours after the testing session.
- Everything I say is confidential and none of the information I give will identify me. I understand that the only people who will have access to my personal information and results will be the researcher and their supervisors.
- All the information gathered in the research will be stored securely on a computer or within a locked filing cabinet at Unitec for a period of 5 years, at which point it will then be destroyed.
- My data may be used for publications or further investigations but my name will not be used in the publication of the results.
- I am able to request a copy of the research findings should I so wish.
- I will be filmed performing both ‘American’ and ‘Russian’ kettle bell swings and that these video files will only be used to measure the swing path of the kettle bell and then deleted.
- I may need to take my t-shirt off to have an ultrasound scan taken of my shoulder and that everything will be done to ensure my privacy throughout testing.
- The form of exercises I will be asked to carry out have the potential to cause physical harm if not performed correctly. For this reason, I agree to carry-out the required exercises with care and as per instructions. I will inform the researchers if any injuries arise during the participation of this study. Failing to do so may put myself at increased risk of harm.
- I consent to having provided the researchers with honest and accurate information and will continue to throughout the study.

I have had time to consider everything and ask any questions and I give my consent to be a part of this project.

Participant Name: ...........................................................................................................

Participant Signature: ....................... Date: ...........................................

Project Researcher: ................................ Date: ........................................
Appendix C

How Awesome are you with kettlebells?

We are looking for males with experience using kettlebells, who would like to participate in a research project looking at shoulder joint position. This will involve using ultrasound to assess your shoulder before and after a kettlebell workout.

We are looking for people 20 – 35 years old, 80 – 90 kg and with no previous shoulder injury or surgery. By participating you’ll get some insight into the way your shoulder joint works, and also receive a measure of body composition (% body fat), and an accurate measure of overall body strength using a force plate.

This will take place over 2 days in March at the Unitec performance lab.

For more information or to volunteer please contact
Liam Jones
Department of Osteopathy
kettlebellresearch@gmail.com
Appendix D

Information for participants
My name is Liam Jones. I am currently enrolled in the Master of Osteopathy degree at Unitec New Zealand. I’m seeking your help in meeting the requirements of a research project which forms a substantial part of this degree.

Research Project Title
The influence of ‘American’ and ‘Russian’ kettlebell swings on subacromial space: A randomised, controlled, cross-over experimental design.

Synopsis of project
This project aims to investigate the relationship between shoulder position and two styles of kettlebell exercise.

What we are doing
We are investigating the changes in shoulder positioning following two types of fatiguing exercise - the ‘American’ and ‘Russian’ kettlebell swings. We will be looking at these changes using ultrasound.

What it will mean for you
Participation in this study requires attendance to three 1 hour sessions. The first of these will be an information and familiarisation session. During this session you will have your spinal mobility measured and your skin folds taken. You will also be asked to swing a kettlebell using both techniques. This will be videotaped to help us prescribe a desired number of swings for you to complete in the following sessions. Guidance will be given so that swings meet movement standards.

The second and third sessions will be similar to each other and 1 week apart. These sessions require participants to complete a warm-up exercise, be scanned by ultrasound directly onto skin with clothing removed this will be on location at Unitec Clinic 41, complete a prescribed exercise routine using either kettlebell swing style then scanned again.

If you agree to participate, you will be asked to sign a consent form at the familiarisation session. This does not stop you from changing your mind if you wish to withdraw from the project you may withdraw your results up until 24 hours after the testing session.

Any information that may identify you will be kept completely private and confidential. All information that is collected from you will be stored on a password protected file and only the researcher and supervisors will have access to this information. This information will be kept for 5 years then destroyed.

Please contact us if you need more information about the project. If you have any concerns about the research project - at any time you can contact the supervisor:

Mr Rob Moran, phone 815-4321 or email rmoran@unitec.ac.nz
Full name of author: Liam Paterson

ORCID number (Optional): ..........................................................

Full title of thesis/dissertation/research project ('the work'):
The Influence of American & Russian kettlebell swings on glenohumeral position

Practice Pathway: Osteopathy

Degree: M.Ost

Year of presentation: 2019

Principal Supervisor: Rob Moran

Associate Supervisor: Megan McEwen

Permission to make open access
I agree to a digital copy of my final thesis/work being uploaded to the Unitec institutional repository and being made viewable worldwide.

Copyright Rights:
Unless otherwise stated this work is protected by copyright with all rights reserved.
I provide this copy in the expectation that due acknowledgement of its use is made.

AND

Copyright Compliance:
I confirm that I either used no substantial portions of third party copyright material, including charts, diagrams, graphs, photographs or maps in my thesis/work or I have obtained permission for such material to be made accessible worldwide via the Internet.

Signature of author: ..........................................................

Date: 27.1.03.2019