The acute effects of a standardised osteopathic manual therapy protocol on the vertical jump and reach performance in healthy basketball players: A cross-over design

Master of Osteopathy Thesis

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Declaration

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This Research Project entitled

‘Effects of a short-term osteopathic manual therapy protocol on the vertical jump and reach performance in healthy male basketball players: A cross-over design’

Candidate’s Declaration

I confirm that:

• This research project represents my own work;
• Research for this work has been conducted in accordance with the Unitec Institute of Technology Research Ethics Committee Policy and Procedures, and has fulfilled the requirements outlined for this research project by the Unitec Institute of Technology Ethics Committee.

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Introduction to the thesis

Many sporting movement patterns benefit from good overhead ranges of motion (ROMs). Proficiency in range of motion (ROM) is believed to enable more effective performance in tasks such as shooting, blocking and spiking. It is safe to presume that the closer an athlete can orient his or her arms to an overhead target, such as a basket or a ball, the more likely they are going to be able to perform critical actions such as dunking/laying up in basketball or blocking a ball. Currently there is a paucity of literature examining the effect of osteopathic manual therapy (OMT) on sports performance. Research on joint mobility has been primarily conducted in the context of sport and exercise science or physiotherapy. However, osteopathic interventions also have the potential to be beneficial to the performance of a wide array of sports, and may have added advantages over other modalities. These potential advantages arise from the inherent holistic approach of osteopathy, which takes into account biomechanical and anatomical principles and their influences on one another.

Limitations in shoulder mobility are a common observance in overhead and throwing athletes (Almeida et al., 2013; Clarsen, Bahr, Andersson, Munk, & Myklebust, 2014; Hosseinimehr, Anbarian, Norasteh, Fardmal, & Khosravi, 2015). In other contexts, manual therapy techniques have been shown to improve movement deficits originating in the musculoskeletal system (Amico & Morin, 2013; Lenehan, Fryer, & McLaughlin, 2003; Moore, Laudner, McLoda, & Shaffer, 2011; Mosler, Blanch, & Hiskins, 2006). Therefore, there is potential for these techniques to be effective for improving vertical jump and reach, and thus sport performance. The study reported in this thesis attempted to address the void in sport-related osteopathy literature by (1) identifying male basketball players who are thought to have prevalent overhead reach restrictions; (2) use commonly implemented osteopathic techniques to address these movement deficits; and (3) determine the effects of these techniques on jump performance.

The primary aim of this thesis study was to identify the benefits of osteopathic manual therapy on bilateral upper extremity reach height during a vertical jump. The information gathered validated the chosen osteopathic treatment package, and provide a basis for further research in this area. Potential benefits of this study include increasing the awareness of the potential benefits of osteopathic medicine in the sports sector, evoking more research into osteopathy and sports, and identifying a treatment protocol that may enhance sports performance.

The thesis is presented in three sections. The first section is a literature review which addresses the current literature on topics relevant to the research question by critically reviewing the outcomes of the included studies. The second section is a report of the aforementioned study in the form of a manuscript for the *Journal of Strength and Conditioning Research*. The third section contains respective appendices.
Section 1: Literature Review

Vertical jump height is considered an important performance measure regarding lower-limb capacities. Specific to court-based athletes, vertical jump height also enables the athlete to achieve a greater overhead reach for offensive or defensive objectives (for example in a volleyball spike or block or in a basketball layup). Two potential determinants of the jump and reach height achieved are power generation and the mobility of the thoracic spine and shoulder girdle. Power generation is predominantly achieved by the lower extremities and is also known as concentric lower body power (McNeely & Sandler, 2006). Many studies focus on the effectiveness of a range of training methods implemented to improve lower body power. The mobility of the thoracic spine and shoulder girdle is what allows optimal reach. Limitations in such ROMs could result from repetitive execution of motor patterns, muscular hypertrophy (Oyama, Myers, Blackburn, Troy, & Colman, 2011), posterior shoulder tightness (Myers, Laudner, Pasquale, Bradley, & Leiphart, 2006), and osseous adaptation (Crockett et al., 2002). Additionally, these factors may be influenced by handedness (Conte, Marques, Casarotto, & Amado-João, 2009) and gender (Barnes, Van Steyn, & Fischer, 2015). Other pathological processes, such as repetitive injury and subacromial impingement can also contribute to movement restrictions (Lewis, Wright, & Green, 2005).

The majority of previous studies investigating vertical jump enhancement in a sports context investigate training methods that focus on improving power generation of the leg and hip muscles to propel the individual during take-off (Adams, O’Shea, O’Shea, & Climstein, 1992; Carlson, Magnusen, & Walters, 2009; Keiner, Sander, Wirth, & Schmidtbleicher, 2014; Kubo et al., 2007). Many of these training methods have been shown to increase vertical jump height. For example, a comparison study by Arabatzi et al., (2010) compared the effect of Olympic weightlifting training (OL), traditional resistance training (RT), plyometric training (PL) and combined OL & PL training programs on vertical jump performance. All methods demonstrated an improvement in squat jump (SJ) and countermovement (CMJ) vertical jump height.

The following review will cover the current modes of training used to improve vertical jump performance, the importance of thoracic and shoulder mobility in overhead and throwing athletes, and the current methods used in manual therapy and sport to address musculoskeletal deficits in ROM.

Methods to improve lower limb power for vertical jump performance

As there are numerous strength and aerobic conditioning methods used to improve sports performance, it is useful to categorise the key methods used, their respective objectives and what effect each will have on vertical jump performance. Strength and conditioning programmes have a number of goals, including injury prevention and improvement in sports-specific tasks.
Currently, there is substantial data on various training methods for improving vertical jump height (Adams et al., 1992; Carlson et al., 2009; Fatouros et al., 2000; Keller, Lauber, Gehring, Leukel, & Taube, 2014; Kubo et al., 2007; Maffiuletti, Dugnani, Folz, Di Pierno, & Mauro, 2002). The amount of research highlights the importance of vertical jump as a key motor pattern frequently experienced in sports. Training modes implemented in an attempt to improve vertical jump include, but are not limited to, plyometric training, resistance training and resisted jump training. These methods are believed to be beneficial due to commonality between the exercises and sport-specific tasks the athlete will experience in their respective sport. For example, it is recommended that strength and jump training for a sport should incorporate core movements, such as sprinting and jumping, in actions that mimic those used in the sport setting (Young, 2006). Total body training programmes are perhaps the most beneficial for vertical jump performance (Wyon, Guinan, & Hawkey, 2010), as they promote the development of other musculature which, may assist in vertical jump performance such as those of the arms and trunk.

**Plyometric training**

Plyometric training is made up of exercises using maximal lower extremity (usually) muscular exertion for short intervals of time, with the intention of increasing the capacity of power generation. Plyometric training is one of the most commonly implemented and studied training methods by trainers and researchers to improve vertical jump height and leg muscle power (Markovic, 2007). The three predominant movements used to assess jump performance are the squat jump, the countermovement jump, and the drop jump. The squat jump is used to measure concentric capacity in the absence of a preceding eccentric action. The countermovement jump measures lower-limb capacity when eccentric and concentric actions are coupled. The drop jump measures neuromotor function with a more rapid and accentuated stretch-shortening cycle. There are two different phases observed in stretch-shortening cycle movements: an eccentric action (lengthening) followed immediately by a fast concentric contraction (shortening). During the eccentric phase, the agonist musculature lengthens bringing about a rapid deceleration to slow the downward movement of body mass. During the concentric phase, the centre of mass is accelerated in the upward direction which brings about propulsion at take-off. The most notable adaptation resulting from plyometric training may be related to the enhanced recruitment and rate coding of fast twitch motor units during eccentric muscle contractions (Enoka, 1996). It is also possible that plyometric training can improve jump performance by stimulating muscle hypertrophy and maximal force development, particularly of type II fibres, in jumping athletes as observed in volleyball players (Sleivert, Backus, & Wenger, 1995). However, an increase in muscular hypertrophy may be conflicting as it may lead to reduced ROMs (i.e., reduction in flexibility). Conversely, improvements in mechanical stiffness often observed following plyometric training may be advantageous via greater storage and utilization of elastic energy (Bojsen-Møller, Magnusson, Rasmussen, Kjaer, & Aagaard, 2005).
A number of studies have shown that plyometric training can improve vertical jump performance in trained athletes by as much as 13% (Berryman, Maurel, & Bosquet, 2010; Khelifa et al., 2010; Sheppard et al., 2011; Spurrs, Murphy, & Watsford, 2003). Plyometric training is often implemented to improve force generation in relatively small timeframes of training. This has been shown to improve vertical jump height performance by an average of 8 cm across squat jumps, countermovement jumps and drop jumps compared to weight training (WT), a form of resistance training, which only increases by as much as 1.4 cm across the same jumps in healthy untrained males (Kubo et al., 2007). Numerous studies have indicated that the combination of plyometric training with another form of strength training generates greater improvements in vertical jump height than using plyometric training or weight training alone (Adams et al., 1992; Arabatzi et al., 2010; Fatouros et al., 2000; Keiner et al., 2014).

Despite the belief that plyometric training can improve vertical jump height performance in a shorter training duration than other training methods, the amount of time required to see significant improvements in jump height improvements may be impractical. One study suggested that to be effective, at least 7-weeks of plyometric training followed by a 4-week recovery period was necessary (Luebbers et al., 2003). Relative to pre-season training, this may be a practical approach as many teams allocate a significant portion of time prior to commencing in-season competition to facilitate reconditioning, and thus enhancing game fitness. Such regimens, however, become less feasible during the in-season. During this time, it is common to have limited training time between competitions, as seen in the National Basketball League (NBA) in the United States and Football Premier League in the United Kingdom. Therefore, an 11-week cycle of training to attain improvements may not be a practical approach. As immediate athletic advantages can be the difference between a win or a loss, there is a need for interventions that provide immediate jump and reach height improvements especially in high intensity, high stake team sports such as basketball, football, netball, or volleyball.

**Resistance training**

There are a number of different training methods which fall under the gamut of resistance training. These modes of resistance training are commonly referred to as strength training, and include weight training and Olympic-style weightlifting. The primary distinguishing factor between the two methods is that Olympic-style weightlifting exercises are executed at greater velocities than those of weight training. Resistance strength training provides a greater overload of the musculature, typically performed with greater repetitions than Olympic lifting, which has been shown to build anaerobic endurance (Beattie et al., 2014), muscular strength (Kubo et al., 2007), increased muscle size (Schoenfeld et al., 2014) and improved joint function. Generally, weight training uses isoinertial resistance which is driven by the acceleration of gravity to overload both concentric and eccentric muscle actions to facilitate an increase muscular force generation capacity. When loads are 100% of maximal dynamic strength, the resistance is known
as a one-repetition maximum (1-RM). Similarly, loads approximately 80% of maximal dynamic strength are known as 8-RM. Loads within the range of 1-RM to 8-RM can also be lifted for approximately 1 – 8 repetitions with adequate rest allotted. This form of weight training is also known as traditional resistance training and has been shown to produce significant increases of 1-RM through muscle hypertrophy and neural mechanisms (Gabriel, Kamen, & Frost, 2006). When the load lifted is reduced to around 30 – 50% of 1RM, the magnitude of resistance affords more rapid movements when the same maximal effort exerted in traditional resistance training is applied by the performer. Using this approach has been found to be effective in increasing mechanical power in movements that require explosiveness (Lyttle, Wilson, & Ostrowski, 1996; Sáez Sáez de Villarreal, Izquierdo, & Gonzalez-Badillo, 2011; Wilson, Newton, Murphy, & Humphries, 1993). Enhancements in power generation brought about by subsequent morphological, neural and hormonal adaptations observed following weight training have also been shown to enhance 1-RM performance (Folland & Williams, 2007; Kraemer & Ratamess, 2005).

Weight training is often used to improve power output of the musculature associated with vertical propulsion. Exercises such as snatch, clean and jerk, squats and their respective variations are frequently used to influence lower extremity characteristics. Of particular relevance to this thesis is the effect weight training has on vertical jump height. Arabatzi et al., (2010) showed that incorporating power cleans, snatch, clean and jerk, high pull and half-squats into the 8-week training protocol of physically active male physical education students, resulted in a mean squat jump increase of 5.7 cm (20%) and countermovement jump increase of 5.2 cm (15%). Weight training has also been shown to increase the rate of torque development in trained muscles (K. Crockett et al., 2013; Thompson et al., 2015). Torque is considered an important factor as it is the result of rotational forces applied to the joint that serves to support joints and soft tissue whilst simultaneously exerting force upon an object. Torque is ultimately what creates acceleration of the body’s lever systems (i.e. the skeletal system), and maximising torque generated by a muscle will result in greater acceleration of the system mass. It has been shown that weight training can improve the net speed of joint movement (Thompson et al., 2015). Thompson et al. (2015) showed that their participants, college-aged men and women undertaking weight training, had 25.0% increases in peak rate of torque development of knee extensors and 21.3% peak rate of torque development increases in knee flexors. This resulted in vertical jump performance increasing by 7.4% compared to a control group whose peak rate of torque development and vertical jump height reduced (Thompson et al., 2015). Despite these potential advantages for improving rate of torque development, as outlined previously, weight training has shown smaller benefits for vertical jump improvements compared to plyometric training alone or weight training in combination with plyometric training (Adams et al., 1992; Carlson et al., 2009; Kubo et al., 2007).

Studies have also indicated that resistance training may benefit sports performance by increasing
power production (American Academy of Pediarsics, 2008; Blimkie, 1993; Faigenbaum et al., 2009; W. K. Young & Metzl, 2010). Muscular power is the rate of force or torque production and is considered essential for executing many sporting actions (Robert U Newton & Kraemer, 1994; Thibaudeau, 2007). It has been hypothesised that increases in power output and muscular strength resulting from participation in resistance training may improve sporting performance (Faigenbaum et al., 2009; McCambridge & Stricker, 2008; W. K. Young & Metzl, 2010). However, there is a lack of scientific evidence that increases in muscular power and strength alone will improve sporting performance (Blimkie, 1993; McCambridge & Stricker, 2008). A review by Behringer, Vom Heede, Matthews, & Mester, (2011) concluded that resistance training is effective for improving motor performance in children and adolescents. Most of the participants in these studies had no athletic background (66%) and many of the studies included both mixed cohorts of children and adolescents. Based on this it would be plausible that biological maturation may have contributed to the large increases. However, many of the studies in the review controlled for biological maturation by incorporating a control group. In addition, individuals within this age group tend to have a greater potential for improvements than their adult counterparts due to enhanced motor skill acquisition (Blimkie, 1993; Faigenbaum et al., 2009; W. K. Young & Metzl, 2010).

**Resisted jump training**

Another training method used to improve vertical jump performance is resisted jump training. This training method utilises a form of external resistance when performing actions against the line of force. For instance, elastic cords can be attached directly to the athlete often by their waist whilst they perform repetitions of jumping motor patterns. Similar to plyometric training and weight training, a potential disadvantage of resisted jump training is the amount of time required to observe significant improvements in performance outcome such as jump height. A study by Carlson et al. (2009) recruited intercollegiate athletes to compare strength training, strength training combined with plyometric training, strength combined with resisted jump training with arm swing attachments, and strength training combined with resisted jump training without arm swing attachments. The study showed that after six weeks none of the groups displayed significant improvement in jump height. This might indicate training adaptation had yet to occur. Of note, similar studies (Rhea, Lunt et al., 2008; Rhea, Oliverson, Potenziano et al., 2008) utilised training protocols for twice the duration (8 – 12 weeks) and demonstrated improvements in power output greater than control groups (Rhea, Peterson, Lunt, et al., 2008) and eliciting a greater treatment effect (effect size 0.09) than conventional plyometric and resistance training methods alone (Rhea, Peterson, Oliverson, et al., 2008).

It is likely that achieving gains in highly trained populations may be more difficult as it can be presumed that they are closer to their maximum potential than untrained individuals, leaving less room for improvement (i.e., diminishing returns). This shows the difficulty in achieving large
gains in vertical jump height in such populations, and indicates the need for new more effective interventions. Rhea et al. (2008) proposed the main benefit of this new resisted jump training protocol was its effectiveness in highly trained populations.

**Combined training**

It appears a common trend in the literature is the superior effect of using a combination of different training methods when compared to the effects of using a single training method in isolation. The combination of weight training with plyometric training aims to take advantage of the enhancement in 1-RM performance, by emphasising both maximal force production and the rate of force production (Liu, Schlumberger, Wirth, Schmidtleicher, & Steinacker, 2003). Thus, a combination of weight training and plyometric training would be a superior training strategy to enhance power than either plyometric training or weight training in isolation (Cronin, McNair, & Marshall, 2002). It has been demonstrated that the combination of plyometric training and weight training enhanced vertical jump performance in trained participants by 4 – 13% (Maio Alves, Rebelo, Abrantes, & Sampaio, 2010; Marques, Tillaar, Vescovi, & González-Badillo, 2008). Moreover, previous findings by Fatouros et al., (2000) showed participants improved as much as 14.6% compared to weight training (9.3%) or plyometric training (11.3%) alone. Fatouros et al. (2000) determined that combining plyometric training with weight training produced significantly greater improvements in leg strength and vertical jump performance than undertaking plyometric training or weight training individually.

It is difficult to conclude that resistance training is the sole cause of vertical jump improvements seen in many of the discussed studies (Buchheit, Mendez-Villanueva, Delhomel, Brughelli, & Ahmaidi, 2010; Christou et al., 2006; Gorostiaga et al., 2004; King & Cipriani, 2010; Rubley, Haase, Holcomb, Girouard, & Tandy, 2011; Szymanski et al., 2010; Wong, Chamari, & Wisløff, 2010). Improvements may have also resulted from the continuation of sports practice by the intervention and/or control groups while the research is conducted. Despite this there appears to be no adverse effects on sports performance from combining resistance training (RT) with an individual’s regular sports training. In fact some studies have shown benefits of resistance training as an adjunct to regular training (Christou et al., 2006; Meylan & Malatesta, 2009; Wong et al., 2010). Christou et al., (2006) identified the effect of habitual sports practice within a 16-week resistance training program. The study indicated that lower body strength increased significantly in the group who supplemented resistance training with their sports training regime (58.8%), compared to the group who performed sports training only (33.8%). Meylan & Malatesta (2009) also illustrated this benefit with a plyometric training and regular sports training group exhibiting significant increases in vertical jump (Counter movement jump) performance of 7.9% compared to the regular sports training only group, which showed no improvements after the 8-week resistance training intervention. Wong et al. (2010) found similar results in their 12-week intervention suggesting that habitual sports training alone does
not significantly increase muscular power, but can be improved by resistance training or plyometric training.

Despite Wilson et al. (1993) showing that light load weight training is beneficial for trained individuals, Lyttle et al. (1996) observed untrained subjects not benefitting from light load weight training alone. Rather, the combination of light load weight training with plyometric training generated better results when participants had to perform stretch-shortening cycle (SSC) activities. Perhaps such results may be explained by the fact that plyometric training requires the activation and control of a greater number of muscles and joints at any given time than weight training applied to a single muscle or muscle group, and potentially better facilitates the less trained neural and mechanical mechanisms that determine performance in SSC activities. Similarly, Newton, Kraemer, & Häkkinen, (1999) have shown that 8 weeks of ballistic training, another form of low-load explosive weight training, improved vertical jump performance among elite volleyball players. The study demonstrated ballistic training resulted in enhancements in force, velocity, power, and RFD during jumping on a force plate.

The influence of arm swing on vertical jump

Despite there being a focus on improving muscular strength and activation of the lower limbs, it is important to consider other components of the musculoskeletal system that may have an influence on vertical jump performance. It is important to take in to account the effect of upper limb and trunk strength on vertical jump performance, as it is possible they both influence vertical propulsion. In contrast to the contribution of lower extremities to propulsion, more research is needed in examining thoracic spine and shoulder girdle mobility as determinants of vertical jump and reach performance.

There may be a number of reasons why arm swing might be beneficial for vertical jump. It may, for example, help contribute to the upward momentum of the body ultimately providing more upward propulsion. The force-velocity profile is an important relationship to consider within training methods used to help increase athletic performance. This relationship depicts the neuromuscular properties of muscle whereby the more force that is applied against a greater resistance, the lower the velocity of the muscle contraction. An aim of vertical jump training might be to shift this force-velocity curve to the right to allow application of greater forces at greater velocity, and thus increased power output.

When performing a vertical jump, the individual's arms are swung upwards at high velocity during take-off, to enhance jump height. It has been indicated that a higher jump with arm swing is due to the body mass centre being at a higher vertical position and larger vertical velocity at take-off (Lees, Vanreterghem, & Clercq, 2004). It is believed that shoulders generate work that contributes to the total work during vertical jump with arm swing, this is known as Impart
Energy Theory (Ashby & Delp, 2006; Cheng, Wang, Chen, Wu, & Chiu, 2008). Studies have highlighted the ability of arm swing to improve take-off velocity of a vertical jump by an average of 10% compared to jumping without arm swing (Hara, Shibayama, Takeshita, Hay, & Fukashiro, 2006; Harman, Rosenstein, Frykman, & Rosenstein, 1990; Lees et al., 2004).

It is also thought that arm swing has the ability to increase lower limb work, the hip joint in particular, compared to jumps without arm swing (Cheng et al., 2008; Domire & Challis, 2010; Hara et al., 2006; Lees et al., 2004) in a theory known as the joint torque augmentation theory. Domire & Challis (2010) demonstrated that the use of an arm swing meant that the muscles of the lower extremities involved in the vertical jump, induced more mechanical work as a result (i.e., the product of force and displacement) in the vertical direction. Their study showed that hamstrings and gluteal muscles produced an average of 81 J of vertical work with an arm swing, compared to 36.4 J without an arm swing. Both these results strongly suggest that the use of an arm swing during jumping can contribute to increased jump height.

Floría & Harrison, (2013) found that countermovement jumps with an arm swing facilitate greater vertical propulsion of 18.7% - 22.6% compared to countermovement jumps without arms. These results suggest that muscular strength in regions other than the lower extremity can be important for jumping performance. In this case arm strength provided additional propulsive power generation.

Although upper body exercises are not generally considered a useful form of training for vertical jump, arm movements have thus been identified to have an influence on vertical jump height. This further highlights the importance of considering upper extremity strength and mobility when training for vertical jump and reach performance. Total body strength-training programmes are perhaps the most beneficial for vertical jump performance as they allow for a greater overload stimulus. Moreover, programmes that target the entire body address the development of other musculature which may assist in vertical jump performance, such as those of the arms and trunk.

Despite this there remains different explanations for the cause of increased vertical velocity observed in jumps with arm swings. Some studies indicated arm swing leads to reduced hip extension velocity which, would presumably result in greater hip extension force production, a view supported by Domire & Challis (2010). Other studies oppose these hypotheses, instead crediting the increased hip joint force production to energy restoration as opposed to arm swing work (Lees et al., 2004).

The final influence is the overhead reach component of vertical jump which can presumably be an important determinant of how much force can be generated by arm swing. If the upper extremities are unable to move through a complete arc of movement, free of restrictions from
associated musculoskeletal structures and adjacent regions such as the thoracic spine and scapula, it potentially could limit the amount of work generated.

**Upper limb mobility in sport**

*Why is upper limb mobility important?*

Often, the ability to be as close as possible to an object orientated overhead (e.g. ball or rim) is a great advantage as it improves accuracy in goal-oriented movements as well as reducing the height the legs need to propel the body off the ground. In situations such as when reaching an object directly overhead is a primary objective, the component of spine and shoulder mobility is likely to be relatively important. There are many potential contributing factors to having a reduced thoracic and glenohumeral ROM in athletes. It is important to appreciate the fact that different sports, and even different positions within a sport, require different demands on the body. Having adequate ROM of the joints within the body is important in many sports as it provides the individual with a greater distance to generate force over. On the other hand, excessive ROM could be deemed a disadvantage as it would mean that more work needs to be done for a given movement. Having a good ROM along with symmetry amongst contralateral joints has also been reported to contribute to the reduction in likelihood of injuries (Seminati, Marzari, Vacondio, & Minetti, 2015). Stability of joints is also required to reduce injury, and often comes at the expense of mobility. Joint stability also increases the utilization of generated force by attenuating the amount of force that is leaked or lost. Overhead athletes must command a fine balance of mobility and stability of the shoulder in order to meet their sporting demands (H. C. Crockett et al., 2002).

Reduced upper limb mobility can occur because of a number of different factors across multiple sports. Court-based sports such as basketball, handball and volleyball require repetitive overhead motor patterns which have been associated with reduced upper limb mobility (Baltaci & Tunay, 2004). Often the upper extremity is propelled forward with large amounts of force, with differing degrees of internal and external rotation depending on the sporting action. This is advantageous in performing sporting motor patterns, where objects such as balls are required to be propelled at speed and over distances within a game setting. During these rapid actions the muscle-tendon unit of the rotator cuff experiences brief high eccentric demands as it works to decelerate the upper extremity in many of these actions (Escamilla & Andrews, 2009). On the other hand, sports such as swimming and water polo place a much more constant muscular demand on the athletes’ joints as they propel their bodies through water. Despite the reduced eccentric stress and reduced joint loading in water sports, micro-trauma to the joints from limited muscular recovery between training bouts may be more likely (Allegrucci, Whitney, & Irrgang, 1994; Pink & Tibone, 2000). This may also be less likely due to the fact the studies did not compare the prevalence between sports, therefore it is hard to definitively conclude this is
solely a phenomenon of water sports. In addition, the importance of glenohumeral ROM and its relationship with the thoracic spine needs to be understood in order to attenuate limitations in these ROMs. An understanding of how these limitations come about and why athletes may be susceptible to such restrictions is important. This may, in turn, help with the development of more effective methods for improving musculoskeletal restrictions.

**Glenohumeral mobility**

There is an increased need for glenohumeral external rotation ROM in throwing athletes as they require overhead internal rotational power (Myers et al., 2005). This occurs in manoeuvres such as throwing, in order to maximise the distance over which force can be generated, and allowing for greater final velocity for propulsion. The glenohumeral joint is a primary joint associated with upper limb mobility, and along with its associated muscle-tendon unit forms the main contributing structure to the mobility and stability of the upper limb. Therefore, optimal glenohumeral joint function can be presumed to be vital in facilitating sporting actions. There are a number of changes in an athlete’s body that can result from the demands of training and competition. These changes can occur in the form of biomechanical (Fukuchi et al., 2014), physiological (Costa et al., 2015) or injurious manifestations via a number of mechanisms.

There are presumably a number of common causes of tissue change, both injurious and non-injurious in nature. These different causes of tissue changes have the ability to cause glenohumeral restrictions, potentially having different implications on ROM and glenohumeral strength depending on which soft tissue they effect. Many of the changes that can occur are a result of repetitive actions. The most notable adaptation is muscular hypertrophy. In asymptomatic athletes muscular hypertrophy has been identified as a key contributing factor to shoulder restriction, in particular abduction and internal rotation (Khalaji et al., 2012). When a muscle undergoes repetitive eccentric actions, it results in changes to the sarcomere portion of the muscle (Lauritzen et al., 2009; Lieber et al., 1991; Proske & Morgan, 2001). In response to eccentric exercise induced muscular damage, protein synthesis increases which in turn increases the size of the muscle over time (Isner-Horobeti et al., 2013). This increase in muscle size may reduce the muscles’ ability to lengthen, potentially restricting the ROM about the joint. These hypertrophic changes were demonstrated in a study by Oyama, Myers, Blackburn, & Colman, (2011) who conducted a repetitive shoulder eccentric external rotation exercise program on twenty physically active asymptomatic volunteers. The participants maximally resisted the Biodex Isokinetic dynamometer as it moved their arm into internal rotation at 90°/s for 9 sets of 25 repetitions. The results showed a mean increase in infraspinatus cross-sectional area of 15.7% and reduced ranges of motion of 2.2%, 1.6% and 1.5% for internal rotation, external rotation and horizontal adduction, respectively.

Despite possible ROM restrictions from long term training some data suggest that eccentric
exercise actually has the capacity to improve ROM more than static stretching (Nelson & Bandy, 2004; Nelson, 2006). The studies in question observed the immediate changes following eccentric training (Nelson, 2006), and the effects after a 6 week eccentric exercise program (Nelson & Bandy, 2004). Both studies observed improvements in hamstring ROM greater than those achieved from static stretching.

**Posterior shoulder stiffness**

Another potential cause of restriction is posterior shoulder stiffness. This adaptation to overhead motor patterns has also been indicated in a study by Borsa, Laudner, & Sauer, (2008). Despite the benefits of having optimal ROM, it was identified that male overhead throwing athletes display reduced glenohumeral (shoulder) ROM. A study by Wang & Cochrane, (2001) highlights this deficit in shoulder ROM in overhead throwing athletes. Their results indicate a decreased range of shoulder internal rotation of around 50° in the dominant arm of volleyball players when compared to their non-dominant arm, which they attribute posterior capsule tightness and relatively weak external rotators as a possible cause. Another study by Vairo et al., (2012) report an average active shoulder flexion of 166° ± 8° in a healthy young physically active population.

A tissue which may be a primary cause of posterior shoulder stiffness and reduced shoulder ROM is the capsule itself (Thomas et al., 2011). When a thrower ends the deceleration phase of an overhead action, greater eccentric forces are experienced in the posterior rotator cuff muscles as they contract whilst enduring rapid lengthening in order to stabilise the glenohumeral joint and decrease the velocity of the upper extremity. Due to the repetitive nature of these overhead movements, the rotator cuff muscles may be unable to effectively cope with the eccentric forces due to a lack of strength or fatigue. Ultimately these eccentric forces are transmitted from the muscle to the joint capsule. Although hypertrophy of the posterior capsule may be a beneficial adaptation regarding the stabilization of the glenohumeral joint, it is not considered beneficial for joint ROM, particularly internal rotation. An athlete’s glenohumeral internal rotation can be reduced as much as 12.8° ± 9.4° in their dominant limb irrespective of history of pain (Moreno-Pérez, Moreside, Barbado, & Vera-Garcia, 2015). This pattern of glenohumeral internal rotation deficit (GIRD) of the throwing shoulder is commonly seen amongst overhead throwing athletes.

The relationship between posterior capsular thickening and reduced glenohumeral internal rotation was supported in a study by Thomas et al., (2011) who tested internal rotation, external rotation and posterior capsular thickness of twenty-four asymptomatic baseball players. The study demonstrated significant correlation between posterior thickness and shoulder ROM with results showing the dominant arm experiencing an average increase of 0.38 mm (2.03mm ± 0.27mm dominant arm and 1.65mm ± 0.28mm non-dominant arm) in posterior capsule thickness compared to the non-dominant arm. Also, a 16.5° reduction in internal rotation (58.72°
± 7.03° to 42.19° ± 8.24°) and a 6.25° increase in external rotation (66.01° ± 5.87° to 72.25° ± 6.09°) was observed. The repetitive action of throwing may have caused increased strain on the posterior capsule due to the larger degrees of external rotation observed in the dominant arm. This may suggest there is a longer contractile distance for internal rotation to act over, thus increasing the amount of work undertaken by the shoulder relative to the non-dominant arm. The long term effects of repetitive eccentric exercise are likely to be irreversible as indicated by a review of literature by Tweed & Barnes, (2008) which hypothesized that excessive eccentric contractions correlated with a reduction in compliance and loss of elasticity of the fascia. Reductions in shoulder internal rotation have also been identified in throwers with pain or diagnosed pathologies (Almeida et al., 2013; Dines, Frank, Akerman, & Yocum, 2009; Kinsella, Thomas, Huffman, & Kelly, 2014). These deficits in overhead throwers have ranged from 3° among a sample of baseball players with shoulder pain (Ruotolo et al, 2006), to 8.6° in throwers with diagnosed impingement (Myers et al, 2006), and to as much as 9.3° in throwers with compromised medial (ulnar) collateral ligament of the elbow (Dines et al, 2009).

**Shoulder imbalance and impingement**

Physical requirements and specific motor patterns can lead to maladaptation in the musculoskeletal system (Crockett et al., 2002). Restrictions in joint ROM may result from resting muscle length reduction arising from repeated demands on musculotendinous units sustained over many months or years, as explained by Daneshmandi (2010). It has been observed that athletes who lack flexibility when executing certain motor patterns, such as an overhand throw and vertical jumping, tend to experience a decrease in performance (Hands, 2008). Athletes who frequently execute overhead movements often have sub-optimal glenohumeral ROM which, may lead to the development of shoulder impingement.

Shoulder movement restrictions in overhead and throwing athletes may be exacerbated by the self-selection of motor patterns that rely predominantly on force generation to compensate for a lack in flexibility. This self-selection of advantageous motor skills may be a cause of bias towards either strength, stability or mobility. In sports such as weightlifting or shot put, favouring strength over flexibility could be beneficial for sports performance. It can be hypothesized that this inherent pre-selection results in an increase in one ROM at the expense of another. (Meister, 2000; Seroyer et al., 2009). Longitudinally, these compensatory strategies may lead to the development of musculoskeletal adaptations that severely hamper overhead motor patterns.

There are a number of possible biomechanical changes that may contribute or result in changes to joint ROM. These include imbalances to strength and ROM to the muscles forming the rotator cuff. Imbalances in muscular strength of the rotator cuff may come about from the repeated use of motor patterns in particular sports. This repetitive nature would result in musculoskeletal adaptation to protect the joint from forces associated with the repeated motor pattern. It can also
be presumed that an increase in glenohumeral strength in the dominant limb is advantageous for sporting performance, such as throwing, serving and swinging in sports. Increased glenohumeral strength would also be beneficial in stabilising the glenohumeral joint as it moves through these increased degrees of external rotation seen in throwers, particularly as the head of the humerus moves outside of its normal articulation with the glenoid. Clarsen, Bahr, Andersson, Munk, & Myklebust, (2014) found a significant association between external rotation weakness and an increased likelihood of shoulder pain also seen in a study on volleyball players (Wang & Cochrane, 2001). However, Edouard et al., (2013) found no association between isokinetic external rotation strength and injury in handball players. This perhaps highlights the differences in adaptations and glenohumeral demand between different sports involving repetitive use of the glenohumeral joint, and the differences in the chance of deficits in glenohumeral ROM leading to injury.

Although overhead athletes may demonstrate a reduction in internal rotation of the dominant glenohumeral joint, it is important to understand the effect a relative increase in external rotation may have on sports performance. If the dominant arm achieves optimal external rotation compared to the non-dominant extremity, it is plausible that there is an increased ability to reach overhead unilaterally with the dominant extremity. This imbalance of movement is of particular interest when performing bilateral overhead flexion as it may cause the non-dominant limb to hinder the performance of bilateral overhead tasks. Therefore, although advantageous for repetitive motor patterns seen in dominant arm actions such as pitching and throwing, dominant limb ROM imbalances can become a disadvantage when attempting to perform bilateral motor patterns due to the differences in ROM between dominant and non-dominant extremities.

Reduced shoulder ROM can also result from the impingement of musculoskeletal structures under the subacromial space. Shoulder impingement is frequent among overhead-throwing athletes and physically active adults, and may lead to injuries such as labral pathologies, making participation difficult (Myers et al., 2006). There are reports that as many as 74% of patients visiting general practitioners for shoulder issues present with signs of impingement (Ostör, Richards, Prevost, Speed, & Hazleman, 2005).

The fact that most individuals prefer using one limb over the other generally means one limb will undergo far more repetitive actions than the other. This may explain the changes observed in rapid rotational movements of the glenohumeral joint and deficits in internal rotation of the dominant limb relative to the non-dominant limb. This phenomenon was highlighted by Conte et al., (2009) who compared passive glenohumeral ranges between dominant and non-dominant shoulders of fifty female university students. The results showed movement changes in line with GIRD, with statistically significant decreases in passive internal rotation of - 3.52° (-5.4 to – 1.64) and increases in external rotation of 4.74° (1.61 to 7.87). These findings suggest that handedness
alone is enough to create movement deficits, as the participants were not of a particular sport. Additionally, these findings may imply that these passive ROM restrictions are much more pronounced in overhead athletes. However, this cannot be concluded based on the results of this study alone. As a large number of athletes will continue to favour a particular side when executing sporting actions, handedness or dominance will continue to influence the integrity of the associated tissues (Thomas et al., 2011). Once the tissues potentially responsible for sub-optimal movements have been identified, it is beneficial to identify the exact movements they limit.

In summary sports performance and mobility have a reciprocal relationship, in which changes in one is likely to influence the other. The degree of change in shoulder mobility is variable and sport dependent. In order to ensure optimal sports performance and injury avoidance careful consideration into the degree of mobility desired in a given joint needs to take place. This is due to the fact that decreased and excessive joint ROM both have the ability to benefit certain motor pattern performance as well as increase the likelihood of injury.

**Thoracic spine mobility**

Both thoracic spine mobility and the relationship between scapular and thoracic mobility are thought to be important for functional arm movement. Identifying what factors cause sub-optimal ROM in the thoracic spine and shoulder may be beneficial in improving sports performance. Thoracic spine extension is important for normal shoulder girdle function according to Edmondston et al. (2012). This requirement of optimal thoracic extension in order to achieve full-range arm elevation is supported by studies using thoracic posture modification to improve ROM in patients with subacromial impingement (Bullock et al., 2005; Lewis et al., 2005). The results from these studies also highlight the influence thoracic motion has on arm elevation in young asymptomatic males, despite this relationship varying among individuals. In order to achieve full bilateral arm elevation, asymptomatic males should be able to achieve a mean range of 12.8° ± 7.6° of thoracic extension according to radiographic imaging at least 10.5° ± 4.4° according to photographic analysis (Edmondston et al., 2012). Edmondston et al., (2012) suggest that the inability to achieve these ranges of thoracic extension may lead to inability to achieve full bilateral arm elevation, or result in pain from excessive tissue stretch needed to overcome such deficits in the thoracic spine. It has been demonstrated that even small reductions in thoracic extension have the ability to negatively influence glenohumeral biomechanics, and may contribute to the development of pathologies that limit range of motion such as subacromial impingement (Kalra, Seitz, Boardman, & Michener, 2010).

The coordinated relationship between the ROM of scapulothoracic articulations and the glenohumeral joint is needed to achieve effective overhead reach. An efficient relationship between the thoracic spine and scapular of the shoulder girdle, known as the scapulothoracic
rhythm, is possibly key in the overhead component of vertical jump. This movement relationship is important as the scapular’s movement across the thoracic cage and the thoracic vertebrae movements have a direct influence on each other. If an athlete has reduced unilateral or bilateral upper extremity overhead ROM, this can dramatically decrease their ability to perform overhead arm actions and increase the vertical jump height needed to reach a particular height. Crosbie et al. (2008) investigated the coordination of humeral, scapular and thoracolumbar spine motions during a number of unilateral and bilateral upper limb movements. Their results consistently showed synchronous scapular, humeral and thoracic segment interactions independent of age, weight or height. Therefore, it can be presumed that scapulothoracic rhythm is important in achieving overhead reach, as elevation of the arms in all planes depends on both the shoulder girdle and thoracic spine. It can be further hypothesized that a restriction in either one of these areas could influence the other and decrease the overall overhead ROM.

Posture

Although the anatomical link and functional relationship between spinal posture and shoulder kinematics is known, postural assessments are still scientifically inaccurate or expensive. Despite this, studies have used radiography and photography to determine the ideal spinal positions to achieve arm ROMs. For instance, Edmondston et al., (2012) investigated radiographic and photographic measures of thoracic kyphosis. Their findings indicated that a neutral spine should have 28.7 – 31.5° of kyphosis and should be able to extend 10.5 - 12.8° with full bilateral arm elevation.

In humans, the sole attachment of the upper limb to the trunk is via the scapular, which directly articulates against the thoracic region of the body via the thoracic cage. It can be assumed that any deviations from ideal postures of the thoracic spine or changes in head or shoulder alignment will directly influence the shoulder’s range of motion. Many muscles, including the sternocleidomastoid, trapezius and rhomboids, attach between the spine and the scapular, indicating that any aberrant postures adopted by either one will influence the other.

Forward head posture is a term commonly used by manual therapists as a postural indicator, and can have implications on shoulder mobility. It occurs due to a habitual increase in cervicothoracic flexion, and subsequent reduction in cervicothoracic extension (Thigpen et al., 2010). Thigpen et al., (2010) showed that the scapular had to move an average of 3° more in individuals with increased forward head posture than that of individuals with correct head posture. This increase in scapular ROM resulted in increased scapular muscle activation of the upper trapezius muscles in flexion tasks and both the upper and lower trapezius muscle in reaching tasks. The benefits of correcting undesirable postures, such as forward head posture and rounded shoulders, was highlighted by Kwon, Son, & Lee, (2015). Their findings demonstrated people with a forward head-rounded shoulders posture benefited from having their posture changed to ideal head
posture or correct head posture, as it improved shoulder kinetics and muscle activity during overhead reaching tasks when compared to individuals who adopted a natural head position.

Movement deficiencies of the shoulder from reduced scapular motion can also result from changes in spinal posture in lower regions of the thoracic spine than those seen at the cervicothoracic junction in forward head posture. This was highlighted by Greenfield et al. (1995) who showed individuals with increased mid-thoracic curvature were able to achieve less humeral elevation. The study compared 30 healthy shoulders to 30 painful ones, the painful shoulder group had a mean mid-thoracic curvature of $38^\circ \pm 10.7^\circ$ compared to $34^\circ \pm 11.5^\circ$, and were able to achieve only $144^\circ \pm 24.4^\circ$ of humeral elevation compared to $159^\circ \pm 9.3^\circ$ in the healthy shoulder group. Greenfield et al., (1995) also illustrated forward head posture significantly correlated with lower humeral elevation. These results may indicate that reductions in spinal ranges will reduce the ability to elevate the upper extremity overhead. Additionally, the use of head posture may be a feasible tool to screen for inclusion into the study outlined in this thesis. Alternatively, the results from Greenfield et al. (1995) study may be interpreted as indications that people with chronically painful shoulders adopt postures which result in increased kyphosis.

The study by Edmondston et al., (2012) also highlighted a significant correlation between the amount of thoracic kyphosis measured in a neutral standing posture and kyphosis in full arm elevation. This suggests individuals with increased thoracic kyphosis in a neutral posture would have a more flexed thoracic spine in full bilateral arm elevation. Any limitation in thoracic extension would also have a negative effect on arm elevation as well as absolute reach height due to increased spinal curvature. This is supported by Bullock et al. (2005) who demonstrated having a more extended end range position of thoracic spine enabled a greater degree of arm elevation of $127.32^\circ$ compared to $109.65^\circ$ in a slouched kyphotic posture.

**Injury prevention**

There are a number of key factors attributed to risk of injury, and efforts must be made to carefully manage and minimise potential causes of injury without negatively influencing sports performance in athletes. Risk factors include previous injuries with Saragiotto et al. (2014) revealing that 62% of the studies they reviewed highlighted history of an injury usually in the past 12months as a factor. The study also reported biomechanical changes, higher quadriceps angle of the knee (Q angle) in runners, also had a significant influence on the risk of injury as well as the frequency of training. Despite Saragiotto, Yamato, Hespanhol Junior, et al. (2014) focusing on runners, it can be presumed that the results from their review would be applicable to other sports such as basketball.

The shoulders of throwers are prone to injury when restrictive changes such as attenuation of
anterior capsular constraints or acquisition of a posterior capsular contracture are present (Kinsella et al., 2014). In some instances having good ROM reduces the chance of injury, as shown by Verrall et al., (2007). The prospective cohort study recruited 29 asymptomatic elite Australian football players over the course of two seasons, of whom four developed chronic groin injuries. Verrall et al. (2007) demonstrated that the four players who developed chronic groin injuries had a decreased joint ROM preceding the development of injury.

There are other examples in which sub-optimal ROM increase the risk of tissue injury. Mendonça et al. (2015) showed reductions in iliotibial band (ITB) flexibility (under -0.02°/kg) or increased shank-forefoot alignment above 24° were associated with a 4 – 5 times greater risk of patella tendon abnormalities, compared to athletes with values under the cut-off points. These abnormalities were defined as a tendon possessing hypoechoic regions in both the transverse and longitudinal planes. Although not a direct measure of actual injury rates, the presence of patella tendon abnormalities suggests some level of tissue damage resulting from these deficits in movement. From this information it is plausible to assume that abnormal ranges of motion in other joints, both increased and reduced, have the same potential to cause tissue damage, and therefore can be used as an indicator for the likelihood of injury.

An earlier study by McDonough & Funk (2014) supported the notion that reductions in joint ROM are associated with injury. The injured group had bilateral reductions in glenohumeral internal rotation (36.6° left, 38° right) compared to the non-injured group (47.8° left, 45.3° right). However, it is difficult to conclude that the injuries observed resulted solely from reductions in ROM as the study recruited rugby league players who frequently experience collisions. Motor actions such as tackling and passing under impact are inevitably going to stress the tissues associated with the shoulder complex, ultimately increasing the likelihood of injury. The study supports this with only one of the eight players developing shoulder injuries resulting from an atraumatic onset; all other injuries resulted from being tackled, tackling or direct contact with the ground. Although a small cohort of participants (n = 22) was examined, 36% of them received a total of eleven injuries indicating that shoulder injuries are prevalent in rugby league. The study also supports incorporation of interventions aimed at restoring normal ROMs as a means of injury prevention.

Clarsen et al. (2014) tested shoulder internal and external rotation ROM, isometric strength of internal rotation, external rotation and abduction, as well as scapular control of 206 professional handball players. The study identified several internal risk factors associated with shoulder injury, in particular a reduction in the summative internal and external rotation of the shoulder. This refers to the total amount of internal rotation and external rotation of the glenohumeral joint in question. As previously outlined, reductions in internal rotation and increases in external rotation have been seen throughout literature in the dominant limb of uninjured athletes who
commonly complete overhead arm movements as part of their sport (Almeida et al., 2013; Manske, Wilk, Davies, Ellenbecker, & Reinold, 2013; Myklebust, Hasslan, Bahr, & Steffen, 2013; Trakis et al., 2008; Wilk et al., 2011). Not only can performance be affected by this directly, but the mobility imbalance may predispose injury. For example, glenohumeral deficits of internal rotation over 20° have been deemed to be a significant risk factor for injury in baseball pitchers (Wilk et al., 2011). In general, loss of glenohumeral internal rotation is also a known risk factor for chronic pain (Shanley et al., 2011, 2012; Wilk et al., 2011).

It is important to consider that 75% of the participants in the study by Clarsen et al., (2014) reported a history of shoulder pain associated with handball, and 32% were currently suffering from shoulder pain. This consideration is paramount because a history of shoulder pain may indicate potential underlying musculoskeletal adaptations have taken place, which may ultimately contribute to any changes in ROM. The participants with reported shoulder pain at the time of testing may have adopted antalgic movement patterns (i.e. alterations in movement to alleviate pain). These adjustments in movement patterns may in turn have an effect on the observed internal rotation ROM, external rotation ROM, isometric strength and scapular control.

Often athletes and coaches alike utilise stretching as a means to combat deficits in soft-tissue and joint ROM, provide analgesic action in order to improve muscular extensibility, and reduce injury occurrence or reoccurrence. Research on stretching’s ability to reduce injury is mixed. Smith (1994) conducted a review of literature on stretching, and identified that its resultant improvement in ROM directly contributes to injury prevention. This conflicts with a systematic review by Yeung, Yeung, & Gillespie (2011) on interventions for preventing lower limb soft-tissue running injuries. The review included six trials on stretching. They concluded that there was no evidence supporting the stretching of all lower limb muscle groups as a means of reducing the number of lower limb soft-tissue injuries, or the rate of injury. Shrier (1999) conducted a review of twelve studies and evaluated the evidence for stretching immediately before exercise by reviewing twelve studies. The review showed that only four out of the twelve studies indicated stretching was beneficial each of them used multiple interventions, not just stretching in isolation. The review also highlighted that stretching before exercise alone had no significant effect on the reduction of injury rates, instead showing a trend towards a higher injury rate in individuals who stretch.

However, it can be presumed that static stretching increases tolerance to stretch induced discomfort, giving the individual the sense of better function. Performers may associate pain and discomfort with injury and pathology, although in most cases a tight muscle following prolonged muscular action has not necessarily resulted from an injurious process. Instead this is a normal physiological response to exercise. With that in mind, one may interpret the findings of Smith (1994) as a demonstration of static stretching improving tolerance to muscular tightness rather
than reducing injury per se. If muscle tightness is present, this may alter the biomechanics and motor pattern performance in a way that avoids such discomfort. However, this alteration may also make individuals more susceptible to injury due to hyper-compliant tissue.

Enhanced upper body ROM may facilitate improvements in performance in sports involving throwing, while simultaneously attenuating injury. Furthermore, the resultant decrease in required shoulder flexion may be associated with a decreased risk for certain shoulder injuries. There have been a number of other studies which also hypothesise the injury prevention effect of improved shoulder range of motion (Kaplan et al., 2011; Schmidt-Wiethoff et al., 2004). Despite this, many studies have failed to indicate a relationship between shoulder ROM deficits and increased injury rates (Bak & Magnusson, 1997; Stuelcken, Ginn, & Sinclair, 2008; Wang & Cochrane, 2001).

The effect of osteopathy and manual therapy on joint and soft-tissue function
Numerous techniques are employed by osteopaths as part of osteopathic manipulative treatment (OMT). Four methods that are commonly employed to improve ROM include: (1) muscle energy technique; (2) high velocity low amplitude thrust (HVLA); (3) myofascial active release and (4) soft tissue massage. Techniques such as muscle energy technique and active release share similar characteristics to stretching techniques seen in the sporting and exercise settings. The use of such osteopathic techniques in place of current conventional stretching techniques in a sports setting is relatively unknown, and careful evaluation of both should be taken to make an accurate assumption concerning their potential benefits.

Stretching effect on shoulder ROM
The prescription of stretching is commonly issued as a means of treating restrictions caused by connective tissues. There are, however, multiple forms of stretching. Each method has been shown to have benefits in different settings. In active muscle, it is important to apply dynamic stretching rather than static stretching, the latter potentially having a negative effect on athletic performance. This was demonstrated in the randomized cross-over study by Hough et al. (2009) on the effect of static and dynamic stretching interventions on vertical jump performance. The study found that static stretching to the plantar flexors, hip extensors, hamstrings, hip flexors and quadriceps femoris reduced squat jump performance by an average of 4.2% compared to dynamic stretching and no stretching groups. This indicates that the acute effects of static stretching administered directly to muscles responsible for generating propulsion, decreases their ability to generate force.

As previously discussed, the upper limbs play a role in generating upwards propulsion in a vertical jump and reach task. As lower limb musculature is the primary source of propulsion, it
could be presumed that applying static stretches to muscles of the upper limb may not negatively influence propulsion, and may have a positive effect on the reach component of vertical jump. One study tested the effect of upper limb static stretching on maximal vertical jump performance (Marchetti et al., 2014). They applied static stretch to the upper limb by placing the subject’s hands behind their head, raising their arms above their shoulder joints and then moved their arms into horizontal abduction. This was shown to decrease maximal vertical jump performance, but increase shoulder ROM. The study showed a peak force reduction of 25% and peak propulsion duration increase of 24%. In contrast, several studies have shown that stretching causes significant improvements in posterior shoulder tightness (Cools, Johansson, Cagnie, Cambier, & Witvrouw, 2012; Manske, Meschke, Porter, Smith, & Reiman, 2010; Tyler, Nicholas, Lee, Mullaney, & McHugh, 2010). This would appear to benefit the reach component of vertical jump performance.

The above information on static stretching suggests incorporating active and dynamic forms of stretching may be of greater benefit in instances where maintaining muscular force generation with improvements to ROM is important. There are a number of osteopathic techniques which induce soft tissue stretch, including muscle energy technique and myofascial release. Osteopathic techniques such as active release and muscle energy technique utilise active muscular contractions to address musculoskeletal restrictions. These techniques, along with other manual therapy techniques, may have the ability to improve function without compromising sports performance in the sporting setting.

**Muscle energy technique**

Muscle energy technique is a manual therapeutic treatment procedure that involves the voluntary contractions of the patient’s muscle in a precisely controlled direction at varying levels of intensity against a distinctly executed counter force (DeStefano, 2011). Muscle energy technique consists of passively finding a point of muscular restriction. Once located the practitioner then instructs the patient to resist as they apply force in the direction of the restricted ROM creating a controlled isometric contraction in order to improve ROM and function. Various sources cite different durations for MET to be administered during the contraction phase of muscle. Time periods range from 3 – 10 seconds with a number of osteopathic sources indicating 3 – 7 seconds for 3 – 5 repetitions (American Osteopathic Association, 2003; DeStefano, 2011). Based on this information it could be presumed a MET held for 7 seconds for 3 repetitions on any given muscle would be deemed an appropriate duration to expect changes in ROM where it is being administered. There appears to be limited research on the effect duration for muscle energy technique, with literature indicating the improvements in pain can last 24hours (Selkow et al., 2009) and the improvements in ROM as much as a week (M. Smith et al., 2008).
Muscle energy technique is similar to that of proprioceptive neuromuscular facilitation (PNF) used by physiotherapists. In many instances the procedures described are identical. One potential differentiation between the two is the emphasis on the practitioner identified barrier or point of muscular restriction. In the instance of muscle energy technique this perceived barrier is deemed physiological. The initial bind felt in the muscles length prior to the activation of the muscle spindles, often meaning the manual therapist administering the technique feels the bind but the patient cannot. Proprioceptive neuromuscular facilitation on the other hand seems to emphasise the physical barrier predominantly, that being the length to which the muscle can be stretched, resulting in a barrier the patient feels. The other differentiation is the amount of patient force during isometric contraction phase of both techniques, with proprioceptive neuromuscular facilitation typically using more force.

Proprioceptive neuromuscular facilitation has been shown to improve hamstring flexibility in males and females, by 9.6° on average for self-administered proprioceptive neuromuscular facilitation and 12.6° for physiotherapist applied proprioceptive neuromuscular facilitation. These improvements in ROM are echoed in studies assessing muscle energy techniques effect on the shoulder. When administered to the musculature of the trunk, thoracic spine rotation increased by 10.66° ± 9.80° (Lenehan et al., 2003). Muscle energy technique has also been shown to increase horizontal adduction at the glenohumeral joint by 6.8° ± 10.5° when applied to the associated muscles of the shoulder (Moore et al., 2011).

The observed improvements in thoracic and glenohumeral ROM from these studies (Lenehan et al., 2003; Moore et al., 2011) is of importance to athletes participating in overhead activities. Previous reports have identified overhead athletes often show decreased glenohumeral ROM, which may potentially increase the risk of injury or pathology. Moore et al., (2011) showed acute improvements in glenohumeral ROM into horizontal adduction and internal rotation in asymptomatic baseball players immediately after receiving MET. The results from this study support the validity of including MET as a means to improve overhead ROM.

Previous investigations have also examined the duration of effects associated with MET. A randomized controlled trial by Oliveira-Campelo et al. (2013) showed participants receiving MET to upper trapezius muscles had a large immediate increase in ROM of cervical spine movements (flexion increased by 4.4% and extension by 4.9%). The increase in ROM was maintained at both 10 minutes' post-intervention and 24 hours' post-intervention compared to the control group. The same was true for the passive stretch intervention in this study, indicating 7 days between interventions in a crossover study would be an appropriate time period to limit carry-over effects of MET treatment.

Soft tissue massage & myofascial release

Soft tissue massage is often used in manual therapy to alter the tone and extensibility of the
tissue it is being applied to. Massage has been shown to cause acute increases to joint ROM as shown in a study by Crosman et al., (1984) in which hip flexion increased by 10.6° ± 8.6° relative to 2.4° ± 6.3° in the control group, and knee extension increased by 3.8° ± 3.1° relative to 1.6° ± 2.3° in the control group. Both the experimental group and control group had passive ROM measurements taken prior to receiving a standardized massage treatment to one of their legs at random. Following the intervention both groups had their measurements taken again for both legs. It should be noted only the massaged leg data for the experimental group was analysed and the control group had the non-massaged leg measurements analysed.

Another technique often prescribed, both to be administered by the practitioner, and to be performed by the patient, is myofascial release. Myofascial release aims to reduce restrictive fibrous adhesions between layers of fascia, which are believed to occur in response to injury, inactivity or inflammation (MacDonald et al., 2013). Myofascial release can be administered both actively and passively, just like stretching. It works on the premise that direct manual pressure over an identified adhesion in the fascia, usually in the form of a tender point that may or may not be nodular in feel, with stretch then induced by either the practitioner or via the patient activating related muscles. With the manual pressure in place, either by practitioner applied force or by use of an instrument such as a foam roller, small undulations about this point of pressure place direct and sweeping pressure onto the underlying soft-tissue. This creates friction and subsequent warming of the fascia encouraging the fascia to develop more fluid-like properties (thixotropic property of fascia) breaking up adhesions between fascial layers and in turn restoring soft-tissue extensibility (Sefton, 2004).

As previously mentioned the concern around stretching techniques such as static stretching is the acute reduction in muscular performance. This is not ideal when being administered in game settings or as part of a training program. Myofascial release has demonstrated the ability to improve ROM of the joints it’s being applied to. A study by MacDonald et al., (2013) applied myofascial release to the quadriceps of eleven healthy physically active males. They demonstrated that self-myofascial release was an effective treatment to acutely enhance knee joint ROM, by 10.6° ± 6.7° at 2 minutes and 8.8° ± 5.5° at 10 minutes following administration, without a detrimental effect on muscle performance. The findings of a later study by Macdonald et al., (2014) further supported the beneficial effects of foam rolling indicating it is able to attenuate muscle soreness while improving vertical jump height, muscle activation, and ROM compared with a control. Peacock et al., (2016) also demonstrated that foam rolling applied in either the frontal or sagittal plane, had the ability to increase both flexibility and athletic performance in athletically trained males.

**Spinal manipulative therapy**

Spinal manipulation is administered by osteopaths, manual therapists and chiropractors to treat an array of musculoskeletal disorders, most commonly back and neck pain originating from sub-
optimal mechanics, headaches and spinal stiffness (Goertz, Pohlman, Vining, Brantingham, & Long, 2012; Kuczynski et al., 2012; Michaleff, Lin, Maher, & van Tulder, 2012; Rodine & Vernon, 2012; Vernon, 2003). A significant issue with research of the effect of spinal manipulation is that a clear definition is often lacking, and terms such as ‘joint manipulation’ and ‘joint mobilisation’ are frequently used interchangeably (Mintken, Derosa, Little, & Smith, 2008).

Vertebral joint manipulation is also referred to as high velocity low amplitude (HVLA) mobilization. Spinal HVLA is aimed at restoring vertebral joint mobility and reducing soft tissue tension around the joints. Parsons & Marcer, (2006) explain that HVLA has been shown to increase segmental mobility by freeing up vertebral facet joints and surrounding musculature. This was also supported by Fernández-de-las-Peñas et al., (2007) and Vieira-Pellenz et al., (2014), whose studies demonstrated an increase in all cervical spine motions by an average of 4.3° following a single thoracic spine manipulation, and improved hip flexion of 13.7° following an L5 – S1 spinal manipulation. Although these studies do not directly assess changes in thoracic mobility, it may be presumed HVLA improves ROM in the thoracic segments as well. According to Ernst (2006), spinal mobilization has also been shown to correlate with positive physiological effects, such as the reduction of muscle spasms and inhibition of nociceptive transmissions. However, there have been numerous studies investigating the effectiveness of thoracic spine manipulative treatment that have produced varying results. Furthermore, there appears to be a paucity of research on the mobility of the thoracic vertebrae following spinal manipulation.

**Conclusion**

Currently there is a lack of literature on the effect osteopathic techniques have on sports performance. In particular, there is a scarcity of research on the influence osteopathic methods have on vertical jump and reach performance. Often, attempts at improving vertical jump muscular strength and power are made using training methods such as, plyometric training, weight training and resisted jump training, which focus on the lower limb. They have been shown to yield significant improvements in muscular strength, with combinations of training methods producing the greatest improvements. Despite this, these training methods are time consuming and have been shown to have smaller effect in highly trained populations.

The mobility of upper limb and thoracic spine are additional critical components of the vertical jump to consider. Mobility of these segments enable athletes to reach overhead and generate additional vertical propulsion. It is important to appreciate the relationship between thoracic spine mobility and posture, shoulder complex ROM and ultimately the ability to reach overhead. Therefore, it is reasonable to presume future interventions should seek to address any restrictions in all these areas when examining performance in jumping tasks. Conventional methods used to improve ROM commonly consist of passive static stretching and have demonstrated effectiveness in increasing ROM. However, these methods have also been shown to
acutely reduce muscular performance (Hough et al., 2009). Given this, there is justification for the implementation of active mobilization techniques such as manipulation, MET and active release as a means to improve ROM. There is also justification for examining the use of these methods to limit any reductions in vertical propulsion. Muscle energy technique (MET) has been shown to improve joint ROM, however, there is a lack of investigation concerning its resultant effect on muscular power or sports performance. As sporting situations often require and benefit from immediate changes in function, the development of an acute intervention would be more fitting, compared to concentrating on long lasting treatment effects and implementation of time consuming training protocols. The development and investigation of a study would appear appropriate in an effort to identify whether osteopathic techniques can influence ROM in the desired joints, and whether improvements to these regions of the upper body will result in improved jump and reach performance.
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Note:
This manuscript has been prepared in accordance with the guidelines provided by the Journal of Strength and Conditioning Research which can be viewed here: http://edmgr.ovid.com/jscr/accounts/ifauth.htm. The manuscript is formatted for submission to this journal. For the purposes of the Masters course I have added tables and figures in text rather than at the end of the document, as requested by the Journal of Strength and Conditioning Research. The section ‘Practical Applications’ has also been included with journals requirements for the section in italics.
The acute effects of a standardised osteopathic manual therapy protocol on the vertical jump and reach performance in healthy basketball players: A cross-over design

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Running title: Effect of osteopathic techniques on vertical jump in basketball players

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The acute effects of a standardised osteopathic manual therapy protocol on the vertical jump and reach performance in healthy basketball players: A cross-over design
ABSTRACT

The purposes of the study were to determine the acute effects of upper body manual therapy when performing vertical jump and reach in basketball players, and to quantify the contribution of arm swing to ground reaction force during a counter-movement jump. Thirteen semi-professional to professional basketball players received two 15-minute standardized osteopathic manual therapy protocols one week apart, one implemented to the upper extremity and thoracic spine and a control implemented to the lower extremities, in a balanced, randomized cross-over design. Vertical jump and reach height and peak ground reaction forces with and without arm swinging were measured before and immediately following both protocols. Vertical jump and reach height (mean ± SD) was improved in the group receiving upper body manual therapy (59.3 ± 10.3 cm to 62.1 ± 9.8 cm) compared to the control group (59.3 ± 9.7 cm to 58.3 ± 9.7 cm; p < 0.001 for Time x Protocol interaction). The between-protocol differences were retained when adjusting for changes in peak ground reaction forces. Arm swing increased peak ground reaction force from 2187 ± 357 N without arms to 2330 ± 337 N (p = 0.005 for effect of arm swing). It appears that applying brief upper body manual therapy treatment improved overhead jump and reach height in high level basketball players. The application of these osteopathic techniques could be beneficial for immediate in-game enhancements of vertical jump performance.

Key words: Range of Motion, Articular; Musculoskeletal Manipulations; High Velocity Low Amplitude Thrust; Muscle Energy Technique; Shoulder; Athletic Performance
INTRODUCTION

Performance during vertical jumping tasks is considered a critical attribute in an array of sports, in particular court-based sports such as basketball (Kellis, Tsitskaris, Nikopoulou, & Mousikou, 1999) and volleyball (Sheppard et al., 2011). Jump ability enables the athlete to achieve a greater overhead reach for offensive or defensive objectives (for example in a volleyball spike or basketball layup). There are likely to be two main determinants of the jump and reach height achieved: muscular power generation and the mobility of the thoracic spine and shoulder girdle.

Power generation achieved by the lower extremities depends primarily on the rate of lower limb concentric muscular force development (McNeely & Sandler, 2006). Current training methods aim to improve power output of the lower extremities and have focused on resistance weight training (Arabatzi et al., 2010), plyometric training (Markovic, 2007), resisted jump training (Carlson et al., 2009) and combination training methods (Maio Alves et al., 2010). Despite the focus on lower extremity conditioning for vertical jump performance, there is substantially less literature on the role of the upper body. The arms have an important role in coordinating muscle action of the lower extremity to maximize force production, (Domire & Challis, 2010), independently contributing to upward force generation, and by increasing the duration that upward force is generated over (impulse) (Floria & Harrison, 2013). Furthermore, the ability to be as close as possible to an object orientated overhead (e.g. ball or rim) is of great advantage as it improves accuracy in goal-directed movements as well as reducing the height the legs need to propel the body off the ground. This is reflected in a study by Okazaki & Rodacki, (2012) whose results suggested that a reduction in ball release height and release angle, in addition to the increase in balls release velocity, were potentially the main factors that decreased shot accuracy. Therefore, a reduction in overhead reach height would be comparable to a reduction in release angle like that described in their study. Players should look for release angles of shooting that provide an optimal balls release velocity to improve accuracy. In these situations, the component of shoulder region mobility is likely to be relatively important compared to propulsion from the ground.

Overhead athletes command a fine balance of mobility and stability of the shoulder in order to meet their sporting demands (Crockett et al., 2002). Having a good range of motion (ROM), and having symmetry between the same joints on opposing sides of the body, has also been reported to contribute to the reduction in likelihood of injuries.
There are many potential contributing factors to shoulder region mobility, entailing glenohumeral, scapulothoracic, and thoracic ranges of motion (ROMs). Increased compliance of related tissues may be exacerbated by subacromial impingement, muscle hypertrophy and capsular changes. The demands of sporting performance may also exacerbate tissue changes that cause these restricted ROM (Borsa et al., 2008). Muscular hypertrophy and increased compliance have been identified as a key contributing factor to shoulder restriction in asymptomatic athletes, in particular for abduction and internal rotation (Khalaji et al., 2012). The shoulder capsule can also undergo changes that lead to altered ROM, such as regional thickening from frequently decelerating the arm after an overhead action (Thomas et al., 2011). These tissue changes occur when the eccentric lengthening forces generated by the rotator cuff muscles to decelerate the arm fail to adequately stabilize the glenohumeral joint leading to capsule stress. Furthermore, reduced shoulder ROM can result from the impingement of musculoskeletal structures under the subacromial space. Shoulder impingement is frequent among overhead-throwing athletes, particularly in the physically active adult population, and may lead to inability to participation in sport, and other injuries such as labral pathologies (Myers et al., 2006). Studies have highlighted the importance of optimal thoracic extension in order to achieve full-range arm elevation and improve ROM in individuals with subacromial impingement (Bullock et al, 2005; Lewis et al, 2005).

There is a paucity of research examining the effect of improving limitations in shoulder girdle mobility and thoracic extension and the subsequent influence on overhead reach in vertical jumping. Three manual therapy techniques commonly employed in osteopathic practice to improve ROM include muscle energy technique, high velocity, low amplitude thrust, myofascial active release, and soft tissue massage. Techniques such as muscle energy technique and myofascial active release share similar characteristics to stretching techniques used in sporting and exercise settings. However, static stretching of the lower limb muscles prior to vertical jumping tasks can be acutely detrimental to vertical jump performance, with static stretching to the plantar flexors, hip extensors, hamstrings, hip flexors and quadriceps femoris reducing vertical jump performance by an average of 4.2% compared to dynamic stretching and no stretching (Hough et al., 2009). Conversely, muscle energy technique has more characteristics in common with dynamic stretching. Muscle energy technique is a manual therapy technique that involves the voluntary contractions of patient muscle in a precisely controlled direction at varying levels of intensity against a distinctly executed counter
force (DeStefano, 2011). Applying muscle energy technique to associated muscles groups has been shown to increase ROM of horizontal adduction at the shoulder by 6.8° ± 10.5° when applied to the associated muscles of the glenohumeral joint (Moore et al., 2011). It has also been shown to increase thoracic spine rotation by 10.66° ± 9.80° (Lenehan et al., 2003). This indicates the use of such techniques might be viable as an alternative to static and dynamic stretching. It is also possible that muscle energy technique does not have the same negative effects on force production.

High velocity low amplitude thrust applied to vertebrae of the spine, is thought to possess the ability to increase segmental mobility by freeing up vertebral facet joints and surrounding musculature (Parsons & Marcer, 2006). Improved mobility was shown by Fernández-de-las-Peñas et al. (2007) and Vieira-Pellenz et al. (2014), whose studies demonstrated an increase in all cervical spine motions by an average of 4.3° following a single thoracic spine manipulation and improved hip flexion of 13.7° following an L5-S1 spinal manipulation.

Performance in vertical jump and reach tasks is generally accepted as a useful tool for indicating performance capabilities in many sports (Behringer et al., 2007). We hypothesized that an osteopathic upper body protocol would improve overhead ranges of motion (ROM) in bilateral glenohumeral forward flexion and thoracic extension that were limiting Vertec jump and reach height performance. Therefore, it is of great importance to examine potential interventions that provide a practical method of improving vertical jump and reach performance. The aim of this study was to assess the effects of a standardised osteopathic intervention protocol on vertical jump and reach performance. A secondary aim was to assess the influence of an arm swing in overall vertical propulsion.

**METHODS**

**Experimental Approach to the Problem**

A randomized cross-over design was implemented with the conditions being applied one week apart on the same day of the week and time of the day. Participants were blinded to the existence of a control condition, by not being made aware that one of the conditions (an upper body manual therapy treatment) was designed as the active treatment whilst the other (a lower body manual therapy treatment) was designed as the control. They were told that the aims of the study were to assess the effect of two
different manual therapy packages on jump height. Participants were also blinded to the other group’s treatment prior to cross-over. In addition, study personnel who assessed the outcomes were blinded to which condition the participant had received at that session and the practitioner performing the treatment was blinded to the participants’ outcome scores. The effectiveness of the blinding of participants was checked following the conclusion of the study by asking each participant which of the protocols they thought were effective.

Subjects
Male basketball players aged between 18 – 37 years who played basketball at least at a semi-professional level in the last 18 months were recruited for the study through social media, local basketball association notice boards, and direct contact with managers of local Auckland-based associations. Exclusion criteria included any previous shoulder surgery, dislocation, any shoulder pain that affected shoulder function verbal rating scale (score of ≥1), current lower extremity of pelvic injuries that could affect vertical jump, any cardiac symptoms, such as heart palpitation, shortness of breath, or chest pain any previous or current diagnosis of thoracic outlet syndrome or frozen shoulder and any recent (< 6 months prior) or current neurological symptoms.

Prior to testing, all participants were visually screened for the presence of reduced thoracic extension on bilateral overhead forward flexion of the upper extremities by raising their arms above their head. Participants were deemed as having restriction if thoracic extension was required to achieve bilateral forward flexion or if bilateral forward flexion was <180 degrees from the anatomical position.

All 13 participants enrolled in the study played at least semi-professional level basketball and completed both interventions one week apart with no injuries or drop outs. The sample included a spread of player positions (3 centers, 5 forwards and 5 guards). Their characteristics are shown in Table 1.
Table 1. Participant characteristics

<table>
<thead>
<tr>
<th></th>
<th>Mean ± SD</th>
<th>Range</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>23.2 ± 2.3</td>
<td>20.4 to 28.0</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>89.9 ± 13.4</td>
<td>75.8 to 111.8</td>
</tr>
<tr>
<td>Height (m)</td>
<td>189.6 ± 7.7</td>
<td>176.4 to 204.7</td>
</tr>
<tr>
<td>Body mass index (kg/m$^2$)</td>
<td>24.9 ± 2.5</td>
<td>21.4 to 27.6</td>
</tr>
<tr>
<td>Standing Reach (cm)</td>
<td>237.6 ± 12.3</td>
<td>226.5 to 268.5</td>
</tr>
</tbody>
</table>

An allocation schedule was produced prior to testing using the website http://www.randomization.org to create a block randomization schedule for the two condition orders. The schedule was held by an investigator not involved in the recruitment process and concealed from those recruiting participants. It was delivered to the testing site on the day of testing. A person not involved with either the intervention or control administration or in the measurement of outcome variables directed participants to receive the correct condition allocated.

A sample size of 15 male basketball players was originally sought to detect change effect sizes of 0.8, assuming a level of significance of 0.05 and statistical power of 0.8. An effect size of 0.8 equates to a change of between 1 – 3 cm, according to variability reported in a range of previous studies (Sheppard et al., 2011; Tricoli, Lamas, Carnevale, & Ugrinowitsch, 2005; Woolstenhulme, Griffiths, Woolstenhulme, & Parcell, 2006).

Each participant received information about the study and provided written, informed consent. Ethical approval for the study was granted by the Unitec Research Ethics Committee (UREC 20141093) and registered with the Australia and New Zealand Clinical Trial Registry (ACTRN12615000168550).

Procedures

Anthropometric measures of body height and mass were recorded prior to testing. Participant then performed a standardized 5-minute dynamic warmup conducted by the same trainer immediately before testing. The warmup consisted of glenohumeral circumduction clockwise and anti-clockwise, walking lunges and grapevine walking (participants moved in a straight line opposing rotation of the thorax relative to the lower body whilst crossing their feet over one another as they moved forwards).
Prior to the initial jumps, standing reach height was recorded. Each participant would then perform three trials of jumping without arm swing (i.e., arms folded across the chest with hands on shoulders) on portable uniaxial force plate (Model: 400S Isotronic Force Plate, Fitness Technology, Skye, South Australia, Australia). This was followed by three trials of jump and reach on the force plate using the Swift YardStick™ Vertical Jump Tester (Swift Performance, Wacoi, QLD, Australia) as an overhead objective.

Each of the participant’s jump and reach heights and peak GRF were concealed as much as possible, and recorders were instructed to not reveal the values to the player. Peak vertical ground reaction force (GRF), and peak jump and reach height for arm swing conditions were recorded.

Each participant then received their allocated treatment, either the upper or lower body protocol, and would receive the other the following week. Following the manual therapy, participants repeated the vertical jump and reach tests which were recorded by the same examiner. In an effort to increase internal validity, participants were asked to keep training modes and training volumes (i.e., sets*reps*load) identical prior to each testing session.

**Intervention**

A pre-study investigation identified the specific collection of techniques deemed effective at improving overhead reach, by the researcher and osteopath with over 10 years’ clinical experience.

The 15-minute upper body protocol implemented to restricted areas of the thoracic spine and the upper extremity and consisted of muscle energy technique to pectoralis major, subscapularis, latissimus dorsi; active release to subscapularis, latissimus dorsi, teres major, pectoralis major; and thoracic high velocity low amplitude thrust to restricted segments. Muscle energy technique was administered for 7 second with four repetitions for each restricted movement/muscle. Thoracic high velocity low amplitude thrust was administered once to each spinal segment deemed restricted by the practitioner. Active release was performed with 5 repetitions of the active movement to each muscle being released. The lower body treatment protocol was used as a control, and consisted of muscle energy technique to bicep femoris, semitendinosus, semimembranosus, rectus femoris, vastus medialis, vastus lateralis; and soft tissue to
rectus femoris, bicep femoris and iliotibial band of the lower extremities musculoskeletal system also lasting exactly 15 minutes. Jump testing was administered immediately after intervention and control packages were completed. Muscle energy technique was administered for 7 second with four repetitions for each restricted movement/muscle. Soft tissue massage was administered with medium pressure for no longer than 2 minutes per muscle.

**Statistical Analyses**

All statistical analysis and descriptive statistics were performed using SPSS (Version 23 IBM, Armonk, NY). Means, standard deviations (SD) are reported to represent the centrality and spread of data. Variables were checked for assumptions of normality by examining z-scores for skewness and kurtosis and the results of Shapiro-Wilks and Kolmogorov-Smirnoff tests changes in pre- to post-intervention outcome variables.

The differences in changes in jump variables between conditions were determined by repeated measures analysis of variance (ANOVA) or non-parametric equivalents, with peak vertical GRF applied as a covariate in an addition analysis to control for differences in peak ground reaction force generation between conditions. The level of statistical significance was set at alpha<0.05.

**RESULTS**

**Normal distribution of data**

An analysis of the distribution of changes in ground reaction force for the two arm-swing conditions and the changes in jump height for both interventions showed 75% of z-scores for skewness and kurtosis were within 95% confidence interval for normal distribution. Similarly, normality tests showed 42% of normality tests were violated. Given violations for primary outcome variables were not severe, the results from parametric statistical analyses are reported.

**Effect of the Interventions on Vertical Jump and Reach**

Reliability over the three pre-intervention jumps for both conditions was very high (ICC:3,1 = 0.99), although there was an increase over the three jumps (p = 0.02 for ANOVA), of 0.8 cm (95% CI: 0.2 to 1.4 cm) from the first to the third jump. Using averages of the three jumps, all 13 participants improved vertical jump and reach height following the upper body protocol (Range: 1 to 7 cm), whereas none improved by more
than 0.33 cm following the lower body control protocol. For the group, jump and reach height improved by 2.8 cm (95% CI: 1.7 to 3.9 cm) following the upper body protocol and reduced following the lower body protocol (-1.0 cm; 1.7 to 0.4 cm; Figure 1). The differences between protocols in these changes displayed a very large Effect Size (ES = 3.48 (difference in means / pooled SD of differences for each protocol) (p < 0.001 for the interaction between Time and Protocol). A more conservative non-parametric approach made no difference to the statistical significance of this effect (p = 0.001).

The difference between protocols in changes in jump height retained statistical significance when corrected for changes in peak vertical GRF during the arm swinging conditions (p < 0.001).

Figure 1. Change in jump height for both interventions. Error bars show 95% confidence intervals adjusted for between-subject differences as recommended by Field, 2009 pg 317-24.

**Effect of Arm-Swing on Ground Reaction Force**

In order to establish the effect of arm swing on GRF, the arm swing and non-arm swing trials were compared for before and after both protocols. Arm swinging increased peak vertical GRF by 6.5% compared to no arm swing (Figure 2). When correcting for Time and Protocol effects on GRF, using the arms resulted in a 143.4 [52.6 to 234.2] N greater GRF (p = 0.005 for Arm Swing effect in 3-way ANOVA).
DISCUSSION

Improvements in Vertical Jump and Reach with Upper Body Manual Therapy

The primary findings from this study were that a 15-minute standardized osteopathic manual therapy protocol resulted in a 4.7% immediate improvement in jump and reach performance of professional basketball players. A possible reason for these findings is an improvement in segmental ROM within the thoracic spine and a reduction in muscular-induced joint restriction in the shoulder brought about by the repetitive nature of motor patterns within a basketball game and training.

It has been shown previously that commonly implemented mobilization techniques such as stretching (Cools et al., 2012), and massage (Crosman et al., 1984) improve ROM when applied to the musculoskeletal system. However, there is a lack of past literature investigating the effect of such interventions when applied to the lower extremity (Hough et al., 2009). This further reinforces the novel nature of this study.

The study design deliberately and successfully made both protocols seem plausible to participants for improving jump and reach height. This was reflected by the observation that only two participants did not believe that both were effective. The development and use of a control that could easily be presumed to be plausible meant that there was less chance of performance bias occurring, and using a randomized-order, cross-over design allowed each participant to act as their own control. The cross over design may also
have ethical advantages since all participants receive both treatments within the course of the study, and there was no non-treatment group, as in a randomized, controlled trial.

This study is unique as there seems to be an absence of past literature directly evaluating the effect of manual therapy on vertical jump or other performance measures, despite practitioners such as physical therapists frequently working with athletes. In New Zealand, Australia and the United Kingdom, osteopaths primary scope of practice is to address musculoskeletal complaints including, but not limited to, biomechanical abnormalities, muscle injury, mechanically induced peripheral neuritis and management of common ligamentous and tendinous injuries. Osteopathic treatment tends to be highly adaptive to structural, neurological, systemic and mental presentation of the person being treated, as well as having a large subjective component based on the practitioner's personal treatment and practicing styles.

Careful consideration of the techniques chosen for the study was undertaken to ensure that they would aid mobility and not be detrimental to vertical jump performance. Additionally, an attempt to fully standardize the intervention protocols for both conditions was made to install the utmost consistency in the duration, tissues and particular techniques administered. Because of its simplicity and brevity, the chosen intervention approach is applicable to the in-game situation. If a player exhibits signs of reduced vertical jump performance a coach is able to substitute the player while the protocol is administered. It has been acknowledged that the 15minutes duration for the administration of the protocol, makes it better suited for the beginning portions of the game. However, it may be presumed that a more specific and condensed version of the protocol may have similar effects. Based on the results from this study the treatment protocol might be most beneficial at the start of game or at crucial plays, particularly if administered to impact players who often start on the bench until required to change the dynamics of the game. This study was not designed to explore the duration of the effects from upper extremity protocol and future research would be required to determine if it has a place as a longer term intervention protocol.

Whilst standardization increases the efficacy and internal validity of the study, the use of such a rigid protocol may limit the generalizability to the clinical situation, in which the practitioner might prioritize restricted tissues deemed more important for a particular individual than those prescribed here. It should also be acknowledged that it is still unclear from the results of this study the level of influence that individual
practitioner techniques might have on vertical jump and reach performance. What is clear from this study is that the techniques making up the upper body osteopathic protocol collectively did not have a negative effect on sports performance.

**Importance of Effect**

When applied directly before jumping, the upper body protocol used in this study results in almost 5% or 3cm mean improvements in jump and reach height. In comparison, static stretching to the lower limb has demonstrated decreases in vertical jump performance of 4.2% (Hough et al., 2009), and when applied to the upper limb decreases by 25% (Marchetti et al., 2014). This is despite demonstrating similar improvements in ROM, of around 6% (Marchetti et al., 2014). This decline in lower limb propulsion, and thus vertical jump performance, after upper limb static stretching suggests that the upper limb contributes vertical propulsive force.

The current study has demonstrated increases in peak vertical jump height of 6% or 2cm, such improvements have also been observed in training methods such as plyometric training. The main difference being these improvements occurred over an 8 – 10 week period (Berryman et al., 2010; Khlifa et al., 2010). Weight training on the other hand resulted in larger range of increases in mean squat jump height and countermovement jump height. It has been reported that mean squat jump height and countermovement jump height improved by 20% or 5.7cm and 15% or 5.2cm respectively (Arabatzi et al., 2010), while other studies report increases vertical jump height of 11% or 2.3cm in squat jump and 3% or 0.8cm in counter movement jump (Kubo et al., 2007). However, similarly to plyometric training these results occurred over an extended period of time between 8 – 12 weeks (Arabatzi et al., 2010; Kubo et al., 2007) and required training 3 times a week (Arabatzi et al., 2010).

It has been shown in one study that administration of multiple osteopathic techniques can improve the performance of sporting actions by improving joint ROM (Mosler et al., 2006). That study demonstrated osteopathic techniques were able to generate improvements in passive hip internal rotation by an average of 15° in water polo players, and subsequently increased their eggbeater kick performance by 10 – 15% on average. These results mirrored results from the current study which, noted similar improvements in vertical jump and reach performance. Therefore, despite the differences in the techniques used between the current study and the study in question
(Mosler et al., 2006), both indicate that osteopathic techniques can improve sporting performance.

There still remains an absence of research on the effect of osteopathic manual therapy on vertical jump performance. Although it has been demonstrated muscle energy technique can result in improvements of 7° in glenohumeral joint horizontal adduction (Moore et al., 2011) its effect on muscular strength or power is unknown. Myofascial release on the other hand has been shown to have no significant difference in ROM changes when compared to static stretching, but unlike static stretching it doesn’t compromise isometric strength (Amico & Morin, 2013). This information shows that not only does the protocol in the current study have the ability to improve jump performance by a similar magnitude to other training methods, but that the time periods in which these changes come about, 15 minutes rather then up to 12 weeks, illustrates a clear advantage of this osteopathic manual therapy protocol.

**Importance of the Upper Body in Jumping**

Existing data support the importance of arm swing in vertical jump performance (Floría & Harrison, 2013). Studies have demonstrated increases in vertical propulsion as great as 19% - 23% (Floría & Harrison, 2013), and take-off velocity by an average of 10% (Hara et al., 2006; Harman et al., 1990; Lees et al., 2004) compared to the same jumps without arm swings.

The beneficial effects of arm swing have been echoed throughout literature with studies showing the center of mass height achieved with arm swings equate to 9.1 cm or 7.3% greater than without, with 37.8% of this increase being attributed to a higher center of mass at takeoff and 62.2% due to increased velocity (Cheng et al., 2008).

The influence of arm swing on GRF was a secondary aim of this study which showed a 6.5% or 143 N increased peak GRF. Another study recruiting less abled jumpers has demonstrated very similar improvements in peak GRF from using arm swings as part of the jump. Squat jumps with arm swings were shown to increase GRF by 9% or 140 N compared to squat jumps without arm swings (1.73 ± 0.17 10³N compared to 1.59 ± 0.16 10³N) (Hara et al., 2006).
A component of the upper body that potentially contributes to improvements in GRF resulting from arm swinging, is the thoracic spine. Having normal ranges of thoracic spine extension is described as being important for normal shoulder girdle function (Edmondston, 2012) and the requirement for optimal thoracic extension in order to achieve full-range arm elevation is supported by studies using thoracic posture modification to improve ROM in patients with subacromial impingement (Bullock et al., 2005; Lewis, Green, et al., 2005). By administering high velocity low amplitude thrust it is plausible that this improved thoracic spine ranges of motion, and further increased overhead shoulder ranges of motion.

**Limitations of this Study**

This study had a number of known limitations which included the relatively small sample size used and convenient nature of sampling. These may have limited the generalizability of findings to all basketball players of all skill levels. Despite this, a sample size of 13 was achieved and sample included an even spread of player positions. Further analysis into the difference in effect of the osteopathic manual therapy protocol based on position may be useful in future studies in order to adapt the protocol for each position.

Despite the small sample, the correlation between the age of study’s sample and the age of the target population is also important to consider. The mean age of the participants in the study was 23.2 SD ± 2.35, which is similar to average age of players in the Australian National Basketball League (NBL). Average age of the single New Zealand team in this league is 27 years and 4 months (Australian National Basketball League, 2015). The range of ages in the study was from 20.4 to 28 years, also similar to the NBL, with ages ranging from 20 years, 5 months to 34 years, 10 months as of October 2015 youngest being (Australian National Basketball League, 2015).

Other factors such as the competitive nature of jump and reach testing may have influenced results. In high level sports people there is a high likelihood of competitiveness, which was controlled for here as best as possible by not revealing to the player the jump height achieved unless they were to actively try and look up at the vanes. Future studies might employ objective criteria to monitor other potential influences and biomechanical changes that may have resulted from either the intervention or control, for example balance, flight time, and joint ROM (glenohumeral,
gross thoracic spine extension, knee, hip, or ankle). The inclusion of individual joint
ROM pre- and post-intervention would provide a basis for further analysis into the
primary contributors of the improvements. Analysis of flight time changes and balance
would provide insight into whether there are added advantages from the protocol, or if
in fact it was detrimental to other sporting characteristics despite benefiting jump and
reach performance.

The current study also considered only the effects on males. There are known
differences in the biomechanics and musculoskeletal structures between males and
females including differences in glenoid size, coracoid thickness and carrying angle
(Churchill, Brems, & Kotschi, 2001; Huston & Wojtys, 1996; Ljungquist, Butler, Griesser,
& Bishop, 2012; Takase, Yamamoto, Imakiire, & Burkhead, 2004; Wells, 1991). It has
also been shown that active and passive ROM of forward elevation, abduction, internal
rotation and external rotation of the glenohumeral joint is significantly greater in
females when compared to males (Barnes et al., 2015). This may imply that males have a
greater potential for improvements in these overhead ranges of upper extremity
movements due to discrepancies in glenohumeral ROM between sexes, providing
validity for the decision to select a single sex sample for this study. Although it could be
hypothesized that the osteopathic protocol used in this study would positively influence
female performance, more research is required before we can determine the extent of
such improvements. There are few techniques which are sex specific within osteopathic
and manual medicine, therefore presumably the techniques used in the protocol of the
current study would also improve female jump and reach performance.

Implications on future research

The findings of this study indicate that a manual therapy upper body protocol,
consisting of osteopathic techniques, has the ability to improve vertical jump and reach
performance directly after application in male basketball players. These findings
highlight the importance of maintaining a good degree of mobility in the upper body, in
order to perform vertical jump and reach optimally. The results warrant further
exploration into the effect of targeted manual therapy sports performance, as an
alternative or complementary approach to training. Further research should also be
undertaken to see if a condensed version of the protocol would have beneficial
outcomes on vertical jump performance, as a quicker to administer protocol would
make it more practical. These findings are likely to benefit a multitude of professions
under the umbrella of manual therapy as many of the techniques adopted are used across professions. On the other hand, techniques such as high velocity low amplitude thrust (spinal manipulation) are, in New Zealand, the United Kingdom and Australia, limited to a small number of professions and techniques such as muscle energy technique are predominately osteopathic in nature.

Although the sample size was small, these findings provide a good framework for future research targeted at refining the protocol to maximize effectiveness for different sexes, positions, player levels, and sports. Such research would provide alternative and valid options for the improvement of sports performance of athletes, and might indicate the opportunity for further research into the effect manual therapy can have on athletic performance.

**Conclusion**

This study was conducted to investigate the acute effect of a brief, standardized osteopathic manual therapy protocol on jump and reach performance in professional basketball players, and assess the importance of arms in vertical jumping. We note that arm swinging increases peak GRF in high level basketballers by around 6.5%. Through this blinded cross-over design study, we have shown substantial and immediate improvements in jump and reach heights compared to a control protocol. Therefore, this or similar protocols could be implemented in an elite sporting setting to induce immediate and acute improvements in vertical jump height and reach performance.

**PRACTICAL APPLICATIONS**

The study has identified a protocol which is applicable to basketball players and other similar sports such as netball, volleyball and water polo. It can be used in circumstances where reductions in ROM lead to an athlete needing to generate more force from their lower extremities to overcome these deficits in ROM of the upper body.

The results from this research indicate that an upper body osteopathic manual therapy protocol can be administered during training to maximize the effectiveness of training by enabling the athlete to train longer with optimal ROM. Application of this protocol in the second quarter before half time has the potential to gain athletic advantage by improving vertical jump and reach performance, whilst enabling enough time for its
administration. In a non-competitive training environment, the protocol could be administered by a club practitioner to compliment current training methods for vertical jump. Improvements in vertical jump and reach performance may complement those longer-term gains made from plyometric or weight training.

The manual therapy protocol has the ability to provide an immediate sporting advantage, in a game situation. Potential circumstances for its use in basketball specifically include administration to a player who has not started the game and spent a period sitting on the bench. Incorporating the protocol into pre-substitution warmup could potentially enhance a player’s impact on the game. The protocol could also be administered to a player who is identified as underperforming due to muscle tightness resulting from the game.
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Figures Legends
First, create a page entitled "Figure Legends" in which each of the figure legends are listed. Include this page in your manuscript document. Next, place each of the figures in a PowerPoint presentation if possible. All figures should be labeled and each figure must be referenced in the manuscript. All figures should be professional in appearance. They should also be viable for size reductions to fit manuscript space allocations. One set of figures should accompany each manuscript. Use only clearly delineated symbols and bars. Electronic photographs copied and pasted into Word and PowerPoint will not be accepted. Images should be scanned at a minimum of 300 pixels per inch (ppi). Line art should be scanned at 1200 ppi. Please indicate the file format of the graphics. We accept TIFF or EPS format for both Macintosh and PC platforms.

For the purpose of the submission this page has not been completed but will be satisfied for the final submission to the Journal of Strength and Conditioning Research
Section 3: Appendices

Appendix A: Ethics Approval Letter

Jonathan Hall
19a Deep Creek Road
Torbay 0630
Auckland

11.12.14

Dear Jonathan,

Your file number for this application: 2014-1093

Title: Effects of a short term osteopathic intervention package on the vertical jump and reach height in healthy basketball players: A cross-over design. Substudy A: Male basketball players.

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: 1.12.14
Finish date: 1.12.15

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,

Sara Donaghey
Acting Deputy Chair, UREC

cc: Catherine Bacon

Cynthia Almeida
Appendix B: Participant Information Page

Effects of a short term osteopathic intervention package on the vertical jump and reach height in healthy basketball players: A cross-over design

About This Research
You are invited to take part in a research project investigating the immediate effects of two osteopathic intervention packages. Osteopathy is a form of manual therapy which considers the interconnected function of the whole body, when applying treatment in order to decrease pain and dysfunction.

The techniques chosen for inclusion in this study are soft tissue massage (ST), muscle energy technique (MET) and high velocity low amplitude (HVLA) thrusts. MET and HVLA involve the researcher moving the patient around until they feel as though there is no more slack within the tissues. To perform an MET, the participant will then try to re-centre their body while the researcher restricts the movement. An HVLA will involve a high-speed compressive movement, which may result in a clicking noise occurring. When applying these techniques, the researcher will take you through movements and put you into different positions in order to decrease dysfunction within the tissues.

The researcher will explain the processes every step of the way and will aim to ensure your comfort through the entire treatment. The techniques will be applied to the upper and lower body. This research will undertaken by Jonathan Hall (Unitec, Master of Osteopathy students) and supervised by Catherine Bacon (Unitec, Research Supervisor).

This study has the potential to benefit the osteopathic profession and support the techniques that are commonly used.

Who may participate in this study?
For this study, we are looking for participants between the ages of 18-37 who are part of a basketball playing at a semi-professional competitive level or greater, with a reduced overhead arm range of motion.

Unfortunately, you will not be eligible for this study if you:
- have a previous history of shoulder dislocation or surgery,
- suffer from current upper or lower limb injuries that may hinder your performance,
- are on any medication that may affect the musculoskeletal system, e.g.
- aspirin.
- have received any form of manual therapy in the last 6 weeks.

If you have any questions in regards to your eligibility, do not hesitate to contact the principal researchers.

What will happen in this research?
For this project, you will be asked to attend two days at the Auckland University of Technology Millennium Institute of Sport for data collection.

Each day you will be asked to complete the following:
- A 5 minute warm up consisting of dynamic stretches to the upper and lower body
- Pre-test jump height measurements will be taken
- Osteopathic intervention will be given, focusing on either the upper body or lower body. The opposite area will be worked on the following week
- Jump height will then be measured again

One of the investigators or research assistants will provide instructions for the warm up. Jonathan Hall or Thalia Green will carry out the osteopathic intervention.

How long does the study go on for?
This study will be carried out on two separate days, one week apart. You will be asked to attend both days. Each session will take approximately 2-3 hours. You will be asked to stay for the entire duration.

Are there any discomforts/risks from taking part?
This study does not present with any obvious risks. If you feel discomfort at any stage of the study, it is important to let the researchers know.

We treat your personal information confidentially
All personal information you provide will be treated as confidential and no material that could personally identify you will be used in any reports in this project.

Video footage of you will be required for aspects of this study. Consent for the use of the footage will be obtained on the consent form provided. If you do not feel comfortable about being videoed, you do not have to sign the consent form.

Do I have to participate in this study?
Please note that participation in the study is voluntary and that you are not
obligated to consent to providing your data for research purposes.

You have the right to withdraw from this study at any stage, up to one week following the end of data collection, for any reason.

**Can I consult with my whanauliwi about this study?**
If you provide us with contact details, we are happy to email and speak to a suitable representative from your whanau or iwi and discuss any aspect of study involvement with them. We welcome all communication with your wider community.

**Who can I contact with any further questions?**
If you have any further questions about this research please feel free to contact one of us:

Catherine Bacon (Supervisor)
Tel: 015 4321 ext. 7799 (message only)
Email: c_h_bacon@unitec.ac.nz

Jonathan Hall (Research Student)
Tel: 0212652825
Email: jay_hall15@cloud.com
Appendix C: Participant Consent form

Participant Consent Form

Research Project Title: Effects of a short term osteopathic intervention package on the vertical jump and reach height in healthy basketball players: A cross over 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 up to one week following data collection with no penalty.

I understand that everything I say is confidential and none of the information I give will identify me and that the only persons who will know what I have said will be the researchers and their supervisor. I also understand that all the information that I give will be stored securely on a computer at Unitec for a period of 5 years.

I understand that components of the study will be video recorded.

I understand and consent to all of the outlined techniques and interventions of this study.

I understand that I can see the finished research document.

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

Participant Name: ________________________________

Participant Signature: ______________________ Date: ______________________

Project Researcher: __________________________ Date: ______________________

Whanau/whi Contact Name (optional)

Whanau/whi Contact Details (please provide phone number and email address):

URC REGISTRATION NUMBER: (insert number here)
This study has been approved by the Unitec Research Ethics Committee from [date] to [date]. If you have any complaints or reservations about the ethical conduct of this research, you may contact the Committee through the UREC Secretary [ph: 09 815-4321 ext 8561]. Any issues you raise will be treated in confidence and investigated fully, and you will be informed of the outcome.