TITLE
The Effect of Thoracic Spine Mobilisation on Thoracic Extension and Serratus Anterior and Upper Trapezius Muscle Activation Patterns.

AUTHOR
Knight, Steven

DATE DEPOSITED
1 November 2017

The Effect of Thoracic Spine Mobilisation on Thoracic Extension and Serratus Anterior and Upper Trapezius Muscle Activation Patterns

Authors

Steven Knight. Msc student of strength and conditioning science at St Mary's University London. steve@skpt.co.uk. 50 Rackham road, Worthing, WEST SUSSEX, BN13 1LW. 07787326905

Emily Cushion, Msc. Lecturer in strength and conditioning science at St Mary's University London. Emily.cushion@stmarys.ac.uk

Louis Howe, Msc. Lecturer in sports rehabilitation at University of Cumbria. Louis.howe@cumbria.ac.uk

Dr Dan Cleather, programme director for Msc strength and conditioning science at St Mary's university, London. daniel.cleather@stmarys.ac.uk

Date of submission

21st May 2017

This Research Project is submitted as partial fulfilment of the requirements for the degree of Master of Science, St Mary's University

CONTENTS

Page 2 - List of figures

Page 3 - List of tables

Page 4 - Acknowledgements

Page 5-6 - Abstract

Page 7-10 - Introduction

Page 11-17 - Methods

Page 18 - Results

Page 19-28 - Discussion

Page 29 - Conclusion

Page 30-32 - References

Page 33-39 - Appendices

LIST OF FIGURES

Figure 1. Pictures of the intervention exercises used

Figure 2. An example of the intervention program used

Figure 3. Graph showing changes to subjects’ static thoracic angle across the intervention period

Figure 4. Graph showing changes to subjects’ thoracic extension range across the intervention period

Figure 5. Graph showing changes to the peak activation amplitudes of the subjects’ serratus anterior and upper trapezius muscles across the intervention period

Figure 6. Graph showing changes in the time to peak activation amplitudes of the subjects’ serratus anterior and upper trapezius muscles across the intervention period

Figure 7. Graph showing the changes in peak muscle activation amplitudes across the intervention with subjects grouped by degree of static thoracic angle

LIST OF TABLES

Table 1. Participant characteristics

Acknowledgements

First and foremost I would like to thank my wife and 3 children for their invaluable support and sacrifice during the last 4 years, without them it would not have been possible for me to accomplish this Masters degree. I would like to thank all of the lecturers on the Msc in strength and conditioning science at St Mary’s University over the last 4 years, you have taught me so much and I have enjoyed the journey immensely. I would like to thank my close friend and colleague Iain Jackson for his help on subject testing sessions and being the subject for example photographs of the intervention exercises. I would also like to take this opportunity to thank all of the participants in my study, you gave up a lot of your free time out of the kindness of your hearts and for that I will be forever grateful.

The Effect of Thoracic Spine Mobilisation on Thoracic Extension and Serratus Anterior and Upper Trapezius Muscle Activation Patterns

Context: A distinct lack of research exists in the relationship between kyphosis of the thoracic spine and sub acromial impingement syndrome (SAIS) even though kyphosis is regularly proposed as a mechanism of SAIS. Links have been made between; posture and poor scapula orientation, SAIS and poor posture muscular imbalances, SAIS and poor posture shoulder kinematics. Though no research exists to establish if correcting poor thoracic spine posture will have an effect on primary muscular activation patterns evident in SAIS.

Objective: To determine whether a daily exercise program designed to improve extension of the thoracic spine will improve posture and the muscle activation pattern of upper trapezius (UT) and serratus anterior (SA) during weighted scaption in healthy adults with kyphotic thoracic spines.

Design: Cohort study.

Setting: Home exercise program.

Patients or other participants: 20 healthy adults with thoracic spine angles of over 30cm (8 male, 12 female, average age = 41.5 ± 11.85yrs, average height = 170.89 ± 10.01cm, average weight = 70.84 ± 16.14kg).

Intervention(s): A thoracic extension program of 5 exercises to be performed daily for 30 days.

Main outcome measure(s): Static thoracic angle was measured using a digital inclinometer and thoracic extension was measured using an anthropometric measuring tape to determine the decrease in length of thoracic spine in centimetres (cm) between relaxed and fully extended states. Surface electrode EMG was used to measure absolute peak amplitude in volts (v) and time to peak amplitude in seconds (sec) of UT and SA muscles.

Results: The outcome measures proved to have a non significant difference for the intervention group compared to control as did the relationship between the two muscles for peak activation amplitude and time to peak amplitude.

Conclusions: Although results of the intervention were not statistically significant positive change was found in the two posture variables and a significant relationship was found between thoracic angle and peak muscle activation. Due to the variability of results and the first study in this area more research of the relationship between thoracic kyphosis and scapula muscle activation patterns is recommended.

Key words: Thoracic kyphosis, shoulder, electromyography, scapula muscles.

The shoulder is a very complex part of the human body and highly susceptible to injury with shoulder dysfunctions and/or pain being widely reported disorders.[1,2] One of the most common and heavily researched disorders is subacromial (external) impingement syndrome (SAIS),[3,4] which is defined as compression, entrapment or mechanical irritation of the rotator cuff structures and/or subacromial bursa and/or long head of the biceps tendon beneath the coracoacromial arch.[2,5] SAIS has been proposed as a precursor to the development of rotator cuff disease, long head of biceps tendinopathy and bursitis.[6,7] Many mechanisms have been proposed to be a cause of SAIS including acromial shape, weakness or injury in rotator cuff musculature, joint kinematic dysfunctions, muscular imbalances and kyphotic thoracic spine. Three of these mechanisms have been heavily researched, the first of which being the rotator cuff musculature which plays a major role during elevation of the arm pulling the humeral head inferiorly to stabilise it against the glenoid fossa but it has been shown that dysfunctional or injured rotator cuff musculature allows the humeral head to translate superiorly which compresses the sub acromial space.[8,9] Rotator cuff dysfunction, or injury has also been shown to affect other glenohumeral (GH) and scapulothoracic (ST) joint kinematics relating to SAIS.[5,10]

Changes in shoulder joint kinematics is the second heavily researched mechanism in relation to SAIS with dysfunctional kinematics of the ST, GH and acromioclavicular (AC) joints being highly linked with SAIS.[4,7] The main changes found to the kinematics of the ST joint in subjects with SAIS are a reduced ability of the scapula to upwardly rotate, posteriorly tilt and externally rotate during humeral elevation in all planes.[11,12] Movement of the clavicle needs to occur for the scapula to move freely and a reduction in posterior rotation, retraction and elevation of the clavicle are the most prominent changes to AC joint kinematics in subjects with SAIS.[13,14] Changes to GH joint kinematics found in subjects suffering from SAIS are increased superior translation and general joint laxity along with a decreased range of elevation.[7,15] Normal shoulder joint kinematics elevate the acromion clearing adequate space between the acromion and humeral head for the tissue within to freely move and contract hence the pain experienced from SAIS is generally found during the mid range of humeral elevation, as this part of the range corresponds to the highest sub acromial pressures and least sub acromial space.[7,15] The third highly researched mechanism of SAIS is scapula muscle activation with research of muscle activation patterns found in subjects with SAIS clearly showing changes to normal scapula muscle function. Early and/or overactive activation of the upper trapezius (UT) and pectoralis minor (PM) muscles coupled with delayed and/or decreased activation of the lower trapezius (LT) and serratus anterior (SA) muscles are common findings in patients diagnosed with SAIS.[12,16,17] An optimally functioning SA produces the majority of scapula upward rotation torque, contributes substantially to posterior scapula tilting and scapula stabilisation onto the thorax,[7,18] making it a primary concern in SAIS rehabilitation research.

A large amount of intervention research exists in the search of optimal rehabilitation and preventative protocols for the previously discussed mechanisms of SAIS. These include protocols such as surgery, manual therapies, stretches, exercises and mixtures of two or more of them. Numerous studies report success in improvements of SAIS symptoms with respect to their intervention but the largest and most frequently found improvements in symptoms come through interventions that focus on increasing flexibility of the PM and activation of the SA and LT whilst limiting the over activation of the UT.[3,7,8]

Although thoracic spine angle (the degree of the curve in the upper back, between the neck and the lower back) is widely proposed as having an influence on SAIS, an understanding of what relationships exist between them is lacking due to the low amount of research undertaken in this mechanism. However an increased thoracic spine angle along with other poor static postural conditions such as forward head, winging scapula, rounded shoulders and kyphotic thoracic spine have been observed in subjects with SAIS[19] and the muscular imbalances found to cause these poor postural conditions are very similar to those found in subjects with SAIS.[19] When considering the most frequently found improvements of SAIS come through correcting muscular imbalances and the few studies researching the relationship of the thoracic spine angle with SAIS investigate joint kinematics, it is then imperative that research in this mechanism moves into its relationships with muscle activation to allow clinicians to prescribe the best possible rehabilitation and preventative protocols for their patients.

Therefore the first aim of this study is to clarify if an exercise program targeted at correcting kyphosis of the thoracic spine will change the muscle activation ratio between the UT and SA muscles during elevation of the arm in the scapula plane (scaption) with static thoracic angle and active isolated thoracic extension also being to monitored to determine if the intervention improved kyphosis. It is hypothesised that this study will result in a lower static thoracic spine angle, an increased range of extension through the thoracic spine and more balanced muscle activation ratio between the UT and SA in subjects from participating in the intervention protocol. Static posture and thoracic angle will improve due to an increased mobility of the vertebrae of the thoracic spine, lengthening of the muscles that move the spine into flexion, strengthening of the thoracic extensor muscles and consistently being under stress in positions of thoracic extension. Muscle activation ratio of UT and SA will change from a more dominant UT relationship seen in initial testing due to a flatter angle at the thoracic spine allowing the scapula to generate more posterior tilt and upward rotation.

Our previous experience with posture correction has led us to believe that after postural correction exercises have ceased a detraining effect often occurs therefore this study has been structured in a crossover design meaning at the midway point of the study the intervention and control groups are switched. Hence the second aim of this study is to investigate if a detraining effect will occur from any adaptations made once the intervention stimulus is removed. It is hypothesised here that regression will occur firstly due to the fact the subjects will only perform the intervention for a 30 day period which will not elicit large enough improvements to be long lasting. Secondly it can be assumed their lifestyle and/or genetic predisposition encourages thoracic kyphosis due to the fact they qualified for the study and with the intervention taken away will likely go back to these habits.

METHODS

Participants and study design

We recruited 43 subjects via face to face interaction from the demographic of current gym members at sports direct fitness in Hove, SUSSEX. Inclusion criteria required that all participants be between the age of 18 and 65 years old, be free from medical/professional care or surgery on their neck/shoulder/back for 12 months, not suffer with any recurring neck/shoulder/back complaints, not participated in any thoracic spine mobilisation program for the past 12 months, not suffer from any mental health illness or cognitive impairment and not be pregnant. Additionally a criterion for minimum static thoracic angle was set at 30 degrees which was deciphered at initial testing through the static thoracic angle test, to which 11 of the 43 subjects failed to meet on initial testing. The remaining 32 subjects were split into 2 groups (1 and 2) that were pair matched by sex, age, static thoracic angle, thoracic extension and current training modalities. Eight subjects did not complete the study due to injury or illness that was not related to their participation in the study or a change in personal circumstances not allowing them the time to participate in the intervention and 4 of the remaining 24 did not meet the criteria of 23 days completion of the intervention. This left group 1 with 12 subjects and group 2 with 8 subjects for final data analysis, descriptive statistics are presented in Table 1. Written informed consent was obtained by all participants and the study was granted ethical approval by the school of Sport, Health and Applied Sciences ethical review board at St Marys University, Twickenham, London. The study ran for 10 weeks with pre study testing performed on the first two days, mid study testing performed at the end of week 5 and post study testing performed on the final two days for all subjects. For the period between the pre and mid tests group 1 acted as the intervention group and group 2 the control group then between the mid and post tests the groups were swapped with group 2 acting as intervention group and group 1 the control group. When acting as the intervention group subjects were asked to perform 5 exercises daily at home or gym whilst continuing with their normal routines when acting as controls subjects were asked to perform their normal routines and not to start any new exercise modality or shoulder and upper back remedial/rehab exercises.

Table 1. Participant Characteristics (Mean ± SD)

Characteristic	Group 1 (n=12; 4 male, 8 female)	Group 2 (n=8; 4 male, 4 female)
Age (years)	40.42 ± 12.87	43.13 ± 10.76
Height (cm)	170.54 ± 10.32	171.41 ± 10.21
Weight (kg)	70.23 ± 16.90	71.75 ± 16.02
Initial static thoracic angle (°)	43.32 ± 7.96	43.39 ± 5.21
Initial thoracic extension (cm)	1.02 ± 0.28	0.97 ± 0.38
Intervention days completed	25.0 ± 2.8	26.4 ± 1.4

Procedures

There were 3 tests performed for pre, mid and post experiment testing. Static thoracic angle was measured first by instructing subjects to stand in a relaxed manner after walking on the spot then measuring their static thoracic angle using a digital inclinometer (Neoteck digital angle finder, accuracy of ±0.2 degrees). Two measurements were taken with the inclinometer one at C7/T1 and the other at T12/L1, the two measurements were then added together to give the static thoracic angle in degrees (°). The test was performed 3 times to account for measuring error and the mean ± SD value was used as the comparative data. Secondly thoracic extension was measured by using a method known as Ott's sign. A felt tip pen was used to mark the subjects C7 vertebrae whilst the subject was seated in a relaxed position, 30 cm was then measured down their spine from that mark with a flexible tape measure where another mark was made with the felt tip pen. The subject was then instructed to extend their spine up and arch backwards as much as possible and the length between the two marks was measured again, the difference between to the two measurements was then used as their thoracic extension range in centimetres (cm). The test was performed 3 times to account for measurement error and the mean ± SD value was used as the comparative data. The two thoracic measurement tests have been decided upon from data in previous research of thoracic kyphosis showing their inter test and intra test reliability and validity was high in comparison to highly regarded ultrasound and x ray tests.[20,21] They are also inexpensive, easy to perform and easy to replicate in future research.

The third test was measurement of the muscle activity from the UT and SA on the dominant arm using electromyography (EMG) during a straight arm raise in the scapular plane (scaption), the hand was in a neutral grip (palm facing body with arm by side) holding a 2kg dumbbell and a 3 second tempo was used from bottom to top of lift. Scaption angle was determined on a horizontal axis as the halfway point between frontal and sagittal planes (45° from each plane with arm at 90° of flexion). Subjects were given one untested practice repetition to make sure they could execute the lift properly then were tested for 3 repetitions. Scaption has been chosen as the exercise due to the majority of literature investigating the musculoskeletal changes in SAIS which has formed the background to this study using this exercise as their testing variable.

The raw EMG data was collected at a sampling rate of 1000Hz then Microsoft® Excel was used to remove DC bias, rectify and smooth it. Peak values, first time frame that the peak value occurred and time frame that exercise began were then extracted from the smoothed EMG data. Time frame that exercise began was established as the first time frame that the value 0.0001volts or above was reached by either muscle, this value was ascertained by matching the general trace pattern seen during testing as the exercise began to the average value of 10 data trace patterns at the same observed point. Time to peak value could then be calculated by subtracting the time frame that exercise began from the time frame that the first peak value occurred. As 3 repetitions of the test were performed the mean ± SD of the peak amplitude in voltage (v) was used as the comparative data for peak value for each muscle and the mean ± SD of time to peak amplitude in seconds (sec) was used as the comparative data for time to peak value for each muscle. EMG data of muscle activation from UT and SA was gathered using a Delsys Myomonitor® IV portable wireless device with EMGworks® 3.5 software and dual bipolar surface electrodes placed on each muscle with a 20mm inter electrode distance and a reference electrode placed over the spinous process of the C7 vertebrae. Electrode placement for the UT muscle was two thirds of the distance from the spinous process of the seventh cervical vertebra to the acromial process and for the SA muscle over the muscle fibres anterior to the latissimus dorsi muscle and posterior of the pectoralis major muscle (with the arm flexed 90° in the sagittal plane). Before placement of electrodes skin surface was shaved and scrubbed with alcohol wipes to reduce skin impedance. The rationale for these methods was decided upon in accordance with SENIAM (Surface electromyography for the non-invasive assessment of muscles),[22] previous studies of these muscles in relation to SAIS and equipment manufacturer guidelines.

The intervention was 5 exercises set daily for a period of 30 days, each subject was given a program with detailed descriptions and pictures of each exercise. Each week during the intervention period 3 coached sessions were made available but not mandatory for the subjects to attend. A minimum of 23 days completion of the intervention was set for the subject's data to be used in final analysis without the subject being informed prior to this. The intervention exercises, as shown in Figure 1, were; corner wall stretch, foam roller thoracic mobilisation, kneeling superman, prone superman, and prone YTW's. These exercises were decided upon from previous research showing thoracic kyphosis improvements are greater using an exercise protocol that includes comprehensive exercises simultaneously treating the thoracic region with the wider cervical and scapula regions along with local exercises isolated to thoracic extension.[22, 23] The program for the intervention including sets, repetitions and progression is shown in Figure 2 with compliance to the intervention self monitored by the subjects by way of marking a compliance sheet for each day they completed the intervention.

Figure 1. Intervention Exercises

Far left – corner wall stretch; top left – foam roller thoracic mobilisation; bottom left – kneeling superman; top right – prone superman; bottom right, bottom middle and far right – YTW's.

Figure 2. Intervention program

EXERCISE	SETS	REPETITIONS	TIME WK1	TIME WK2	TIME WK3	TIME WK4
Corner wall stretch	1	3	45 seconds hold			
Thoracic mobilisation	1	6-9	15 seconds hold			
Kneeling supermans	1	5	10 seconds hold	15 seconds hold	20 seconds hold	25 seconds hold
Prone supermans	1	5	10 seconds hold	15 seconds hold	20 seconds hold	25 seconds hold
Prone YTW's	3	4 times round each letter	2 seconds hold each letter	4 seconds hold each letter	6 seconds hold each letter	8 seconds hold each letter

Statistical analysis

Data for all subjects for the 6 variables (static thoracic angle, thoracic extension, peak EMG value for UT and SA, time to maximum value for UT and SA) was collated in Microsoft® Excel where formulas were used to extract the comparative data. An individual repeated measures ANOVA was then used to analyse the comparative data for each variable to determine if one group was significantly different from the other at pre, mid and post study tests using IBM® SPSS® 21 with an alpha level set at .05. A two factor repeated measures ANOVA was then performed by group on UT and SA peak values over the three tests and another on UT and SA time to peak values to determine if there was any change in the pattern of their relationship using IBM® SPSS® 21 with an alpha level set at .05.

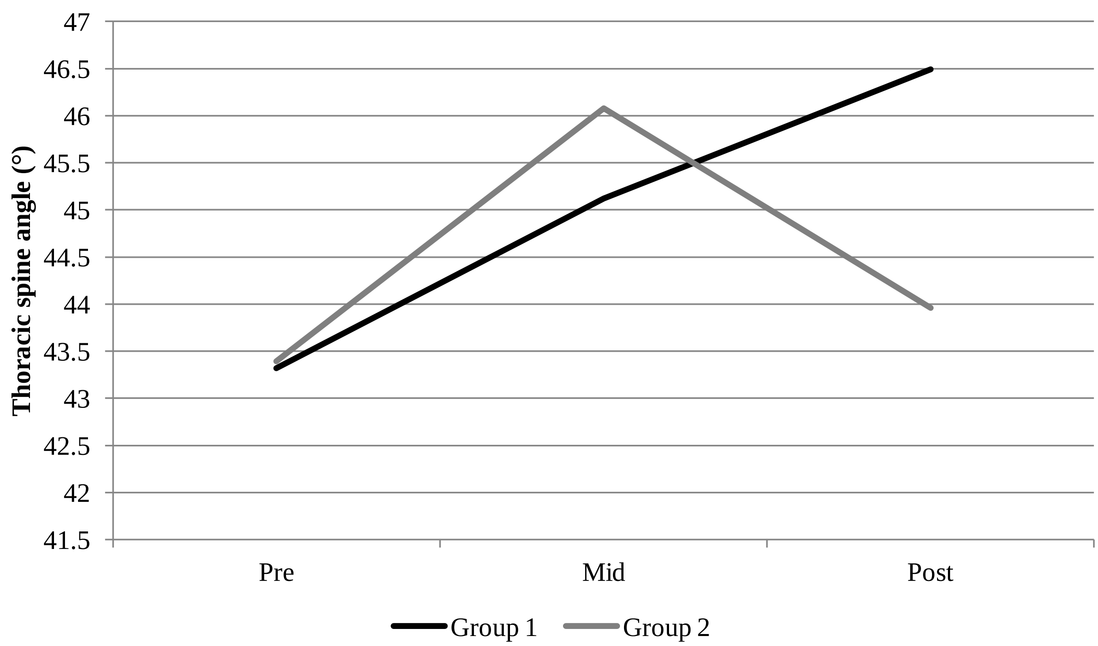
RESULTS

There were no statistically significant changes to the main effects in any of the 6 variables for intervention group 1 against control, intervention group 2 against control or reversal of effects for group 1 after the intervention was ceased. The main effects for group over the pre, mid and post test were: static thoracic posture, $F(2, 36) = 2.824$, $p = .073$; Thoracic extension, $F(2, 36) = 2.370$, $p = .108$; UT peak amplitude, $F(2, 36) = .155$, $p = .857$; SA peak amplitude, $F(2, 36) = 2.316$, $p = .113$; UT time to peak amplitude, $F(2, 36) = .197$, $p = .822$; SA time to peak amplitude, $F(2, 36) = .005$, $p = .995$. There was no statistically significant change in the relationship between UT and SA peak values due to the intervention for either group or for group 1 after the intervention was ceased, $F(2, 36) = .972$, $p = .388$. There was also no statistically significant change in the relationship between UT and SA time to peak values due to the intervention for either group or for group 1 after the intervention was ceased, $F(2, 36) = .135$, $p = .874$.

DISCUSSION

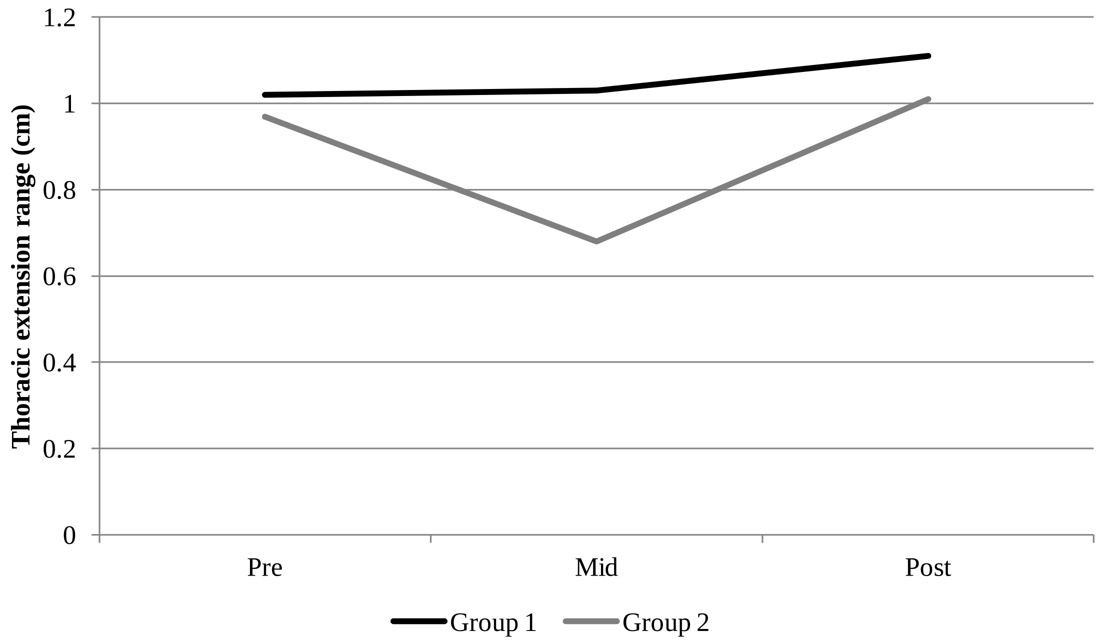
The results of our statistical analysis show no significant difference was made to thoracic spine angle, thoracic extension range or muscle activation of the SA and UT due to our thoracic mobilisation intervention. This rejects our hypotheses that the intervention program would improve the two posture variables, alter the two muscle activation variables and group 1 would show a detraining effect after cessation of the intervention. Figures 3-6 show a graphic representation of the results and although no significance change was found, deviation can be seen in the variables across the three tests.

Figure 3. Static Thoracic Angle (°)



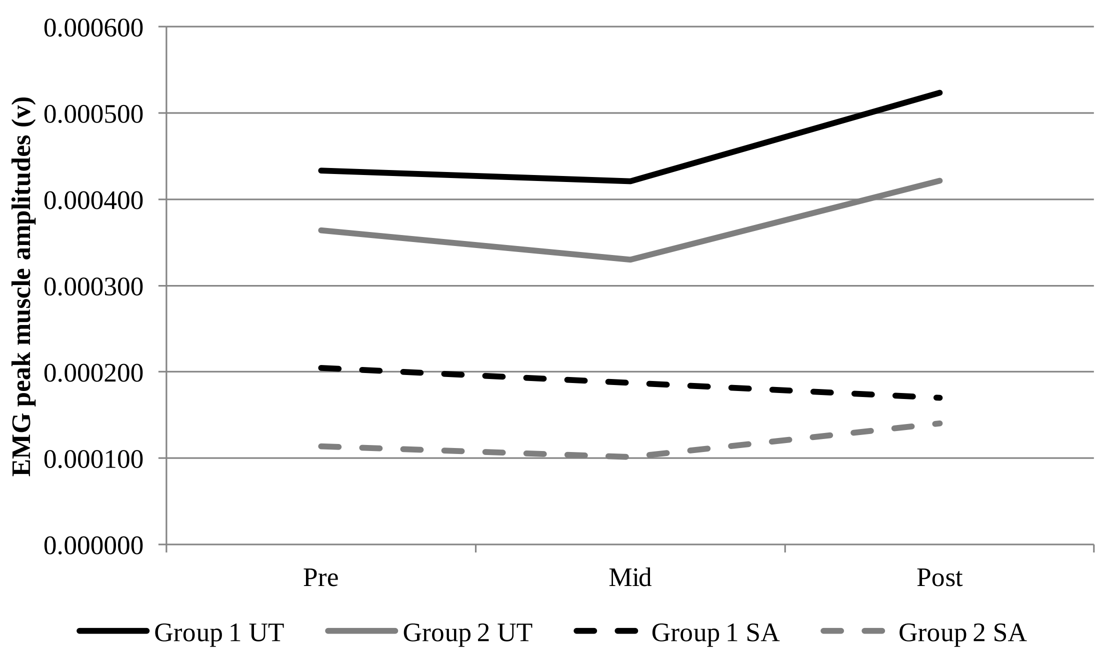
No statistical difference was found between groups for pre test to mid test and mid test to post test

Figure 4. Thoracic Extension range (cm)



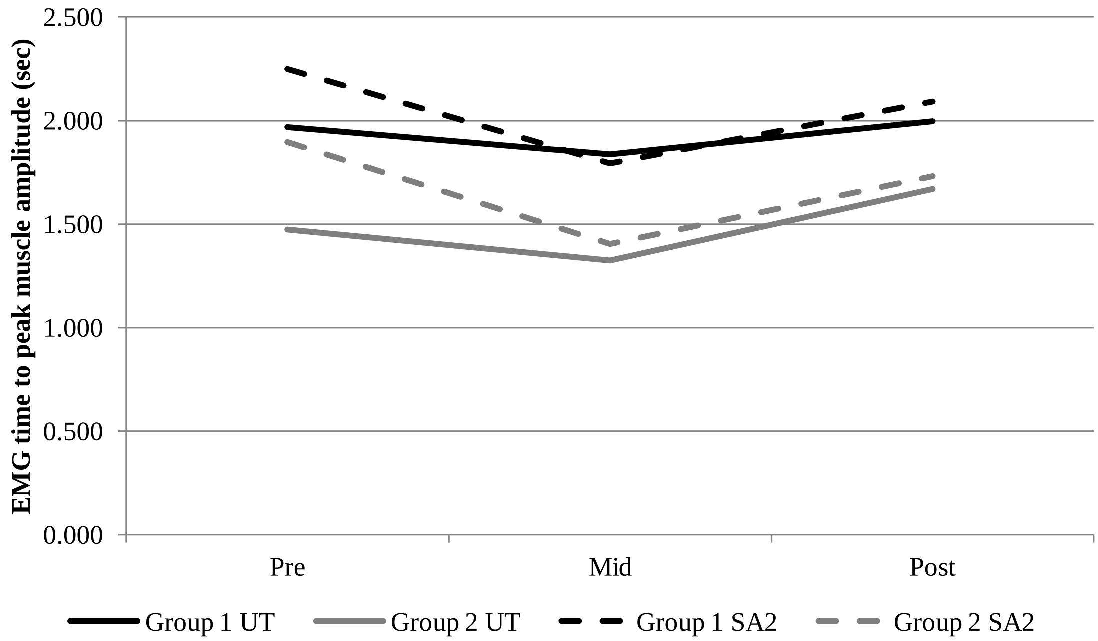
No statistical difference was found between groups for pre test to mid test and mid test to post test

Figure 5. EMG Peak Amplitudes (v)



No statistical difference was found between groups for pre test to mid test and mid test to post test

Figure 6. EMG Time to Peak Amplitudes (sec)



No statistical difference was found between groups for pre test to mid test and mid test to post test

The rationale to our hypothesis that the intervention protocol would improve thoracic spine angle and thoracic extension range was through research of previous investigations in thoracic spine mobilisation interventions. Some investigations give mixed results on their effectiveness to improve static thoracic angle and thoracic extension range[24] although recent research of more comprehensive intervention protocols such as the protocol we used has shown positive effects[22,23]. Figure 3 shows a positive change in thoracic angle (-2.12°) for group 2's exposure to the intervention mid to post test as does Figure 4 for thoracic extension range (0.33cm) with these findings being close to a significant change ($p = .073$ and .108 respectively). Ultimately though our results concur with previous research of thoracic kyphosis that improvements in thoracic angle due to a corrective exercise intervention show some trends yet are largely variable and inconclusive.

The rationale to our hypothesis that the intervention would affect muscle activation of the UT and SA during scaption, more importantly change the pattern of their relationship inducing more SA activation and less UT activation, was through research of previous investigations in scapula function and SAIS due to the lack of research in to the relationship between kyphosis of the thoracic spine and SAIS although being regularly proposed by researchers to be a causative mechanism [3,9]. The relationship between dysfunctional scapula kinematics and SAIS has been heavily researched and conclusions made that a reduced ability of the scapula to upwardly rotate, posteriorly tilt and externally rotate are a common causative mechanism of SAIS.[11,12] These dysfunctional scapula kinematics stop the acromion rising during humeral elevation which in turn compresses the sub acromial space causing damage to the tissue within it.[7,15] However the inferences of a kyphotic thoracic spine being a causative mechanism of SAIS are not due to a direct relationship between kyphosis and the sub acromial space but to the dysfunctional scapula kinematics that impact upon it with a link found between thoracic kyphosis and poor scapula orientation.[25] Also increases in flexion of the thoracic spine have been found to significantly affect kinematics of the scapula and decrease shoulder abduction muscle force,[26] improvements in scapula positioning have been found due to a pectoralis muscle stretching program in subjects with poor posture[27] and elevation of the arm requires extension of the thoracic spine.[28,29]

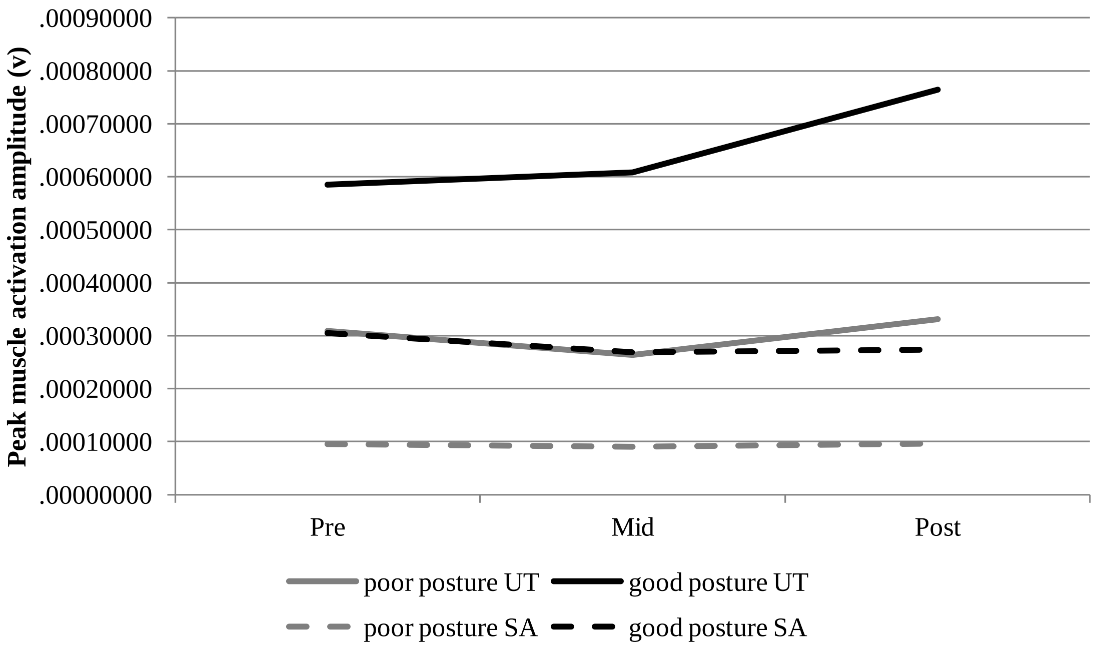
In research of SAIS dysfunctional scapula kinematics and dysfunctional scapula muscle activation patterns are highly correlated,[30,25] with early and/or overactive activation of the UT and PM muscles coupled with delayed and/or decreased activation of the LT and SA muscles[12,16,17] being the most commonly found pattern. Due to the connection of scapula muscle activity to scapula kinematics and scapula kinematics to thoracic spine angle then a relationship between kyphotic thoracic spine and dysfunctional scapula muscle activation patterns can be assumed and a protocol to correct thoracic kyphosis should prove successful in realigning the balance of scapula muscle activation, although only two studies can be found investigating this assumption. ,[31],[32] The first study measured posture and scapula muscle activation against different types of postural braces with the scapula brace improving posture and although highly variable some small positive changes in scapula muscle activation were found, the second found an increase in LT isometric strength due to a short term intervention of thoracic spine manipulation. Neither of these studies used a corrective exercise program as their intervention but their findings add confidence to our hypothesis.

Figure 5 shows a slight increase in peak amplitude of the SA muscle for group 2 when exposed to the intervention mid to post test although so does UT peak amplitude which is in contradiction to our hypothesis. Figure 6 shows the SA peak activation moving from after UT peak activation pre intervention to before UT peak activation post intervention at mid test for group 1. When comparing the graphs from Figure 5 to Figure 6 it can be seen that peak amplitudes are relative to muscle, meaning the UT activation was much greater for every subject than SA activation, whereas the time to peak amplitudes are relative to subject with the group to group pattern being nearly identical. In terms of a relationship between the muscles this means that no matter how strong or weak the activation of each muscle is the pattern of activation between the two muscles during scaption remains relative to each other. Our results show some signs that our hypothesis has value but due to the variability of the results, some of which conflicting with our hypothesis, more research is needed in this area.

A post study evaluation of the testing protocol has brought to light many interesting points for discussion. Static thoracic posture was tested using a digital inclinometer although human error may have existed from the tester in terms of device placement and from the subject in terms of standing posture. Although subjects were instructed to walk on the spot before adopting a still relaxed posture there is a large margin of difference between full flexion and full extension of the spine therefore finding a position at the exact same point on this continuum for all 3 testing sessions would be very unlikely. The majority of subjects also found it difficult to stand completely still for the duration of 3 readings to be taken, without thinking they would scratch their nose, hold their hands together, turn their head or something similar which may have had an effect on the readings. The thoracic extension test was completely dependent on reliability of the human tester and ascertaining the exact position of some subjects C7 vertebrae also proved difficult. Performing the measurement itself proved to be a skill due to the movement of skin, body fat and excessive arching backwards of the head and neck. Like any other skill, practice induces improvement and over the 3 testing sessions the skill of performing the test definitely improved which would have certainly had an impact on the results. This may be responsible for the dramatic reduction in thoracic extension range for group 2 seen in Figure 4 from pre to mid testing. It is highly unlikely the subjects thoracic extension range would have deteriorated by that amount in 5 weeks and adds weight to our theory that lower measurements were returned as the skill of performing the test improved. If our theory is correct then the actual thoracic extension ranges of the two groups at pre test would have been lower than we measured, this may have meant the improvements shown for group 2 from mid to post test would have reached statistical significance. These two thoracic variables would be much more effectively and precisely measured using photo/video analysis, ultrasound, X ray or a motion sensor analysis system however these would be more costly, complex and thus less likely repeatable for future research.

As can be seen from the results the EMG amplitudes measured were very low, this could be due to a number of factors first of which being the exercise used as the test. Although a straight arm raise has been the most popular exercise used in previous shoulder related research for assessing the relationship between UT and SA, maybe it is simply that the muscle force needed to perform it is low. Comparisons to other studies using surface EMG analysis of scapula muscle activation ascertains no feedback as to the strength of our amplitude measurements due to the fact their comparative EMG data was a percentage of maximum voluntary isometric contraction whereas our comparative EMG data is absolute values but it is widely recognised that surface EMG testing returns low measurement amplitudes. Although the voltage measured from both muscles was low it was the SA amplitude that was in some subjects close to nil, when retrospectively matching the data to the subjects a pattern can be seen that the lowest SA activations were retrieved from the subjects with the poorest postures. In order to clarify this we performed a repeated measures ANOVA on the peak activation amplitude data for both muscles with the subjects split into two groups determined by static thoracic angle (Figure 7), the poor posture group (n=13) was determined by a thoracic angle of 37°< and the good posture group (n=7) was determined by a thoracic angle of <37°. The main effect for group on SA peak activation amplitude was significant, $F(1, 18) = 14.074$, $p = .001$, as was the main effect for group on UT peak activation amplitude, $F(1, 18) = 13.489$, $p = .002$. This statistically confirms that our subjects with greater kyphotic angles had significantly lower SA muscle activation, which reinforces the theory that this study was based on and although our hypothesis was rejected these finding may imply that our hypothesis was rejected due to our intervention not having a positive impact on our subjects thoracic kyphosis not that improvements in thoracic kyphosis do not improve SA muscle activation. These interesting findings may then allude to an opinion that an intervention of longer duration would find more positive results, research findings[24,33] support this suggesting that individuals need to be subjected to postural correction and movement re-education exercises for much longer periods of time to have a positive effect on static postural alignments and joint kinematic dysfunctions however specific time guidelines have yet to be clarified which is an area to be considered for future research. Alternatively a change to the intervention in this study may generate the postural changes needed for a positive impact on the SA muscle activation as well as the postural variables. However the significant finding that UT muscle activation amplitudes were higher in the good posture group and lower in the poor posture group contradicts the dysfunctional scapula muscle activation patterns commonly found to relate to SAIS. As previously mentioned SAIS and dysfunctional scapula kinematics relate to overactive UT muscle activation therefore greater thoracic kyphosis angles should relate to higher UT muscle activations and a decrease in thoracic kyphosis should relate to lower UT muscle activations, more research is needed comparing scapula muscle activation patterns in subjects with thoracic kyphosis to subjects with thoracic kyphosis and SAIS to clarify this.

Figure 7. Peak Muscle Activation Amplitudes with Subjects Grouped by Posture



The difference between groups for SA peak amplitude was significant ($F(1, 18) = 14.074$, $p = .001$) as was the difference between groups for UT peak amplitude ($F(1, 18) = 13.489$, $p = .002$).

Another pattern found when retrospectively matching the data to the subjects is the lowest SA amplitudes were found in subjects holding the most body fat, although this is likely to always be found when measuring muscle activity with surface EMG due to more tissue being present between the electrodes and muscles being measured and due to the lack of subject's body fat data a statistical test could not be performed to clarify this. Alternatively the low SA amplitudes found could simply be down to poor electrode placement.

The largest lack of control in the study came over the intervention although this type of study design with participants needing to perform daily exercises is nearly impossible to fully control. Firstly trust is at question for a home exercise intervention with subjects needing to be honest when reporting how many days they completed the exercises, although there was no reason to mistrust any of the subjects here. Secondly participants self motivation is a factor, maybe a fully coached intervention would finish with more subjects completing the required amount of intervention days which would add strength to the outcome. Thirdly technique and effort of exercises is under question, during the intervention period 3 coached sessions were made available to the subjects each week but not mandatory attendance and of those who attended at any time all were performing at least one of the exercises incorrectly. Also the effort level to push the stretch to its furthest point, raise the arms to their highest position, hold the position for the desired time, etc was found lacking in some subjects. When consideration is given to the fact that only 10 of the final 20 subjects attended a coached session it has to be assumed the remaining 10 would have done the same things therefore it is possible these issues over the intervention may have had an impact on the outcome of the study and even opens an avenue for future research in which a fully coached intervention design can be used.

Conclusion

This study has given some insight in to the relationship between thoracic spine angle and scapula muscle activation albeit not providing anything conclusive. Practical recommendations from the findings here when treating patients with SAIS are to assess their thoracic posture along with a more comprehensive shoulder function assessment outlined in the research referenced to in this manuscript. If kyphosis of the thoracic spine is found then corrective exercises such as the ones used in this study should be included as part of their SAIS rehabilitation protocol. Due to the limitations of this study and that it is the first piece of research investigating this relationship it is recommended that future research of this relationship is undertaken. To account for the limitations found by this study future research should use an intra muscular electrode method for reading EMG muscle activation signals, as long as placement of the electrodes is correct this will negate all the variables found in skin surface electrode methods which may have been encountered in this study. Tighter control needs to be set for future interventions in to this relationship, this is hard due to the daily requirements of a posture correction routine but a fully coached intervention is the only way to control for this. Future research should also look at different lengths and types of intervention for posture correction as the intervention here did not make a significant change in posture and also different types of postural dysfunctions such as rounded shoulders and forward head posture. Although the UT and SA relationship has previously been shown to be an essential one in SAIS with the findings here adding weight to that, other scapula muscles need investigating for their relationship with posture as does more research into shoulder joint kinematics relationship with posture.

REFERENCES

1. Struyf F, Cagnie B, Cools A, et al. Scapulothoracic muscle activity and recruitment timing in patients with shoulder impingement symptoms and glenohumeral instability. *J Electromyogr Kinesiol*. 2014;24(2):277-284. doi:10.1016/j.jelekin.2013.12.002.

2. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther*. 2009;39(2):90–104.

3. Ellenbecker TS, Cools A. Rehabilitation of shoulder impingement syndrome and rotator cuff injuries: an evidence-based review. *Br J Sports Med*. 2010;44(5):319–327.

4. Lukasiewicz AC, McClure P, Michener L, Pratt N, Sennett B. Comparison of 3-dimensional scapular position and orientation between subjects with and without shoulder impingement. *J Orthop Sports Phys Ther*. 1999;29(10):574–586.

5. Lewis J. Rotator cuff related shoulder pain: Assessment, management and uncertainties. *Man Ther*. 2016;23:57-68. doi:10.1016/j.math.2016.03.009.

6. Kibler WB, Ludewig PM, McClure PW, et al. Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the "Scapular Summit." *Br J Sports Med*. 2013:bjsports–2013.

7. Ludewig PM, Braman JP. Shoulder impingement: Biomechanical considerations in rehabilitation. *Man Ther*. 2011;16(1):33-39. doi:10.1016/j.math.2010.08.004.

8. Reinold MM, Escamilla R, Wilk KE. Current concepts in the scientific and clinical rationale behind exercises for glenohumeral and scapulothoracic musculature. *J Orthop Sports Phys Ther*. 2009;39(2):105–117.

9. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech*. 2003;18(5):369–379.

10. Wilk KE, Obma P, Simpson CD, Cain EL, Dugas J, Andrews JR. Shoulder injuries in the overhead athlete. *J Orthop Sports Phys Ther*. 2009;39(2):38–54.

11. Forthomme B, Crielaard J-M, Croisier J-L. Scapular positioning in athlete's shoulder. *Sports Med*. 2008;38(5):369–386.

12. Lin J, Hanten WP, Olson SL, et al. Functional activity characteristics of individuals with shoulder dysfunctions. *J Electromyogr Kinesiol*. 2005;15(6):576–586.

13. Kibler WB, Sciascia A. Current concepts: scapular dyskinesis. *Br J Sports Med*. 2010;44(5):300–305.

14. Ludewig PM, Behrens SA, Meyer SM, Spoden SM, Wilson LA. Three-dimensional clavicular motion during arm elevation: reliability and descriptive data. *J Orthop Sports Phys Ther*. 2004;34(3):140–149.

15. Silva RT, Hartmann LG, de Souza Laurino CF, Biló JR. Clinical and ultrasonographic correlation between scapular dyskinesia and subacromial space measurement among junior elite tennis players. *Br J Sports Med*. 2010;44(6):407–410.

16. Cools AM, Witvrouw EE, Declercq GA, Danneels LA, Cambier DC. Scapular muscle recruitment patterns: trapezius muscle latency with and without impingement symptoms. *Am J Sports Med*. 2003;31(4):542–549.

17. Cools AM, Declercq GA, Cambier DC, Mahieu NN, Witvrouw EE. Trapezius activity and intramuscular balance during isokinetic exercise in overhead athletes with impingement symptoms. *Scand J Med Sci Sports*. 2007;17(1):25–33.

18. Castelein B, Cagnie B, Parlevliet T, Cools A. Serratus anterior or pectoralis minor: Which muscle has the upper hand during protraction exercises? *Man Ther*. 2016;22:158-164. doi:10.1016/j.math.2015.12.002.

19. Lewis JS, Green A, Wright C. Subacromial impingement syndrome: the role of posture and muscle imbalance. *J Shoulder Elbow Surg*. 2005;14(4):385–392.

20. Lewis JS, Valentine RE. Clinical measurement of the thoracic kyphosis. A study of the intra-rater reliability in subjects with and without shoulder pain. *BMC Musculoskelet Disord*. 2010;11:39. doi:10.1186/1471-2474-11-39.

21. Barrett E, McCreesh K, Lewis J. Reliability and validity of non-radiographic methods of thoracic kyphosis measurement: a systematic review. *Man Ther*. 2014;19(1):10–17.

22. Welcome to SENIAM. http://www.seniam.org/. Accessed June 13, 2017.

23. Seidi F, Rajabi R, Ebrahimi I, Alizadeh MH, Minoonejad H. The efficiency of corrective exercise interventions on thoracic hyper-kyphosis angle. *J Back Musculoskelet Rehabil*. 2014;27(1):7-16.

24. Yoo W. Effect of Thoracic Stretching, Thoracic Extension Exercise and Exercises for Cervical and Scapular Posture on Thoracic Kyphosis Angle and Upper Thoracic Pain. *J Phys Ther Sci*. 2013;25(11):1509-1510. doi:10.1589/jpts.25.1509.

25. Hrysomallis C, Goodman C. A review of resistance exercise and posture realignment. *J Strength Cond Res*. 2001;15(3):385–390.

26. Borstad JD. Resting Position Variables at the Shoulder: Evidence to Support a Posture-Impairment Association. *Phys Ther*. 2006;86(4):549-557.

27. Kebaetse M, McClure P, Pratt NA. Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil*. 1999;80(8):945-950. doi:10.1016/S0003-9993(99)90088-6.

28. Roddey TS, Olson SL, Grant SE. The effect of pectoralis muscle stretching on the resting position of the scapula in persons with varying degrees of forward head/rounded shoulder posture. *J Man Manip Ther*. 2002;10(3):124–128.

29. Clinical and Radiological Investigation of Thoracic Spine Extension Motion During Bilateral Arm Elevation. *J Orthop Sports Phys Ther*. 2012;42(10):861-869. doi:10.2519/jospt.2012.4164.

30. Jelínková I. KINEMATICS OF THE CERVICAL-THORACIC SPINE AND THE SHOULDER GIRDLE. *Acta Univ Carol Kinanthropologica*. 2012;48(2). http://search.ebscohost.com/login.aspx?direct=true&profile=ehost&scope=site&authtype=crawler&jrnl=12121428&AN=87552911&h=AbhH58niE2n1pffcJYGmH%2FqrL8HYeOBeQ8xS3338V1xJIPKsp4yJmx5rqRGa%2BmVf%2BtZPsMe7FtMB1Ny4EEUzEQ%3D%3D&crl=c. Accessed October 12, 2016.

31. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. *Phys Ther*. 2000;80(3):276–291.

32. Cole AK, McGrath ML, Harrington SE, Padua DA, Rucinski TJ, Prentice WE. Scapular Bracing and Alteration of Posture and Muscle Activity in Overhead Athletes With Poor Posture. *J Athl Train*. 2013;48(1):12-24. doi:10.4085/1062-6050-48.1.13.

33. Cleland J, Selleck B, Stowell T, et al. Short-Term Effects of Thoracic Manipulation on Lower Trapezius Muscle Strength. *J Man Manip Ther J Man Manip Ther*. 2004;12(2):82-90.

34. Harman K, Hubley-Kozey CL, Butler H. Effectiveness of an exercise program to improve forward head posture in normal adults: a randomized, controlled 10-week trial. *J Man Manip Ther*. 2005;13(3):163–176.

Ethical approval form

St Mary's University Twickenham London

Approval Sheet

Name of applicant: Steve Knight

Name of supervisor: Louis Howe

Programme of study: Strength and Conditioning Masters

Title of project: The effect of thoracic spine mobilisation on thoracic extension and serratus anterior and upper trapezius muscle activation patterns

Supervisors, please complete section 1 or 2. If approved at level 1, please forward a copy of this Approval Sheet to the School Ethics Representative for their records.

SECTION 1

Approved at Level 1

Signature of supervisor (for student applications

Date:

SECTION 2

Refer to School Ethics Representative for consideration at Level 2 or Level 3

Signature of supervisor...

Date..

SECTION 3

To be completed by School Ethics Representative

Approved at Level 2

Signature of School Ethics Representative: J Hill
Date 19/01/2017

Participant information sheet

Title of study: The effect of thoracic spine mobilisation on thoracic extension and serratus anterior and upper trapezius muscle activation patterns

Lead researcher:
Steven Knight
Contact: 134109@live.stmarys.ac.uk

Research supervisor:
Louis Howe
Contact: Louis.howe@stmarys.ac.uk

We would like to invite you to take part in a research study. Before you decide whether you would like to take part it is important that you understand why the research is being done and what it would involve for you. Please take time to read the following information carefully and discuss it with others if you wish. Ask us if there is anything that is not clear or if you would like more information.

What is the purpose of the study?
To establish if a relationship exists between kyphosis of the thoracic spine and dysfunction of the scapula due to research of shoulder dysfunctions suggesting a lack of extension through the thoracic spine may play a role in reduced movement of the scapula. Subjects with kyphotic thoracic spines will participate in an intervention aimed at improving thoracic extension and the muscle activation pattern of their serratus anterior and upper trapezius muscles (the main muscle pairing highly correlated with scapula function) will be compared pre and post intervention during a straight arm raise (the predominant movement used in shoulder function research).

Why have I been invited?
You have been chosen due the fact you passed the inclusion criteria of having a rounded upper back posture and a lack of ability to straighten your upper back posture. You will be one of a minimum of 24 participants in this study

Do I have to take part?
Participation in the project is voluntary, and you can choose not to participate in part or all of the project. You can withdraw at any stage of the project without being penalised or disadvantaged in any way.
It is up to you to decide whether or not to take part. If you do decide to take part you will be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

What will happen if I take part?

- The study will start on 1st February 2017 and finish on 7th April 2017
- Participants will need to be available for one 4 week period in which to complete a 25 minute exercise routine daily. Either 4th February to 4th March or 8th March to 5th April
- Participants will also need to be available to attend a test at all 3 testing intervals; 1st and 2nd February, 5th and 6th March, 6th and 7th April
- You will meet with the researchers at all 3 testing sessions and also during the 4 weeks of exercise there will be 3 coach led sessions per week run at the venue
- All participants will be required to fill in health screening questionnaires and consent forms. The tests during the trial will consists of measurements of spine angle and collection of muscle activation patterns of the back and shoulder using skin surface electrodes and a electromyography machine

The testing sessions and all coach led exercise sessions will be taking place at Sports direct fitness, St Heliers Ave, Off Portland Road, Hove, East Sussex, BN3 5RE

What are the possible disadvantages and risks of taking part?

The only risk from taking part in this study is of pain or injury but due to the exercises being used having no external load this risk is very minimal

What are the possible benefits of taking part?

A benefit of taking part may be an improvement in function of the spine and shoulder

Will my taking part in the study be kept confidential?

- Only me and my project supervisor will have access to all personal data and testing data
- The only data published in the final draft of the study will be testing data that will not relate to any individual on a personal level
- There will be no future use of any data collected for this project without consultation and consent from each individual
- All personal data will be stored in a locked filing cabinet and on a password encrypted computer that only I have access to

What will happen to results of the research study?

The results of the study will be submitted to St Marys University in the form of my Msc dissertation and may also be published in a relevant scientific journal. A digital copy of my submitted dissertation and any future journal publications will be sent to each participant via email.

What will happen if I don’t want to carry on with the study?

The bottom of the consent form has a withdrawal section that can be signed and given to the head researcher.

What if there is a problem?

If you have any problems, concerns or questions about this study, you should contact a member of the research team. If you remain unhappy and wish to complain formally, you can do this through contact with the project supervisor

Who has reviewed the study?

This study has been approved by St Mary's University, Twickenham School of sport, health and applied sciences Research Ethics Committee

Thank you for taking the time to read this information sheet.

Participant consent form

Name of Participant: ____

Title of the project: The effect of thoracic spine mobilisation on thoracic extension and serratus anterior and upper trapezius muscle activation patterns

Main investigator: Steven Knight

Contact details: 134109@live.stmarys.ac.uk

1. I agree to take part in the above research. I have read the Participant Information Sheet which is attached to this form. I understand what my role will be in this research, and all my questions have been answered to my satisfaction.
2. I understand that I am free to withdraw from the research at any time, for any reason and without prejudice.
3. I have been informed that the confidentiality of the information I provide will be safeguarded.
4. I am free to ask any questions at any time before and during the study.
5. I have been provided with a copy of this form and the Participant Information Sheet.

Data Protection: I agree to the University processing personal data which I have supplied. I agree to the processing of such data for any purposes connected with the Research Project as outlined to me.

Name of participant (print)…………………………………………………………………………..

Signed………………..…………………   Date…………………………........

If you wish to withdraw from the research, please complete the form below and return to the main investigator named above.

Title of Project: ____

I WISH TO WITHDRAW FROM THIS STUDY

Name: ____________________________________

Signed: ______________________________   Date: ___________________