ABSTRACT

Background/Aims: Glenohumeral subluxation (GHS) is commonly reported in people with stroke. Lycra sleeves provide a compressive and supportive effect, influencing the neuromuscular activity in the affected body segment. A recent study reported reduction in GHS (acromion-greater tuberosity (AGT) distance) following application of Lycra arm sleeve, however, its mechanism on the shoulder region as a whole is unclear. The aim of this study was to investigate if application of a Lycra sleeves changes the AGT distance, muscle activity around the shoulder region and scapular position. **Methods:** Healthy participants aged over 18 years who gave informed consent were recruited. Measurements were taken before and immediately after application of the sleeve. Portable diagnostic ultrasound, surface electromyography and a tape measure were used to measure AGT distance, muscle activity (biceps, triceps, deltoid, and supraspinatus) and position of the scapula respectively. **Findings:** Thirty one participants (11 men, 20 women) with mean age 25±10 years participated. Paired-test showed significant mean reduction of 0.12 cm (95% confidence intervals (CI) 0.07-0.16cm) in AGT distance measurements ($t=5.112$, $df=30$, $p=0.003$), and scapula measurements (0.3cm, 95% CI 0.04-0.4cm; $t=2.501$; $df=30$, $p<0.01$) when compared without and with sleeve application.

Conclusions: Future research should investigate the effects of the Lycra sleeve on people with GHS in the different phases of rehabilitation.

Key words: Lycra sleeve, Acromion-greater tuberosity distance, muscle activity, shoulder girdle, Glenohumeral Subluxation

ABBREVIATIONS

AGT- Acromion-greater Tuberosity

CI –Confidence intervals

Df – degrees of freedom

EMG – Electromyography

ER –External Rotation

FES –Functional Electrical Stimulation

GHS – Glenohumeral subluxation

ICC – Intra class correlation

SD- Standard Deviation

INTRODUCTION

The shoulder is a highly mobile and less stable joint. As compared with the hip joint, the glenoid is a much shallower than the acetabulum, allowing for a greater range of motion of the glenohumeral joint in various planes.[1] Given this increased mobility, the glenohumeral joint is associated with increased instability as compared with other joints. Consequently disorders of shoulder complex are common after stroke leading to pain, glenohumeral subluxation (GHS) and impaired upper limb function.[2,3]

GHS is a common post-stroke complication reported in up to 81% of patients depending on the measurement methods used and the time frames over which it is assessed.[2] The rotator cuff provide force coupling mechanism to align the head of the humerus in the glenoid cavity, however, this mechanism is compromised due to loss of motor control following stroke causing GHS.[4,5] A cross-sectional study on chronic pateints with stroke (n=45) investigated the correlation between postural alignment and postural control in sitting.[6] The study found that the degree of forward head posture correlates directly with seated postural control and inversely with degree of kyphosis and that the postural control is directly related with Brunnstrom's stage of recovery in the affected upper extremity in sitting.[6] There is some evidence to support the relationship between scapular orientation and GHS.[7,8]

Varied approaches including supportive devices, functional electrical stimulation have been proposed for prevention and management of GHS,[9,10,11,12] however, evidence to support the effectiveness of current approaches for management of GHS is limited.[13] The functional basis of Lycra garments is to exert a compressive, and supportive effect, increases sensory attention and thus positively influence alignment, biomechanics, and neuromuscular activity in the affected body segments.[14] Limited studies have shown some beneficial effects of Lycra arm sleeve in people with post stroke hemiplegia.[15,16] In a small (n=16) cross-over study, people with post-stroke hemiplegia were asked to wear a Lycra sleeve (from the wrist to the middle of the upper arm) for 3 hours period. Patients showed improvement in the wrist posture, reduced wrist and finger flexor spasticity and a mean (4.1°±13.0°) increase in passive range of movement at the shoulder joint (across all movements).[15] These effects were significantly different when compared to patients not wearing the sleeve.

In our recent study on people with chronic stroke (n=5)[16], the Lycra arm sleeve was applied from the wrist joint up to the insertion of deltoid on the humerus. Patients were advised to wear the sleeve for at least 7 hours/day. GHS was measured using ultrasound (acromion-greater tuberosity (AGT) distance) before and after the application of the sleeve on day 1 and after one week of wearing a sleeve. There was a mean reduction of 0.24 cm and 0.18 cm in AGT distance on days 1 and 8 respectively. When AGT distance measurements from 'sleeve off' on day 1 were compared to 'sleeve on' on day 8, it showed a mean reduction of 0.27cm. Despite the fact that Lycra arm sleeve does not cross the shoulder joint, there was a reduction in AGT distance. However, the mechanism of Lycra arm sleeve on the shoulder region is not clearly understood.

To the best of our knowledge, no previous study has investigated the mechanism of Lycra arm sleeves on the shoulder region. The purpose of this pilot study was to understand the changes in shoulder biomechanics (acromion-greater tuberosity distance, shoulder muscle activity and scapula position) following application of the Lycra sleeve on healthy individuals prior to testing this on people with post-stroke hemiplegia.

METHODS

Study Design

This was a cross-sectional, observational study where a sample of convenience (n=31) was recruited between February and March 2016. This study adhered to the guidelines of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement.[17]

Participants and Raters

Healthy individuals aged over 18 years of age were eligible to participate in the study and a convenient sample of n=31 were recruited from the authors' academic institution. Participants were invited by email and those who expressed interest were provided with study details and recruited into the study. People with a previous history of injury to the neck or shoulder were excluded from the study. The study received approval from the Research Ethics Committee of the xxxxxxxxxxxxxxxxxx, xxxxxx, and each participant gave informed written consent to take part.

Three raters (final year physiotherapy students) were involved in the assessment procedure. One rater was involved with ultrasound measurements of AGT, second rater was involved with EMG recordings and the third rater was involved with scapula measurements using standard protocols. For ultrasound measurements of AGT, a previously tested training protocol for ultrasound measurements of acromion-greater tuberosity (AGT) distance was used.[18] That study reported good intra-rater (ICC 0.88-0.91) reliability when assessed by three physiotherapy students in healthy individuals. The ultrasound training in this study included 1) one hour of formal training on the portable ultrasound technique for AGT measurements 2) practice on five healthy volunteers (2-3 hours) to become familiar with the protocol and measurement procedure.

Apparatus

A portable diagnostic ultrasound, (TITAN model, M-Mode, Depth 3.9, L38/10-5MHz broadband 38 mm linear array transducer, Sonosite Limited, Hitchin, UK) was used for scanning the shoulder and for recording the AGT distance. The equipment was tested and calibrated according to the manufacturer's guidelines prior to commencement of the data collection process. The precision of linear measures based on manufacturer specifications is ± 2%. A portable electromyography device (Bio-Trac Plus, EMS Physio Ltd, England) was used for recording muscle activity. A tape measure was used to record measurements of scapula position.

Procedure

Baseline demographic data including age, gender and dominant arm were collected prior to data collection. AGT distance using ultrasound, muscle activity using EMG and scapula position measurements were taken before and with application of a Lycra sleeve (fig 1). The order of data collection was ultrasound measurements, EMG muscle activity (biceps brachii, Triceps, Deltoid and Supraspinatus), followed by scapula position measurements. All measurements were taken on the participant's dominant arm.

For ultrasound measurements of AGT distance, each patient was placed in a standardised position to allow measurement of AGT distance. The shoulder was in neutral rotation, with the elbow at 90° of flexion and the forearm in pronation. The forearm rested on a pillow placed on the participants lap with the elbow joint itself remaining unsupported. The ultrasound transducer then was placed over the lateral border of the acromion along the vertical/longitudinal axis of the humerus to scan the shoulder. AGT distance was recorded on the frozen image using an on-screen caliper that automatically calculates distances (fig 2). AGT distance was defined as the relative lateral distance between the lateral edge of the acromion process of the scapula and the nearest margin of the superior part of the greater tuberosity of the humerus.[19] A dark linear acoustic shadow beneath the acromion helped to identify the lateral edge of the acromion. The tendon of supraspinatus was clearly visible as a thick band (acoustic hyperechoic appearance) at its point of insertion, which facilitated identification of the greater tuberosity (fig 2). In order to ensure the rater was blind to measurements, the values displayed were obscured by placing a sticker on the ultrasound screen.

For electromyography, each participant was seated in a relaxed position with arms down by the side. To measure the levels of muscle activity, electrodes were placed on supraspinatus, deltoid, triceps and biceps in the positions advised by SENIAM[20] and the measurement was taken individually with the muscles at rest. For biceps and triceps, the surface electrodes were in-situ and the Lycra sleeve was applied over the top of electrodes.

Scapula measurements were recorded in both sitting and standing positions, with arms relaxed at the side using the previously described protocol.[21] To facilitate a natural posture, participants were asked to swing their arms gently backward and forward 3 times by their sides and stop in a position that felt natural and comfortable to them. To ensure consistency, each participant received this instruction prior to each data collection period. Two linear measurements were taken for the position of the scapula: 1) from the medial aspect of the spine of scapula (point A) and the spinous process parallel to the spine of the scapula (B); and 2) from the inferior angle of the scapula (C) to the parallel spinous process (D).[21] Both sitting and standing positions were selected because upper limb plays an important role in functional activities in sitting and during standing for balance and gait.[22]

Researcher 4 (another physiotherapy student) received training from the manufacturer on the application of sleeve and practiced on few healthy participants prior to data collection. According to the manufacturers' recommendations, the wrist circumference was measured for each participant and the correct size sleeve was provided. The sleeve was applied from the wrist joint up to the insertion of deltoid on the humerus using the donning on/doffing off material. **Each participant was seated in a chair with the arm resting in their lap and the forearm in the mid-prone position. First the donning on/doffing off material was applied, followed by the application of the Lycra sleeve. During the application, a torque was applied while pulling up to assist with external rotation and this was confirmed with the label and 'see' facing posterior-lateral aspect of the arm (fig 1).**

Statistical Analysis

Data were analysed using Statistical Package for the Social Sciences (SPSS) software, version 22.0 (IBM Chicago, Illinois). Descriptive statistics such as the mean and standard deviation of AGT distance measurements, EMG muscle activity, and scapula measurements were calculated without and with the Lycra sleeve.

A Shapiro-Wilk test was used to test for normality. The mean difference between the recorded variables (AGT distance, EMG and scapula measurements) without and with the Lycra sleeve was tested using a Paired sample *t*-test (parametric test) for the normally distributed data. For the data that was not normally distributed, a non-parametric equivalent (Wilcoxon test) was used. Except AGT distance and inferior scapula measurements, all other measurements showed non-normal distribution. A confidence interval of 95% ($p = <0.05$) was set as the acceptable level of statistical significance for AGT distance. Pair-wise comparisons using Bonferroni corrected levels of significance (0.05/4 = 0.0125) to account for multiple tests for EMG (4 muscles) and scapula measurements (4 positions).

RESULTS

Over a period of 4 weeks, 31 healthy participants (11 men, 20 women) with a mean age±SD of 25±10 years (range 19-58 years) were approached and recruited into the study. A summary of descriptive data for AGT, EMG and scapula measurements both without and with a sleeve is presented in Table 1.

Insert Table 1 here

Paired-test showed significant mean reduction of 0.12 cm (95% confidence intervals 0.07-0.16cm) in AGT distance measurements (t=5.112, df=30, p=0.003), and scapula measurements (0.3cm, 95% confidence intervals 0.04-0.4cm; t=2.501; df=30, p<0.01) when compared without and with sleeve application. Both Wilcoxon test and post hoc testing with pair-wise comparisons using Bonferroni corrected levels of significance revealed no statistically significant mean difference for all other tested variables when compared without and with sleeve application (table 2).

Insert Table 2 here

DISCUSSION

The aim of this study was to understand the mechanism of Lycra sleeves on the shoulder girdle by exploring AGT distance, muscle activity and scapular position. To do this, healthy participants were recruited and the measurements were recorded without and with the application of Lycra sleeves. Paired-test showed significant mean reduction of 0.12 cm in AGT distance measurements and 0.3cm in inferior scapula measurements after the application of Lycra sleeve.

Application of the Lycra sleeve resulted in a statistically significant reduction in the AGT (mean 0.12cm) when compared to the distance prior to application of the sleeve. This is in agreement with a previous study on people with stroke which showed a mean reduction of 0.24 cm immediately after the application of sleeve.[16] In that study an experienced rater was involved with ultrasound measurements of AGT distance. In contrast, in this study, a physiotherapy student trained in ultrasound measurements recorded AGT distance. Ultrasound was found to be a reliable and valid tool for measurement of AGT distance, both in healthy[19] and stroke populations[23,24,25] even when used by novice raters including physiotherapy students.[18,26] One study involving three physiotherapy students reported excellent interrater reliability (ICC 0.79) of AGT measurements for the right shoulder in a relatively younger age group (mean age of 21 years SD 2).[16] Another recent study assessed interrater reliability of ultrasonographic measurements of AGT distance between experienced and novice raters in healthy individuals. This study found good (ICC 0.61) to excellent (0.87) inter-rater reliability.[26]

Previous studies have shown that ultrasound is sensitive to detect minor changes in AGT distance. A study on young healthy participants (mean age±SD 28±11 years), that investigated the effect of different arm position reported that a change of greater than ±0.1cm in AGT distance measurements would be necessary to indicate a real change in measurements across different arm positions.[27] These findings suggest a beneficial effect for the Lycra sleeve in reducing the AGT distance which is equivalent to the smallest detectable change previously observed in healthy participants.

Previous studies have proposed that Lycra garments provide a directional pull, which encourages the arm to adopt an improved position for functional tasks.[14] The application of Lycra arm sleeve in this study may have caused approximation of the humerus into the socket and external rotation (ER) at the shoulder joint. During shoulder ER, the infraspinatus muscle, one of the RC muscles, stabilizes the shoulder joint and acts as the prime mover.[28] The infraspinatus muscle reportedly has a larger stabilizing role than torque-producing role during shoulder ER and it is more active with the arm in adduction.[29] It is possible that increased activity in infraspinatus following application of Lycra arm sleeve may potentially contribute to reduction in the AGT distance. This assumption however needs to be tested in the future study as EMG activity was not recorded for the infraspinatus muscle in our study.

The changes noted in AGT distance could be attributed to the effect Lycra sleeve has on the forearm. One study investigated the mechanical effects of Lycra garments on ten healthy people.**[30]** The aim was to assess the stretch of pronator muscles produced by a specifically designed upper-limb Lycra garment that could have a better acceptability than rigid splints in treating upper-limb spasticity.**[30]** **The study investigated if custom-designed Lycra garments exert continuous stretch in predetermined directions and focused on a supinator action. The Lycra sleeve was applied with the arm in neutral position with a pull in the direction of supination.** The study found that the supinator garment supinated the forearm in all subjects (mean, 17°; $p < 0.01$; range, 5° to 44°). **The Lycra garments can improve range because of the arm was placed in a better alignment, due to increased stability in the arm as a**

result of compression, and awareness to assist with active movement proximally in the shoulder.

Similarly, another study on people with stroke found a mean (4.1°±13.0°) increase in passive range of movement at the shoulder joint (across all movements) following application of Lycra arm sleeve applied from wrist to the insertion of deltoid.[15] Also, that study reported improvement in elbow proprioception task following application of Lycra sleeve. There is some evidence to suggest that Lycra sleeve provides proprioceptive feedback to the skin.[15,30] **The authors postulated that the changes noted distally may have produced improvements proximally due to the effect occurring at the spinal level by the multi-segmental, large-fibre, cutaneous input from the skin due to contact of the sleeve.[31,32]**

EMG measurements showed no statistically significant difference in the activity of the biceps and triceps when wearing the sleeve. However, there was some increase in the activity in these muscles leading to the assumption that any resulting contraction of these muscles was helping pull the head of the humerus into better alignment with the glenoid fossa, thereby reducing the AGT distance.[33] This could potentially explain the reduction in AGT distance found in this study. As biceps and triceps are two-joint muscles, their activation in the elbow region may lead to the positive effects found in the shoulder region. A recent study found that electrical stimulation of the long head of biceps along with supraspinatus and posterior deltoid was more effective in reducing GHS following stroke, when compared to just stimulating the supraspinatus and deltoid alone.[34]

This study found a reduction in the inferior angle of the scapula position measurements after wearing the Lycra sleeve. The position of the scapula that enables optimal function of the upper limb for functional tasks is the retraction position.[35] It allows for maximal activation of the muscles that originate on the scapula, and puts muscles at a biomechanical advantage for normal scapulohumeral rhythm which is necessary for smooth, controlled shoulder motions.[36,37] Although, not all scapular measurements reached a statistically significant difference in our study, evidence from the literature supports the positive effect of scapula retraction on shoulder joint rehabilitation.

Limitations

Despite these favorable findings, the present study has several limitations. First, a small convenient healthy sample with a relatively younger age group was selected; therefore, generalisability is limited. Second, because of a lack of randomisation, the raters always performed the measurements in the same order; therefore, order effects cannot be excluded. Thirdly, a portable EMG machine was used. EMG signal acquires noise while travelling through different tissues. Moreover, the EMG detector, particularly if it is at the surface of the skin, collects signals from different motor units at a time which may generate interaction of different signals. Detection of EMG signals with powerful and advance methodologies is recommended and this should be considered for future research. Fourthly, pre-post postural alignment in standing or sitting focusing on a plumb line bisecting the ear-acromion-humerus side view or posterior view of the scapula was not recorded and would be helpful in the future study. Finally, Lycra sleeves were not worn for a long period of time and measurements were not repeated over time. This should be considered when testing the effect of Lycra sleeves on patient populations.

CONCLUSIONS

In conclusion, the application of Lycra sleeves reduced AGT distance, increased activity in some muscles in the shoulder region and positioned scapula in a mechanically advantaged position in healthy individuals. Further investigations on patients with stroke and targeting other rotator cuff muscles during EMG testing are required to understand the mechanism and to establish the clinical effectiveness of Lycra sleeve.

ACKNOWLEDGEMENTS

This project has been undertaken as part of an undergraduate research study on the BSc. (Hons) Physiotherapy programme at the xxxxxxxxxxxxx, xxxxxx. The authors would like to thank xxxxxxxx and xxxxxxxxx for help with the data collection, xxxxxx from xxxxxxx, xxxx for providing the Lycra sleeves for the study, Professor xxxxxx xxxxxx, Dr xxxxx xxxxxxx, xxxxx xxxxxx and xxx xxxx for their critical comments and volunteers for their participation.

Declaration of Interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the article.

REFERENCES

1. Palastanga N, Field D, Soames R. Anatomy and Human Movement: Structure and Function. 2013; 2nd Edition. Butterworth-Heinemann

2. Lindgren, I., Jonsson, A., Norrving, B. and Lindgren, A. (2007) Shoulder Pain after Stroke: A Prospective Population-Based Study. Stroke. 38 (2): 343-48.

3. Wang RY, Yang YR, Tsai MW, Wang WT, Chan RC. Effects of functional electric stimulation on upper limb motor function and shoulder range of motion in hemiplegic patients. Am J Phys Med Rehabil. 2002; 81(4):283-90.

4. Faghri PD, Rodgers MM, Glaser RM, Bors JG, Ho C, Akuthota P. The effects of functional electrical stimulation on shoulder subluxation, arm function recovery, and shoulder pain in hemiplegic stroke patients. Arch Phys Med Rehabil. 1994; 75(1):73–79.

5. Paci M, Nannetti L, Taiti P, Baccini M, Rinaldi L. Shoulder subluxation after stroke: relationships with pain and motor recovery. Physiother Res Int 2007; 12(2): 37-50

6. Iyengar YR, Vijayakumar K, Abraham JM, Misri ZK, Suresh BV, Unnikrishnan B. Relationship between postural alignment in sitting by photogrammetry and seated posturalcontrol in post-stroke subjects. NeuroRehab 2014;35 (2): 181-90.

7.Culham EG, Noce RR, Bagg SD. Shoulder complex position and glenohumeral subluxation in hemiplegia. Arch Phys Med Rehabil. 1995; 76 (9): 857-64

8. Price C, Rodgers H, Franklin P, Curless R and Johnson G. Glenohumeral subluxation, scapula resting position and scapula rotation after stroke: a non invasive evaluation. Arch Phys Med Rehabil. 2001; 82 (7): 955-60.

9. Griffin C. Management of the hemiplegic shoulder complex. Top Stroke Rehabil. 2014; 21(4): 316–318

10. .Ada L, Foongchomcheay A, Canning C. Supportive devices for preventing and treating subluxation of the shoulder after stroke. Cochrane Database Syst Rev. 2009; **5** (1): DOI: 10.1002/14651858.CD003863.pub2

11. Dajpratham P, Sura P, Lektrakul N, Chanchairujira G. Efficacy of shoulder slings in shoulder subluxation of stroke patients. J Med Assoc Tha. 2006; **89**(12): 2050-5.

12. Vafadar AK, Cote JN, Archambault PS. Effectiveness of functional electrical stimulation in improving clinical outcomes in the upper arm following stroke: a systematic review and meta-analysis. BioMed Res Int. 2015; [online]. https://www.hindawi.com/journals/bmri/2015/729768/

13. Stolzenberg D, Siu G, Cruz E. Current and future interventions for glenohumeral subluxation in hemiplegia secondary to stroke. Top Stroke Rehabil. 2012; 19(5):444-56.

14. Watson M, Crosby P and Matthews M. An Evaluation of the Effects of a Dynamic Lycra Orthosis on Arm Function in a Late Stage Patient with Acquired Brain Injury. Brain Inj. 2007; 21(7): 103-107.

15. Gracies J, Marosszeky JE, Renton R, Sandanam J, Gandevia SC and Burke D Short-term Effects of Dynamic Lycra Splints on Upper Limb in Hemiplegic Patients. Arch Phys Med Rehabil. 2000; 81(12):1547-1555.

16. Kumar P. The effects of Lycra arm sleeve on Glenohumeral Subluxation in Post-stroke Hemiplegia – A Preliminary Study. J Prosthet Orthot. (In Press).

17. Elm V E, Altman D G, Pocock S J, Gotzsche P C, Vandenbroucke J P The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) statement: guidelines for reporting observational studies. Epidemiology. 2007; 18(6):800-4.

18. Kumar P, Chetwynd J, Evans A, Wardle G, Crick C and Richardson B. Inter-rater and intra-rater reliability of ultrasonographic measurements of acromion-greater tuberosity distance in healthy people. Physiother Theory and Pract. 2011; 27(2): 172-175.

19. Kumar P, Bradley M, Swinkels A. Within-day and day-to-day intrarater reliability of ultrasonographic measurements of acromion-greater tuberosity distance in healthy people. Physiother Theory and Pract. 2010; 26(5): 347-351

20. SENIAM,. Recommendations for sensor locations on individual muscles. 2016. Available from: http://www.seniam.org

21. Lewis J and Valentine R. Intraobserver reliability of angular and linear measurements of scapular position in subjects with and without symptoms. Arch Phys Med Rehabil. 2008; 89(9): 1795-1802.

22. Au-Yeung SS, Ng JT, Lo SK. Does balance or motor impairment of limbs discriminate the ambulatory status of stroke survivors? Am J Phys Med Rehabil. 2003; 82(4): 279-83

23. Park GY, Kim JM, Sohn SI, Shin IH, Lee MY. Ultrasonographic measurement of shoulder subluxation in patients with post-stroke hemiplegia. J Rehabil Med 2007;39(7):526-30

24. Kumar P, Mardon M, Bradley M, Gray S, Swinkels A Assessment of glenohumeral subluxation in post-stroke hemiplegia: Comparison between ultrasound and fingerbreadth palpation methods. Phys Ther. 2014; 94(11):1622-31.

25. Kumar P, Bradley M, Gray S and Swinkels A. Reliability and validity of ultrasonographic measurements of acromion-greater tuberosity distance in poststroke hemiplegia. Arch Phys Med Rehabil. 2011; **92**(5): 731-736.

26. Kumar P, Attwood M. Inter-rater reliability of ultrasound measurements of acromion-greater tuberosity distancebetween experienced and novice raters in healthy people**.** Musculoskeletal Care. 2017. 1-4. https://doi.org/10.1002/msc.1206

27. Kumar P, Bourke C, Flanders J, Gorman T, Patel H The effect of arm position on the ultrasonographic measurements of the acromion-greater tuberosity distance. Physiother Theory Pract. 2014; 30(3):171-177.

28. Terry GC, Chopp TM: Functional anatomy of the shoulder. J Athl Train, 2000, 35: 248–255.

29. Bitter NL, Clisby EF, Jones MA, et al. : Relative contributions of infraspinatus

and deltoid during external rotation in healthy shoulders. J Shoulder Elbow Surg, 2007, 16: 563–568

30. Gracies J, Fitzpatrick R, Wilson L, Burke D and Gandevia S 1997 Lycra garments designed for patients with UL spasticity: Mechanical effects in normal subjects. Arch Phys Med Rehabil. 1997; 78(10):1066-1071.

31. Melzack R, Wall PD. Pain mechanisms: a new theory. A gate control system modulates sensory input from the skin before it evokes pain perception and response. Science 1965;150:971-9.

32. Willer JC. Comparative study of perceived pain and nociciptive flexion reflex in man. Pain 1977;3:69-80.

33. Reinold M, Macrina L, Wilk K, Fleisig G, Dun S, Barrentine S, Ellerbusch M et al. Electromyographic Analysis of the Supraspinatus and Deltoid Muscles During 3 Common Rehabilitation Exercises. J Athl Train. 2007; **42**(4): 464-469.

34. Manigandan J, Ganesh G, Pattnaik M and Mohanty P. Effect of Electrical Stimulation to Long Head of Biceps in Reducing Gleno Humeral Subluxation after Stroke. NeuroRehabilitation. 2014; **34**(2): 245-252.

35. Kibler WB and Sciascia A. Current Concepts: Scapula Dyskinesis. Br J Sports Med. 2010; **44**(5): 300-5.

36. Kibler WB, Sciascia A and Dome D. Evaluation of Apparent and Absolute Supraspinatus Strength in Patients with Shoulder Injury using the Scapular Retraction Test. Am J Sports Med. 2006; **34**(10): 1643-1647.

37. Smith J, Dietrich CT, Kotajarvi BR and Kaufman KR. The Effect of Scapular Protraction on Isometric Shoulder Rotation Strength in Normal Subjects. J Shoulder Elbow Surg. 2006; **15**(3):339-343.

Suppliers

a. SonoSite Ltd, Alexander House, 40A Wilbury Way, SG4 OAP Hitchin, Herts, UK.

b. Jobskin Limited UK, Unit 13a Harrington Mill, Leopold St, Long Eaton, Nottingham NG10 4QG

c. IBM UK, Business Analytics - SPSS, 2 New Square (B32S), Bedfont Lakes, Feltham, Middlesex TW14 8HB, UK.

Figure Legend:

Figure 1: Application of the Lycra arm sleeve on the arm

Figure 2: Ultrasonographic measurement of Acromion-Greater Tuberosity (AGT) distance

Table 1: Descriptive data for AGT distance, EMG activity and scapula position without and with Lycra Arm Sleeve

	Pre-sleeve				With Sleeve			
	Min	Max	Mean±SD	95% CI	Min	Max	Mean±SD	95% CI
AGT (cm)	1	2	1.8±0.3	1.7-1.9	1	2	1.7±0.2	1.6-1.8
EMG Activity (μV)								
Biceps	1	4	2.7±1	2.4-3.0	2	7	4.0±1	3.2- 4
Triceps	1	5	2.5±1	2.1-2.9	2	13	4.5±2	3.6–5.3
Supraspinatus	1	20	4±3	2.8-5.1	2	12	5.1±3	4.1 – 6.1
Deltoid	2	7	3.6±1	3.1–4.0	2	9	4.6±2	4 – 5
Scapula position (cm) Standing								
Superior (A to B)	5.5	11.5	7.7±1	7.2-8.2	4.7	10	7.4±1	6.9-7.9
Inferior (C to D)	6	12.5	9.1±1	8.6-9.6	6	11	8.7±1	8.2-9.2
Scapula position (cm) Sitting								
Superior (A to B)	6.5	11	8±1	7.5-8.4	5	10	7.7±1	7.3-8.2
Inferior (C to D)	7.5	13.5	9.7±1	9.1-10.1	7.5	13.5	9.4±1	8.9-10

AGT- Acromion-greater tuberosity Distance; EMG –Electromyography, A to B – the medial aspect of the spine of scapula (point A) and the spinous process parallel to the spine of the scapula; C to D - from the inferior angle of the scapula (C) to the parallel spinous process (D)
SD- Standard Deviation; CI – Confidence interval

Table 2: Mean difference, SE, CI for AGT distance, EMG muscle activity and scapula measurements without and with sleeve for the right shoulder

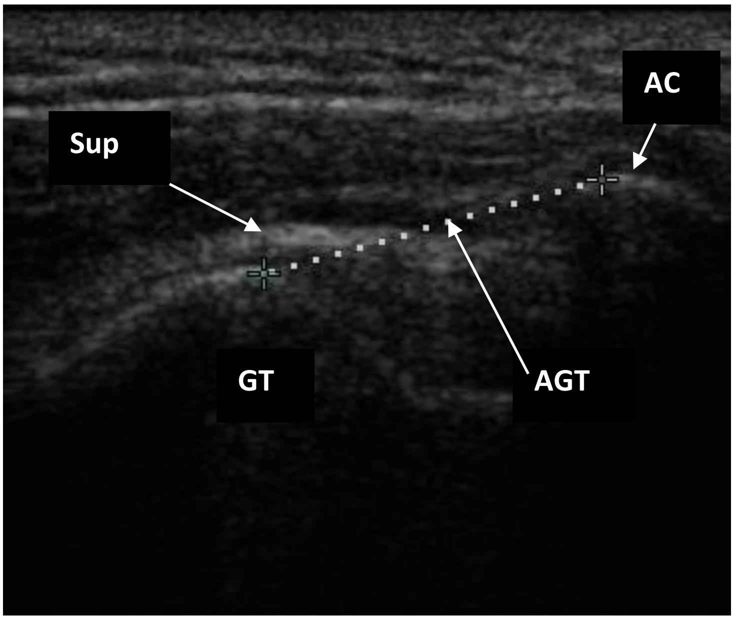
	MD	SE	95% CI	p-value
AGT distance (cm)*	0.1	0.02	0.02 - 0.2	0.003
EMG activity (μV)				
Biceps	0.8	0.22	-0.05-1.78	
Triceps	1.9	0.47	-0.01–3.81	
Supraspinatus	1.2	0.55	-1.07-3.40	
Deltoid	0.9	0.31	-3.40-2.21	
Scapula Measurements (cm) (Sitting)				
Superior (A to B)	0.24	0.08	-.59-0.10	
Inferior (C to D)	-0.24	0.01	-0.63-0.15	
Scapula Measurements (cm) (Standing)				
Superior (A to B)	0.25	0.10	-.67-0.17	
Inferior (C to D)*	-0.50	0.10	-0.85- -0.05	0.01

MD – Mean Difference; SE – Standard error; CI – Confidence Interval; A to B – the medial aspect of the spine of scapula (point A) and the spinous process parallel to the spine of the scapula; C to D - from the inferior angle of the scapula (C) to the parallel spinous process (D)
*statistically significant

Figure 1

Figure 1: Application of Lycra Arm sleeve

Figure 2: Ultrasonographic measurement of Acromion-Greater Tuberosity (AGT) distance



Longitudinal view of ultrasonographic image measuring the distance between the lateral tip of the acromion process and the nearest medial margin of the greater tuberosity (GT). The tendon of Supraspinatus (Sup) is visible above the GT.