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original research

Forward Shoulder Posture in Collegiate Swimmers: A Comparative Analysis of Muscle-Energy Techniques

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Context: Empirical data for treating forward shoulder posture supports stretching the anterior shoulder musculature. Although muscle-energy techniques (METs) have been hypothesized to lengthen muscle, no data have described the usefulness of this technique among swimmers.

Objective: To determine if an MET provides improvements in resting pectoralis minor length (PML), forward scapular position, and scapular upward rotation in female collegiate swimmers.

Design: Controlled laboratory study.

Setting: Athletic training room.

Patients or Other Participants: Thirty-nine asymptomatic National Collegiate Athletic Association Division I women's swimmers (19 experimental, 20 control).

Intervention(s): The experimental group received 2 treatment sessions per week for 6 weeks. The control group received no intervention during this 6-week period.

Main Outcome Measure(s): We administered pretest and posttest measurements for PML, forward scapular position, and scapular upward rotation in positions of rest and 60°, 90°, and 120° of humeral elevation. The MET consisted of a 3-second stretch in the direction of the pectoralis minor fibers, followed by a 5-second isometric horizontal adduction contraction at 25% of maximum force. Immediately after this contraction, the entire sequence was repeated with the muscle being stretched to the new endpoint. A total of 4 cycles of MET were continuously applied per treatment session twice per week for 6 weeks. We conducted 1-way analyses of covariance to determine any between-groups postintervention test differences.

Results: The MET group had a greater increase in PML postintervention ($P = .001$, effect size $= 1.6$) and a greater decrease in forward scapular position postintervention ($P = .001$, effect size $= 1.07$) compared with the control group. No differences were found for scapular upward rotation ($P > .10$).

Conclusions: Our results indicate that 6 weeks of MET treatments applied to the pectoralis minor of asymptomatic female swimmers provided improvements in PML and forward scapular position compared with a control group.

Key Words: manual therapy, scapular kinematics, injury prevention

Key Points

- The muscle-energy technique applied to the shoulders of collegiate female swimmers improved pectoralis minor length and forward scapular position.
- Applications of the muscle-energy technique may assist in reducing the number of shoulder injuries associated with pectoralis minor tightness and rounded shoulders.

The biomechanics and excessive shoulder revolutions performed by competitive swimmers often cause hypertrophy of the anterior shoulder musculature.[1,2] Tightness of the anterior musculature, such as the pectoralis minor, has been associated with the development of shoulder pain among competitive female swimmers and can lead to forward shoulder posture, which has been described as forward head and rounded shoulders.[2,3] These muscular imbalances and subsequent forward pull on the shoulders may result in increased scapular anterior tilt, internal rotation, and downward rotation.[4–7] This forward shoulder posture has further been associated with painful shoulders in swimmers and may predispose swimmers to shoulder injuries, such as subacromial impingement syndrome,[1,3,8] thoracic outlet syndrome,[9] and glenohumeral instability.[8,10,11]

Current practices to aid in preventing and treating forward shoulder posture focus on stretching the anterior shoulder musculature and strengthening the elongated posterior scapular stabilizers.[2] Therefore, stretching exercises that provide optimal lengthening of the anterior soft tissue structures are critical when working with such athletes. One exercise that can be implemented is muscle-energy technique (MET).

Muscle-energy technique is a manual therapy intervention in which the patient actively contracts a targeted muscle(s) against a precise, clinician-controlled counterforce, followed by relaxation and a passive stretch.[12] This technique is commonly used to strengthen and lengthen muscles, reduce edema, improve circulation, and mobilize restricted articulations.[12] Muscle-energy technique has been demonstrated to be more effective in improving the extensibility of shortened muscles than static stretching.[13]

Several groups have shown the positive effects of using MET for improving range of motion in the cervical, thoracic, and lumbar regions of the spine[14,15] and the upper extremity.[16] Although MET has been used to treat patients with painful conditions, such as low back pain,[17] it can also

Table 1. Descriptive Statistics for Demographic Variables (Mean ± SD)

Group	Age, y	Height, cm	Mass, kg
Muscle-energy technique	19.6 ± 1.2	170.7 ± 6.3	66.3 ± 7.0
Control	19.6 ± 1.0	169.9 ± 6.4	64.9 ± 7.9

be used on asymptomatic individuals.[14–16] Despite research supporting the use of MET for a large number of conditions, to our knowledge, no investigators have determined the effectiveness of MET for lengthening the anterior shoulder musculature among swimmers. Examining the efficacy of MET for improving forward shoulder posture in asymptomatic swimmers may assist clinicians in preventing and treating shoulder injuries in this group. Therefore, the purpose of our study was to determine the effects of MET on forward shoulder posture in asymptomatic female competitive collegiate swimmers. We hypothesized that resting pectoralis minor length (PML), forward scapular position, and scapular upward rotation would improve after 6 weeks of MET compared with a control group.

METHODS

Participants

Initially, a total of 40 National Collegiate Athletic Association Division I women's swimmers from the same swim team volunteered for this study. Data were collected over a 2-year period during the competitive collegiate swim seasons. In the first year, 20 swimmers received an MET intervention; however, 1 swimmer developed shoulder pain during the season and was excluded from further participation in the study. This resulted in 19 swimmers receiving an MET intervention (Table 1). In the second year, 20 different swimmers served as control participants and did not receive any intervention (Table 1). Exclusion criteria were upper extremity injury within the previous 6 months or any history of upper extremity surgery.

Instrumentation

Two 12-in (30.48-cm) combination squares (Johnson Level & Tool Manufacturing Inc, Mequon, WI) were used to measure forward scapular posture. To construct this specific instrument, we attached 1 square in an inverted position to the ruler of the second square.

Scapular upward rotation was measured using the Pro 3600 digital inclinometer (SPI-Tronic, Garden Grove, CA). According to the manufacturer, this inclinometer delivers an immediate digital reading of angles with respect to either a horizontal or vertical reference and is accurate to 0.1°. We modified the inclinometer by attaching 2 locator rods, about 10 cm in length, to the bottom of the inclinometer. The Y-shaped ends of the rods were designed to fit over the root of the scapular spine and the posterolateral portion of the acromion. A small bubble level was attached to the top of the inclinometer and was used to maintain the body of the inclinometer in a plane perpendicular to the horizontal plane.

Procedures

Before data collection, all participants signed an informed consent form approved by the university institutional review board, which also approved the study. All initial testing occurred at the beginning of the competitive season. Baseline measurements were obtained for dominant-arm PML, forward scapular position, and scapular upward rotation. The order of the measurements was randomized; however, the investigators were not blinded to each participant's group. Participants in the intervention group received MET treatments 2 times a week for 6 weeks. Participants in the control group received no MET treatment during the 6-week period between testing sessions. During the time between pretesting and posttesting, participants in both groups completed their typical team practices and strength and conditioning sessions, and no testing was conducted after a swim practice or competition. Swimmers were instructed not to participate in any upper body exercises or stretches outside of team activities. This included any modalities, foam rolling, etc. Weekly reminders were sent to all participants to ensure compliance with these instructions. Posttesting occurred approximately 48 hours after the final MET application for the experimental group.

Resting PML Measurement

We measured PML according to guidelines established by Borstad and Ludewig.[5] Participants were instructed to stand in a normal, relaxed posture during data collection. The examiner palpated the medial-inferior angle of the coracoid process of the scapula and just lateral to the sternocostal junction of the inferior aspect of the fourth rib. The examiner then measured the distance between these landmarks with a cloth tape measure (Figure 1). Three measurements were taken; the average was divided by the participant's height and multiplied by 100 to calculate the PML index for analysis.[5] The PML index allows each measurement to be normalized to each participant's height to provide the relative resting length of the individual pectoralis minor. Previous investigators[18] reported that individuals with a PML index of less than 7.44 could be considered to have a relatively short muscle. Our intratester reliability for the PML measurement showed good reliability (intraclass correlation coefficient [ICC] [3,3] = 0.85) and our standard error of measurement (SEM) was 0.26. This technique has also shown good validity when compared with a 3-dimensional electromagnetic system (ICC = 0.96).[18]

Forward Scapular Position Measurement

To measure forward scapular position, we used the technique introduced by Peterson et al.[19] For this measurement, the participant was instructed to stand in a relaxed position with her back against a wall. In this position, 1 square of the double square was placed flush against the wall, over the participant's test shoulder. The second square was extended along the 12-in (30.48-cm) ruler until it touched the anterior tip of the participant's acromion (Figure 2). The distance between the 2 squares was then determined and measured 3 times, with the average used for analysis. Our a priori reliability of the

Figure 1. Measurement of pectoralis minor length.

double-square method showed good reliability (ICC [3,3] = 0.84) and an SEM of 0.46 cm.

Scapular Upward-Rotation Measurement

Scapular upward rotation was measured with the digital inclinometer using a 2-dimensional measurement described by Johnson et al.[20] Scapular upward rotation was measured statically in a resting position and at 60°, 90°, and 120° of humeral elevation while in the scapular plane with the thumb pointed toward the ceiling. Humeral elevation was maintained in the scapular plane by positioning each participant next to a wall to assist in guiding the arm through this plane of motion (Figure 3). The order of angle measurements was randomized before each test session. The inclinometer was positioned over the scapular spine, using the locator rods, at each position to determine the angle between the scapular spine and a horizontal reference. A rest period of 5 seconds was allowed between measurements. Two measurements were taken at each angle, and the average was used for analysis. Our a priori reliability for measuring scapular upward rotation at rest, 60°, 90°, and 120° of humeral elevation had excellent reliability (ICC [3,1] = 0.95, 0.93, 0.95, and 0.92, respectively) and SEMs of 0.5°, 0.8°, 1.0°, and 1.1°, respectively.

Figure 2. Measurement of forward position of the scapula.

Figure 3. Measurement of scapular upward rotation.

Muscle-Energy Technique

All MET treatments were performed before swim practice. For the MET treatment, participants were asked to lie supine on a standard treatment table with the treatment arm off the table. The treatment arm was then passively moved into horizontal abduction, in line with the pectoralis minor and sternal fibers of the pectoralis major muscle fibers, until the end range of motion was reached (Figure 4). Due to the possibility of glenohumeral instability among swimmers, we proceeded cautiously in all participants during the MET application. The arm was held at this barrier for 3 seconds. The shoulder was then brought out of the stretch slightly, and the participant was instructed to "pull against the investigator's resistance towards the opposite hip." This contraction was performed isometrically with approximately 25% of the participant's maximal effort for 5 seconds. We chose this percentage of the maximal contraction for several reasons, including participant comfort and limiting both muscle guarding and injury risk. Furthermore, a 5-second isometric contraction has been shown to be more effective than a 20-second isometric contraction in increasing range of motion in asymptomatic patients[21] and is consistent with the current MET literature.[14–16,21] Immediately after this contraction, the entire sequence was repeated with the arm again being passively horizontally abducted to the new range of motion

Figure 4. Muscle-energy technique for the pectoralis minor.

barrier before another contraction. Four cycles of this stretch-contract sequence were continuously applied per MET treatment session. The entire sequence for applying MET took approximately 45–60 seconds per participant.

Data Analysis

Separate 1-way analyses of covariance were conducted to determine differences between groups using SPSS statistical software (version 20; IBM Corporation, Armonk, NY). The independent variable was group (MET, control). The dependent variables were PML, forward scapular position, and scapular upward rotation at rest and at 60°, 90°, and 120° of humeral elevation. Pretest measurements were used as the covariate to statistically correct for any differences between participants before the intervention. Effect sizes were also calculated to provide insight into the clinical significance of the results. The within-group effect size was calculated as (posttest mean – pretest mean)/pretest standard deviation. An effect size of 0.2 or less was considered *small*, 0.5 was considered *moderate*, and above 0.8 was considered *large*.[22] A Bonferrroni correction was used to protect against type I error caused by multiple tests ($P < .008$).

RESULTS

Descriptive statistics for PML, forward scapular position, and scapular upward rotation can be viewed in Tables 2–4, respectively. Preliminary *t* tests showed no between-groups differences for forward shoulder posture ($P = .10$) or PML ($P = .67$) at the pretest. Although there were also no between-groups differences in scapular upward rotation while at rest ($P = .06$) or in 60° ($P = .63$) of humeral elevation, differences were evident at 90° ($P = .01$) and 120° ($P = .003$). The covariate-adjusted posttest variables are shown in Table 5. The MET group had greater improvement in PML than the control group ($F_{1,36} = 52.7$, $P = .001$). Similarly, the forward-scapula position of the MET group decreased compared with the control group after the intervention ($F_{1,36} = 19.7$, $P = .001$). No difference was seen in scapular upward rotation at rest ($F_{1,36} = 0.07$, $P = .80$) or at 60° ($F_{1,36} = 2.3$, $P = .14$), 90° ($F_{1,36} = 1.75$, $P = .19$), or 120° ($F_{1,36} = 2.84$, $P = .10$) of humeral elevation between groups. Scapular upward rotation while at rest violated the assumption of equality of variance. However, no other violation of the assumptions of normality, linearity, homogeneity of variances, homogeneity of regression slopes, or reliable measurement of the covariate was noted.

Table 2. Normalized Pectoralis Minor Length Index

Group	Mean ± SD, Muscle Length/Participant Height × 100			Effect Size
	Pretest	Posttest	Difference	
Muscle-energy technique	8.0 ± 0.5	8.8 ± 0.5[a]	0.9 ± 0.5	1.60
Control	7.9 ± 0.5	7.7 ± 0.5	–0.1 ± 0.5	0.40

[a] Increase in length compared with pretest measurement ($P = .001$).

Table 3. Forward Scapular Position

Group	Mean ± SD, cm			Effect Size
	Pretest	Posttest	Difference	
Muscle-energy technique	13.6 ± 1.4	12.1 ± 1.1[a]	−1.5 ± 1.1	1.07
Control	12.8 ± 1.3	12.7 ± 1.3	−0.1 ± 0.6	0.08

[a] Decrease in position compared with pretest measurement ($P = .001$).

DISCUSSION

The repetitive nature of competitive swimming can result in the development of postural adaptations and subsequent shoulder injuries.[8] As such, swimmers and the clinicians who treat these athletes use various stretches and manual therapies in an effort to lengthen the anterior shoulder musculature. Although MET is a popular technique used by many clinicians, no previous researchers have assessed the usefulness of this technique in asymptomatic swimmers. Therefore, we are the first to show that MET applied to the pectoralis minor produced improvements in forward shoulder posture.

Table 4. Scapular Upward Rotation[a]

Position	Mean ± SD, °			Effect Size
	Pretest	Posttest	Difference	
Rest				
MET group	−5.3 ± 4.4	−6.5 ± 3.9	−2.2 ± 4.5	0.27
Control group	−7.4 ± 3.6	−7.8 ± 2.3	−0.4 ± 2.7	0.11
Humeral elevation				
60°				
MET group	−3.2 ± 4.9	−3.1 ± 3.5	−0.9 ± 4.9	0.02
Control group	−1.1 ± 4.3	−0.7 ± 3.4	−1.1 ± 3.2	0.09
90°				
MET group	6.3 ± 4.3	6.8 ± 3.1	0.5 ± 2.8	0.11
Control group	−9.6 ± 4.1	−9.4 ± 2.7	0.1 ± 3.1	0.05
120°				
MET group	15.8 ± 4.4	16.8 ± 3.4	−0.1 ± 3.9	0.23
Control group	21.0 ± 3.2	21.2 ± 2.9	1.4 ± 3.3	0.06

Abbreviation: MET, muscle-energy technique.

[a] Negative values indicate a downwardly rotated scapular position.

Table 5. Covariate-Adjusted Posttest Statistics for Forward Shoulder Position[a]

Variable	Group, Mean ± SD (95% Confidence Interval)	
	Muscle-Energy Technique	Control
Pectoralis minor length index[b]	8.8 ± 0.1 (8.6, 9.0)	7.8 ± 0.1 (7.6, 8.0)
Forward scapular position, cm[b]	11.8 ± 0.2 (11.4, 12.2)	13.0 ± 0.2 (12.6, 13.4)
Scapular upward rotation, °		
Resting	−7.0 ± 0.6 (−8.2, −5.9)	−7.2 ± 0.6 (−8.4, −6.1)
Humeral elevation		
60°	−2.5 ± 0.6 (−3.7, −1.3)	−1.3 ± 0.6 (−2.4, −0.9)
90°	7.7 ± 0.5 (6.7, 8.6)	8.5 ± 0.5 (7.6, 9.4)
120°	18.3 ± 0.6 (17.1, 19.5)	19.8 ± 0.6 (18.6, 21.0)

[a] Posttest values adjusted for covariate (pretest variables).
[b] Indicates difference between groups ($P = .001$).

Pectoralis minor tightness can be common among overhead athletes and is reported to produce increased scapular anterior tilting, internal rotation, and downward rotation.[4–7] These scapular patterns are similar to those present in patients diagnosed with subacromial impingement syndrome.[23–26] Due to the common presence of this tightness and the associated risk of shoulder injury, previous authors have attempted to identify optimal techniques for lengthening this tissue. Borstad and Ludewig[27] found that 3 passive-stretching techniques each increased PML during the time of stretch. Williams et al[28] showed that swimmers treated with a single gross stretch had immediate increases in PML compared with a control group. Using a cadaveric model, Muraki et al[29] observed that both scapular retraction at 30° of flexion and horizontal abduction produced greater lengthening of the muscle than retraction at 0° of flexion. Our results support these previous findings and demonstrated that not only did the MET assist in lengthening the pectoralis minor, but this increased resting length was sustained for at least 48 hours after the final application. The change in resting PML index (0.90) showed a large effect size (1.6) that was larger than the SEM (0.26), which may indicate clinical significance. Thus, MET should be considered when increased muscle length is desired for an extended period of time. Furthermore, because tightness of the pectoralis minor has been associated with the development of shoulder pain,[3] this technique may assist in decreasing the prevalence of shoulder pain among competitive female swimmers. However, further research is necessary to confirm this hypothesis.

Insufficient scapular positioning can lead to decreased glenohumeral rotation strength,[30] altered neuromuscular-activation patterns,[31] an increased risk of developing subacromial and internal impingement syndrome,[31,32] and increased stress on the anterior glenohumeral ligaments.[33] As such, determining optimal techniques for improving scapular posture in overhead athletes is critical. Kluemper et al[2] reported that a 6-week program involving stretching of the anterior shoulder muscles and strengthening of the posterior muscles improved forward scapular position compared with a control group. Hibberd et al[34] conducted a similar study design but used an intervention that did not target lengthening anteriorly and strengthening posteriorly. Rather, these researchers had their experimental group perform global strengthening and stretching exercises for the shoulder and did not report any improvements in scapular protraction compared with a control group. Our results support those of Kluemper et al[2] and suggest that stretches targeting the anterior shoulder muscles are effective for improving forward scapular position. Due to the association between forward shoulder position and shoulder pain,[35] the MET technique we used may also assist in decreasing the risk of shoulder injury. However, further research is necessary in this area.

Peterson et al[19] were the first authors, to our knowledge, to report the validity and reliability of the double-square method for determining forward shoulder posture. Using radiographic evidence, they classified participants as either having or not having forward shoulder posture. The mean and standard deviation values were 13.5 ± 1.9 cm for the individuals with forward shoulder posture and 12.4 ± 2.0 cm for those without forward shoulder posture. Similarly, the initial values for our MET participants were 13.6 ± 1.4 cm, which would suggest that they began testing with forward shoulder posture and ended without this dysfunction after the MET applications (12.1 ± 1.1 cm), further suggesting the clinical benefit of this technique. The change in forward scapular position (1.5 cm) showed a large effect size (–1.5) and was larger than the SEM (0.46 cm), which may also indicate clinical significance.

Insufficient scapular upward rotation has been associated with various shoulder injuries and is often addressed in the prevention and rehabilitation of such injuries.[36,37] We hypothesized that, by lengthening the pectoralis minor and major muscles in the MET group, these swimmers would subsequently improve their scapular upward rotation compared with the control group. However, no differences were evident between groups for scapular upward rotation at any level of humeral elevation. This may have been due to the other muscles that play a role in scapular upward rotation, which our MET treatment for the pectoralis minor would not have affected. For example, tightness of the rhomboids and levator scapula, as well as weakness of the lower trapezius and serratus anterior, can also play a role in downward rotation of the scapula and should therefore be considered when treating patients with limited scapular upward rotation.

As with any study, several inherent limitations are worth noting. First, our intervention targeted the pectoralis minor but obviously could not isolate this muscle, so reciprocal lengthening and contraction of the pectoralis major may have also occurred and contributed to our findings. The specific strokes and lengths of races and each practice, as well as off-season conditioning programs, were not recorded among participants. Therefore, we cannot confirm that there were no differences in training and racing between the 2 groups. In regard to the procedures used for our MET application, participants were in control of how much force they produced during the contraction phase. This is an inherent limitation of any intervention involving a voluntary patient contraction. We controlled this limitation by clearly instructing the participants to contract at only 25% of their maximum force. However, based on differences in perceived exertion among participants, we cannot state that every participant contracted with the appropriate amount of force. Another limitation of MET is the different protocols for its use. The ideal length of time for the postisometric stretch used in MET has not yet been determined. However, Smith and Fryer[13] found no difference between the 3- to 5-second and 30- to 60-second stretching period lengths. Future researchers should investigate the differences between the stretching periods with the use of a control group. Although we assessed forward scapular posture and scapular upward rotation, scapular kinematics occur in a 3-dimensional manner. Unfortunately, at the time of our study, no valid clinical technique was available for measuring scapular anterior-posterior tilt or internal-external rotation. Our study included a relatively small sample size, partially due to our having access to only 1 collegiate swim team. Despite the small sample size, our results showed that swimmers treated with MET had improvements in PML and forward scapular position compared with a control group. More specifically, the MET group had a 0.9 increase in their PML index and a 1.5-cm reduction in the forward scapular position. Both of these changes resulted in a large effect size and are larger than their respective SEMs, which suggests clinical significance.

CONCLUSIONS

Our findings indicate that MET applied twice a week for 6 weeks to the pectoralis minor and major muscles of asymptomatic swimmers resulted in increased resting PML and decreased forward scapular position. However, this stretching technique did not increase scapular upward rotation. Therefore, routine applications of MET may assist in preventing and treating various shoulder injuries associated with forward shoulder posture and pectoralis minor tightness among swimmers.

REFERENCES

1. Bak K, Fauno P. Clinical findings in competitive swimmers with shoulder pain. *Am J Sports Med*. 1997;25(2):254–260.
2. Kluemper M, Uhl T, Hazelrigg H. Effect of stretching and strengthening shoulder muscles on forward shoulder posture in competitive swimmers. *J Sport Rehabil*. 2006;15(1):58–70.
3. Tate A, Turner GN, Knab SE, Jorgensen C, Strittmatter A, Michener LA. Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *J Athl Train*. 2012;47(2):149–158.
4. Ludewig PM, Reynolds JF. The association of scapular kinematics and glenohumeral joint pathologies. *J Orthop Sports Phys Ther*. 2009;39(2):90–104.
5. Borstad JD, Ludewig PM. The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther*. 2005;35(4):227–238.
6. Borstad JD. Resting position variables at the shoulder: evidence to support a posture-impairment association. *Phys Ther*. 2006;86(4): 549–557.
7. Phadke V, Camargo P, Ludewig P. Scapular and rotator cuff muscle activity during arm elevation: a review of normal function and alterations with shoulder impingement. *Rev Bras Fisioter*. 2009; 13(1):1–9.
8. Allegrucci M, Whitney SL, Irrgang JJ. Clinical implications of secondary impingement of the shoulder in freestyle swimmers. *J Orthop Sports Phys Ther*. 1994;20(6):307–318.
9. Sanders RJ, Rao NM. The forgotten pectoralis minor syndrome: 100 operations for pectoralis minor syndrome alone or accompanied by neurogenic thoracic outlet syndrome. *Ann Vasc Surg*. 2010;24(6): 701–708.
10. Thigpen CA, Padua DA, Michener LA, et al. Head and shoulder posture affect scapular mechanics and muscle activity in overhead tasks. *J Electromyogr Kinesiol*. 2010;20(4):701–709.
11. Weon JH, Oh JS, Cynn HS, Kim YW, Kwon OY, Yi CH. Influence of forward head posture on scapular upward rotators during isometric shoulder flexion. *J Bodyw Mov Ther*. 2010;14(4):367–374.
12. Goodridge JP. Muscle energy technique: definition, explanation, methods of procedure. *J Am Osteopath Assoc*. 1981;81(4):249–254.
13. Smith M, Fryer G. A comparison of two muscle energy techniques for increasing flexibility of the hamstring muscle group. *J Bodyw Mov Ther*. 2008;12(4):312–317.
14. Burns DK, Wells MR. Gross range of motion in the cervical spine: the effects of osteopathic muscle energy technique in asymptomatic subjects. *J Am Osteopath Assoc*. 2006;106(3):137–142.
15. Lenehan K, Fryer G, McLaughlin P. The effect of muscle energy technique on gross trunk range of motion. *J Osteopath Med*. 2003; 6(1):13–18.
16. Moore SD, Laudner KG, McLoda TA, Shaffer MA. The immediate effects of muscle energy technique on posterior shoulder tightness: a randomized controlled trial. *J Orthop Sports Phys Ther*. 2011;41(6): 400–407.
17. Selkow NM, Grindstaff TL, Cross KM, Pugh K, Hertel J, Saliba S. Short-term effect of muscle energy technique on pain in individuals with non-specific lumbopelvic pain: a pilot study. *J Man Manip Ther*. 2009;17(1):E14–E18.
18. Borstad JD. Measurement of pectoralis minor muscle length: validation and clinical application. *J Orthop Sports Phys Ther*. 2008;38(4):169–174.
19. Peterson DE, Blankenship KR, Robb JB, et al. Investigation of the validity and reliability of four objective techniques for measuring forward shoulder posture. *J Orthop Sports Phys Ther*. 1997;25(1): 34–42.
20. Johnson MP, McClure PW, Karduna AR. New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther*. 2001;31(2):81–89.
21. Fryer G, Ruszkowski W. The influence of contraction duration in muscle energy technique applied to the atlanto-axial joint. *J Osteopath Med*. 2004;7(2):79–84.
22. Cohen J. *Statistical Power Analysis for the Behavioral Sciences*. 2nd ed. Hillsdale, NJ: L. Eerlbaum Associates; 1988.
23. 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.
24. Hebert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. *Arch Phys Med Rehabil*. 2002; 83(1):60–69.
25. 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):574–583; discussion 584–586.
26. Michener LA, McClure PW, Karduna AR. Anatomical and biomechanical mechanisms of subacromial impingement syndrome. *Clin Biomech (Bristol, Avon)*. 2003;18(5):369–379.
27. Borstad JD, Ludewig PM. Comparison of three stretches for the pectoralis minor muscle. *J Shoulder Elbow Surg*. 2006;15(3):324–330.
28. Williams JG, Laudner KG, McLoda T. The acute effects of two passive stretch maneuvers on pectoralis minor length and scapular kinematics among collegiate swimmers. *Int J Sports Phys Ther*. 2013;8(1):25–33.
29. Muraki T, Aoki M, Izumi T, Fujii M, Hidaka E, Miyamoto S. Lengthening of the pectoralis minor muscle during passive shoulder motions and stretching techniques: a cadaveric biomechanical study. *Phys Ther*. 2009;89(4):333–341.
30. Smith J, Dietrich CT, Kotajarvi BR, Kaufman KR. The effect of scapular protraction on isometric shoulder rotation strength in normal subjects. *J Shoulder Elbow Surg*. 2006;15(3):339–343.
31. Cools AM, Witvrouw EE, Declercq GA, Vanderstraeten GG, Cambier DC. Evaluation of isokinetic force production and associated muscle activity in the scapular rotators during a protraction-retraction movement in overhead athletes with impingement symptoms. *Br J Sports Med*. 2004;38(1):64–68.
32. Laudner KG, Myers JB, Pasquale MR, Bradley JP, Lephart SM. Scapular dysfunction in throwers with pathologic internal impingement. *J Orthop Sports Phys Ther*. 2006;36(7):485–494.
33. Weiser WM, Lee TQ, McMaster WC, McMahon PJ. Effects of simulated scapular protraction on anterior glenohumeral stability. *Am J Sports Med*. 1999;27(6):801–805.
34. Hibberd EE, Oyama S, Spang JT, Prentice W, Myers JB. Effect of a 6-week strengthening program on shoulder and scapular-stabilizer strength and scapular kinematics in Division I collegiate swimmers. *J Sport Rehabil*. 2012;21(3):253–265.
35. Ruivo RM, Pezarat-Correia P, Carita AI. Cervical and shoulder postural assessment of adolescents between 15 and 17 years old and association with upper quadrant pain. *Braz J Phys Ther*. 2014;18(4): 364–371.
36. Paletta GA, Warner JJ, Warren RF, Deutsch A, Altchek DW. Shoulder kinematics with two-plane x-ray evaluation in patients with anterior instability or rotator cuff tearing. *J Shoulder Elbow Surg*. 1997;6(6):516–527.
37. Warner JJ, Micheli LJ, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using Moire topographic analysis. *Clin Orthop Relat Res*. 1992;(285):191–199.

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