JSES International 6 (2022) 116–122

Contents lists available at ScienceDirect

JSES International

journal homepage: www.jsesinternational.org

A comparison of teres minor and infraspinatus muscle activation in the prone position

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ARTICLE INFO

Keywords:
Horizontal abduction exercise
Infraspinatus
Teres minor

Level of evidence: Basic Science Study; Kinesiology

Background: The electromyography (EMG) activity of the teres minor (TMi) and infraspinatus (IS) muscle has been demonstrated to vary depending on the arm position, such as in the coronal or scapular position, during intervention exercises. This may be reflected by different EMG activities demonstrated between the TMi and IS muscle during the acceleration and deceleration phases of the pitching motion. Tenderness in the scapular attachment site of the TMi muscle is often seen in baseball pitchers after pitching but not the attachment site of the IS muscle. However, few studies have investigated an interaction between TMi and IS muscle activity across different resistance exercises with different arm positions. The purpose of this study was to identify the feature of TMi and IS muscle activity in the presence of manual resistance applied in the prone position.
Methods: Eighteen collegiate baseball players volunteered their participation. Raw EMG amplitudes of the TMi, IS, posterior deltoid, middle deltoid, and upper trapezius muscles on the dominant shoulder were measured during intervention exercises. All subjects performed manual isometric resistance exercises: horizontal abduction (HABD) and external rotation (ER) of the glenohumeral joint with 40% of the manual maximum strength test in prone. The subjects also performed each of the HABD and ER resistance exercises with the arm actively positioned at 0° and 45° of ER of the glenohumeral joint in the coronal and scapular planes.
Results: Both TMi and IS muscle activities significantly increased with the arm positioned at 45° of ER compared with 0° of ER regardless of the exercise ($P < .05$). TMi activity was significantly greater with HABD resistance than IS muscle activity regardless of the arm positions, whereas it was significantly less with ER resistance than IS muscle activity.
Conclusion: The findings of this study indicated that the TMi and IS muscles were most highly activated during the HABD resistance with the arm actively positioned at 45° of ER in the coronal plane. The results of this study have clinical implications regarding the careful selection of arm position in both exercise and clinical examination for the TMi and IS muscles.

Previous literature has extensively demonstrated external rotation (ER) of the glenohumeral joint (GHJ) exercises in a variety of arm postures.[3,4,7,8,11,21,24] The infraspinatus (IS) and teres minor (TMi) muscles synergistically co-contract to generate ER force of the GHJ along with the posterior deltoid (PD) muscle.[16] However, the tensile force of the IS muscle, which has been demonstrated in a cadaveric study, decreases in abduction (ABD) of the GHJ, compared with adduction (ADD) of the GHJ owing to a decrease in the moment arm.[19] In contrast, the tensile force of the TMi muscle was increased in the position of ABD.[19] In view of this, TMi muscle activity has been demonstrated to be highly activated during the acceleration and deceleration phases of throwing motion from the late cocking phase, whereas IS muscle activity was decreased.[10,12] This may be also associated with clinical relevance in which baseball pitchers frequently complain of tenderness at the attachment site of the TMi muscle on the scapula after repetitive overhead throwing.[10,19] Tsuruike et al[26] also demonstrated that IS muscle electromyography (EMG) activity was significantly decreased when the elbow was extended during standing elastic band horizontal ABD (HABD) exercises compared with standing ER exercise with the elbow flexed to 90°. Recently, TMi muscle activity has been studied and found to increase by resistance applied to HABD in the coronal plane more than that of the scapular or sagittal plane.[27,28]

This study has been approved by the Office of Research at San Jose State University (IRB Protocol #: F19136).

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https://doi.org/10.1016/j.jseint.2021.09.005

Consequently, somehow the IS and TMi muscles play a different role in activity from the perspective of HABD resistance, whereas both muscles contribute to ER force.

PD muscle EMG activity, which also contributes to ER force, varies with ABD of the GHJ. For example, standing ER isometric contraction at 60° and 90° of ABD increases PD muscle activity, compared with that of 0° of ABD.[2,22] The reason for this variation has been assumed to be attributed to the muscle length–tension relationship.[22] In light of this view, different amounts of ER force have been demonstrated in professional baseball players, in which maximum ER force was greater when measured at 90° of ABD in the prone position than when measured at 0° of ADD in the seated position.[5] It is plausible to assume that the PD muscle is more involved during generation of ER force in ABD than ADD. In addition, ER force at 70% of maximum voluntary isometric contraction (MVIC) suppressed the relative effectiveness of IS muscle activity measured at 0° of ABD, compared with 40% of MVIC.[4,7] This finding suggests that the amount of exercise intensity can be critically important to efficaciously activate rotator cuff muscles in ER exercises especially for overhead athletes.

Although IS muscle EMG activity has been demonstrated to vary with the superior, middle, and inferior subregions in different arm postures,[6] to date, there have been few studies that have investigated an interaction between TMi and IS muscle activities across arm positions and exercises. Therefore, the purpose of the present study was to examine the EMG activity of the TMi and IS muscles during prone resistance exercises with and without the arm actively positioned in ER of the GHJ. This study hypothesized that both TMi and IS muscle activities would be increased during resistance application with the arm actively positioned in ER. Based on the previous study,[27] TMi and IS muscle activities would differ in response to HABD resistance application regardless of the ER positions.

Methods

During the baseball off-season, 18 collegiate baseball players belonging to the National Collegiate Athletic Association Division I conference (height: 182.9 ± 7.3 cm, mass: 86.1 ± 9.7 kg, age: 19.5 ± 1.1 years) participated in this study. This study obtained institutional review board approval before the start of the study (IRB Protocol #: F19136). All participants read and signed the informed consent confirming their voluntary participation. All subjects were asymptomatic, competitive baseball players without neurologic or physiologic deficits in the upper body as per the completion of a preliminary screening questionnaire. All tests were conducted in the Kinesiology Laboratory.

Electrode placement

Raw EMG amplitudes of the TMi and IS muscles on the throwing shoulder were collected. In addition, the EMG activity of the PD, middle deltoid (MD), and upper trapezius (UT) muscle was collected to determine the degree of intensity in each intervention exercise.[27] Bipolar surface silver (Ag) EMG electrodes with a bar length of 10 mm, width of 1 mm, and a distance of 1 cm between active recording sites (Delsys Bagnoli-8; Delsys Inc., Natick, MA, USA) were used. Electrodes were placed on the center of the muscle belly in line with the muscle fibers for the specific manual muscle test.

The electrode for the TMi muscle was placed on one-third of the distance from the posterior portion of the acromion process to the inferior angle of the scapula and the lateral aspect of the lateral border of scapula, which was just below the definition of the PD muscle.[13,20] As surface EMG recordings were used in this study, we presumed that for the theoretical basis of the study, this electrode location was representative of TMi function in our subjects.[27,28] For the IS muscle, the electrode was placed on just below the scapular spine and at the middle of the infrascapular fossa.[4,29] For the PD muscle, the electrode was placed in an oblique direction parallel to the muscle fibers of the deltoid muscles at the lateral border of the scapular spine[4,15,27-29], whereas the electrode was placed halfway between the tip of acromion and the deltoid tubercle for the MD muscle.[4,26-28] For the UT muscle, the electrode was placed at halfway between the C7 spinous process and the acromion process.[14,26-28]

Procedures

Once the electrodes were secured, the subjects performed a 4-second MVIC after ramp-up contraction for each muscle using the manual muscle testing (MMT) procedures for normalization of EMG data.[26-28] The manual pressure was applied by the same examiner for all testing positions to determine each of the MVICs. For the MVICs of UT muscle activity, subjects resisted downward pressure applied on the arm with the shoulder abducted to 90° with the elbow flexed in the standing position.[15,26-28] For the MVICs of PD and MD muscle activity, subjects abducted their arm to 90° with the shoulder horizontally abducted to 0° and the elbow flexed in the prone position.[15,26-28] The subjects resisted downward pressure applied on the distal portion of the arm in the coronal plane while they lifted the arm barely off the table. For the MVICs of TMi and IS muscle activity, the subjects resisted manual pressure applied toward internal rotation of the shoulder with the elbow flexed to 90° and the shoulder abducted to 90° in the prone position.[5]

All subjects performed two different manual isometric resistance exercises at 90° of ABD during a prone position for EMG data collection: HABD resistance and ER resistance. In addition, two HABD angles were included during isometric resistance applications: 90° or the arm positioned in the coronal plane, in which the elbow was placed at the edge of a standard treatment table, and 50° or the arm positioned in the scapular plane, in which the axilla was placed at the edge of the treatment table. For ER resistance, the examiner held the elbow joint with one hand and applied resistance toward internal rotation of the GHJ with the other hand, whereas ER exercise consisted of having the subject not lift the arm off the table during the ER resistance exercises in the coronal plane. Thus, the subjects had the four different manual isometric resistance exercises: HABD and ER resistance in the coronal and scapular plane each. The subjects also performed each of the resistance exercises with the arm actively positioned at two different ER angles: 0° and 45° of ER of the GHJ (Fig. 1). The subjects had a 10-second rest period after each of the three trails, whereas a 20-second rest period was given across different arm positions.

The amount of force (N) was determined in each of the four arm positions at both 0° and 45° of ER in the MMT by the same examiner with a handheld dynamometer (MicroFET, Hoggan Scientific, LLC, Salt Lake City, UT, USA) for each subject before the intervention exercises. The external load of 40% of the corresponding MMT was given in each of the arm positions for 10 seconds. The amount of exercise load was selected as described by Bitter et al.[4,7,27] The subjects were asked to match the external load pressure given just above the posterior portion of the elbow flexed at 90° for each of the HABD resistance exercises while they barely lifted the examined arm off a table during the coronal plane

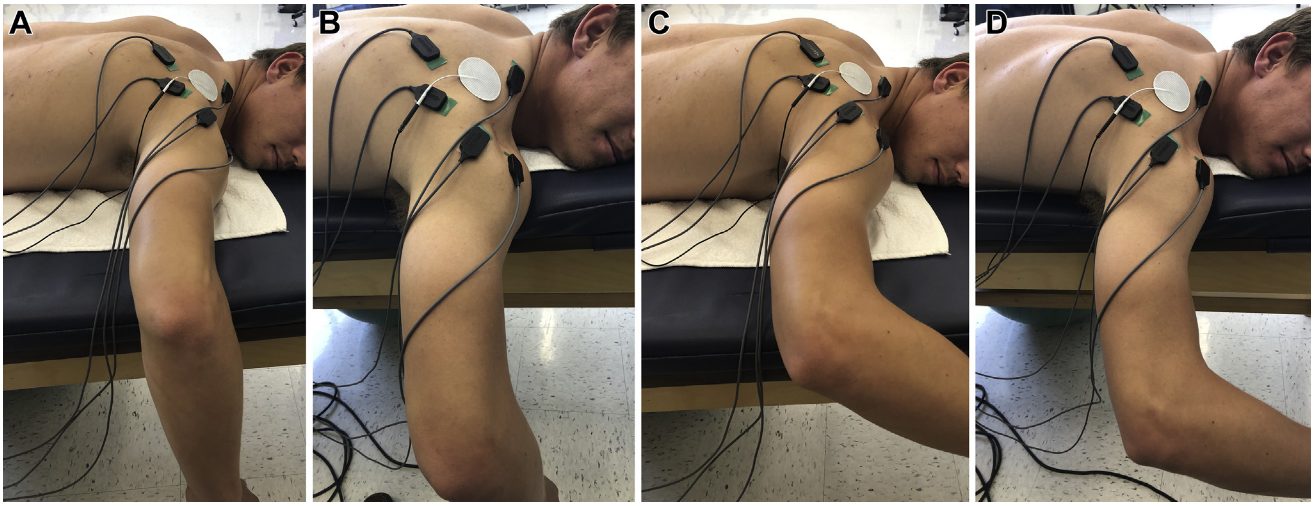

Figure 1 The subjects performed manual isometric horizontal abduction (HABD) resistance and external rotation (ER) resistance on the dominant arm at 90° of abduction of the glenohumeral joint in the prone position. Each of the HABD and ER resistance exercises was implemented with four different arm positions: at 0° of ER in the coronal plane (**A**) and scapular plane (**B**) and at 45° of ER in the coronal plane (**C**) and scapular plane (**D**).

exercises. For the ER resistance exercises, the subjects matched the external load given to the distal portion of the pronated forearm to create shoulder internal rotation while the examiner stabilized the elbow joint with the other hand. All throwing (dominant) shoulders were tested for this EMG study. Each subject was randomly assigned to perform the manual isometric resistance exercises for 3 trials in each of the four positions (HABD coronal plane, HABD scapular plane, ER coronal plane, ER scapular plane) at each of the positions of ER (0° and 45°) to minimize the systematic effect of motor learning and fatigue.

Data analysis

The EMG electrodes were preamplified (X 10) and routed through the EMG mainframe, which were further amplified (X 100) with the common mode rejection ratio that ranged from 94 to 100 dB and band-pass filtered (20-450 Hz) the signals. The EMG activities were then collected using a data collection program (MP 150 Data Acquisition System; Biopac System, Inc., Goleta, CA, USA) with a sample rate of 1000 Hz; all data were recorded and stored in a computer for off-line analysis. The mean EMG activity of the middle two seconds of each 4-second MMT was calculated to determine the individual's MVIC. For the exercises, the mean EMG activity of the middle 5 seconds of each 10-second intervention exercise was calculated. All data were calculated in root-mean-square values, normalized to MVIC of the corresponding muscles, and presented as a percentage of MVIC (% MVIC).

A 2 x 2 x 4 (2 muscles x 2 ER arm positions x 4 exercises) mixed-measures analysis of variance (ANOVA) design between TMi and IS muscles and within subjects across 0° and 45° of ER and HABD-CP, HABD-SP, ER-CP, and ER-SP was used to determine any difference in the mean values of normalized EMG muscle activity. A post hoc test with a Tukey honestly significant difference was used to measure any significant difference across the four different exercises. This study also identified reliability using intraclass correlation coefficients (ICCs; model 3, 1) in which a within-subject (subject 3 trial) ANOVA design was used. This study further determined Pearson correlation coefficients between TMi and PD muscle activities and between IS and PD muscle activities in each of the intervention exercises. The significance level was set at $\alpha = 0.05$.

Results

Force during MMT

Mean values and 95% confidence intervals for maximum force (N) measured by MMT during each of the exercises with two ER arm positions are presented in Table I. Subsequently, the mean amount of 40% MMT load that the subjects were asked to match was ranged from 44 N to 51 N.

Teres minor and infraspinatus

Mean values and 95% confidence intervals for TMi and IS EMG activities (% MVIC) are presented in Table II. A within-subject (subject 3 trial) ANOVA design was used to calculate ICCs. The mean of the ICCs (3, 1) in the four different arm positions at the two positions of ER was 0.85 of an individual's true score, and each of the ICCs is also presented in Table I.

No significant 3-way interaction was observed between TMi and IS muscle EMG activities by the two ER arm positions and the four intervention exercises ($F [3, 102] = 1.07$, $P = .365$). However, analysis of the results indicated a significant 2-way interaction in the mean values between the TMi and IS muscle across ER positions ($F [1, 34] = 16.0$, $P < .001$, effect size $[\omega^2] = 0.295$). Specifically, both the TMi and IS muscles significantly increased the mean values of EMG activity with the arm actively positioned at 45° of ER, compared with 0° of ER (35.3% and 29.0% MVIC for the TMi muscle, respectively) ($F [1, 136] = 46.1$, $P < .001$) and (37.6% and 26.0% for the IS muscle, respectively) ($F [1, 136] = 153.0$, $P < .001$), regardless of HABD or ER resistance exercises and the arm positioned in the coronal or scapular plane. However, no difference was observed in the mean values between the TMi and IS muscle at each of the ER positions (Fig. 2).

Analysis of the results indicated another significant 2-way interaction in the mean values between the TMi and IS muscle across the exercises ($F [3, 102] = 33.5$, $P < .001$, $\omega^2 = 0.479$). Specifically, the mean value in the TMi muscle was significantly greater in both HABD coronal and scapular planes than that of the IS muscle (52.3% and 37.8% MVIC in the coronal and scapular plane for the TMi muscle; 36.7% and 27.5% MVIC for the IS muscle, respectively) ($P = .001$), whereas the mean values in the TMi muscle were

Table I
Mean values and 95% confidence intervals for maximum force (N) measured by MMT during horizontal abduction (HABD) and external rotation (ER) resistance (R) in the coronal and scapular plane at 0° or 45° ER of the glenohumeral joint.

MMT	HABD-R		ER-R	
	Coronal	Scapular	Coronal	Scapular
0° ER	114 (103, 124)	134 (125, 142)	121 (112, 129)	125 (119, 132)
45° ER	107 (96, 117)	121 (110, 133)	118 (110, 126)	118 (109, 127)

MMT, manual muscle testing.

Table II
Mean values and intraclass correlations (ICCs) (3, 1) of the teres minor (TMi) and infraspinatus (IS) muscle electromyography (EMG) activities during horizontal abduction (HABD) and external rotation (ER) manual resistance (R) in the coronal and scapular plane at 0° or 45° ER of the glenohumeral joint.

Teres minor and infraspinatus muscle activity	HABD-R				ER-R			
	Coronal plane		Scapular plane		Coronal plane		Scapular plane	
	0° ER	45° ER	0° ER	45° ER	0° ER	45° ER	0° ER	45° ER
TMi	46 (40, 52)	58 (51, 66)	37 (32, 42)	39 (33, 45)	16 (12, 20)	22 (17, 28)	17 (14, 21)	22 (17, 27)
ICC (3, 1)	0.75	0.80	0.83	0.78	0.92	0.94	0.82	0.86
IS	30 (24, 36)	43 (37, 49)	23 (19, 26)	32 (28, 37)	27 (22, 31)	39 (34, 43)	25 (21, 29)	36 (31, 40)
ICC (3, 1)	0.91	0.87	0.88	0.85	0.85	0.86	0.83	0.89

significantly less in both ER coronal and scapular plane than those of the IS muscle (19.1% and 19.6% MVIC for the TMi muscle; 32.6% and 30.4% MVIC for the IS muscle, respectively) (P = .001). The mean value with HABD coronal plane was significantly greater than that of HABD scapular plane and ER coronal and scapular planes for the TMi muscle (Tukey honestly significant difference critical value [D_{Tukey}] = 5.19, $P < .05$). Likewise, the mean value with the HABD scapular plane was significantly greater than that of ER coronal and scapular planes for the TMi muscle ($P < .05$), whereas no difference was observed in the mean values between the ER coronal and scapular plane (Fig. 3). For the IS muscle, the mean value with the HABD coronal plane was significantly greater than that of both the HABD scapular plane and ER scapular plane ($P < .05$), whereas no differences were observed across other exercises (Fig. 3).

In addition, a third significant 2-way interaction was observed in the mean values between the two ER positions across the exercises (F [3, 102] = 4.83, P = .003, ω^2 = 0.098). Specifically, each of the mean values with the arm actively positioned at 45° of ER was significantly greater than that of 0° of ER regardless of the exercises ($P < .001$) (Fig. 4). The mean value in the HABD coronal plane was significantly greater than that of the HADB scapular plane and ER coronal and scapular planes for 0° of ER position (38.1%, 29.6%, 21.3%, and 21.2% MVIC, respectively) (D_{Tukey} = 5.19, $P < .05$). Likewise, the mean value in the HABD scapular plane was significantly greater than that of ER coronal and scapular planes for 0° of ER position ($P < .05$), whereas no difference was observed in the mean values between the ER coronal and scapular plane (Fig. 4). For 45° of ER position, the mean value in the HABD coronal plane was significantly greater than that of the HABD scapular plane and ER coronal and scapular planes (50.9%, 35.6%, 30.5%, and 28.8% MVIC, respectively) ($P < .05$). Likewise, the mean value in the HABD scapular plane was significantly greater than that of the ER scapular plane for 45° of ER position ($P < .05$), whereas no difference was observed in the mean values between the HABD scapular plane and ER coronal plane and between the ER coronal and ER scapular plane.

Posterior deltoid, middle deltoid, and upper trapezius

Mean values for PD, MD, and UT EMG activities (% MVIC) are presented in Table III. In addition, the Pearson correlation coefficient (r) matrix of TMi, IS, and PD muscle activities during each of the MMTs is shown in Table IV.

Discussion

The present study identified differences in the EMG activity between the TMi and IS muscles across prone HABD and ER resistance exercises performed with the moderate intensity in the coronal and scapular plane. Both the TMi and IS muscle activities significantly increased in all the four intervention exercises with the arm actively positioned at 45° of ER compared without ER positioning.

IS muscle tension has been demonstrated in cadaveric studies to decrease with ABD owing to a decrease in moment arm or length-tension relationship in the coronal plane.[17,19] The findings were also in line with an in vivo study in which the subjects significantly decreased IS muscle EMG activity at 60° of ABD during ER isometric contraction in the coronal plane, compared with 0° of ABD.[22] However, standing ABD exercise against gravity in the scapular plane, known as “scaption”, can progressively increase IS muscle activity up to 60° of ABD.[1] In addition, IS muscle activity at 90° of ABD and ER with the elbow flexed to 90° (90/90) during standing ER exercise with an elastic band was significantly greater in the scapular plane than that of the coronal plane. However, no difference in IS muscle activity was observed between the two planes during standing 90/90 ER exercise when HABD resistance was added with a second elastic band placed at the distal portion of the arm.[28] Moreover from the perspective of HABD exercise, IS muscle activity significantly increases in the coronal plane during the quadruped position, compared with the scapular plane.[27] The present study further revealed that the subjects significantly increased IS muscle activity in prone HABD resistance exercise in the coronal plane more than that of the scapular plane and even more than prone ER resistance exercise in the scapular plane. This prone HABD resistance included the arm that was actively positioned at 45° of ER.

The modulation of TMi muscle activity appears different from that of IS muscle activity, particularly ER exercises in ABD. A previous study using positron emission tomography revealed that the TMi muscle was more activated at 90° of ABD than ADD.[16] Furthermore, TMi muscle activity most significantly increased in

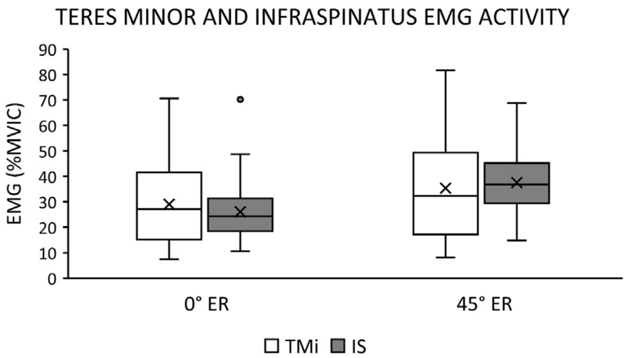

Figure 2 A comparison of teres minor (TMi) and infraspinatus (IS) muscle electromyography (EMG) activity normalized to maximum voluntary isometric contraction (MVIC) of the corresponding muscle and presented as a percentage of MVIC (% MVIC) between the arm actively positioned at 0° and 45° of external rotation (ER). The line in the *Middle* is the median, and the X is the mean. The box represents the interquartile (IQ) range. The whiskers show the maximum and minimum values, except for the outliers (circles) with the values between 1.5 and 3.0 IQ range.

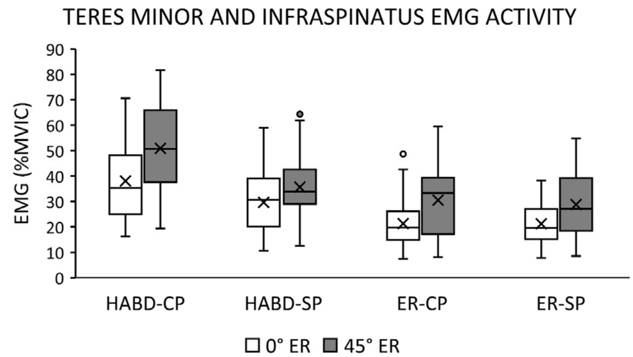

Figure 4 A comparison of the coronal and scapular plane across the four different manual isometric resistance exercises: horizontal abduction (HABD) and external rotation (ER) resistance for the marginal mean values of teres minor (TMi) and infraspinatus (IS) muscle electromyography (EMG) activity normalized to maximum voluntary isometric contraction (MVIC) of the corresponding muscle and presented as a percentage of MVIC (% MVIC). The line in the *Middle* is the median, and the X is the mean. The box represents the interquartile (IQ) range. The whiskers show the maximum and minimum values, except for the outliers (circles) with the values between 1.5 and 3.0 IQ range.

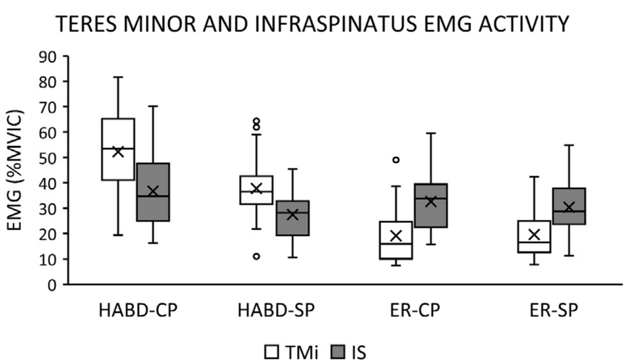

Figure 3 A comparison of teres minor (TMi) and infraspinatus (IS) muscle electromyography (EMG) activity normalized to maximum voluntary isometric contraction (MVIC) of the corresponding muscle and presented as a percentage of MVIC (% MVIC) across the four different manual isometric resistance exercises: horizontal abduction (HABD) and external rotation (ER) resistance in the coronal and scapular plane each. The line in the *Middle* is the median, and the X is the mean. The box represents the interquartile (IQ) range. The whiskers show the maximum and minimum values, except for the outliers (circles) with the values between 1.5 and 3.0 IQ range.

prone HABD exercise at 90° of ABD with ER positioning with the elbow extended, which was identified among 17 different exercises associated with a baseball rehabilitation program.[24] Likewise, TMi muscle activity significantly increased in quadruped HABD resistance exercise in the coronal plane, compared with the scapular plane.[27] The findings were also in line with another previous study in which TMi muscle activity was significantly increased by applying HABD resistance during standing 90/90 ER elastic band exercises in the coronal plane, compared with the scapular plane.[28] The present study further revealed that the subjects significantly increased TMi muscle activity in HABD resistance exercise with the arm actively positioned at 45° of ER in the coronal plane more than that of the scapular plane. Because no difference in the mean value of normalized EMG activity between the TMi and IS muscles when the arm was actively positioned at 45° of ER, it plausibly suggests that the TMi muscle can be involved with HABD resistance more than the IS muscle while both the IS and TMi muscles are co-contracted in ER movement.

TMi muscle activity appeared to be associated with PD muscle activity with ER resistance more than IS muscle activity. The stabilized elbow position used in this study significantly decreased PD muscle activity as well as UT and MD muscle activity during ER resistance. The IS muscle has been suggested to be co-contracted with the PD muscle during ER exercise.[4,7] However, this study found that the correlation between IS and PD muscle activity was decreased during ER resistance using a stabilized elbow position, whereas it was comparable between TMi and PD muscle activity. Consequently, TMi and PD muscle activity must closely generate co-contraction at 90° of ABD during ER exercise. Assuming that, it can be clinically important especially for baseball pitchers to maintain strength and flexibility of the TMi muscle.[10,19] Posterior shoulder tightness along with TMi muscle tenderness due to repetitive overhead throwing[10] may create glenohumeral internal rotation deficit.[18,23] Glenohumeral internal rotation deficit may subsequently cause anterior tilt of the scapula or what is known as “a wind-up effect” of the scapula.[14] In addition, scapular dyskinesis has been demonstrated to decrease throwing arm conditions during the course of a college baseball season.[25] The findings of this study suggest that individuals in habitual throwing sports include HABD exercise with the arm actively positioned in ER in the coronal plane that can effectively activate the TMi muscle as well as the IS muscle in their rehabilitation program.

Limitations

This study included collegiate baseball players with asymptomatic shoulders. Thus, the implication of the findings to individuals with differing age, levels of performance, and presence of shoulder symptoms may have limitations. In addition, the number of subjects included in this study was 18, which must have limited statistical power. TMi muscle activity measured using a surface EMG electrode signal may not be as accurate as an indwelling EMG signal.[13,21,24] This study used an interelectrode spacing distance of 10 mm for surface EMG, which has been demonstrated to reduce such contamination of crosstalk signals.[9] Although the contamination effect of crosstalk signals cannot be completely removed,[27,28] it is plausible to assume that valid TMi muscle EMG activities were measured in this study.

Conclusion

This study compared TMi and IS muscle activity during manual resistance exercises at 90° ABD of the GHJ in the prone position. The

Table III
The mean values of posterior deltoid (PD), middle deltoid (MD), and upper trapezius (UT) muscle electromyography activity (% MVIC) during horizontal abduction (HABD) and external rotation (ER) resistance (R) in the coronal and scapular plane at 0° or 45° ER of the glenohumeral joint.

EMG (% MVIC)	HABD-R				ER-R			
	Coronal plane		Scapular plane		Coronal plane		Scapular plane	
	0° ER	45° ER	0° ER	45° ER	0° ER	45° ER	0° ER	45° ER
PD	45	48	36	33	7	7	11	11
MD	46	42	33	28	8	6	13	10
UT	32	36	17	19	10	13	15	18

MVIC, maximum voluntary isometric contraction; *EMG*, electromyography.

Table IV
Pearson correlation coefficients (r) between teres minor (TMi) and posterior deltoid (PD) electromyography (EMG) activity and between infraspinatus (IS) and PD EMG activity during horizontal abduction (HABD) and external rotation (ER) resistance (R) in the frontal and scapular plane at 0° or 45° ER of the glenohumeral joint.

Pearson correlation coefficient matrix	Coronal plane	Scapular plane	Coronal plane	Scapular plane
0° ER	PD	PD	PD	PD
TMi	0.56*	0.49*	0.56*	0.53*
IS	0.49*	0.29	0.03	0.26
45° ER	PD	PD	PD	PD
TMi	0.58*	0.57*	0.51*	0.76*
IS	0.47*	0.27	0.16	0.49*

*Significant difference ($P < .05$).

findings of this study indicated that the TMi and IS muscles were most highly activated during the HABD resistance with the arm actively positioned at 45° of ER in the coronal plane than during ER resistance. The results of this study have clinical implications regarding the careful selection of arm position in both exercise and clinical examination for the TMi and IS muscles.

Disclaimers:

Funding: No funding was disclosed by the authors.
Conflicts of interest: The authors, their immediate family, and any research foundation with which they are affiliated have not received any financial payments or other benefits from any commercial entity related to the subject of this article.

Acknowledgments

The authors thank Yohei Mukaihara, MA, ATC, for his assistance with data collection during this study.

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