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Effect Of Different Grip Position And Shoulder-Abduction Angle On Muscle Strength And Activation During The Seated Cable Row

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ABSTRACT

The purpose of this study was to compare the peak force and electromyographic activation in different techniques of the seated row. Eleven recreationally trained male (28±5 years, 176±5 cm, 94±16 kg) and ten female (27±5 years, 168±8 cm, 65±11 kg) performed an isometric and a dynamic assessment of the seated cable row and the preacher curl: pronated grip (PRO), supinated grip (SUP), neutral grip (NEU), 30° (30°), 60° (60°), 90° (90°) of shoulder abduction, and cable preacher curl (PC). Peak force measured by a load cell and surface myoelectric activity of upper trapezius (UT), middle trapezius (MT), upper latissimus (UL), lower latissimus (LL), posterior deltoid (PD), and biceps brachii (BB) were recorded during the isometric and dynamic assessment of the exercises. *p* values<0.05 were considered statistically significant. The peak force was greater when shoulder abduction angle was closer to 0° (PRO, SUP, and NEU) and decreased as abduction angle increased (60° and 90°). Muscle activation of the upper back (UT, MT, and PD) increased as abduction angle increased (60° and 90°) on both isometric and dynamic analysis. Muscle activation of the UL and LL increased as abduction angle was closer to 0° (PRO, SUP, and NEU) on both isometric and dynamic analysis. BB activation on both isometric and dynamic analysis during the PC was greater than all other rowing conditions; among the rowing techniques, BB activation was greater during SUP, NEU, and 90° techniques. In conclusion, the closer to 90° shoulder abduction the greater UT, MT, and PD activity, on the other hand, the closer to 0° shoulder abduction the greater peak force, UL, and LL activity during the variations of the rowing exercise.

Keywords: Resistance training, electromyography, force.

INTRODUCTION

The seated cable row is a multi-joint exercise widely used to increase strength and hypertrophy of the upper and lower back, and elbow flexors [1-3]. In addition to being used in the context of resistance training, variations of the seated cable row are frequently used in shoulder rehabilitation programs for the strengthening of the scapula and shoulder stabilizing muscles [4]. Despite its popularity, to date, few studies have investigated the muscle activation pattern of this exercise or its variations [2, 3, 5-7].

Possibly, the position (neutral, pronated, and supinated) and the width of the hands affect the production of force and the involvement of the back muscles in the exercise. Regarding the position of the hands, Youdas et al. [7] observed greater activation of the latissimus dorsi and less activation of the upper portion of the trapezius in the inverted row with the supinated grip compared to the pronated grip. Regarding the grip width, in the more conventional technique, the hands are shoulder-width apart; thus, the main movements in the concentric phase are elbow flexion, downward adduction/rotation of the scapula, and shoulder extension [8, 9]. In another variation, commonly known as the "wide-grip row", the hands are further apart and the bar is pulled towards the chest; in this technique, the main movements in the concentric phase are elbow flexion, downward adduction/ rotation of the scapula and horizontal abduction of the shoulder [9]. However, to date, no studies have been found comparing strength performance and myoelectric activation patterns in such variations of cable-seated rowing.

Another concern regarding the technique variations on the seated cable row is the effect on the magnitude of activation of the biceps brachii. First, is not known if the activation of the biceps brachii would differ during the variations of the seated cable; and second, it is not known whether the activation during the variations of the seated cable row is comparable to more specific single-joint exercise to the elbow flexors. That information may help strength coaches and physical therapists in prescribing this exercise. Therefore, the purpose of this study was to compare the peak force and electromyographic activation in different techniques of the seated row (SR). Specifically, we tested the following techniques: seated cable row with a pronated grip (PRO), supinated grip (SUP), neutral grip (NEU), 30° (30°), 60° (60°), 90° (90°) of shoulder abduction, and cable preacher curl (PC). We presumed three main hypotheses. First, peak force would be larger in the rowing techniques with narrower grip width. Second, muscle activation of the upper back (upper trapezius, middle trapezius, and posterior deltoid) may increase as the shoulder abduction angle increases, whereas the muscle activation of the latissimus dorsi (upper and lower portions) may increase as the shoulder abduction angle decreases. Second, we expect greater biceps brachii activation during the cable preacher curl than all other rowing techniques.

METHODS

Experimental approach to the problem

This randomized study with repeated measures was conducted in two sessions that were each separated by 48-72 hours. In the first session, participants' anthropometric data were collected and familiarization with the experimental procedures was conducted. Seven exercises were tested: seated cable row with a pronated grip (PRO), supinated grip (SUP), neutral grip (NEU), 30° (30°), 60° (60°), 90° (90°) of shoulder abduction, and cable preacher curl (PC). First, the 7 exercise conditions were randomized for each subject (https://www.randomizer.org/). The same random order was used during all the following procedures. Both sessions were divided into three moments: warm-up, maximal voluntary isometric contraction (MVIC) test, and dynamic test. There were only two differences between sessions: during the first session, subjects used a pendulum inclinometer attached to the back aspect of the arm to assist with technique consistency; during the second session, surface electromyography (sEMG) was measured from the upper trapezius (UT), middle trapezius (MT), upper latissimus (UL), lower latissimus (LL), posterior deltoid (PD), and biceps brachii (BB). All testing involving EMG was performed in the second session to avoid changes in electrode placement and to improve the reliability of the data.

Subjects

A convenience sample of twenty-one recreationally resistance-trained participants (11 males, 28±5 years, 176±5 cm, 94±16 kg, and 10 females, 27±5 years, 168±8 cm, 65±11 kg) was recruited to participate in this study. All participants had experience in resistance training for at least 1 year (minimum 3 sessions/week) and reported implementing some rowing variation in their training routine. Moreover, participants were free from any existing musculoskeletal disorders; or history of injury (with residual symptoms of pain, or weakness) in the trunk and upper limbs within the last year. The participants were informed of the risks and benefits of the study before any data collection and then read and signed an institutionally approved informed

Figure 1. Exercise technique. Seated cable row with a pronated grip (PRO), supinated grip (SUP), neutral grip (NEU), 30° (30°), 60° (60°), 90° (90°) of shoulder abduction, and cable preacher curl (PC). PRO, SUP, and NEU techniques were performed with 0° (0°) of shoulder abduction.

consent document.

Exercise technique

All exercises and tests were performed in a cable pulley system (Model: RC030; Brand: Portico Fitness Equipment, Brazil). The tested techniques are presented in Figure 1. All exercises were performed to the full range of movement. Specifically, participants initiated the concentric phase with their elbows fully extended and pulled the bar/handle until it touched their torso, and then returned to the starting position. Subjects used a grip width equal to the bi-acromial width to perform the PRO, SUP, and PC conditions. For the NEU condition, two individual handles were attached to a single anchor point in the cable pulley system. For the 30°, 60°, and 90° conditions, the arm length (acromion process to olecranon process) was multiplied to the sine of the tested angle of shoulder abduction and added to the bi-acromial distance on each side. All hand positions were recorded and kept constant at all MVIC and dynamic tests.

Procedures

Warm-up

For the warm-up, subjects performed one set of 10 repetitions with a load that the subject considered able to perform 20 repetition maximum (20RM) for each exercise condition. One minute of rest interval was allowed between warm-up sets. A metronome set at 60bpm assisted the subjects to keep a cadence of 2s eccentric and concentric phase. Additional sets were performed if the exercise technique was not considered satisfactory by the researcher.

MVIC test

A load cell sampling at 2000 Hz (EMG832C, EMG system Brazil, Brazil) was fixed to the cable pulley system to measure the peak force during each exercise condition. The weight stack of the cable pulley system was fixed with straps to disable cable movement. For the rowing conditions, subjects were instructed to keep the trunk perpendicular to the floor (not to lean back or forward) and pull the handle with arms beside the trunk, with the elbows flexed at 90°. During the PC test, subjects supported the arm at the PC bench with elbows flexed at 90°. Subjects performed 3 MVIC tests of 5s for each condition. One and two minutes rest interval was allowed between MVIC tests and exercise conditions respectively. Strong verbal encouragement was given during the MVIC. The test-retest intraclass correlation coefficient (ICC) between the three MVIC trials was above 0.932 for peak force data and above 0.923 (UT), 0.693 (MT), 0.776 (UL), 0.717 (LL), 0.917 (PD), and 0.925 (BB) for peak EMG data.

Dynamic test

After the MVIC test, subjects performed one set of 5 repetitions for each exercise condition. The external load for all seated cable row conditions was set at 50% of the peak force obtained during the MVIC of the PRO condition and the external load for the PC was set at 50% of the peak force obtained during the MVIC of the PC condition. A metronome set at 60bpm assisted the subjects to keep a cadence of 2s eccentric and concentric phase. The standardization of the external load and cadence was deemed necessary to avoid its influence on muscle activity. One minute of rest interval was allowed between exercise conditions.

Recording the sEMG and kinematic data

The sEMG signals were recorded during the MVIC and dynamic tests by an 8-channel data acquisition system (SAS1000V8, EMG System do Brasil, São José dos Campos, Brazil) with a sampling rate of 2000 Hz using the software program (EMG Lab, EMG System do Brasil, São José dos Campos, Brazil). EMG activity was amplified (bi-polar differential amplifier, input impedance = 2MΩ, common-mode rejection ratio > 100 dB min (60 Hz), gain x 20, noise > 5 μV), and analog-to-digitally converted (12 bit). The concentric and eccentric phases were defined by a unidimensional electrogoniometer sampling at 2000hz positioned on the elbow joint and synchronized to the same data acquisition system.

The skin was shaved, then cleaned, and abraded with alcohol and cotton before the placement of the electrodes. Next, the bipolar electrodes Ag/AgCl (Kendall 100, Medtrace, Brazil) were placed on the dominant side, 2cm center-to-center apart in a longitudinal orientation to the presumed underneath muscle fibers. All electrodes were further secured with a bandage to avoid movement artifacts from the wires. The electrode placement of the UT, MT, PD, and BB was oriented by the European Project "Surface ElectroMyoGraphy for the Non-Invasive Assessment of Muscles" (SENIAM: http://www.seniam.org/). The electrode placement of the UL and LL was oriented by the study of Beaudette et al [10]. Electrodes were placed as follows: UT - 50% the distance on the line from the acromion to the spine on vertebra C7; MT - 50% the distance between the medial border of the scapula and the spine, at the level of T3; PD - in the area about two fingerbreadths behind the angle of the acromion; BB - on the line between the medial acromion and the fossa cubit at 1/3 the distance from the fossa cubit; UL – 50% the distance between the T10 and the posterior axillary fold, about two fingerbreadths below the inferior angle of the scapula; LT - 50% the distance between the L1and the posterior axillary fold, about the waistline. The ground electrode was placed on the bony prominence of C7.

Data analysis

sEMG, electrogoniometry, and force data were analyzed with a customized Matlab script (MathWorks Inc., Natick, MA, USA).

For the MVIC test, force-time data were low-pass filtered at 10 Hz using a fourth-order Butterworth filter with a zero lag. The raw digitalized sEMG data were band-pass filtered at 20-400Hz and the force-time data were low-pass filtered 10Hz, both using a fourth-order Butterworth filter with a zero lag. For muscle activation time-domain analysis, a root mean square (RMS EMG) (150 ms moving window) was calculated, and the peak value was obtained. The peak force (kgf) and the peak activation (uV) were defined as the highest value in the range of 1-4 s. The mean value of three MVIC trials was used in further statistical analysis.

For the dynamic test, the first and last repetitions were removed to avoid body adjustment, change in exercise cadence, or fatigue. First, the raw digitalized sEMG data were band-pass filtered at 20-400Hz and the electrogoniometry data were low-pass filtered 10Hz, both using a fourth-order Butterworth filter with a zero lag. For muscle activation time-domain analysis, RMS (150 ms moving window) was calculated, and the mean values of the concentric and eccentric phases were determined. The mean RMS sEMG data from the second, third, and fourth repetitions for each phase were normalized to the peak activation obtained during the MVIC test of the PRO condition. The mean of the three repetitions for each phase was used in further statistical analysis.

Statistical analysis

The normality and homogeneity of the variances were verified using the Shapiro-Wilk and Levene tests, respectively. The mean, standard deviation (SD), and 95% confidence intervals (CI) were calculated where data normality was confirmed. A repeated-measures analysis of variance (ANOVA) was used to compare the effect of exercise conditions on peak force and muscle activation. Post hoc comparisons were performed with the Bonferroni correction. Assumptions of sphericity were evaluated using Mauchly's test. Where sphericity was violated ($p < 0.05$), the Greenhouse–Geisser correction factor was applied. In addition, effect sizes (ES) in ANOVA were evaluated using the partial eta squared (η^2_p), with < 0.06, 0.06 - 0.14, and, > 0.14 indicating a small, medium, and large effect, respectively. The test-retest reliability of each dependent variable was assessed by calculating the intraclass correlation coefficient (ICC) in the familiarization session. All analyses were conducted in SPSS-22.0 software (IBM Corp., Armonk, NY, USA). An alpha level of 5% was used to determine statistical significance. The figures were formatted in GraphPad Prism version 7.0 software (La Jolla, CA, USA).

RESULTS

Peak force (PF)

Figure 2 shows the PF in the seven tested conditions. The repeated measures ANOVA revealed a significant effect of condition ($F_{(3.236,64,713)}$ =69.705, p<0.001, η^2_p =0.777). The PRO condition presented greater PF than 60° (p=0.023, 95% CI [0.92, 20.20]), and 90° (p<0.001, 95% CI [8.07, 23.01]). The SUP condition presented greater PF than 60° (p=0.024, 95% CI [0.71, 16.25]), and 90° (p<0.001, 95% CI [7.82, 19.10]). The NEU condition presented greater PF than 90° (p=0.001, 95% CI [3.74, 20.14]). Lastly, all rowing conditions presented greater PF than the PC condition: PRO (p<0.001, 95% CI [32.64, 63.43]), SUP (p<0.001, 95% CI [33.51, 58.39]), NEU (p<0.001, 95% CI [34.20, 54.64]), 30° (p<0.001, 95% CI [29.86, 54.93]), 60° (p<0.001, 95% CI [25.16, 49.78]), 90° (p<0.001, 95% CI [21.12, 43.86]).

Muscle activation during the MVIC (Figure 3)

Upper trapezius

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.461,\ 49.224)}$ =40.034, p<0.001, η^2_p =0.667). The 90° condition presented greater peak activation than all other rowing conditions (PRO (p<0.001, 95% CI [0.10, 0.40]), SUP (p<0.001, 95% CI [0.12, 0.40]), NEU (p<0.001, 95% CI [0.12, 0.38]), 30° (p=0.012, 95% CI [0.02,

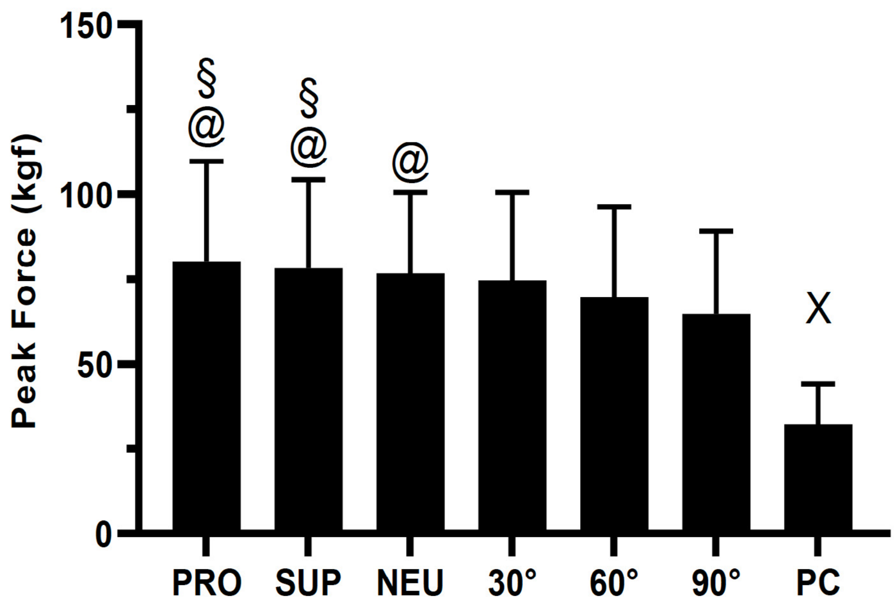

Figure 2. Mean and standard deviation of peak force. § = Significantly greater than 60° condition (p<0.05), @ = Significantly greater than 90° condition (p<0.05), X = Significantly lower than all other conditions (p<0.05).

0.33]), 60° (p=0.004, 95% CI [0.01, 0.12]). The 60° condition presented greater peak activation than PRO (p=0.003, 95% CI [0.04, 0.31]), SUP (p=0.001, 95% CI [0.07, 0.31]), and NEU (p=0.001, 95% CI [0.06, 0.30]).

Middle trapezius

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.588,\ 51.763)}$ =5.612, p=0.003, η^2_p =0.219). The 90° condition presented greater peak activation than SUP (p=0.010, 95% CI [0.02, 0.24]), and NEU (p=0.026, 95% CI [0.01, 0.24]). The 60° condition presented greater peak activation than the SUP condition (p=0.016, 95% CI [0.01, 0.15]).

Upper latissimus

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.001,\ 40.014)}$ =14.040, p<0.001, η^2_p =0.429). The SUP condition presented greater peak activation than 60° (p=0.033, 95% CI [0.01, 0.25]), and 90° (p=0.018, 95% CI [0.02, 0.32]). The NEU condition presented greater peak activation than the 90° condition (p=0.028, 95% CI [0.01, 0.28]). The 30° condition presented greater peak activation than the 90° condition (p=0.022, 95% CI [0.01, 0.21]).

Lower latissimus

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.989,\ 59.790)}$ =15.494, p<0.001, η2p =0.437). The PRO condition presented greater peak activation than 60° (p=0.007, 95% CI [0.02, 0.18]), and 90° (p=0.001, 95% CI [0.04, 0.24]). The SUP condition presented greater peak activation than 60° (p=0.005, 95% CI [0.03, 0.26]), and 90° (p=0.002, 95% CI [0.05, 0.33]). The NEU condition presented greater peak activation than 60° (p=0.001, 95% CI [0.03, 0.17]), and 90° (p<0.001, 95% CI [0.07, 0.21]). The 30° condition presented greater peak activation than 60° (p=0.021, 95% CI [0.01, 0.09]), and 90° (p=0.001, 95% CI [0.04, 0.20]).

Posterior deltoid

The repeated measures ANOVA revealed a significant effect of condition ($F_{(3.226,\ 64.526)}$ =61.432, p<0.001, η^2_p =0.754). The 90° condition presented greater peak activation than PRO (p=0.001, 95% CI [0.06, 0.28]), SUP (p<0.001, 95% CI [0.07, 0.28]), and NEU (p=0.008, 95% CI [0.02, 0.26]). The 60° condition presented greater peak activation than SUP (p=0.024, 95% CI [0.01, 0.23]).

Biceps brachii

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.700,\ 53.995)}$ =21.168, p<0.001, η^2_p =0.514). The PC condition presented greater peak activation than the other conditions (PRO (p<0.001, 95% CI [0.24, 0.83]), NEU (p=0.007, 95% CI [0.60, 0.56]), 30° (p<0.001, 95% CI [0.27, 0.83]), 60° (p<0.001, 95% CI [0.18, 0.77]), 90° (p=0.01, 95% CI [0.06, 0.66]), except for SUP condition. The SUP condition presented greater peak activation than PRO (p<0.001, 95% CI [0.11, 0.41]), 30° (p<0.001, 95% CI [0.10, 0.44]), and 60° (p=0.014, 95% CI [0.27, 0.37]). The NEU condition presented greater peak activation than PRO (p<0.001, 95% CI [0.09, 0.36]), and 30° (p<0.001, 95% CI [0.09, 0.39]). The 90° condition presented greater peak activation than PRO (p=0.009, 95% CI [0.03, 0.32]), 30° (p=0.022, 95% CI [0.01, 0.37]), and 60° (p=0.003, 95% CI [0.03, 0.21]).

Muscle activation during the dynamic test (Table 1)

Upper trapezius

The repeated measures ANOVA revealed a significant effect of condition ($F_{(1.869,\ 37.388)}$ =59.100, p<0.001, η^2_p =0.747), phase ($F_{(1,\ 20)}$ =174.783, p<0.001, η^2_p =0.897), and the interaction condition*phase ($F_{(1.945,\ 38.902)}$ =21.970, p<0.001, η^2_p =0.523).

Concentric phase: The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [36.21, 98.42]), SUP (p<0.001, 95% CI [50.76, 110.94]), NEU (p<0.001, 95% CI [43.21, 107.79]), and 30° (p<0.001, 95% CI [15.68, 63.53]). The 60° condition presented greater peak activation than PRO (p<0.001, 95% CI [30.14, 90.16]), SUP (p<0.001, 95% CI [45.67, 101.70]), NEU (p<0.001, 95% CI [37.25, 99.42]), and 30° (p=0.003, 95% CI [8.42, 56.46]). The 30° condition presented greater peak activation than PRO (p=0.001, 95% CI [9.22, 46.20]), SUP (p<0.001, 95% CI [25.76, 56.71]), and NEU (p<0.001, 95% CI [20.22, 51.56]). The PRO condition presented greater peak activation than SUP (p=0.012, 95% CI [2.14, 24.93]).

Eccentric phase: The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [21,67, 53,74]), SUP (p<0.001, 95% CI [27.27, 61.24]), NEU (p<0.001, 95% CI [25.04, 60.74]), and 30° (p<0.001, 95% CI [11.12, 36.34]). The 60° condition presented greater peak activation than PRO (p<0.001, 95%

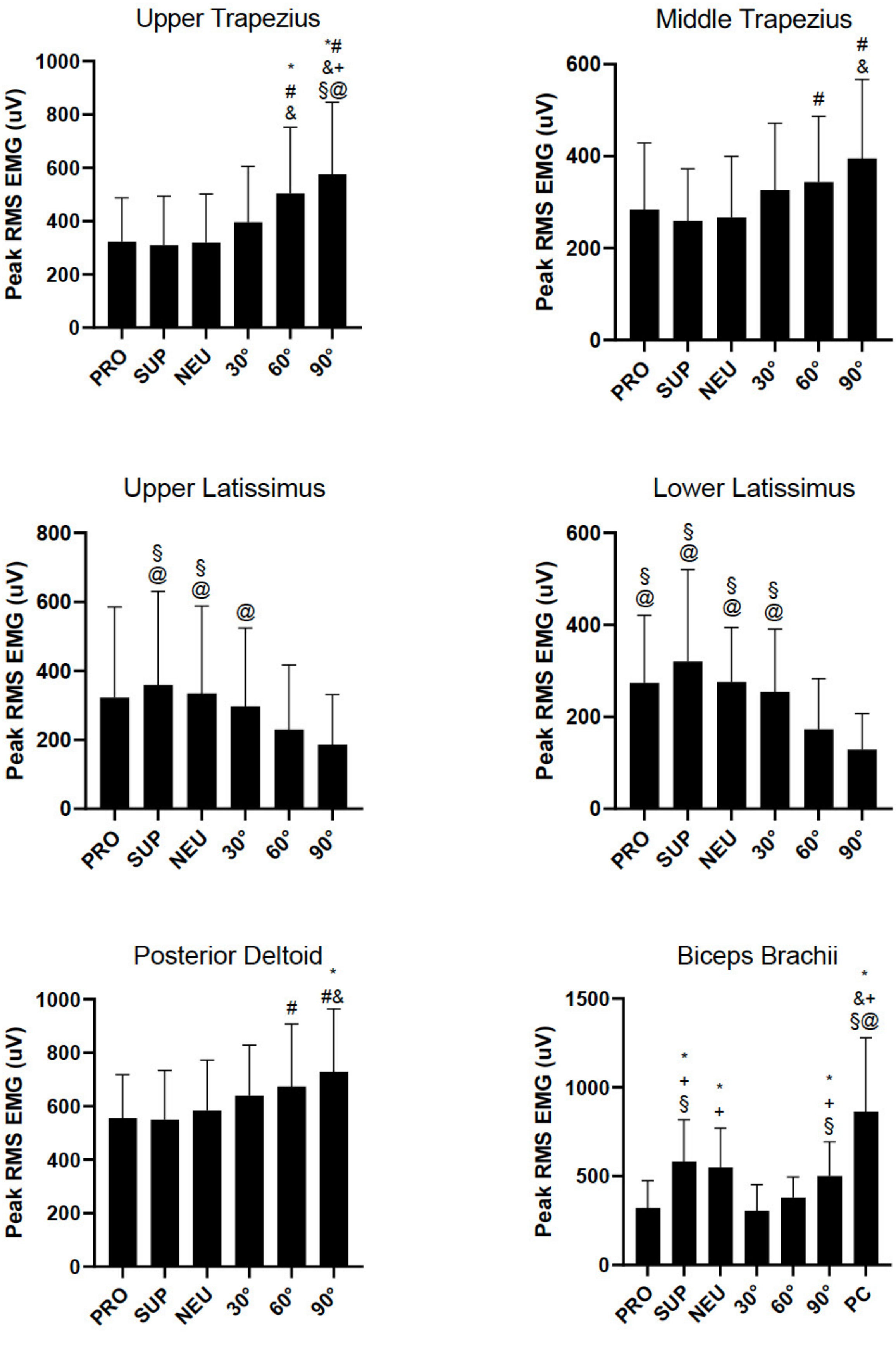

Figure 3. Peak RMS EMG during the MVIC. * = Greater than PRO (p<0.05), # = Greater than SUP (p<0.05), & = Greater than NEU (p<0.05), + = Greater than 30° (p<0.05), § = Greater than 60° (p<0.05), @ = Greater than 90° (p<0.05).

CI [19.77, 42.63]), SUP (p<0.001, 95% CI [26.24, 49.27]), NEU (p<0.001, 95% CI [24.19, 48.59]), and 30° (p<0.001, 95% CI [6.85, 27.60]). The 30° condition presented greater peak activation than PRO (p=0.001, 95% CI [5.15, 22.79]), SUP (p<0.001, 95% CI [10.31, 30.74]), and NEU (p<0.001, 95% CI [9.30, 29.02]). The PRO condition presented greater peak activation than SUP (p=0.003, 95% CI [1.68, 11.42]), and NEU (p=0.043, 95% CI [0.09, 10.28]).

Middle trapezius

The repeated measures ANOVA revealed a significant effect of condition ($F_{(1.711,\ 34.219)}$ =25.905, p<0.001, η^2_p =0.564), phase ($F_{(1,\ 20)}$ =87.618, p<0.001, η^2_p =0.814), and the interaction condition*phase ($F_{(2.051,\ 41.020)}$ =11.408, p<0.001, η^2_p =0.363).

Concentric phase: The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [15.49, 62.57]), SUP (p<0.001, 95% CI [21.58, 84.10]), NEU (p=0.001, 95% CI [17.58, 85.39]), and 30° (p=0.025, 95% CI [1.57, 37.11]). The 60° condition presented greater peak activation than PRO (p=0.001, 95% CI [11.14, 54.48]), SUP (p<0.001, 95% CI [19.17, 74.07]), and NEU (p=0.002, 95% CI [13.72, 76.81]). The 30° condition presented greater peak activation than PRO (p=0.001, 95% CI [6.38, 32.99]), SUP (p<0.001, 95% CI [15.45, 51.55]), and NEU (p=0.002, 95% CI [9.60, 54.68]). The PRO condition presented greater peak activation than SUP (p=0.014, 95% CI [1.92, 25.69]).

Eccentric phase: The 90° condition presented greater peak activation than PRO (p=<0.044, 95% CI [0.28, 37.02]), SUP (p=0.001, 95% CI [8.29, 42.37]), NEU (p<0.001, 95% CI [14.55, 43.75]), and 30° (p=0.003, 95% CI [4.28, 26.65]). The 60° condition presented greater peak activation than SUP (p=0.004, 95% CI [4.81, 34.35]), NEU (p<0.001, 95% CI [11.05, 35.75]), and 30° (p=0.048, 95% CI [0.55, 19.37]). The 30° condition presented greater peak activation than NEU (p<0.001, 95% CI [5.18, 22.19]).

Upper latissimus

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.877,\ 57.539)}$ =20.536, p<0.001, η^2_p =1.000), phase ($F_{(1,\ 20)}$ =89.477, p<0.001, η^2_p =1.000), and the interaction condition*phase ($F_{(2.901,\ 58.028)}$ =19.170, p<0.001, η^2_p =0.489).

Concentric phase: The PRO condition presented greater peak activation than 60° (p=0.001, 95% CI [5.68, 30.75]), and 90° (p<0.001, 95% CI [13.05, 48.83]). The SUP condition presented greater peak activation than NEU (p=0.032, 95% CI [0.53, 19.30]), 60° (p<0.001, 95% CI [10.96, 39.90]), and 90° (p<0.001, 95% CI [17.78, 58.54]). The NEU condition presented greater activation than 60° (p=0.031, 95% CI [0.90, 30.12]), and 90° (p<0.001, 95% CI [13.25, 43.20]). The 30° condition presented greater activation than 90° (p<0.001, 95% CI [8.93, 38.57]).

Eccentric phase: The PRO condition presented greater peak activation than 60° (p=0.006, 95% CI [1.58, 12.93]), and 90° (p=0.003, 95% CI [2.95, 19.93]). The SUP condition presented greater peak activation than 60° (p=0.001, 95% CI [3.20, 14.76]), and 90° (p<0.001, 95% CI [4.93, 21.39]). The NEU condition presented greater peak activation than 60° (p=0.003, 95% CI [2.05, 13.14]), and 90° (p<0.001, 95% CI [5.89, 17.67]). The 30° condition presented greater peak activation than 90° (p=0.001, 95% CI [2.89, 14.16]).

Lower latissimus

The repeated measures ANOVA revealed a significant effect of condition ($F_{(1.232,\ 24.636)}$ =4.377, p=0.040, η^2_p =0.180) and phase ($F(1,\ 20)$ =60.685, p<0.001, η^2_p =0.752).

Concentric phase: The PRO condition presented greater peak activation than 60° (p=0.008, 95% CI [4.54, 43.72]), and 90° (p=0.010, 95% CI [6.06, 64.18]). The SUP condition presented greater peak activation than 60° (p=0.001, 95% CI [7.40, 38.69]), and 90° (p<0.001, 95% CI [16.57, 51.50]). The NEU condition presented greater peak activation than 90° (p=0.003, 95% CI [7.70, 49.97]). The 30° condition presented greater peak activation than 90° (p=0.002, 95% CI [5.07, 31.06]).

Eccentric phase: The NEU condition presented greater peak activation than 90° (p=0.002, 95% CI [1.97, 11.61]).

Posterior deltoid

The repeated measures ANOVA revealed a significant effect of condition ($F_{(2.088,\ 41.760)}$ =34.612, p<0.001, η^2_p =634), phase ($F_{(1,\ 20)}$ =221.38, p<0.001, η^2_p =0.917), and the interaction condition*phase ($F_{(2.261,\ 45.225)}$ =10.556, p<0.001, η^2_p =0.345).

Concentric phase: The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [17.25, 57.08]), SUP (p<0.001, 95% CI [18.88, 57.89]), NEU (p<0.001, 95% CI [12.81, 53.36]), and 30° (p<0.001, 95% CI [9.10, 34.18]). The 60° condition presented greater peak activation than PRO (p<0.001, 95% CI [12.06, 48.61]), SUP (p<0.001, 95% CI [14.02, 49.09]), NEU (p=0.001, 95% CI [8.39, 44.12]), and 30° (p=0.011, 95% CI [2.38, 27.24]). The 30° condition presented greater peak activation than PRO (p=0.001, 95% CI [5.00, 26.04]), SUP (p=0.004, 95% CI [4.25, 29.23]).

Eccentric phase: The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [8.51, 27.61]), SUP (p<0.001, 95% CI [11.54, 30.20]), NEU (p<0.001, 95% CI [9.98, 28.43]), and 30° (p=0.001, 95% CI [2.87, 15.28]). The 60° condition presented greater peak activation than PRO (p<0.001, 95% CI [7.78, 23.34]), SUP (p<0.001, 95% CI [10.64, 26.11]), NEU (p<0.001, 95% CI [9.56, 23.86]), and 30° (p=0.002, 95% CI [1.86, 11.30]). The 30° condition presented greater peak activation than PRO (p=0.001, 95% CI [2.80, 15.16]), SUP (p=0.001, 95% CI [4.39, 19.19]), and NEU (p<0.001, 95% CI [4.43, 15.81]).

Biceps brachii

The repeated measures ANOVA revealed a significant effect of condition ($F_{(1.403,\ 28.061)}$ =31.523, p<0.001, η^2_p =0.612), phase ($F(1, 20)$ =96.258, p<0.001, η^2_p =0.828), and the interaction condition*phase ($F_{(1.715,\ 34.293)}$ =23.571, p<0.001, η^2_p =0.541).

Concentric phase: The PC condition presented greater peak activation than all other rowing conditions: PRO (p<0.001, 95% CI [82.12, 269.11]), SUP (p<0.001, 95% CI [54.17, 235.18]), NEU (p<0.001, 95% CI [54.51, 239.46]), 30° (p<0.001, 95% CI [70.35, 252.15]), 60° (p=0.001, 95% CI [48.10, 232.83]), and 90° (p=0.001, 95% CI [40.64, 197.93]). The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [24.63, 88.01]), and 30° (p=0.001, 95% CI [14.59, 69.50]). The 60° condition presented greater peak activation than PRO (p<0.001, 95% CI [15.45, 55.29]), and 30° (p=0.011, 95% CI [3.32, 38.88]). The 30° condition presented greater peak activation than PRO (p=0.024, 95% CI [1.19, 27.35]). The NEU condition presented greater peak activation than PRO (p=0.003, 95% CI [7.30, 49.95]). The SUP condition presented greater peak activation than PRO (p=0.002, 95% CI [9.05, 52.82]).

Eccentric phase: The PC condition presented greater peak activation than all other rowing conditions: PRO (p<0.001, 95% CI [58.45, 186.27]), SUP (p<0.001, 95% CI [37.93, 160.23]), NEU (p<0.001, 95% CI [37.75, 161.55]), 30° (p<0.001, 95% CI [50.72, 175.44]), 60° (p<0.001, 95% CI [36.72, 162.86]), and 90° (p<0.001, 95% CI [31.49, 140.14]). The 90° condition presented greater peak activation than PRO (p<0.001, 95% CI [6.14, 27.38]), and 30° (p=0.021, 95% CI [1.19, 23.77]). The 60° condition presented greater peak activation than PRO (p<0.001, 95% CI [4.90, 15.13]). The 30° condition presented greater peak activation than PRO (p=0.025, 95% CI [0.33, 8.23]). The NEU condition presented greater peak activation than PRO (p<0.001, 95% CI [8.08, 25.47]), and 30° (p<0.001, 95% CI [5.22, 19.76]). The SUP condition presented greater peak activation than PRO (p<0.001, 95% CI [6.27, 24.96]), and 30° (p=0.008, 95% CI [2.12, 20.53]).

DISCUSSION

The purpose of this study was to compare the peak force and electromyographic activation in different techniques of the seated row (SR). Specifically, we tested the following techniques: PRO, SUP, NEU, 30°, 60°, 90°, and PC. The results partially confirmed our hypothesis. The peak force was higher in rowing techniques with smaller shoulder abduction angles than during the techniques with greater shoulder abduction angles. Surface electromyographic assessment during the isometric and dynamic tasks demonstrated greater activation of the UT, MT, and PD in the techniques with greater shoulder abduction angle; on the contrary, it was observed greater activation of the UL and LL in the techniques with smaller shoulder abduction angle. BB activation was greater in PC than in all other rowing techniques; among the rowing techniques, the greatest activation of the BB was observed in the SUP, NEU, 60°, and 90° techniques.

The greater peak force observed during the PRO, SUP, and NEU techniques may be explained by the narrower grip width and the altered working conditions of the muscles. To our knowledge, no previous study has investigated either isometric or dynamic force production during different techniques of the seated cable row. However, data from the lat pull-down, indicated that greater 6RM loads were lifted when the exercise was performed with a narrow grip (1x bi-acromial distance [BD]) compared to a medium (1.5x BD), and a wide grip(2x BD) [11], which correspond to the findings in our study. Possibly, changes in the external and internal moment arm to the shoulder and elbow joint and changes in the line of traction of the muscles

Table 1. Mean ± standard deviation of the normalized sEMG (%MVIC).

Muscle	Action	Conditions						
		PRO	SUP	NEU	30°	60°	90°	PC
Upper trapezius	Concentric	70.7 ± 24.7#	57.2 ± 20.5	62.5 ± 27.2	98.4 ± 31.1*#&	130.9 ± 47.2*#&+	138.0 ± 47.9*#&+	-
	Eccentric	29.9 ± 9.1#&	23.3 ± 10.0	24.7 ± 10.9	43.9 ± 18.3*#&	61.1 ± 21.6*#&+	67.6 ± 28.5*#&+	-
Middle trapezius	Concentric	77.0 ± 30.0#	63.2 ± 25.4	64.5 ± 27.7	96.7 ± 40.8*#&	109.8 ± 50.9*#&	116.0 ± 54.8*#&+	-
	Eccentric	39.7 ±18.8	30.0 ± 15.4	29.2 ± 14.5	42.9 ± 16.7&	52.6 ± 23.6#&+	58.4 ± 25.6*#&+	-
Upper latissimus	Concentric	60.5 ± 32.0§@	67.8 ± 35.3&§@	57.8 ± 29.7§@	53.3 ± 24.9@	42.3 ± 27.6	29.6 ± 18.4	-
	Eccentric	25.4 ± 16.4§@	27.2 ± 15.8§@	25.8 ± 13.8§@	22.5 ± 12.3@	18.2 ± 13.0	14.0 ± 9.2	-
Lower latissimus	Concentric	60.0 ± 46.3§@	58.9 ± 29.4§@	53.7 ± 28.6@	42.9 ± 20.0@	35.8 ± 24.9	24.8 ± 14.0	-
	Eccentric	36.6 ± 73.4	32.7 ± 48.2	22.3 ± 8.7@	18.4 ± 9.3	15.2 ± 9.3	11.6 ± 6.7	-
Posterior deltoid	Concentric	68.3 ± 18.7	67.0 ± 20.0	72.3 ± 25.6	83.8 ± 23.7*#	98.6 ± 32.0*#&+	105.4 ± 32.6*#&+	-
	Eccentric	28.4 ± 10.2	25.6 ± 9.0	27.2 ± 10.0	37.4 ± 13.3*#&	44.0 ± 14.5*#&+	46.5 ± 17.1*#&+	-
Biceps brachii	Concentric	50.5 ± 18.3	81.4 ± 36.9*	79.1 ± 35.9*	64.8 ± 29.1*	85.9 ± 33.7*+	106.8 ± 52.8*+	226,1 ± 136,2*#&+§@
	Eccentric	16.2 ± 7.3	31.9 ± 16.5*+	33.0 ± 14.3*+	20.5 ± 10.2*	26.3 ± 9.9*	33.0 ± 17.1*+	85,3 ± 50,3*#&+§@

Legend:
** = Greater than PRO (p<0.05);*
 # = Greater than SUP (p<0.05);
& = Greater than NEU (p<0.05);
+ = Greater than 30° (p<0.05);
§ = Greater than 60° (p<0.05);
@ = Greater than 90° (p<0.05).

have favored force production in the techniques with narrower grip widths. For example, one might expect a reduced ability of the latissimus dorsi to pull the humerus backward when the shoulder is abducted as compared to the adducted position. In other words, by increasing the shoulder abduction angle, the line of traction of the latissimus dorsi change its main function as shoulder extensor in the sagittal plane to shoulder adductor in the frontal plane rather than horizontal abduction. Concomitant to this, another possible explanation is the greater activation and relative contribution of the latissimus dorsi in the techniques with smaller angles of shoulder abduction and vice-versa. In general, peak activation of the upper and lower portions of the latissimus dorsi was higher during PRO, SUP, and NEU techniques as compared to 60° and 90° techniques. Thus, our first hypothesis was confirmed.

Concerning muscle activation, the peak and mean values obtained during the isometric and dynamic tests confirmed our second hypothesis. The greater activation of the UT, MT, and PD occurred in the techniques with greater shoulder abduction angles (60° and 90°); on the contrary, the greater activation of the UL and LL occurred in the techniques with smaller shoulder abduction angles (PRO, SUP, and NEU). Previous studies investigating variations of the rowing exercise found results similar to the present one [2, 12-14]. García-Jáen et al. [2] while studying the dumbbell chest-supported row, observed an increase in UT, MT, and PD activation when subjects were oriented to perform the exercise with 90° of shoulder abduction in comparison to shoulder adduction. On the other hand, the activation of the latissimus dorsi was greater in the technique with shoulder adduction. Possibly, one might expect a reduction in latissimus dorsi activation when the shoulder is maintained abducted due to reciprocal inhibition caused by the activation of the shoulder abductors. Kara et al. [12] investigating the scapular-retraction exercise at 0°, 45°, and 90° of shoulder abduction also reported an increase in MT and UT activity from 0° to 45°, 0° to 90°, and 45° to 90° of shoulder abduction. Botton et al. [14] and Franke et al. [13] also reported high activation of the posterior deltoid (>40% of MVIC) during the machine seated row with 90° of shoulder abduction. In both studies, DP activity during the machine seated row was comparable to the incline lat pull-down but lower than the reverse fly machine. Collectively, the present and the previous studies suggest that the closer to 90° shoulder abduction the greater UT, MT, and PD activity, on the other hand, the closer to 0° shoulder abduction the greater UL and LL activity during the variations of the rowing exercise.

To the author's knowledge, three studies have measured BB activation during the rowing exercise [3, 7, 15]. Lehman et al. [15] reported low (>20% MVIC) activation of the BB while performing the seated row with a load equivalent to 10-12 repetition maximum (RM). However, Youdas et al. [7] and Youdas et al., reported very high (>60% MVIC) activation of the BB while performing different techniques of the inverted row. Possibly, the differences in external load and normalization procedure may explain the differences between our studies. In the present study, BB activation during the PC was greater than all other rowing conditions in both isometric and dynamic analysis. Although the acute assessment of muscle activation cannot be used to directly infer chronic adaptations to resistance training, our results are in line with the studies of Soares et al. [16] and Mannarino et al. [17]. Soares et al. [16] reported dissimilar recovery of the elbow flexors after performing 8 sets of 10 RM of unilateral seated row and unilateral PC. Specifically, the unilateral PC induced a greater reduction in elbow flexion peak torque and BB delayed onset muscle soreness. Moreover, Mannarino et al. [17] compared the effects of 8 weeks of training with the unilateral dumbbell row vs. unilateral PC on elbow flexors strength and hypertrophy. They observed specific increases of strength in the trained exercise but greater increase in BB hypertrophy after training the PC (11.06%) than the unilateral dumbbell row (5.16%). Together, the studies suggest that the variations of the rowing exercise activate, fatigue, and hypertrophy the BB, however, the addition of a single joint exercise may be necessary to further stimulate this muscle group.

Among the rowing techniques, BB activation was greater during SUP, NEU, 60°, and 90° techniques. It has been reported that BB presents greater activity [18] and elbow flexor strength [19] while performing elbow flexion with forearm supination, possibly due to a reduced neural drive to the muscle when the forearm is pronated [19]. With regard to multi-joint pulling exercises, Youdas et al. [20] reported an increase in BB activation from the pull-up (forearm pronation) to the chin-up (forearm supination) exercise, however, no significant differences in BB activation were observed between the body weight inverted row with pronated vs. supinated forearm [7]. Finally, the comparable BB activity observed with the NEU, 60°, and 90° techniques may be attributed to the similar forearm orientation angle to the arm.

This study has some limitations. First, people of different ages, health conditions, and training levels may respond differently than the ones that composed our sample (healthy, resistance-trained adults). Second, for the isometric and dynamic sEMG assessment, it is necessary to determine specific electrode placements, normalization procedures, cadence, joint positions, and external load. Possibly the results would diverge if any of these procedures were different.

Despite its limitations, this study has practical applications. The results indicate that rowing techniques with smaller shoulder abduction angles generate greater force production, which can be helpful for practitioners seeking to increase overall strength and hypertrophy by using heavier loads and increasing training volume. Additionally, the study demonstrates that the rowing technique can modify muscle activation during the exercise. Greater shoulder abduction angles resulted in increased muscular activation of the UT, MT, and PD, whereas smaller shoulder abduction angles resulted in greater activation of the UL and LL. Coaches and physiotherapists can use this information to select exercises tailored to individual goals and needs. The study also found that BB activation during rowing exercises was lower than that observed during PC. This suggests an additional benefit of performing single-joint exercises for the BB compared to multi-joint exercises like the seated cable row, based on our results and previous research[16, 17]. Overall, these findings provide important insights for practitioners looking to optimize their training routines.

CONCLUSION

This research showed that the peak force is higher in rowing techniques with smaller shoulder abduction angles than during the techniques with greater shoulder abduction angles. Muscle activation of the UT, MT, and PD is greater in the techniques with greater shoulder abduction angles, and the activation of the UL and LL is greater in the techniques with smaller shoulder abduction angles. BB activation is greater in the PC than in all other rowing techniques and among the rowing techniques, the greatest activation of the BB occurs in the SUP, NEU, 60°, and 90° techniques.

FUTURE RECOMMENDATIONS

Future studies may compare the seated row to other single-joint exercises that target the back muscles (i.e. straight-arm pulldown, reverse fly). Furthermore, it would be interesting to investigate other variations of the exercise (i.e. bent over row, machine row) and other muscles involved (i.e. lower trapezius).

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