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Effects of Slingshot with Relative Intensity on Repetitions to Failure, Myoelectric Activity, and Perception of Effort During the Bench Press Exercise in Recreationally-Trained Men

Paulo H. Marchetti[1], Roberto A. Magalhaes[2], Willy A. Gomes[3], Luis F. M. Teixeira[5], Gustavo H. Dos Santos SA[5], Rafael A. D. Baldin[2], Josinaldo J. Da Silva[4]

[1]Department of Kinesiology, California State University-Northridge, CA, USA, [2]Department of Physical Education, Mogi Guaçu University, SP, Brazil, [3]Federal Institute Education, Science and Technology of Sao Paulo, Sorocaba, Brazil, [4]Federal Institute Education, Science and Technology of Sao Paulo, Guarulhos, Brazil, [5]BOS Institute, SP, Brazil

ABSTRACT

The purpose of this study was to evaluate the effects of the slingshot (SS) with the relative intensity between two conditions (with SS and without SS) on repetitions to failure at 70%1RM (RF70%1RM), myoelectric activity (sEMG), and perception of effort (sRPE) during the bench press exercise in recreationally-trained men. Sixteen recreationally-trained men (31.7±7.1years, 173.2±6.0cm, 85.4±15.9kg) performed the 1RM test with SS (107.3 ± 23.7 kg) and without SS (102.1 ± 21.9 kg). Then, all subjects performed RF70%1RM in two experimental conditions: with (WSS) and without (WTSS) the slingshot device. sEMG of the pectoralis major (PM), anterior deltoid (AD), lateral head of triceps brachii (TL), and long head of triceps brachii (TLO) was measured during both experimental conditions. sRPE was measured after both experimental conditions. Two-way ANOVAs (2x4) were used to test differences between conditions (WSS and WTSS) and muscle groups (PM, AD, TL, TLO) for iEMG and peak RMS. A paired t-test was used to measure differences between RF70%1RM (WSS and WTSS) and sRPE. Statistical difference was observed between $RF_{70\%1RM}$ (WSS > WTSS, p=0.015). Statistical difference was observed between conditions for PM (peak RMS: WTSS > WSS, p=0.05). Statistical differences were observed for PM (iEMG: WTSS > WSS, p=0.05) and TLO activation (iEMG: WTSS > WSS, p=0.044). In conclusion, the use of the SS device induced a greater number of repetitions to failure and less myoelectric activation for the pectoralis major and long head of the triceps brachii. The perception of effort was similar between experimental conditions.

Keywords: exercise; strength; performance.

INTRODUCTION

The sling shot (SS) is an accessory (or support device) widely used in strength training, during the bench press exercise. SS is made from an elastic material that, when stretched (eccentric phase), accumulates elastic energy that is subsequently transferred to the lifter (concentric phase). SS is directly responsible for the increase in the maximum load lifted (10-15%), which indirectly leads to an increase in the load volume, bar velocity, and the maximal number of repetitions until muscular failure (Gavanda et al., 2021; Nicblock & Steele, 2017; Pedrosa et al., 2020; Wojdała & Krzysztofik, 2023; Ye et al., 2014). Although all studies demonstrated superior performance with SS, the external load (1RM or %1RM) used in all experimental conditions was defined without SS. Possibly, if the reference value (1RM) was previously defined in both conditions (with and without SS), the results could be different presenting a similar improvement.

Another point to be considered is that the additional assistance provided by SS is expected to improve performance but might interfere with muscle patterns or perception of effort during the bench press exercise. Studies have shown that the use of SS affects the prime mover's activation on bench press exercise such as pectoralis major (PM), anterior deltoid (AD), and triceps brachii (TB) (Dugdale et al., 2019; Wojdala et al., 2020; Wojdala et al., 2022). Wojdala et al. 2020 and Wojdala et al.2022, respectively, evaluated the myoelectric activity values of all prime movers of the flat bench press at 70%-85%-100% 1RM and 85%-100% 1RM. In both studies, the 1RM value was assessed without SS. The authors reported significantly lower myoelectric activity during the SS condition when compared to a control condition (without SS). The PM was the only muscle that showed no difference for the 70%1RM condition. On the other hand, Dugdale et al. (Dugdale et al., 2019) examined the myoelectric activity of the prime movers with and without SS in competitive powerlifters. The authors reported a significant reduction of the triceps brachii activation with SS at 87.5%1RM (without SS). The use of the SS device seems to affect the triceps brachii activation, however, only the lateral head was analyzed. It is well known that only two of three portions of the triceps brachii are monoarticular (lateral and medial heads) influencing only the elbow movement, however, the long head is biarticular affecting the shoulder and elbow joints. Therefore, considering the multi-joint pattern during the bench press movement, the force production and myoelectric activation of the long head of the triceps brachii might be affected by changes in the length-tension relationship and affect the muscle pattern of all prime movers. To the best of the authors' knowledge, no study analyzed the long head of the triceps brachii activation with and without SS. Finally, the use of submaximal external loads points to small changes in the myoelectric activity pattern between muscles in the bench press exercise (Dugdale et al., 2019; Wojdala et al., 2022). So, it is possible that the physical performance with submaximal external loads and adjusted intensity might not affect sets until failure or the perception of effort.

Therefore, the purpose of this study was to evaluate the effects of the slingshot (SS) with the relative intensity between two conditions (with SS and without SS) on repetitions to failure at 70%1RM ($RF_{70\%1RM}$), myoelectric activity (sEMG), and perception of effort (sRPE) during the bench press exercise in recreationally-trained men. The main hypotheses are that 1) the number of repetitions to failure (RF70%1RM) is similar with and without SS, 2) PM, AD, TL, and TLO activation are similar with and without SS, 3) sRPE is similar between experimental conditions. The rationale for this study is based on the assumption that neuromuscular performance and myoelectric activity should not be different when using relative loads (70%1RM), but rather due to different absolute loads defined by the use or not of the SS device.

METHODS

Subjects

The sample size was justified by a priori power analysis based on a pilot study where the superficial electromyography (pectoralis major) and $1RM_{bench\ press}$ testing in four recreationally-trained subjects, an alpha level of 0.05, and a power (1−β) of 0.80 (Eng, 2003). Therefore, sixteen healthy, recreationally-trained men (age: 31.7±7.1years, height: 173.2±6.0cm, total body mass: 85.4±15.9kg, biacromial distance: 37.9±2.5cm, $1RM_{WSS}$: 107.3±23.7kg, and $1RM_{WTSS}$: 102.1±21.9kg) volunteered to participate. All subjects had previous experience in resistance training (8±6years), previous experience with bench press exercise, and performed upper limb workouts at least twice a week. Subjects had no previous upper back injuries, surgery on their upper extremities, and no history of injury with residual symptoms (pain, "giving-away" sensations) in their upper limbs within the last year. The subjects were informed of the risks and benefits of the study prior to any data collection and then read and signed an institutionally informed consent document approved by the Institutional Review Board at the University (IRB # 6.003.724).

Procedures

This study used a within-subjects design to compare two different experimental conditions with and without the SS device. All procedures were randomized and counterbalanced across subjects and experimental conditions. Subjects attended three sessions in the laboratory and refrained from performing any upper body exercise other than activities of daily living for at least 48 hours prior to testing. All subjects were asked to identify their preferred arm for writing (dominant arm) and anthropometric data were evaluated (height, weight, and biacromial distance).

The bench press exercise was performed using a flat bench using the "5 points of contact" (head, shoulder blades, thoracic trunk, buttocks, and feet on the floor) (Haff & Triplett, 2016). All subjects performed the bench press exercise with a neutral spine position, without arching their backs (Bartolomei et al., 2024). The barbell was lowered to the chest at approximately nipple level (Haff & Triplett, 2016). The bench press handgrip width was set at 1.5x biacromial distance and the same distance was maintained during all conditions. The bench press technique was similar during all sessions and experimental conditions.

During the first and second sessions, all subjects performed a one-repetition maximum (1RM) test on the bench press exercise in one of two different conditions, performed randomly: 1. with SS ($1RM_{WSS}$) or 2. without SS ($1RM_{WTSS}$). The warm-up for both conditions was conducted as follows: subjects performed 5 repetitions with 20% of estimated 1RM, followed by 3 repetitions at 50% of estimated 1RM, 2 repetitions at 70% of estimated 1RM, and 1 repetition at 80% of estimated 1RM. Subjects had a maximum of 6 attempts to reach their 1RM with 3-min rest between attempts. The load was incrementally increased until the subjects could no longer maintain proper form or execute one full repetition (Haff & Triplett, 2016). The SS device was positioned on the subjects' arms.

During the third session, the subjects performed the bench press with repetitions to failure at 70%1RM ($RF_{70\%1RM}$) in both experimental conditions [with (WSS) and without (WTSS)] in random order. Each experimental condition was conducted with their respective 1RM values (WSS or WTSS). Therefore, the $RF_{70\%1RM}$ with SS condition used 70% of $1RM_{WSS}$ and the $RF_{70\%1RM}$ without SS condition used 70% of $1RM_{WTSS}$. The subjects performed a specific warm-up on the bench press (1 set of 10 repetitions at 30% 1RM) and took 3-min rest between the warm-up and the first experimental condition. For the experimental condition with SS, the subjects performed one set of maximal repetitions to failure at $70\%1RM_{WSS}$, and; for the experimental condition without SS, the subjects performed one set of maximal repetitions to failure at $70\%1RM_{WTSS}$ (Wojdała & Krzysztofik, 2023). No time was given between concentric and eccentric actions and muscle failure was defined as the inability to maintain proper form or execute one full repetition. The movement velocity was controlled by a metronome at 60 beats per minute. In the same session, both experimental conditions were performed with a 40-min rest interval. The number of repetitions to failure, elbow joint angle, superficial electromyography (sEMG), and rating of perceived exertion (sRPE) were measured for further analysis. Subjects received similar verbal encouragement during both experimental conditions and all measurements were performed between 9 am and 12 pm and measured by the same researcher (CSCS certified).

Measurements

Elbow Joint Angle: An electrogoniometer was positioned at the center of the elbow joint (on the dominant arm) and the data were used to define the phases (concentric and eccentric) of each repetition and the beginning and end of each full repetition. Data were acquired and synchronized with the sEMG using the same acquisition system and software (EMG832C, EMG system Brasil, São José dos Campos, Brazil) with a sampling rate of 2000 Hz. The elbow joint angle, sEMG, and sRPE were measured during the bench press with repetitions to failure (RF70%1RM) in both experimental conditions (with and without SS).

Surface Electromyography (sEMG): The subjects' body hair was shaved at the site of electrode placement and the skin was cleaned with alcohol before affixing the sEMG electrodes. Bipolar active disposable dual Ag/AgCl snap electrodes spanning 1-cm in diameter for each circular conductive area with 2-cm center-to-center spacing were used in all trials. Electrodes were placed on the dominant arm along the axes of the muscle fibers according to the SENIAM/ISEKI protocol (Hermens et al., 2000): pectoralis major (PM): electrodes were positioned at 50% on the line between the muscular belly and the middle fibers (sternal-costal); anterior deltoid (AD): electrodes were positioned one finger width distal and anterior to the acromion; triceps brachii:

lateral head (TL): electrodes were positioned at 50 % on the line between the posterior crista of the acromion and the olecranon at 2 finger widths lateral to the line; and triceps brachii, long head (TLO): the electrodes were positioned at 50 % on the line between the posterior crista of the acromion and the olecranon at 2 finger widths medial to the line. The sEMG signals were recorded by an electromyographic acquisition system (EMG832C, EMG system Brasil, São José dos Campos, Brazil) with a sampling rate of 2000 Hz using a commercially designed software program (EMG system 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 converted from an analog to digital signal (12 bit). A ground electrode was placed on the right clavicle. The sEMG signals collected during all experimental conditions were normalized to a maximum voluntary isometric contraction (MVIC) against a fixed strap resistance. One trial of five-second MVICs was performed for each muscle with a one-minute rest interval between actions for the dominant upper limb. The first MVIC was performed to familiarize the subject with the procedure. For PM and AD MVICs, the subjects were positioned in ventral decubitus with the shoulder joint abducted at 90°, the subjects performed a horizontal shoulder abduction against external resistance applied in the elbow region. For TL and TLO MVICs, the subjects were positioned in ventral decubitus with the elbow flexed at 90° and resistance placed on the wrist region. The subjects performed elbow extension for TL and TLO MVIC. Verbal encouragement was given during all MVICs. The order of MVICs was counterbalanced to avoid any potential neuromuscular fatigue. The sEMG and electrogoniometer data were analyzed with a customized Matlab routine (MathWorks Inc., Massachusetts, USA). All sEMG data were defined by the electrogoniometer data, characterizing both the concentric and eccentric phases of each repetition of the bench press exercise during both experimental conditions with repetitions to failure (WSS and WTSS). The digitized angle data were low-pass filtered at 10Hz using a fourth-order zero-lag Butterworth filter. The first repetition was removed from the beginning of the data to ensure any body or neuromuscular adjustment or change in exercise velocity. Then, five sequential repetitions were used for further analysis. The digitized sEMG data were band-pass filtered at 20-400 Hz using a fourth-order zero-lag Butterworth filter. For each muscle group, the root mean squared (RMS) (250ms moving window, sEMG RMS) was calculated for the MVICs and the sEMG data. The peak MVIC for each muscle (PM, AD, TL, and TLO) was used to normalize the sEMG RMS data. Then, for each muscle group, the sEMG RMS (normalized by MVIC) was integrated (five repetitions). Both data (peak RMS and iEMG) were used for further analysis.

Rating of Perceived Exertion (sRPE): The sRPE was assessed with a CR-10 scale (Sweet et al., 2004). Subjects were asked to use an arbitrary unit (A.U.) on the scale to rate their overall effort after both experimental conditions. A rating of 0 was associated with no effort and a rating of 10 was associated with maximal effort and the most stressful exercise ever performed. All subjects answered the following question based on CR-10 scale: "How was your workout?" The sRPE was asked 15-min after the end of each experimental condition.

Statistical Analyses

The normality and homogeneity of variances within the data were confirmed by the Shapiro-Wilk and Levene's tests, respectively. Mean, standard deviation, delta percentage (Δ%), and 95% confidence interval (CI95%) were calculated. Two-way repeated-measures ANOVAs (2 x 4) were used to test differences between conditions (WSS and WTSS) and muscle groups (PM, AD, TL, TLO) for the iEMG and peak RMS. Post-hoc comparisons were performed with the Bonferroni test when necessary. A paired t-test was used to measure differences between WSS and WTSS on RF70%1RM, 1RM, and sRPE. Cohen's formula for effect size (d) was calculated, and the results were based on the following criteria: <0.35 trivial effect; 0.35-0.80 small effect; 0.80-1.50 moderate effect; and >1.5 large effect, for recreationally-trained subjects (Rhea, 2004). An alpha of 5% was used to determine statistical significance. The intraclass correlation coefficient (ICC) was calculated for all muscle groups (PM, AD, TL, TLO) during five repetitions with and without SS device: Peak RMS (WSS: 0.97, 0.94, 0.97, 0.99; and WTSS: 0.95, 0.96, 0.95, 0.97) and iEMG (WSS: 0.97, 0.96, 0.97, 0.98; and WTSS: 0.99, 0.96, 0.99, 0.99).

RESULTS

For 1RM value, there was observed a significant greater value WSS when compared to WTSS (107.3 ± 23.7 kg vs. 102.1 ± 21.9 kg, respectively, p = 0.001, CI95% = [2.54 / 7.70], Δ% = 4.8, d = 0.22 [trivial]).

For RF70%1RM, there was observed a significant greater value for WSS when compared to WTSS (11.2±2.8 repetitions and 9.3±1.9 repetitions, respectively, p = 0.015, CI95% = [0.42 / 3.32], Δ = 16.9, d = 0.79 [moderate]).

For peak RMS, there was a significant main effect only for conditions (p = 0.001). There was significant interaction between conditions and muscle groups (p = 0.041) (Figure 1a). For PM, there was a significant higher value for WTSS when compared to WSS (p = 0.05, CI95% = [-53.4 / 0.30], Δ% = 20.7, d = 0.77 [small]) (Figure 1a).
For iEMG, there was a significant main effect only for conditions (p = 0.012). There was no significant interaction between conditions and muscle groups (p = 0.079) (Figure 1b). For PM, there was observed a significant greater value for WTSS when compared to WSS (p = 0.05, CI95% = [-49.4 / 0.23], Δ% = 14.7, d = 0.33 [trivial]). For TLO, there was observed a significant greater value for WTSS when compared to WSS (p = 0.044, CI95% = [-149.2 / -1.16], Δ% = 32.6, d = 0.66 [small]).

For sRPE, there was no significant difference between WSS and WTSS (8.3±1.1 A.U. and 8.1±1.1 A.U., respectively, p = 0.59, CI95% = [-0.54 / 0.92], Δ% = 2.4).

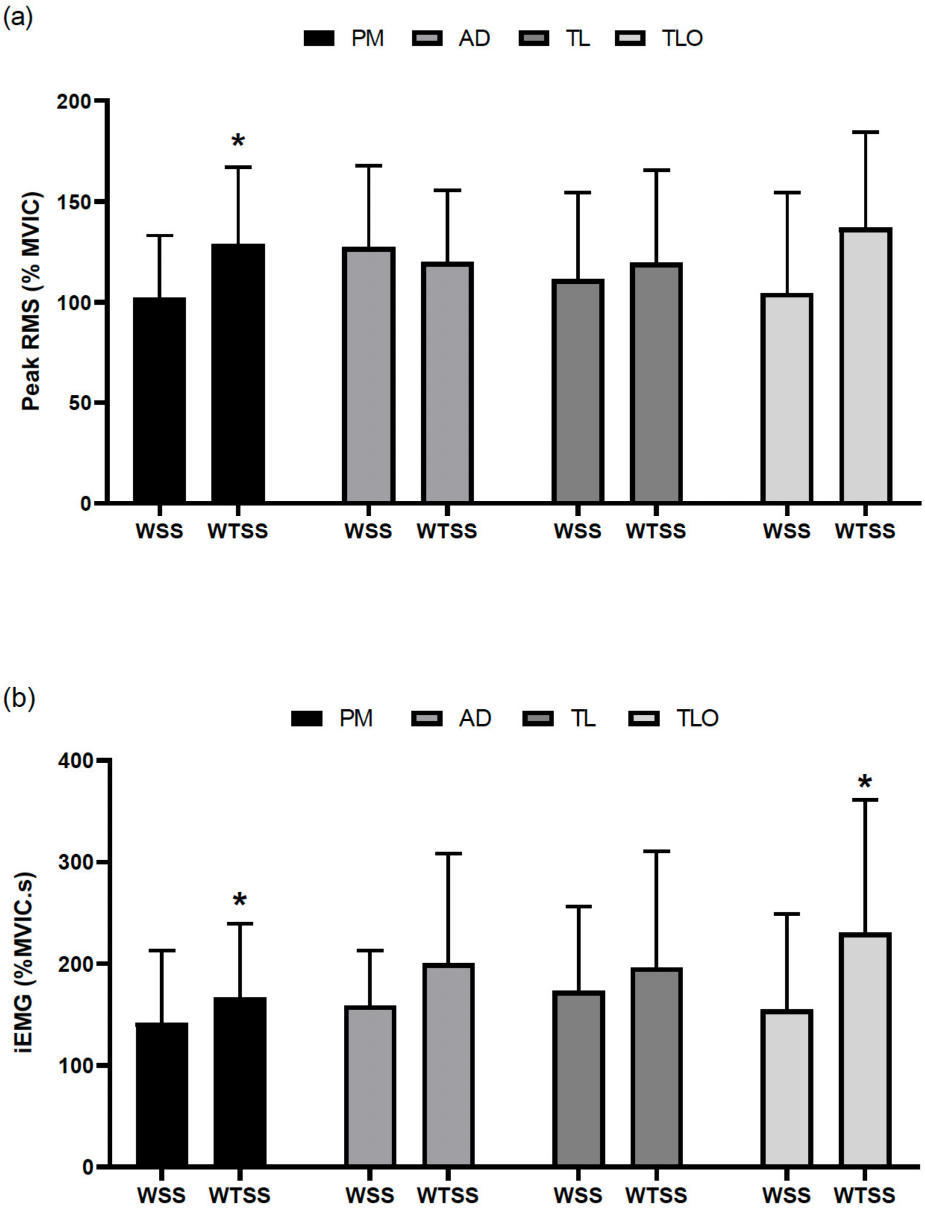

Figure 1. Mean ± standard deviation of (a) peak RMS and (b) iEMG in five repetitions to failure at 70%1RM with (WSS) and without SS (WTSS). *Significant difference between WSS and WTSS for the same muscle group, $p < 0.05$. **Legend:** PM – Pectoralis Major, AD – Anterior Deltoid, TL – Lateral Head of Triceps Brachii, TLO – Long Head of Triceps Brachii.

DISCUSSION

The main purpose of this study was to evaluate the effects of the slingshot (SS) with the relative intensity between two conditions (with SS and without SS) on repetitions to failure at 70%1RM (RF70%1RM), myoelectric activity (sEMG), and perception of effort (sRPE) during the bench press exercise in recreationally-trained men. The main findings were 1) the use of the SS device induced a greater number of repetitions, 2) the use of the SS device induced less myoelectric activation for the pectoralis major and long head of the triceps brachii, 3) the perception of effort was similar in both experimental conditions.

Studies have demonstrated superior performance with SS when compared to without SS (Gavanda et al., 2021; Nicblock & Steele, 2017; Pedrosa et al., 2020; Wojdała & Krzysztofik, 2023; Ye et al., 2014). Dugdale et al., (2019) measured 1RM values with and without SS in fifteen powerlifters and reported a 12.9% (~20kg) increase in 1RM with SS. A similar result was observed by Ye et al., (2014) who reported a 13.2% (17.5kg) increase in 1RM values in recreationally-trained individuals. In the present study, the use of SS induced a 4.9% (~5.2kg) increase in 1RM values when compared to not using it in recreationally-trained individuals. The discrepancy in 1RM values (with and without SS) between studies can be explained by differences in training status and greater neural adaptations in individuals more accustomed to using external loads close to maximum. Regarding the use of the SS device, in submaximal external loads, studies have presented contradictory results. Niblock et al., (2017) measured the maximal number of repetitions with and without SS in nine trained male subjects. The authors observed a higher volume load using SS, however, the 1RM value was measured only without SS and used in both conditions. On the other hand, Pedrosa et al., (2020) reported an increase in the maximal number of repetitions in both groups (most vs. less experienced group) after 3 sets of 80%1RM using the SS device. However, no statistical difference was observed in the maximal number of repetitions between groups with the SS device. In the present study, the muscular capacity to endure neuromuscular fatigue until failure (RF70%1RM) was tested under two relative intensities. The relative external load (70%1RM) was tested in both experimental conditions (with and without the SS device) since the use of the SS device affects the maximum force production. In this way, the two experimental conditions had the same relative load value (70%1RM) but different absolute load values (in kg). Considering this initial load adjustment, the main hypothesis was that the maximal number of repetitions to failure ($RF_{70\%1RM}$) would be similar with and without SS. However, our results did not corroborate the main hypothesis. The results have shown a significantly higher number of repetitions to failure during the experimental condition with SS (16.9%, moderate effect size). Curiously, only a 4.8% (trivial effect size) difference between the 1RM values ($1RM_{WSS}>1RM_{WTSS}$) induced 16.9% more repetitions to failure ($RF_{WSS}>RF_{WTSS}$). Finally, as presented in the present study, even with the use of relative load values in both experimental conditions, the additional elastic energy of the SS device generated greater muscular performance by reducing neuromuscular fatigue in recreationally trained individuals.

The superficial myoelectric activity (sEMG) signals are formed by neurophysiological variations in the state of muscle fiber membranes under different external and internal conditions. The myoelectric activity is a useful tool aiming to understand the pattern or level of each muscle action. Several studies have shown that the myoelectric activity is affected by whether or not the SS device is worn during the bench press exercise (Dugdale et al., 2019; Wojdala et al., 2020; Wojdala et al., 2022). During the present study, two complementary temporal sEMG analyses were applied to quantify the muscle action during the bench press exercise. First, the peak RMS (maximal value of a complete repetition) was defined per muscle group in each experimental condition (Figure 1a). The main hypothesis was that using the same relative external load (70%1RM), defined with and without SS, would induce similar peak RMS between experimental conditions. However, our results partially corroborate the main hypothesis. The results of the present study showed a 20.7% reduction in PM activity with the use of SS when compared to the experimental condition without SS. It is possible that the use of SS device was capable of reducing the shoulder demand, and consequently, contributing to the PM effort during the bench press exercise. Additionally, prime movers such as AD, TL, and TLO presented a similar peak RMS with and without SS. Wojdala et al. (2020) evaluated the peak of the myoelectric activity of all prime movers of the flat bench press at 70%-85%-100%1RM. The authors reported significantly lower myoelectric activity (PM, AD, and TB) during the SS condition when compared to a control condition (without SS) at 85% and 100%1RM. However, at 70%1RM, only AD and TB presented lower peak myoelectric activity with SS. PM did not change the myoelectric activity with or without SS. Similar results were observed in another study by the same authors (Wojdala et al., 2022) with external loads of 85% and 100%1RM. Both studies mentioned above have reported opposite muscle patterns to those observed in the present study. Probably, such differences might be attributed to 1. differences in the barbell velocity, since the peak of myoelectric activity is sensible to such changes, or 2. The use of two different external loads (70%1RM with and without SS) may have affected the peak RMS in the present study. As a way of complementing the temporal analysis, the integral of the RMS (iEMG) was also defined for all prime movers during five sequential repetitions in both experimental conditions (Figure 1b). The main hypothesis was that using the same relative external load (70%1RM), defined with and without SS, would induce similar iEMG between experimental conditions. However, our results partially corroborate the main hypothesis. The results of the present study showed a 14.7% reduction in PM activity and a 32.6% reduction in TLO with the use of SS when compared to the experimental condition without SS. Dugdale et al. 2019 examined the myoelectric activity of the prime movers with and without SS in competitive powerlifters. The authors reported a significant reduction in the RMS of the triceps brachii with SS at 87.5%1RM. However, in this study, only the lateral head was analyzed. It is well known that only two of three portions of the triceps brachii are monoarticular (lateral and medial heads) influencing only the elbow movement, and, the long head is biarticular affecting the shoulder and elbow joints. Therefore, the evaluation of the long head of the triceps brachii is essential to verify its muscular function with and without SS. Interestingly, AD and TL were not affected by whether or not the SS device was used. However, PM and TLO were deloaded with the SS device. The SS device has influenced both joint movements (horizontal shoulder adduction and elbow flexion) during the bench press exercise since the elastic component of the SS is greater during the concentric phase of the movement. In the present study, both experimental conditions were evaluated with their respective absolute loads (70%1RM with and without SS), which may have affected the results when compared to other studies.

Finally, the session rating of perceived exertion (sRPE) is frequently used to indirectly quantify the level of effort after RT sessions or conditions (Halperin & Emanuel, 2019; Marchetti, 2022). sRPE represents a relationship between the physiological and performance measures and assists in quantifying the overall internal load (Halperin & Emanuel, 2019). It was hypothesized that the use or not of the SS device would induce a similar perception of effort (sRPE) in recreationally-trained subjects. The results of the present study corroborated the main hypothesis, after all, both experimental conditions presented high scores (WTSS: 8.3±1.1A.U. vs. WSS: 8.1±1.1A.U.). It is well known that the perception of effort is affected by the level of neuromuscular fatigue in tasks reaching muscle failure in recreationally-trained participants (Fusco et al., 2020; Marchetti et al., 2023). Probably, the similarity of the results can be attributed to the induction of maximum neuromuscular fatigue with or without the SS device. This study has some limitations that should be considered when interpreting the current results. Both experimental conditions were evaluated in the same session. However, the exercises were randomized for each subject, and 40-min of rest was sufficient to remove any level of fatigue as observed in the pilot study. We evaluated the pectoralis major in only one region (sternocostal portion). Possibly, the clavicular portion could present a different pattern. However, even knowing that the pectoralis major is a pennate muscle, this position minimizes electrode movement during both experimental conditions. The subjects did not have a large experience with the SS device, but they performed a familiarization before the main session. We also measured only healthy, recreationally-trained men, and, therefore, our findings are not generalizable to other conditions, populations, or women.

CONCLUSIONS

In conclusion, the use of the SS device induced a greater number of repetitions to failure and less myoelectric activation for the pectoralis major and long head of the triceps brachii. The perception of effort was similar between experimental conditions. The practical implications for resistance training based on the present study are that the SS device promotes a greater number of repetitions, improving physical performance during maximal and submaximal external loads. However, when aiming to develop the prime movers of the bench press exercise, the use of the SS device would not be recommended.

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