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Electromyographic and Performance Analysis during Three Sets of Resistance Exercises among Untrained Women

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Abstract*: *The number of sets need to be performed in a resistance training session has been debated for decades. As more recent studies showed the superiority of performing multiple sets in resistance training, the aim of this study was to determine and compare the muscle activation and performance during three sets of resistance exercises among untrained women. Thirty-two recreationally active, untrained women were recruited as participants. Muscle activation was obtained from the pectoralis major during bench press and vastus lateralis during squat using electromyography method. Performance was measured by the number of repetitions performed in the three sets during both exercises. Results showed that the number of repetitions decreased significantly as early in the second set and continued to reduce in the third set. No significant changes were found for muscular activation. As the conclusion, among untrained women, it seems that performance in resistance training tend to decrease as early as during the second set. It is recommended for untrained women to perform more than a single set for each exercises in a resistance training to enhance their muscular strength and endurance.

Index Terms*: *Multiple set, Muscle activation, Number of repetitions, Acute responses, Training volumes

I. INTRODUCTION

For any individuals involved in resistance training, it is important to design a proper training program. Multiple sources are now available to be referred such as original research articles, review articles, books and any strength and conditioning blog/website. One of the resistance training variables that need to be well planned is volume. Volume is the amount of work performed. Volume in resistance training is affected by the number of sets, number of repetitions and the amount of loads lifted. Among these, the number of sets has been debated for decades. Several studies showed the superiority of multiple sets [1, 2] while some other studies showed the similar effectiveness of performing single set and multiple sets [3-6]. More recent studies showed the superiority of performing multiple sets [7, 8]. Despite of this, looking at the studies been conducted previously, it seems that less studies been conducted among untrained women.

Besides that, based on the authors' knowledge, less study had been conducted on comparing the muscle activation and performance changes during a number of sets during major upper and lower body exercises. The knowledge on this is indeed important as we will be able to look whether there are any changes of performance and muscle activation when performing multiple sets in resistance training.

As not much studies had been conducted among untrained women, it is the aim of this study to determine and compare the muscle activation and performance during three sets of bench press and squat exercises among untrained women.

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II. METHODOLOGY

A. Participants

Thirty-two recreationally active, resistance-untrained women were recruited as participants. Participants were unfamiliar with systematic resistance training, but do have knowledge on how to perform a proper bench press and squat exercises. All participants were screened using Physical Activity Readiness Questionnaire (PAR-Q) and had filled in the informed consent. All participants were free from any injuries.

B. Procedures

1 Repetition Maximum

One repetition maximum tests were performed in the week prior to the main data collection. After ten minutes of warm up session, all participants were evaluated of their one repetition maximum (1RM) test in bench press and squat as indicated by a formerly depicted incremental protocol [9]. As a safety precautions, both squat and bench press exercises tests were conducted in a power rack.

Bench Press

The participants positioned themselves supine on the bench and gripped the bar approximately 20-30 cm greater than shoulder width with arms extended. The elbows were positioned out and wrists straight. With the assistance of spotters, the bar was slowly lowered through flexion at the elbow joint until the bar touched the chest in line with the nipples. From this position the bar was raised until the arms were fully extended again. This complete movement was considered as one full repetition.

Squat

The participants positioned themselves under the bar with the bar aligned across the middle portion of the trapezius and posterior to the deltoid. The hands grasped the bar at a comfortable point. Upon setting the feet the subject lifted the bar from the rack and began to lower the bar through flexion at the knee joint until the bottom of the thighs were parallel to the floor. Then, participant need to ascended back to starting position. This was counted as one full repetition.

EMG procedure

The reading of muscle activation was recorded by using electromygraphy (EMG) method. EMG signals were recorded from pectoralis major during bench press, and vastus lateralis during squat by using a wireless electromyogram (TrignoDelsys, USA). All of the electrodes were placed on the dominant side of participants' body.

The surface EMG for non-invasive assessment of muscles (SENIAM) was used as guidelines for muscle determination [10]. The raw data from EMG signal were recorded at an analogue-to-digital conversion rate of 2000 Hz and 16- bit resolution after being amplified (1000x). Recorded signals were full-wave rectified and filtered using a dual-pass, sixth-order, 10-500 Hz band-pass Butterworth filter, and then a linear envelop was created using a low-pass, second-order Butterworth filter with a cut-off frequency of 6 Hz [11, 12]. For each muscle, the signal of EMG was collected from the start of the movement until the participant finished their movement.

Maximum voluntary contraction (MVC) test was first conducted. Then, participants' EMG data was collected during the bench press and squat exercises. The EMG data during this study was presented in the form of percentage of MVC.

Data Collection

After familiarization session, participants were tested on their 1RM for bench press and squat. 48 hours after that, 16 participants underwent bench press test followed by the squat tests after another 48 hours. The other 16 performed squat first than followed by bench press. Participants lifted 70% of their 1RM value during both exercises for three sets, with two minutes of rest interval.

C. Statistical Analysis

The data collected from this study were analysed by using Statistical Package for the Social Science (SPSS) version 20 for Windows software. The descriptive analysis were used to report and measure demographic data such as the means and standard deviation of physical characteristics. Repeated measure analysis of variance (ANOVA) was used to analyse the differences of muscles activation and number of repetitions completed between the sets performed. The statistical significant α-level of this research were accepted at $\rho < 0.05$.

III. RESULTS

Physical characteristics of participants involved in this study were shown in Table 1.

Table 1. Physical characteristics of participants

Variables	Mean ± SD
Age (years)	21.434± 1.03
Body Mass (kg) pre-test	50.34 ± 3.51
Height (cm)	157.83 ± 5.83

Table 2 showed the number of repetitions completed in Set 1, Set 2 and Set 3 during both bench press and squat exercises. Referring to the pairwise comparison in the repeated measure ANOVA, it was showed that number of repetitions during bench press was higher in Set 1 compared to Set 2 (p = 0.000) and Set 3 (p = 0.000). Set 2 showed greater number of repetition than Set 3 (p = 0.000). For squat, the number of repetitions was higher in Set 1 compared to Set 2 (p = 0.0006) and Set 3 (p = 0.000). Number of repetitions in Set 2 was higher than Set 3 (p = 0.000).

Table 2. Number of repetitions completed

	Set 1	Set 2	Set 3
Bench press	8.67 ± 0.76	8.00 ± 0.74	7.27 ± 0.58
Squat	9.67 ± 0.80	9.43 ± 0.73	9.03 ± 0.77

Table 3 showed the muscle activation of pectoralis major during bench press and vastus lateralis during squat in Set 1, Set 2 and Set 3. Results showed that the EMG during bench press and squat were not significantly different between sets ($p > 0.05$).

Table 3. Muscle activation

	Set 1	Set 2	Set 3
Pectoralis major (% of MVIC)	65.85 ± 3.94	64.48 ± 4.76	62.88 ± 5.23
Vastus lateralis (% of MVIC)	69.50 ± 2.46	68.05 ± 3.55	66.98 ± 4.52

Table 4 showed the percentage changes of muscle activation and number of repetitions in Set 2 and Set 3. Results on number of repetitions showed that the percentages of reduction in Set 2 and Set 3 was higher in bench press compared to squat, p = 0.000 and p = 0.001 respectively. In contrast, the reduction percentages of muscle activation in Set 2 and Set 3 were not different between both bench press and squat, p = 0.971 and p = 0.09 respectively. Pearson correlation showed no significant relationship between the percentages changes of EMG and percentage changes of number of repetitions performed.

Table 4. Percentage changes during Set 2 and Set 3

Variables	Percentage changes (%)
Pectoralis major Set 2	-1.99 ± 3.42
Pectoralis major Set 3	-1.92 ± 2.45
Vastus lateralis Set 2	-1.78 ± 1.97
Vastus lateralis Set 3	-1.54 ± 2.01
Bench press number of repetitions Set 2	-7.59 ± 5.52
Bench press number of repetitions Set 3	-8.92 ± 5.53
Squat number of repetitions Set 2	-2.28 ± 4.22
Squat number of repetitions Set 3	-4.15 ± 5.18

IV. DISCUSSIONS

This study was conducted to determine and compare the muscle activation and performance during three sets of resistance exercises among untrained women. Electromyography method was used to obtain muscle activation of pectoralis major during bench press and vastus lateralis during squat. Number of repetitions performed during the three sets of exercises was obtained as indicator for performance.

The loading that was chosen to be lifted for both exercises in this study was 70% of participants' 1RM. It has been suggested [13] that high-load resistance training (i.e., ≥60% 1RM) to maximize muscle strength and hypertrophy is based on Henneman's size principle [14], which states that the recruitment of high-threshold motor units is dependent on the intensity of the stimulus [14]. Thus, motor unit recruitment is suggested to be great enough during resistance exercise at 70% 1RM.

Looking at the performance, results showed that the number of repetitions performed decreased significantly during the second set compared to the first set. The third set also showed significantly lesser number of repetitions compared to the second set. Results next analysed the percentage changes of number of repetitions in Set 2 (compared to Set 1) and in Set 3 (compared to Set 2). Results showed that the percentages of reduction in Set 2 and Set 3 was higher in bench press compared to squat. The smaller pectoralis major muscle compared to the quadriceps might be the possible reason for the greater decrease of bench press performance compared to squat.

Unlike the number of repetitions, for muscle activation variable, it was found that both pectoralis major EMG and vastus lateralis EMG were not significantly changed during all sets. This findings was in line with what was found previously [15]. Results also showed the percentages of EMG reduction in Set 2 and Set 3 were not different between both bench press and squat. Thus, despite decrement of performance, muscle activation was found not to be significantly changed across the three sets. However, despite no changes were found, it should be noted that the number of repetitions performed during the earlier sets for both exercises were greater. Future studies are suggested to look deeper on these findings.

No correlation were found between percentage reduction in EMG and number of repetitions. Thus, it can be said that decrement of EMG value was not the reason of decrement of performance in this study.

V. CONCLUSIONS

As the conclusion, among untrained women, it seems that performance in resistance training tend to decrease as early as during the second set. It is recommended for untrained women to perform more than a single set for each exercises in a resistance training.

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