Single- Versus Three-Set Resistance Training on Strength and Power Among Untrained Men

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Abstract The purpose of this study was to compare the effects of single- versus three (3)-set resistance training on muscular strength and muscular power among untrained men. Thirty-six untrained men were recruited in this study. Participants were randomized into 3 groups; single set ($n = 12$, age = 20.92 ± 0.79), 3 set ($n = 12$, age = 21 ± 0.74), and control group ($n = 12$, age = 21 ± 0.67). Muscular strength was measured by bench press and squat performance. Static strength was measured by handgrip strength test and muscular power by the vertical jump test. The intervention groups were engaged in 6 weeks of training three times per week. Common exercises were performed to the point of achieving muscular failure for every set. Significant improvement was recorded in muscular strength and muscular power performances, ($p < 0.05$) for both the single- and three-set groups. However, no significant differences were found for all the test performances between the invention groups ($p > 0.05$). In conclusion, single-set and three-set resistance trainings showed similar training effects on muscular strength and muscular power among untrained men.

Keywords Resistance training · Single set · Multiple set · Strength · Power · Untrained men

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1 Introduction

Resistance training is one of the best alternatives to achieve great improvement in muscular strength [1]. However, designing a resistance training program is a complex process that requires the recognition and manipulation of several program design variables [2].

One of the most important considerations within resistance training is the volume of exercise. Volume relates to the total amount of weight lifted in a training session derived from the number of sets, load lifted, and the number of repetitions performed.

For decades, debate has persisted regarding the volume or number of sets a person must perform to elicit maximal strength gains. Coaches were more adhered to the traditional training regimens which were based on the findings of Berger [3]. This early research found that a volume of three sets provided the best strength gains in individuals.

However, several studies had challenges the long held standards of strength training. In particular, many exercise scientists have found that single-set training volumes may be as effective as multiple-set protocols [4–7].

Propagators of one set strongly claimed that one-set resistance training would induce similar training effects for strength and power development as multiple-set resistance training. It is also time-saving and may help to prevent the onset of overtraining. However, multiple sets propagators insist on the superiority of multiple-set resistance training due to the increment of training volumes. Thus, the question of the number of sets that should be performed in a training session is still inconclusive.

In determining the answer for this question, the study needs to be conducted in a way that no methodological biasness could occur. Certain previous studies conducted were without controlling the intensity and repetitions performed, [8–10], thus raising the questions whether the results were affected by the number of sets or other variables.

A reduction in lifting volume from three sets per exercise to a single set would reduce the time needed for weight training by nearly one-third. However, it is still inconclusive whether performing single set is as effective as performing three sets.

In response to the current problem, the present study was designed to compare the effects of single- and multiple-set resistance training on muscular strength and muscular power among untrained men.

This study can help to provide greater understanding for the educationist, researchers, sports scientist, and strength and conditioning professionals on the effects of the different volume or number of sets performed in resistance training. This study is also important to the untrained populations in helping them to design effective training programs in resistance training. Having good muscular strength and muscular power is undoubtedly important to all concerned as these can benefit on their functionality and sporting performance.

2 Methodology

2.1 Participants

Thirty-six healthy and untrained men were selected and recruited for this study. Convenience sampling technique was used due to some specified criteria in selecting the sample. Participants selected were males aged between 18 and 25 years based on their year of birth. Participants had no experience in resistance training and were free from injury, endocrine and/or medical problems, and not consuming any performance-enhancing supplementation.

Participants were screened prior to testing using PAR Q and ECG test. Each participant had read and signed an informed consent for testing and training approved by the UiTM Research Ethics Committee. Participants were assigned into single-set, three (3)-set, and the control groups based upon randomized control trial of their bodyweight.

2.2 Static Strength Test

A calibrated Takei grip dynamometer with a reported reliability coefficient of 0.90 was used to measure handgrip strength. The participant performed the test in the standing position with head in the midposition (facing straight ahead). The grip size was adjusted so that the middle finger's (third digit's) midportion (second phalanx) is approximately at a right angle. The instructor then recorded the grip setting. The same setting was used for further tests on the same person. The participant's forearm was placed at 90° of the upper arm; the upper arm hanged in a vertical position. The participants were given three trials alternately with each hand, with at least 30 s or up to 1 min between trials for the same hand. The instructor reset the dynamometer's pointer to zero after each trial. The sum of the best of the left and right grip was divided by body weight for the relative strength score.

2.3 Upper Body Strength Test

Bench press performance was used to measure upper body strength. The equipments used were a Cybex bench station, a calibrated UESAKA (IWF approved) bar, calibrated UESAKA, and Olympic weight plates and calibrated locks. The testing procedures involved the protocols as mentioned by Baechle and Earle [11].

After adjusting the desired amount of weight on the bar, the participants assume a supine position on the bench and two spotters place the bar in his/her hands and across the chest. With the hands approximately shoulder-width apart, the participant extends the arm, pressing the bar to a "locked out" (elbow straight) position. The two spotters remove the bar on completion of the trial. The multiple RM achievement of not more than 8 repetitions to failure is then calculated to attain the 1RM score (in kg). It was divided by body weight for the relative strength score.

2.4 Lower Body Strength Test

Back squat exercise was used to measure lower body dynamic strength. All equipments were calibrated prior to the test. Calibrated UESAKA and Olympic weight plates and calibrated locks were used.

After adjusting the desired amount of weight on the bar, it was then placed on the shoulders behind the neck with the hands gripping the bar in pronated forearm position. The participant begins the lift from full knee extension and then bends at the knee until the top of the thigh is parallel with the ground. Once the thigh was parallel with the ground, the investigator gave a verbal signal and the subject lifted the weight to the starting position [12]. Similar scoring procedure as used in the bench press test was adopted.

2.5 Muscular Power

The vertical jump was measured by using a Vertec. Three vertical jump trials were performed with 1-min rest period between trials. The vertical jump was performed by having the participant standing upright with both arms fully extended overhead. Participants were to jump and touch the highest possible vane. Vertical jump score was measured by the difference of the standing height and the jumping height.

2.6 Resistance Training Program

Participants were assigned to three (3) groups; single-set ($n = 12$), three-set ($n = 12$), and the control group ($n = 12$). Single-set group trained one set for each exercise, while three-set group trained three sets for each exercise. Control group did not perform any training.

Both the experimental groups trained at 80 % of 1RM until momentary muscular failure is achieved at the eight repetitions. A rest interval of 2 min was fixed between sets, and exercises as 2 min were sufficient for muscular recovery [11].

All participants recorded their training details in a log book provided by the researcher. The training log helped to track the participants' training compliance. Training was conducted three days per week, with a minimum of 48 h between

Table 1 Characteristics of participants based on group

Group	n	Age (years)	Height (m)	Weight (kg)
Single	12	20.92 ± 0.79	1.67 ± 0.04	65.28 ± 3.02
Multiple	12	21 ± 0.74	1.68 ± 0.04	65.27 ± 3
Control	12	21 ± 0.67	1.67 ± 0.04	64.71 ± 2.92

(mean ± SD; n = number of participants)

sessions, for 6 weeks subscribing to ACSM's recommendations to allow for full muscle recovery before the next training session is conducted. Three times per week was chosen because based on current ACSM position stand [13], adults should train each major muscle group two or three days each week using a variety of exercises and equipment.

2.7 Statistical Analysis

Descriptive statistic was used to describe the demographic data of the participants. Kolmogorov-Smirnov, descriptive statistic, and boxplot were used to check for the normality of data in each group. Mixed between within analysis of variance (ANOVA) were used to determine the significant interactions and main effect between the three resistance training protocols (single set, multiple set, control) on muscular strength and muscular power. Post hoc test with Tukey adjustment test was conducted to determine which intervention group showed more changes on variables tested.

3 Results

3.1 Participant Characteristics

Table 1 presented the physical characteristics of the samples selected including the age, height, and weight of each group.

3.2 Muscular Strength and Muscular Power

3.2.1 Upper Body Muscular Strength

Table 2 showed changes in bench press performances between groups across observation. Results showed single-set group demonstrated a 4.31 % improvement

Table 2 Changes in bench press performances between groups across observation

Variable	Time period	Single-set group $M \pm SD$	Multiple-set group $M \pm SD$	Control group $M \pm SD$
Bench press	Pre-test	0.95 ± 0.05	0.96 ± 0.05	0.93 ± 0.05
	Post-test	0.99 ± 0.05	1.03 ± 0.05	0.94 ± 0.05

of bench press performance, while multiple-set group demonstrated a 7.75 % improvement. Control group demonstrated a 0.21 % improvement in performance.

A significant main effect for time was obtained, Wilk's Lambda = 0.054, $F(1, 33) = 575.97$, $p < 0.001$, partial eta squared = 0.946 (large effect size), indicated that there was a significant increment in participants' strength across observations. A significant interaction was found between number of sets and time, Wilk's Lambda = 0.087, $F(2, 33) = 173.62$, $p < 0.001$, partial eta squared = 0.913 (large effect size). This shows that a significant improvement in participants' upper body strength scores across observations was influenced by the intervention. A significant main effect between groups, $F(2, 33) = 4.743$, $p < 0.05$, partial eta squared = 0.223 (small effect size), was also observed.

Post hoc test showed that both the single- and three-set groups showed significant difference compared to control group, $p < 0.05$. However, no significant difference was found between both of these groups, $p > 0.05$. Hence, the hypothesis is failed to be rejected.

3.2.2 Lower Body Muscular Strength

Table 3 showed changes in squat performances between groups across observation. Results showed single-set group demonstrated a 6.01 % improvement of squat performance, while multiple-set group demonstrated a 10.44 % improvement. Control group demonstrated a 0.33 % reduction in performance.

A significant main effect for time was obtained; Wilk's Lambda = 0.04, $F(1, 33) = 802.025$, $p < 0.001$, partial eta squared = 0.960 (large effect size), shows that there was a significant increment in participant's strength across observations. A significant interaction was found between number of sets and time, Wilk's Lambda = 0.057, $F(2, 33) = 273.23$, $p < 0.001$, partial eta squared = 0.943 (large effect size). This shows that a significant improvement in participant's lower body strength scores across observations was influenced by intervention. Besides, there was a significant main effect between groups, $F(2, 33) = 11.347$, $p < 0.001$, partial eta squared = 0.407 (moderate effect size).

Post hoc test showed that both the single- and multiple-set groups showed significant difference compared to control group, $p < 0.05$. However, no significant difference was found between both the groups, $p > 0.05$. Hence, hypothesis is failed to be rejected.

Table 3 Changes in squat performances between groups across observation

Variable	Time period	Single-set group $M \pm$ SD	Multiple-set group $M \pm$ SD	Control group $M \pm$ SD
Squat	Pre-test	1.25 ± 0.04	1.25 ± 0.05	1.23 ± 0.04
	Post-test	1.32 ± 0.05	1.38 ± 0.05	1.22 ± 0.05

Table 4 Changes in handgrip strength between groups across observation

Variable	Time period	Single-set group $M \pm$ SD	Multiple-set group $M \pm$ SD	Control group $M \pm$ SD
Handgrip strength	Pre-test	0.67 ± 0.05	0.67 ± 0.04	0.65 ± 0.04
	Post-test	0.74 ± 0.05	0.74 ± 0.04	0.65 ± 0.05

3.2.3 Static Strength

Table 4 shows changes in handgrip strength between groups across observation. Results showed single-set group demonstrated a 10.15 % improvement of hand-grip strength, while multiple-set group demonstrated a 10.57 % improvement. Control group demonstrated a 0.61 % reduction in performance.

A significant main effect for time was obtained; Wilk's Lambda = 0.065, $F(1, 33) = 475.22$, $p < 0.001$, partial eta squared = 0.935 (large effect size), shows that there was a significant increment in participant's strength across observations. A significant interaction was found between number of sets and time, Wilk's Lambda = 0.107, $F(2, 33) = 137.06$, $p < 0.001$, partial eta squared = 0.893 (large effect size). This shows that a significant improvement in participant's static strength scores across observations was influenced by the interventions. There was significant main effect between groups, $F(2, 33) = 6.318$, $p < 0.01$, partial eta squared = 0.277 (small effect size).

Post hoc test showed that both single- and multiple-set groups were significantly higher than control group, $p < 0.05$. However, no significant differences were found between both of the groups, $p > 0.05$. Hence, hypothesis is failed to be rejected.

3.2.4 Muscular Power

Table 5 showed changes in vertical jump between groups across observation. Results showed single-set group demonstrated a 12.63 % improvement of vertical jump performance, while multiple-set group demonstrated a 11.19 % improvement. Control group demonstrated a 1.2 % improvement in performance.

A significant main effect for time was obtained; Wilk's Lambda = 0.143, $F(1, 33) = 198.19$, $p < 0.001$, partial eta squared = 0.857 (large effect size), shows that there was a significant increment in participant's muscular power across

Table 5 Changes in vertical jump between groups across observation

Variable	Time period	Single-set group $M \pm$ SD	Multiple-set group $M \pm$ SD	Control group $M \pm$ SD
Vertical jump	Pre-test	41.58 ± 2.15	42.42 ± 2.47	41.75 ± 2.30
	Post-test	46.83 ± 1.80	47.50 ± 1.45	42.25 ± 1.42

observations. A significant interaction was found between number of sets and time, Wilk's Lambda = 0.310, $F(2, 33) = 36.81$, $p < 0.001$, partial eta squared = 0.690 (moderate effect size). This shows that a significant improvement in participant's muscular power scores across observations was influenced by the interventions. Besides, there was a significant main effect between groups, $F(2, 33) = 8.596$, $p < 0.01$, partial eta squared = 0.343 (small effect size).

Post hoc test showed that both the single- and multiple-set groups were significantly higher than control group, $p < 0.05$. However, no significant differences were found between the two groups, $p > 0.05$. Hence, hypothesis is failed to be rejected.

4 Discussion

Finding of the present study clearly indicated that resistance training was effective in improving upper and lower body strength, static strength, and muscular power and there were no significant differences in the measured parameters recorded from single- versus three-set trainings.

The study sought to compare the effects of single- versus multiple-set resistance trainings on muscular strength, muscular power, and physiological responses among untrained men. Participants underwent 6-week resistance training treatment three times per week for a total of 18 sessions.

The effects of resistance training on muscular performance recorded that the upper body strength, lower body strength, static strength, and muscular power were all significantly improved. This proved that both number of sets performed were effective in improving muscular strength and muscular power.

Resistance training had been shown to produce compensatory growth of skeletal muscle especially among initially untrained healthy subjects, which is potentially helpful in increasing the strength of the skeletal muscles. This hypertrophy is a result from the increment in the rate of protein synthesis over the rate of protein degradation which in turn produces a deposition of myofibrillar proteins within existing muscle fibers [14, 15]. This thus helps to explain the possible mechanism underlying the improvements of muscular performance.

The improvement can also be related to the neuromuscular adaptations. Apart from the quality and quantity of the involved muscles, neuromuscular performance also depends on the nervous system's ability to appropriately activate the muscles [16]. Resistance training had been proven to induce positive adaptations within the nervous system [17]. These positive adaptations include the increment in the firing rate of each motor unit, changes in the pattern of motor unit activation, and the recruitment of more motor units [18].

In attaining optimal increment of muscular performance, resistance training program had to be designed based on the specific objectives. The ACSM's recommendation that multiple-set resistance training will produce greater effects to the performance had been criticized in some of the reviews that claimed the recommendations had been made without strongly proven evidence and supported by earlier studies [1].

This present study found that the higher number of sets had not significantly induced more improvement of upper and lower body muscular strength, static strength, and muscular power but noted a very slight superiority of the three-set group in upper and lower body strength test achievements. Findings of this study is in line with Arthur Jones' earliest [19] to his final writing [20] who argued that the muscular strength and hypertrophy can be optimally improved by performing one set of resistance training carried to the point of momentary muscular failure and that further sets are therefore unnecessary. This was further supported by Smith and Bruce-Low [13].

Several other studies indicated and supported parallel findings that there were no additional benefits to perform multiple sets when training for strength [4–7, 21].

The similar gains in strength increment could be related to the same muscular size increment of participants. Ostrowski et al. [22] investigated the 10-week effects of 1, 2, or 4 sets of resistance training. Results showed that there were significant increases in body mass, rectus femoris circumference, rectus femoris hypertrophy, and tricep brachia thickness for the 1-, 2-, and 4-set groups, respectively, but there were no significant differences between the groups. This present study proved that in 6 weeks, the increment of number of sets failed to induce more muscle size increment compared to just performing one set.

The findings of the present study contradicts the guidelines of the ACSM [23] and Baechle and Earle [11] in which multiple sets have been recommended to produce more significant effects compared to single set. Further supporting the effectiveness of multiple set was a study by Kelly et al. [24] which concluded that performing 3 sets of isokinetic knee extensions was more effective than performing a single set for increasing peak torque.

Kemmler et al. [25] examined the effects of single- and multiple-set resistance trainings on untrained women. The participants were tested for strength gains in their shoulders, chests, arms, abdominals, backs, and legs. Results showed the multiple-set group increased their strength by 3.5–5.5 %. However, the single-set group showed 1.1–2.0 % decrements in strength. This finding suggested multiple-set resistance training is better for increasing strength for older women. The contradicting findings of the present study with the study by Kelly et al. [24] and Kemmler et al. [25] can be attributed to the methodology used in these studies. The participants in the present study were subjected to a total body workout, whereas the participants in the study by Kelly et al. [24] were only trained in isokinetic knee extensions. The participants used in the present study were untrained men compared with the study by Kemmler et al. [25] which recruited untrained women. The differences of exercises used and different populations might be the contributing factors to these contradicting results. Other than that, other contributing factor could be the intensity used in the study, rest between set, order of exercises, and many more.

Unlike the muscular strength effects, the study on the comparison of single- versus multiple-set resistance trainings on the static strength and muscular power had not been well documented. No significant differences of static strength and muscular power had been found between both groups. One study that could give explanation behind the finding of static strength was the study by Vincent et al. [26] which found that a single-set group resulted in similar improvement of peak isometric torque as multiple-set group. This showed that the isometric strength had not significantly been affected by the increment in the number of sets.

The rationale behind the insignificant difference of increment of muscular power between single set and multiple set could be related to the similar improvement of muscular strength between both groups. Strength and speed are the components that will make up the muscular power [11]. Without any speed training and the same muscular strength improvement, it was rationalized that the muscular power increment will also become insignificant.

In conclusion, findings from the present recommends that a single-set resistance training program suffice to promote strength and power gain among untrained. The minimum number of set may be more suited to the busy schedule of untrained population as it saves time for the same result.

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