# Volume load and efficiency with different strength training methods

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**Summary**

This study compared differences in volume load (VL), efficiency and rating of perceived (RPE) exertion between four different workout methods. Twelve trained men selected by convenience (28.1 ± 4.8 years, 1.72 ± 0.6 cm, 72.2 ± 5.5 kg, 24.4 ± 1.4 body mass index) with at least three years' strength training experience performed the following exercises: biceps curl with a barbell (BC), triceps press using a pulley with a straight bar (TP), seated leg curl (LC), and seated leg extension (LE). Four different workout formats were performed, in a counterbalanced entrance: the traditional method (TM) - three successive sets of each exercise; the paired agonist-antagonist paired set method (APS) - three sets of each exercise alternating between agonist/antagonist muscles (BC/TP and LC/LE); the paired alternating limb method (PAL) - three sets of each exercise in an upper limb/lower limb interaction (BC/LC and TP/LE); and the circuit method (CM) - one set of each exercise repeated three times (BC, TP, LC, LE). The load was held constant at an absolute 15 repetition maximum previous tested, and with one-minute rest intervals between sets and exercises, characterized as an endurance training. Volume load (set x repetition x load), efficiency (VL/workout time) and RPE were recorded. Significantly higher VL and efficiency were observed for the CM versus the TM and APS ($p < 0.05$). The CM was not significantly different versus the PAL. The CM resulted in the best performance when compared to the other methods and can be a good alternative to improve workout volume and efficiency.

**Key words:**
Resistance training. Strength training. Exercise.

## Carga de volumen y eficiencia con diferentes métodos de entrenamiento de fuerza

**Resumen**

Este estudio comparó las diferencias en la carga de volumen (CV), la eficiencia y la calificación del esfuerzo percibido (CEP) entre cuatro métodos de entrenamiento diferentes. Doce hombres entrenados, seleccionados por conveniencia (28,1 ± 4,8 años, 1,72 ± 0,6 cm, 72,2 ± 5,5 kg, índice de masa corporal 24,4 ± 1,4) con al menos tres años de experiencia en entrenamiento de fuerza realizaron los siguientes ejercicios: bíceps con barra recta (BC), tríceps presione usando una polea (TP), flexión de rodillas sentado (FR) y una extensión de pierna sentada (EX). Estos ejercicios se realizaron en cuatro formatos de entrenamiento diferentes, en una entrada contrapesada: el método tradicional (MT): tres series sucesivas de cada ejercicio; el método emparejado de conjunto agonista-antagonista emparejado (AA): tres conjuntos de cada ejercicio alternando entre músculos agonistas/antagonistas (BC/TP y FR/EX); el método de miembro alterno emparejado (AE): tres series de cada ejercicio en una interacción miembro superior / miembro inferior (BC/FR y TP/EX); y el método del circuito (MC): un juego de cada ejercicio repetido tres veces como un circuito (BC, TP, FR, EX). En todos los formatos de trabajo, la carga se estableció en un absoluto 15 repeticiones máximas antes de la prueba, y con un minuto de intervalo entre los sets y los ejercicios, como un entrenamiento de resistencia. Se registró la CV (series x repetición x carga), la eficiencia (CV/tiempo de entrenamiento) y la CEP. Se observó una CV y una eficacia significativamente mayores para el MC frente a MT y AA ($p < 0,05$). El MC no fue significativamente diferente frente al AE. El MC resultó en el mejor rendimiento en comparación con los otros métodos y puede ser una buena alternativa para mejorar el volumen y la eficiencia del entrenamiento.

**Palabras clave:**
Entrenamiento de resistencia. Entrenamiento de fuerza. Ejercicio.

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## Introduction

Strength training (ST) has been recommended for athletes and practitioners to develop muscle strength, power, endurance, and hypertrophy[1,2]. Several ST prescriptive variables can be manipulated to optimize these outcomes, such as volume load, rest interval between sets, training frequency, load intensity, and exercise order[3]. In this sense, the manipulation and combination of these variables in ST are often expressed in different workout formats[4].Volume load (repetition x loads x sets) is one of the variables often adopted by practitioners to estimate the magnitude of mechanical stress during a ST session and can affect strength or hypertrophy outcomes[5]. Thus, it has been suggested that a higher volume load (VL) stimulates greater strength gains[5-7]. Conversely, training efficiency is the ability to perform a higher VL with reduced workout duration (VL/ workout time in minutes).

In this context, a few training methods have the objective of reducing the workout duration, without comprimising the VL[6,9]. For example, the agonist-antagonist paired set method (APS) is characterized by alternating sets of two exercises for muscle groups with an agonist-antagonist relationship[5.] Robbins *et al*.[6] investigated the effectiveness of the APS method, measuring the VL and efficiency versus the traditional method (TM). As a result, bench pull exercise (alternating bench pull with bench press), the APS method enabled higher VL and efficiency versus the TM (successive sets). In the bench press exercise, same behavior was observed, with higher VL and efficiency under the APS method versus the TM. Several studies have shown that the APS method is an interesting alternative to improve the VL in a time-efficient manner without compromising strength gains[4-9].

In addition, the circuit method (CM) is often adopted with the objective of reducing workout duration, without compromising workout performance[10]. The CM is traditionally characterized by performing sets of different exercises with relatively shorter rest intervals, lower loads, and higher repetitions per set[10]. However, alterations in the traditional CM has been investigated, as proposed by Alcaraz *et al*.[10] that compared the acute effects of the CM versus the TM with same relative load, using 6-RM loads. For the TM, subjects performed five sets of the bench press with a passive three-minute rest interval between sets. Conversely, in the CM, subjects performed one set of the leg extension and one set of the ankle extension during each bench press rest interval (three minutes), performing a total of five sets to failure. As a result, CM was a time-efficient method, presenting same training volume without compromising the duration of the workout.

However, there is still lack of evidence regarding the acute effect of different ST methods on performance and efficiency[5-13]. Additionally, set configuration is a possibility of manipulation in ST during the prescription, and different combinations can differ acute performance[13,14]. Successive sets, as proposed by TM, are generally prescribed in ST, however, alternating sets as proposed by APS and CM can optimize training volume without compromise session duration[5-12]. In this sense, evidence showing different alternating sets schemes of these training methods may contribute to the body of knowledge for both coaches and ST practitioners. Therefore, the purpose of this study was to compare the VL, training efficiecy (VL/ workout time), and rating of perceived exertion during ST sessions with differing training methods (TM, APS, paired alternating limb, and CM) in trained men. Is was hypothesized that alternating sets methods would result in greater performance with same workout time versus TM.

## Material and method

### Subjects

Twelve trained men volunteered to participate in this study (28.1 ± 4.8 years, 1.72 ± 0.6 cm, 72.2 ± 5.5 kg, 24.4 ± 1.4 body mass index) and selected by convenience. For the sample size calculation, we used the recommendation of Hopkins *et al*.[15], which considered the smallest and largest main effect (–0.06 and 0.06); and the Type 1 error at 5% and Type 2 error at 25%. Due to the small sample size, this study had internal validation, and the data obtained here should be considered for subjects with similar characteristics. All subjects had previous ST experience (5.5 ± 2.6 years). The anthropometrics measures were done on the first day of the study.

The inclusion criteria were: a) have at least three years of ST experience; and b) to have performed the same exercises required in the present study during their regular exercise program. The exclusion criteria were: a) if they had some positive item in the Physical Active Readiness Questionnaire (PAR-Q); b) reported any kind of injury that could preclude being able to execute the exercises used in this study; c) if they were consuming any kind of ergogenic aids such as creatine monohydrate or anabolic steroids. The conditions of the study were in accordance with the norms of the Brazilian National Health Council, under resolution no. 466/2012, referring to scientific research on human subjects and the Helsinki Declaration.

During the study, subjects were instructed to maintain their dietary habits, to remain properly hydrated and avoid any kind of exercise in the 48 hours prior to each session. All of them reported doing three to five days per week of ST, with one to two hours per session, doing both free weight and machine type exercises. At the time that they were recruited they were doing a hypertrophic phase in a periodized program; with 8-12 repetitions, approximately one-minute rest intervals between sets, three sets per exercise in a split-body routine[1,16] (Table 1).

### Procedures

This study utilzed a within subjects repeated measures design, which consisted of a total of six visits on non-consecutive days with 48-72 hours recovery (e.g. Monday, Wednesday and Friday). The first two visits consisted of fifteen repetitions maximum (15-RM) test and retest trials. The last four visits involved performance of four different workout formats in a randomized counterbalanced design.

**Table 1. Anthropometric measures of the subjects.**

| | Age (years) | Height (cm) | Weight (kg) | BMI |
|---|---|---|---|---|
| Mean ± SD | 28.1 ± 4.8 | 172 ± 0.6 cm | 72.2 ± 5.5 | 24.4 ± 1.4 |

SD: Standard deviation; BMI: body mass index

## Fifteen repetition maximum (15-RM) testing

During the first two sessions, subjects underwent 15-RM test and retest trials to determine the training load for the following exercises in this order: biceps curl with barbell (BC), triceps press using a pulley with a straight bar (TP), seated leg curl (LC) and seated leg extension (LE). These exercises are generally present in training programs and can contribute for better practical applications. There were 48-72 hours interval between the test and retest trials. The 15-RM testing protocol was adapted from Miranda *et al*.[17]. The initial load was estimated based on the weight that the subjects frequently used in their training sessions. Before starting the test, one set was considered a warm-up with 50% of the estimated load. Three to five minutes rest interval was adopted between trials for a better recovery according to proposed by Miranda *et al*.[17]. Between exercises, the recovery period was 10 minutes, adopted to optimize the load for 15-RM. Each subject performed three attempts for each exercise. On the retest day, the same protocol was done to optimize the accuracy of the load achieved for 15-RM. The test was stopped at the moment the subject reached a failure in technique or a repetition maximum. The higher load obtained in both days was used in the experimental sessions.

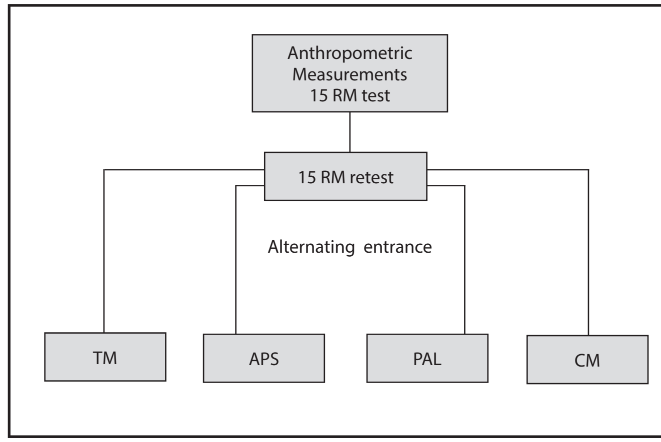
The following strategies were adopted in order to optimize results and reduce the margin of error in testing: 1) the explanation of the testing methodology; 2) standardization and guidance on exercise execution; 3) the researcher carefully monitored exercise execution; 4) verbal encouragement to motivate subjects.

In order to control the performance of each exercise, subjects were instructed to follow these exercise guidelines: the BC was executed with the arms extended along the body and the hands in a supinated position gripping a straight bar. During the concentric phase, subjects flexed their elbows and during the eccentric phase, extended their elbows back to the starting position. The TP was executed using a pulley for which the elbows were flexed statically at an initial elbow angle less than 90º at the starting point, and then fully extended during the concentric phase, and then flexed back to the staring positiong during the eccentric phase. The LC (Cybex International Inc.; Owatonna, Minnesota, EUA) was executed from a seated position with the hips flexed to approximately 90º and the knees extended to approximately 180º. During the concentric phase, subjects flexed the knees and during the eccentric phase, extended the knees back to the starting position. Subjects were instructed to touch the plates when extending the knees back to the start position. The LE (Cybex International Inc.; Owatonna, Minnesota, EUA) was executed from a seated position with the hips and knees flexed to appoximately 90º. Subjects fully extended their knees during the concentric phase and then flexed their knees to return to the start position.

## Experimental session

During sessions three, four, five and six, subjects performed four different workout formats in a randomized crossover design with 48-72 hours recovery between sessions. Before starting all experimental sessions, a warm-up was done for the first exercise. In all protocols, the first exercise was the BC, and the warm-up consisted of 50% of the 15-RM for 15 repetitions with 30 seconds to one-minute rest interval before starting the protocol[17]. No attempt was made to control the exercise pace and subjects were instructed to mantain consistent and correct technique.

**Figure 1. Schematic representation of the study.**




15RM: 15 repetition maximum; TM: traditional method; APS: agonist-antagonist paired set method; PAL: paired alternating by limb method; CM: circuit method.

The following four workout formats were performed: the traditional method (TM)—three successive sets of each exercise; the agonist-antagonist paired set method (APS)—three sets of each exercise alternating between agonist/antagonist muscles (BC/TP and LC/LE); the paried alternating limb method (PAL)—three sets of each exercise in an upper limb/lower limb interaction (BC/LC and TP/LE); and the circuit method (CM)—one set of each exercise repeated three times as a circuit (BC, TP, LC, LE). In all workout formats, the load was held constant at an absolute 15-RM and with one-minute rest intervals between sets and exercises. The volume load (set x repetition x load), efficiency (VL/workout time, in minutes) and rating of perceived exertion (REP) using the OMNI scale were recorded following each protocol. For RPE, a previous orientation was made before starting protocol to familiarize the participants with the OMNI scale (Figure 1).

## Statistical analysis

The statistical analysis was performed using SPSS software, version 20.0 (Chicago, IL, USA). The statistical analyses were initially performed using the Shapiro-Wilk normality test and homoscedasticity test (Barlett's criterion). All variables showed normal distribution and homoscedasticity. The intra class coeficient correlation (ICC = $(MS_b - MS_w)/[MS_b + \{k-1\}*Ms_w]$) was calculated to verify the reproducibility of the 15-RM test and retest, where MSb = mean-square between, Msw = mean-square within, and k = the average group size. The two-way ANOVA [protocol (4) x sets (3)] for repeated measures followed by Bonferroni post hoc tests was applied to determine if there were significant differences or interations in repetition performance between protocols and sets[1-3]. The two-way ANOVA for repeated measures followed by Bonferroni post hoc tests was used to determine if there were significant differences or interations between protocols for VL. The value of $p \leq 0.05$ was adopted for all interferential analyses to establish the significance between comparisons.

## Results

The ICC for the 15-RM test and retest trials ranged between 0.90 to 0.98. The 15-RM training loads were: BC (10.7 ± 3.1kg), TP (24.4 ± 4.3kg), LC (114.5 ± 21.7kg), LE (155.8 ± 34.3kg).

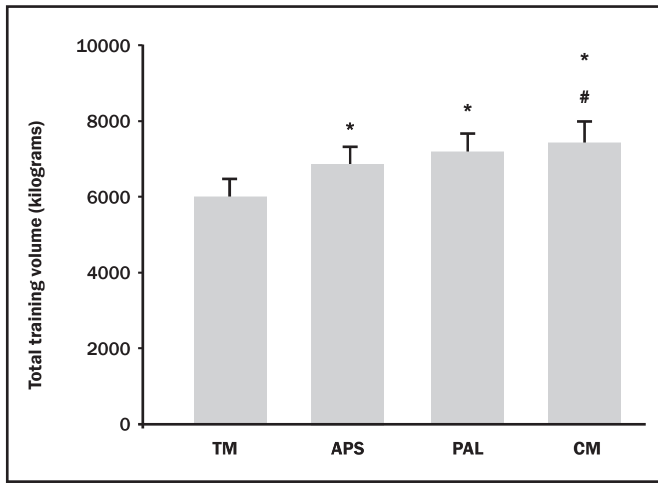
The two-way ANOVA showed significant differences between protocols in total repetitions for the BC ($F = 18.264$; $p = 0.0001$), TP ($F = 18.992$; $p = 0.0001$), LC ($F = 11.966$; $p = 0.0001$), and LE ($F = 20.323$; $p = 0.0001$; Table 2). When considering the repetition results for the BC exercise, higher repetition performance was noted under the APS ($p = 0.012$), PAL ($p = 0.003$), and CM ($p = 0.000$) protocols versus the TM protocol. The CM protocol also showed significant increases in total repetitions versus the APS ($p = 0.023$). For the TP exercise, greater total repetitions were noted under the APS ($p = 0.006$) and CM ($p = 0.0001$) protocols versus the TM protocol. The CM protocol also showed significant increases in total repetitions versus the PAL ($p = 0.002$) protocol. However, for the LC exercise, greater total repetitions were noted under the PAL ($p = 0.006$) and CM ($p = 0.001$) protocols versus the TM protocol. Conversely, the LE exercise showed higher total repetitions under the APS ($p = 0.002$), PAL ($p = 0.000$) and CM ($p=0.000$) protocols versus the TM protocol.

For the VL results, the two-way ANOVA showed significant differences between protocols for the BC ($F = 16.868$; $p \le 0.0001$); TP ($F = 17.545$; $p = 0.0001$); LC ($F = 11.766$; $p = 0.0001$); and LE ($F = 16.193$; $p = 0.0001$). When considering the VL results for the BC exercise, a higher VL was noted under the PAL ($p = 0.007$) and CM ($p = 0.000$) protocols versus the TM protocol. The CM protocol also showed a significant increase in VL versus the APS ($p = 0.019$) protocol. For the TP exercise, higher VL results were noted under the APS ($p = 0.008$) and CM ($p = 0.000$) protocols versus the TM protocol. The CM protocol showed significant increases versus the PAS ($p = 0.004$) protocol. For the LC protocol, higher VL results were noted under the PAL ($p = 0.005$) and CM ($p = 0.002$) protocol versus the TM protocol. However, for the LE exercise, higher VL results were shown in the APS ($p = 0.004$), PAL ($p = 0.002$) and CM ($p = 0.000$) protocols versus the TM protocol.

Regardless of these differences, when analyzing the session total training volume [(repetition * load * set) + all exercises)] for each protocol (Figure 2), there were significant differences between protocols ($F = 28.477$; $p = 0.0001$). Higher total training volume (TTV) was noted under the APS [6930.5 (±458.1) kg; $p = 0.005$] PAL [7239.2 (±458.1) kg; $p = 0.0001$] and CM [7507.9 (±501.8) $p = 0.0001$] protocols versus the TM [6092.5 (±433) kg] protocol. The CM protocol also showed significant differences versus the APS ($p = 0.026$) protocol.

When analyzing the efficiency (VL/workout time in minutes) of each method (Figure 3), there were significant difference between protocols.

**Figure 2. Total training volume, in kilograms, in traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method (CM).**



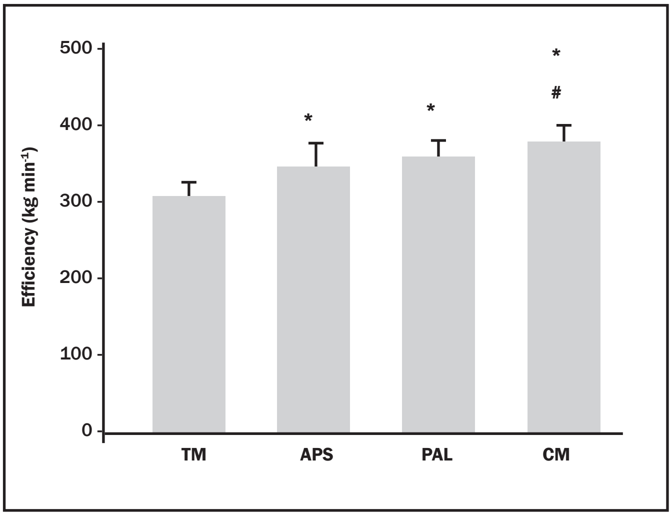

*significant difference for TM; #significant difference for APS.

**Table 2. Total work (TW) in number of repetitions and volume load (VL) in kilograms of the traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method CM. Results expressed in mean (standard deviation).**

| | Biceps curl | Triceps press | Leg curl | Leg extension |
|---|---|---|---|---|
| **Volume load (kilograms)** | | | | |
| TM | 993.7 (290) | 825.9 (158.9) | 1860.5 (621.1) | 2415.5 (732) |
| APS | 1104.3 (235) | 983.3 (180.6)* | 2069.8 (613.3) | 2773.1 (759.8)* |
| PAL | 1149.1 (265.9)* | 919 (136.6) | 2336.2 (612.1)* | 2835.0 (906.2)* |
| CM | 1221.6 (255.1)*# | 1074.1 (185.1)*& | 2255.0 (722.3)* | 2957.4 (847.6)* |
| **Total Work (repetition)** | | | | |
| TM | 34.7 (7.6) | 34.2 (5.5) | 35.2 (7.3) | 33.8 (5.3) |
| APS | 38.7 (5.8)* | 40.5 (5.2)* | 39.2 (7.4) | 38.7 (4.4)* |
| PAL | 40.1 (5.8)* | 38.3 (6.7) | 44.6 (8.4)* | 39.3 (5.9)* |
| CM | 42.8 (5.9)*# | 44.4 (6.4)*& | 42.5 (8.0)* | 41.2 (4.5)* |

*Significant difference for TM protocol ($p \le 0.05$); #significant difference for APS protocol ($p \le 0.05$). & significant difference for PAL protocol ($p \le 0.05$).

**Figure 3. Training efficiency (total training volume/workout time in minutes) in traditional method (TM), agonist-antagonist paired set method (APS), paired alternating by limb method (PAL) and circuit method (CM).**




*significant difference for TM; #significant difference for APS.

Higher results were noted under the APS (p = 0.005), PAL (p = 0.000) and CM (p = 0.000) protocols versus the TM protocol. The CM protocol also showed significant differences versus the APS (p = 0.02) protocol. The results of RPE, in median (minimum – maximum) for each protocol were: TM = 7.5 (5 – 10); APS = 8.0 (5 – 10); PAL = 8 (6 – 10); CM = 8.5 (8 – 10). No significant differences were observed between protocols (p = 0.072).

## Discussion

The main finding of the current study was the higher TTV noted under the APS, PAL and CM protocols versus the TM [6092.5 (±433) kg] protocol. The CM protocol was also significantly greater versus the APS (p = 0.026) protocol. In summary, the TM protocol showed the lowest total TTV and efficiency, while the CM protocol showed the highest total TTV and efficiency (Figure 1 and 2).

In the present study, the recovery period between sets and exercises was similar between protocols; however, exercise order manipulation between training methods was crucial to promote changes in muscle endurance performance. In the TM protocol, the exercise sets were performed successively; conversely, during the APS, PAL, and CM protocols, the exercises were applied in an alternating manner. Higher repetition performance for the APS, PAL, and CM protocols may have been possible due to the greater recovery between like sets.

Previous studies indicated that repetition performance maintenance is impaired when shorter rest intervals (i.e., 30 s to one-min) are adopted between sets for the same exercise or muscle group, likely due to a decreasing concentration of creatine phosphate and elevated H+ concentrations due to rapid hydrolysis of ATP[18-20]. Therefore, performing paired exercise sets for muscle groups may improve muscle endurance performance due to a longer recovery period between like sets.

In a previous study, Schoenfeld *et al.*[21] compared different rest intervals between sets in an eight week periodized program in twenty-one recreationally trained men. The independent variable was the rest interval, where one group adopted shorter rest intervals (one minute) and the other group, longer rest intervals (three minutes) between exercise sets. The ST program was composed of seven different exercises for several muscle groups. Three sets of each exercise were performed for eight to 12 repetitions, and with 10-RM loads. At the beginning and end of the training period, muscle thickness was assessed via ultrasound for the elbow flexors, triceps branchii, and quadriceps femoris. Muscle strength (1-RM) and endurance (50% 1-RM to failure) in the bench press and back squat were also assessed. The authors noted that subjects which adopted the longer rest interval presented greater hypertrophic outcomes in the lower and upper limbs; and improved the 1-RM loads in both exercises tested versus the shorter rest interval group. These findings were attributed to higher VL performed in the longer rest interval training protocol. Although evident the importance of VL on training outcomes, the results of the present study should be carefully considered since only single joint exercises were used and only performance results of acute session were investigated.

Thus, rest interval between sets is important to improve performance, specially considering the VL of training session. In order to investigate different rest intervals, Scudese *et al.*[20] evaluated its effect on the repetition performance over five sets of the bench press exercise with 3-RM loads. Sixteen recreationally trained men performed four protocols with differents rest intervals between sets (one, two, three and five minutes). The protocols that used two, three and five minutes showed greater performance when compared to the one-minute rest interval. However, no significant differences were observed between two, three, and five minutes rest. The present study adopted same rest interval between sets in each method, however, the methods APS, PAL and CM provided longer recovery for the same muscle group. This can justify the findings of higher VL for these methods when compared to TM. Additionaly, this study implemented exercises for upper and lower limbs with an absolute load often prescribed to develop muscular endurance (15-RM), differing from Scudese *et al.*[20] that evalutated high-load training (i.e., 3-RM).

In this context, the APS method has been associated with a higher VL versus the TM. Paz *et al.*[9] compared VL and workout efficiency for the APS method versus the TM for the upper limb musculature in trained men. For the APS method, subjects performed alternating sets of bench press and a wide grip seated row, with two minutes between agonist-antagonist paired sets. In the TM, subjects performed three successive sets of the bench press and then three successive sets of the wide grip seated row, with two minutes of rest between exercise sets. The authors observed higher VL and efficiency under the APS method versus the TM. In the present study, considering the strength performance between methods, the APS method resulted in a significantly lower VL versus the PAL and CM. Important to consider that during lower body multijoint exercises, the APS method presents limitations since coactivation of agonists and antagonists muscles occurs, and PAL can be an alternative for prescription when both limbs were performed in the same training session.

Considering that all training methods investigated had same total sets performed and same rest interval between sets, all the training sessions were performed with the same duration (20 minutes). Thus, CM seems to be a good alternative for increasing the efficiency of ST sessions, perfoming higher VL with same training duration. In a previous study, Alcaraz *et al.*[22] compared the effects of the TM versus the CM over a period of eight months in 33 healthy men experienced in ST. The total session time for the TM was initially 105 minutes and by the end of the study was 125 minutes, since it followed a periodization scheme that increased the number of sets for each exercise. The CM followed the same periodization scheme, but the total session time was initially 55 minutes and at the end of the study was 78 minutes, being a time-efficient method since the VL was not different between protocols. The results showed no differences in strength development between protocols, measured with a 1-RM test for the upper and lower limb musculature in the bench press and half squat exercises, and the CM also showed a better result for body composition improvement. Thus, time-efficient methods can be a good alternative for practitioners that do not have too much time for training, but desire to improve strength and body composition.

The present study was limited by a small sample size. However, the procedures adopted in the current study had greater practical applications, since the exercises selected are generally prescribe in ST and the methods implemented in this study can be applied in gyms and training centers. However, only single joint exercises were performed, and future investigations should consider different exercises. Future studies should investigate the effect different training methods with a larger sample; novice and trained subjects; and assessing biochemical markers.

# Conclusion

In conclusion, the TM condition resulted in the worst performance, and PAL and CM training systems promoted better results, considering the TTV and efficiency. When the goal is to achieve greater muscle endurance performance in a time-efficient manner, the PAL and CM may be a good alternative to be implemented by coaches and practitioners.

## Conflict of interest

The authors do not declare a conflict of interest.

# Bibliography


1. American College of Sports Medicine. Position stand: Progression models in resistance training for healthy adults. *Med Sci Sports Exerc.* 2011;42(3):1334-59.
2. Warburton DE, Nicol CW, Bredin SS. Prescribing Exercise as Preventive Therapy. *Canadian Medicine Association Journal*. 2006;174(7):961–74.
3. Williams TD, Tolusso DV, Fedewa MV, Esco MR. Comparison of periodized and non-periodized resistance training on maximal strength: a meta-analysis. *Sports Med.* 2017;47(10):2083-100.
4. Paz G, Robbins DW, Oliveira CG, Bottaro M, Miranda H. Volume load and neuromuscular fatigue during an acute bout of agonist-antagonist paired-set versus traditional-set training. *J Strength Cond Res.* 2017;31(10):2777-84.
5. Robbins DW, Young WB, Behm DG, Payne WR. The Effect of a Complex Agonist and Antagonist Resistance Training Protocol on Volume Load, Power Output, Eletromyographic Responses, and Efficency. *J Strength Cond Res.* 2010a;24(7):1782-9.
6. Robbins DW, Young WB, Behm DG. The Effect of an Upper Body Agonist-Antagonist Resistance Training Protocol on Volume Load and Efficiency. *J Strength Cond Res.* 2010b;24(10):2632-40.
7. Robbins DW, Young WB, Behm DG, Payne WR. Agonist-Antagonist Paired Set Resistance Training: a Brief Review. *J Strength Cond Res*. 2010c;24(10):2873-82.
8. Robbins DW, Young WB, Behm DG, Payne WR. Effects of agonist-antagonist complex resistance training on upper body strength and power development. *J Sport Sci.* 2009;27(14):1617–25.
9. Paz GA, Maia MF, Lima VP, Miranda H. Efeito do Método Agonista-Antagonista Comparado ao Tradicional no Volume e Ativação Muscular. *Rev Bras Ativ Fis Saúde* 2014;19(1):56-65.
10. Alcaraz PE, Sanchez-Lorente J, Blazevich AJ. Physical performance and cardiovascular responses to an acute bout of heavy resistance circuit training versus traditional strength training. *J Strength Cond Res*. 2008;22(3):667-71.
11. Carregaro RL, Cunha RR, Cardoso JR, Pinto RS, Bottaro M. Efeitos da ordem de pré-ativação dos músculos antagonistas nas respostas neuromusculares dos extensores do joelho. *Rev Bras Fisioter.* 2011:15(6):452-9.
12. Deminice R, Sicchieri T, Mialich MS, Milani F, Ovidio PP, Jordao AA. Oxidative stress biomarker responses to an acute session of hypertrophy-resistance traditional interval training and circuit training. *J Strength Cond Res.* 2011;25(3):798-804.
13. Paz GA, Iglesias-Soler E, Willardson JM, Maia MF, Miranda H. Postexercise hypotension and heart rate variability responses subsequent to traditional, paired sets, and superset training methods. *J Strength Cond Res.* 2017, in press.
14. Tuffano JJ, Brown LE, Haff GG. Theoretical and practical aspects of different cluster sets structures: a systematic review. *J Strength Cond Res*. 2016;31(3):848-67.
15. Hopkins WG, Marshall SW, Batterham AM, Hanin J. Progressive statistics for studies in sports medicine and exercise science. *Med Sci Sports Exerc*. 2009;41(1):3-13.
16. Schoenfeld BJ, Ratamess NA, Peterson MD, Contreras B, Tiryaki-Sonmez G. Influence of resistance training frequency on muscular adaptations in well-trained men. *J Strength Cond Res.* 2015;29(7):1821-9.
17. Miranda H, Maia MF, Paz GA, De Souza JA, Simão R, Farias DA, *et al.* Repetition performance and blood lactate responses adopting different recovery periods between training sessions in trained men. *J Strength Cond Res*. 2018;32(12):3340-7.
18. Filho JC, Gobbi LT, Gurjão AL, Gonçalves R, Prado AK, Gobbi S. Effect of different rest intervals, between sets, on muscle performance during leg press exercise, in trained older women. *J Sport Sci Med.* 2013;12(1):138-43.
19. Hargreaves M, Mckenna MJ, Jenkins DG, Warmington SA, Li JL, Snow RJ, *et al.* Muscle metabolites and performance during high-intensity, intermittent exercise. *J Appl Physiol.* 1998;84:1687-9.
20. Scudese E, Willardson JM, Simão R, Senna G, De Salles BF, Miranda H. The effects of rest interval length on repetition consistency and perceived exertion during near maximal loaded bench press sets. *J Strength Cond Res.* 2015;29(11):3079-83.
21. Schoenfeld BJ, Pope ZK, Benik FM, Hester GM, Seller J, Nooner JL, *et al*. Longer interset rest periods enhance muscle strength and hypertrophy in resistance-trained men. *J Strength Cond Res.* 2016;30(7):1805-12.
22. Alcaraz PE, Perez-Gomez J, Chavarrias M, Blazevich AJ. Similarity in adaptations to high-resistance circuit vs. traditional strength training in resistance-trained men. *J Strenght Cond Res.* 2011;25(9):2519-27.