Energy expenditure estimation of a moderate-intensity strength training session

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Abstract: An accurate method for quantifying associated metabolic cost has yet to be developed for a strength training session (ST). The aim of this study was to quantify the energy expenditure (EE) in an ST session composed of eight exercises at moderate intensity using indirect calorimetry and, from the values obtained, develop a prediction equation for estimating EE. Fifteen males (22.9 ± 2.61 years old), with at least 12 months of experience in ST performed one session of strength training composed of 8 exercises. Three sets of repetitions were performed until concentric failure for each exercise at 75% of 1-repetition maximum (75% of 1RM). The model demonstrated that session time and load volume of ST was a significant predictor of EE (p < 0.05). We found that the energy cost of an ST session at an intensity of 75% of 1RM could be predicted using the equation of \( Y' = -473.595 - 1.2110X_1 + 17.5723X_2 \) (\( R^2 = 0.61, p < 0.05 \)). Where \( X_1 \) = load-volume (no. of sets x no. of repetitions); \( X_2 \) = session time (minutes). Although our equation may have limited accuracy, our regression formula accounted for 61% of the variability in a strength training session at a moderate intensity of 75% of 1RM. Session time in the total variability of EE in ST was an important consideration.

Subjects: Applied Sport Science; Physiology of Sport; Sports Performance Analysis; Strategic Sports Development; Sports Coaching; Sports Medicine; Individual Sports; Sports Medicine

Keywords: metabolism; resistance training; estimation of energy expenditure; caloric cost

1. Introduction

Strength training has been recommended as one of the main strategies to promote increases in energy expenditure (EE). The American College of Sports Medicine (ACSM) included ST in its recommendations for healthy living in adults from 1990 to the present day. Strength training sessions should involve the major muscle groups (Fragala et al., 2019; Garber et al., 2011; Jakicic et al., 2009).

ABOUT THE AUTHOR

Currently, our Translational Physiology Laboratory Group of São Judas Tadeu University and Experimental Physiology and Biochemistry Laboratory of the Federal University of Espírito Santo have been researching energy expenditure in strength training with various exercises, intensities, the time during the session, and other variables. And from there, assist coaches, athletes, and practitioners to choose the most appropriate training program individually.

PUBLIC INTEREST STATEMENT

The high cost of equipment to assess energy expenditure makes it impossible to monitor the same strength training practitioners. Therefore, this research tries to solve this gap, from our predictor any individual will be able to predict or expend training energy in a simple and free of cost.
However, most studies in this particular field of sports science have evaluated EE based on one or two exercises, continuously such as steady-state (Byrd et al., 1998, 1996; N. Ratamess et al., 2014; Reis et al., 2017; Robergs et al., 2007; Scott et al., 2009).

Steady state can be defined as the moment when oxygen consumption and heart rate are constant during exercise (Karvonen & Vuorimaa, 1988). Byrd et al. (1998) were one of the first to investigate the metabolic relationship between work done and EE during steady-state exercises, bench press exercise and later, the parallel squat exercise (Byrd et al., 1996). They developed regression equations to predict EE. Robergs et al. (2007) investigated the metabolic cost of strength training using steady-state and regression to predict EE at vigorous intensities, using two predictive equations to determine EE during the bench press and squat exercises. The equations were able to predict 65.6–72.8% of the total EE variability. Their values, however, were limited as they only reflect two exercises that were performed continuously during steady state to estimate EE of strength training. These values may be different from energy expended in a strength training protocol using several muscle groups and sets that conform with the main recommendations for strength training (Fragala et al., 2019; Kraemer et al., 2017; Teixeira et al., 2018).

Robergs et al. (2007) stated that there were difficulties in accurately measuring energy demands in strength training with different intensities of exercise (moderate/vigorous) using indirect calorimetry. These include adaptation to the use of the mask during the training session. Subtle differences may have gone unnoticed, and therefore, it is difficult to support data provided by previous studies because different methods, exercises, equipment, intensities and volumes vary widely. Therefore, the aim of this study was to quantify EE in a strength training session composed of eight popular exercises at a moderate intensity using indirect calorimetry and from the values obtained, develop a predictive equation for the estimation of EE.

1.1. Methods
To investigate the EE during strength training using moderate intensities, all participants performed one training session using eight exercises. All performed three sets of exercise until exhaustion, and all exercises and data collection were, respectively, collected at the same time of day. It should be noted that only the measurement of aerobic energy expenditure was recorded during recovery and effort periods. Thus, in these periods, aerobic energy partially includes the production of anaerobic energy during the effort although it does not represent quantitatively the same aspect of metabolism.

1.2. Subjects
Fifteen males, with an average age of 22.9 ± 2.61 years (body mass: 83.60 ± 9.76 kg; height: 183.07 ± 5.60 cm; fat-free mass: 72.97 ± 7.47 kg; % body fat: 9.96 ± 3.31; fat mass: 8.33 ± 2.90 kg) with at least 12-month experience of strength training and familiar with the proposed exercises voluntarily participated in this study. All procedures were approved by the Institutional Review Board of São Judas Tadeu University (protocol: 2.022.898) and were conducted in accordance with the principles expressed in the Declaration of Helsinki.

The volunteers were told to refrain from any resistance exercise during the period of the experiment. The following exclusion criteria were established: 1) smoker; 2) adherence to diets designed for both reduction of body mass and/or muscle mass increase; 3) individuals with any metabolic disorders that were taking medications that affect EE (sympathomimetics, bronchodilators, antidepressants, amphetamines, illicit drugs); 4) muscle or tendon injury in the last 3 months; 5) being under the treatment of infectious disease; 6) have used in the last 6 months or using, at the time of this study, any type of ergogenic agent of hormonal origin with the purpose of increasing strength or hypertrophy; 7) and change in the diet as reported by food recall questionnaire. Inclusion criteria: 1) minimum experience of 12 months in strength training; 2) reports of minimum training frequencies of 3 times per week; 3) present resting systolic blood pressure
between 120 and 130 mmHg and diastolic blood pressure between 80 and 89 mmHg; 4) medical clearance for clinical fitness for participation in the study. All individuals participating in the present study answered the socio-demographic questionnaire with open questions about physical activity history, nutritional information, disease history and family aspects.

Strength training was strictly controlled so that individuals only exercised under the direct supervision of an experienced strength and conditioning professional. Individuals were not allowed to perform any other strength training exercises during this period. To avoid potential effects of diet confounding the results, subjects were advised to maintain their customary nutritional regimens and to avoid taking any supplements. They were also instructed to refrain from consuming caffeine and energy drinks during the study period. The individuals were continuously monitored by phone calls and personal interviews to ensure study compliance.

1.3. Experimental design
There were three phases of data collection (Table 1). Preliminary assessments (Phase 1) on the first day involved the application of the inclusion and exclusion criteria for the selection of study participants, measuring body composition and 1-repetition maximum (1-RM). The second day was used for measuring resting metabolic rate (RMR). During the next 2 weeks (Phase 2), subjects followed familiarization periods for each exercise using the equipment (mask) for gas analysis using enough loads to perform one set of 20 repetitions. During the day of the exercise sessions (Phase 3), one strength training session at a moderate intensity (75% of 1-RM) was performed using 8 common strength training exercises. These included chest press; pec deck; squat; lat pulldown; biceps curl; triceps extension; hamstrings curl; crunch machine, respectively, in the same order.

1.4. Parameters evaluated

1.4.1. Body composition
Body mass (BM) was measured using the G-Tech® (Accumed Prod Med Hosp Ltda) scale with an accuracy of 0.100 g with the individuals positioned barefoot and wearing minimum possible clothing. Height (H) was measured using a Sanny® stadiometer with a precision of 0.1 cm. To assess body composition and subcutaneous fat thickness, an ultrasound imaging unit was used (BodyMetrix® PRO System, Intelametrix, Livemore, Calif., USA—BodyViewTM software) with a wave frequency of 2.5 MHz (Selkow et al., 2011). The ultrasound probe was applied perpendicularly to the skin for measurement of body composition according to procedures outlined and validated by (Pineau et al., 2007) and as utilized in previous studies (Johnson et al., 2012; Utter & Hager, 2008). A water-soluble gel was used on the transducer to help acoustic coupling and avoid excessive skin pressure. The individuals were instructed to fast for 3 hours before testing and the assessments were performed at the same time at both the pre- and post-testing stages. Imaging was

| Table 1. Simplified protocol design |
|-------------------------------------|
| Phase 1                             |
| Day 1                               |
| - Application of the inclusion and exclusion criteria of study participants—Body composition and 1-RM |
| Day 2                               |
| - RMR                               |
| Phase 2                             |
| Two weeks:                          |
| - Familiarization period in each exercise with the equipment (mask) for gas analysis using sufficient load to perform one set of 20 repetition |
| Phase 3                             |
| Day 1                               |
| - Moderate intensity = 75% 1-RM     |

1-RM: 1-repetition maximum; RMR: resting metabolic rate.
performed on the right side of the individuals’ bodies and to further ensure the accuracy of the assessments at least three pictures were taken. The average of the three assessments was used for statistical analysis.

1.4.2. Maximum dynamic muscular strength
Maximum dynamic muscular strength (1-repetition maximum) was assessed at the same time of day using a 1-RM test for the following exercises: bench press, pec deck, squat, lat pulldown, biceps curl, triceps extension, hamstring curl and crunch. All exercises were performed using strength training machines (fitness line equipment, GervaSport®, Spain) the same order. The testing protocol followed previous recommendations by Haff and Triplett (2008). Subjects reported to the laboratory having refrained from any exercise other than activities of daily living for at least 72 hours before testing.

Briefly, subjects warmed up for 5 minutes on a treadmill (Movement Technology, São Paulo, Brazil) at 60% of maximum heart rate (Karvonen & Vuorimaa, 1988). During the first set, subjects performed five repetitions at 50% of the usual load followed by one set of three repetitions at a load corresponding to ~60-80% of the usual load with a three-minute rest interval between sets. After the warm-up sets, subjects had five attempts to find their 1-RM load with three-minute intervals between trials. 1-RM was defined as the maximum weight that could be lifted no more than once using the correct technique. Verbal encouragement was given throughout testing. All testing sessions were supervised by the research team and were deemed valid and reliable (Table 2).

1.4.3. Oxygen consumption and blood lactate
The volume of oxygen expired (VO₂) during the RT sessions was measured through a gas analyzer (Fitmate pro; COSMED®, Fitmate, Rome, Italy) with a flexible flow line as described previously (Lee et al., 2011). The gas analyzer was calibrated following the manufacturer’s specifications prior to each test. The participants’ VO₂ was obtained breath-by-breath. Following removal of outliers to exclude discrepant breaths, breath-by-breath data were interpolated and the area under the curve (AUC) was assumed as the oxygen cost during the experimental sessions minus the area of RMR (i.e., product of RMR and the session length). The integral was obtained using Origin software (OriginPro 8.0, OriginLab Corporation, Microcal, Massachusetts, USA). The VO₂ data was converted into energy units (calorie) using the equivalents of 5.05 calorie (kcal) per liter of oxygen consumed (W. Phillips & Zirraitis, 2003).

Lactate concentration was determined using a lactometer model Accusport Plus Roche® following recommendations from previous studies (Foxdal et al., 1990; Franchini et al., 2004). Blood samples were taken from finger capillary sites before the protocol at rest, and at precisely 5, 10, 15 and 20 min following the RT session. Anaerobic metabolic demand was measured as the difference between peak and baseline values, using the equivalent of 3 mI·kg⁻¹ of oxygen for each unit of lactate accumulated (Bertuzzi et al., 2016; Hunter & Byrne, 2005; Kelleher et al., 2010; Milioni et al.,

| Parameters       | 1-RM (kg) | 75% of 1-RM (kg) |
|------------------|-----------|------------------|
| Chest press      | 93 ± 22   | 70 ± 17          |
| Pec deck         | 79 ± 18   | 60 ± 14          |
| Squat            | 103 ± 26  | 78 ± 20          |
| Lat pulldown     | 104 ± 19  | 79 ± 14          |
| Biceps curl      | 46 ± 9    | 35 ± 7           |
| Triceps extension| 92 ± 13   | 70 ± 10          |
| Hamstrings curl  | 110 ± 18  | 83 ± 14          |
| Crunch machine   | 107 ± 14  | 81 ± 11          |

Values expressed in mean ± standard errors.
The caloric quotient of 5.05 kcal was used (W. Phillips & Ziuraitis, 2003).

1.4.4. Exercise session protocol

Subjects reported to the laboratory having refrained from any exercise other than activities of daily living for at least 72 hours before testing. In brief, subjects warmed up for 5 minutes on a treadmill at 60% of maximum heart rate (Karvonen & Vuorimaa, 1988) followed by specific warm-up one set in each exercise. After that, all subjects began the strength training session at an intensity of 75% of 1-RM, performing three sets (approximately 10 reps). All sets were carried out to the point of momentary concentric muscular failure, operationally defined as the inability to perform another concentric repetition while maintaining proper form. All protocols observed a recovery of 120 seconds between sets and between exercises. The cadence of repetitions was maintained in a controlled fashion, with concentric and eccentric actions of approximately 1.5 seconds, for a total repetition duration of approximately 3 seconds. The external load was adjusted for each exercise as needed on successive sets to ensure that subjects achieved failure in the target repetition range. The subjects were well informed about how to properly perform the exercises and were under direct supervision by the investigative team.

1.4.5. External training load control

The method to quantify resistance exercise uses the repetition method to determine training volume. To calculate the load-volume, we used the repetition summated number of repetitions performed during a specific exercise, in a training session (B. R. B. R. Scott et al., 2016) according to equation outlined below (Eq. 1):

\[ \text{Load-volume} = \text{no. of sets} \times \text{no. of repetitions} \]

The load-volume intensity is obtained by multiplying the number of repetitions performed in each exercise by the absolute load lifted for the repetitions. The absolute volume load for each different exercise performed in a training session can then be summated to calculate the total weight lifted during the training period (B. R. B. R. Scott et al., 2016) according to following equation (Eq. 2):

\[ \text{Absolute-load} = \text{no. of sets} \times \text{no. of repetitions} \times \text{weight lifted (kg)} \]

The repetition, volume and absolute load were calculated from training logs filled out by research assistants during each strength training session.

1.4.6. Statistical analysis

Sample size calculations were performed using GPower 3.1 software (Faul et al., 2007). Under a framework assuming an estimating error of \( \alpha = 0.05 \), power = 80%, moderate intensity \( \times \) 8 exercises, an \( n \) of 15 was necessary to reach a statistical power of 80.8%. Therefore, 15 individuals were initially assigned to perform strength training sessions at a moderate intensity. Pearson tests were used to verify the correlations between the EE measured during strength training and the independent variables. Correlations were rated weak (\( r \ 0.30–0.50 \)), moderate (\( r \ 0.50–0.70 \)) and high (\( r \ 0.70–1.00 \)) according to a previous publication (Atkinson & Nevill, 1998). Multiple linear regression with stepwise variables was used to obtain a parsimonious model that would allow independent prediction of EE during the strength training session. The normality residue assumptions, homogeneity and multicollinearity were analyzed as follows: the first two being validated graphically and the assumption of multicollinearity by the Durbin–Watson test (Durbin & Watson, 1951). Variance inflation factors (VIF) were used to diagnose multicollinearity (Fox & Monette, 1992). Bland–Altman was used to evaluate the agreement between the indirect calorimetry method and the predictor models (Bland & Altman, 1986, 1990; Hirakata & Camey, 2009). Overall data were presented as averages, standard deviations and 95% confidence
interval. Significance was set at 5%. The data were processed in R version 1.0.44 for Macintosh software.

2. Results
Table 3 presents the EE observed for the eight exercises at moderate intensity, as well as the factors related to strength training (duration of the session, load-volume and absolute-load) and EE prediction using the equations.

Table 4 outlines the models approved for ST. No model used ST variables (total volume, absolute load and training time) associates muscle mass (kg) to the predator or CG. Although model 1 is significant (F$_{4,10}$: 5.5, r² = 0.69, adj r² = 0.56, p value: 0.013), only the time variable was a predator of the equation (p = 0.004). In model 2, using TF variables (total volume, absolute load and training time) for the predator or CG. There was a significance in model 2 (F$_{3,11}$: 7.7, r² = 0.68, adj r² = 0.59, 0.0048), but only for the variables load volume (p = 0.04) and session time (p = 0.0007) were predictors. Model 3 used the variables (total volume and training time) for the caloric cost. There was significance in model 3 (F$_{3,12}$: 11.79, r² = 0.66, adj r² = 0.60, 0.001472); thus, as the load-volume (p = 0.046039) and time session (p = 0.000464) variables were predictors.

Regarding the factors related to strength training, our model demonstrated that session time, and load-volume of strength training was a significant predictor of EE (p < 0.05) as shown in Table 4.

The regression summary values, the Durbin–Watson test and the VIF test values, as well as the correlations between the strength training variables, are presented in Table 5. The VIF is collinearity diagnostics that indicates whether a predictor has a strong linear relationship with the other predictor(s).

The regression summary values, the Durbin–Watson test and the VIF test values, as well as the correlations between the strength training variables, are presented in Table 5. The VIF is collinearity diagnostic indicates whether a predictor has a strong linear relationship with the other predictor(s). Figure 1 presents the correlation for energy expenditure at 75% of 1-RM and predictor equation (model 3). Significant correlations (p = 0.0002) were found indicating effects of predictor equation.

3. Discussion
To the best of our knowledge, this is the first study to measure EE in a strength training session using eight exercises at moderate intensity (75% of 1-RM). In addition, we propose a linear regression predictor of EE in a strength training session at this intensity. Regarding the factors related to strength training (time of session; load-volume; and absolute-load), our model demonstrated that session time, and; load-volume strength training is a significant predictor of EE

| Table 3. Average of energy expenditure, session length total repetitions and total load of the strength training session |
|-------------------------------------------------------------|
| **Parameters** | **75% of 1-RM** |
| EE—session (kcal) | 341.86 ± 69.20 (0.20) |
| Duration the session (min) | 61.40 ± 3.27 (0.05) |
| Load-volume (reps) | 217.47 ± 22.17 (0.10) |
| Absolute-load (kg) | 15,028.19 ± 2274.56 (0.15) |
| [La] rest (mmol/L$^{-1}$) | 2.11 ± 1.38 (0.65) |
| [La] peak (mmol/L$^{-1}$) | 11.15 ± 3.0 (0.26) |
| **Model 3** | | |
| EE—predictor equation (kcal) | 332.07 ± 56.86 (0.17) |

Values expressed in means ± SD and (coefficient of variation). Load-volume = no. of sets × no. of repetitions. Absolute-load = no. of sets × no. of repetitions × weight lifted; [La]rest: before session; [La]peak: peak blood lactate concentration after session.
Table 4. The prediction equation of expenditure energy in the strength training session

|                          | Adj. R² | B          | SE B | β       | Lower  | Upper  |
|--------------------------|---------|------------|------|---------|--------|--------|
| Model 1                  | 0.56    |            |      |         |        |        |
| Constant                 |         | −584.53    |      |         |        |        |
| Muscle mass              |         | 1.3530     | 2.1977 | .1460  | −3.54  | 6.250  |
| Load-volume (reps)       |         | −1.0027    | 0.7587 | −.3210 | −2.69  | 0.688  |
| Absolute-load            |         | 0.0026     | 0.0058 | .0864  | −0.01  | 0.015  |
| Time session             |         | 16.3891    | 4.4637 | .7736* | 6.44   | 26.335 |
| Model 2                  | 0.59    |            |      |         |        |        |
| Constant                 |         | −520.07    | 240.197 |        |        |        |
| Load-volume (reps)       |         | −1.2982    | 0.5707 | −.4156* | −2.554 | −0.042 |
| Absolute-load            |         | 0.0037     | 0.0054 | .1214  | −0.0081 | 0.015  |
| Time session             |         | 17.7332    | 3.7820 | .8371*** | 9.4091 | 26.057 |
| Model 3                  | 0.61    |            |      |         |        |        |
| Constant                 |         | −473.595   | 225.5139 |        |        |        |
| Load-volume (reps)       |         | −1.2110    | 0.5443 | −.3877* | −2.4   | −0.025 |
| Time session             |         | 17.5723    | 3.6917 | .8295*** | 9.5   | 25.616 |

***p < 0.001. **p < 0.01. *p < 0.05.

(p < 0.05). We found that the energy cost of a strength training session at an intensity of 75% of 1-RM could be predicted using the equation of $Y' = −473.595 + −1.2110(X_1) + 17.5723(X_2)$ ($R^2 = 0.61, p < 0.05$). Where $X_1 =$ load-volume (no. of sets x no. of repetitions); $X_2 =$ time session (minutes). To our surprise, absolute-load was not a predictor of energy expenditure during the strength training session.

Although we recognize the limitations of the equation in predicting EE in exercises with a predominance of anaerobic metabolism in the non-steady-state (Reis & Scott, 2016), our predictor is statistically significant at an intensity of 75% of 1-RM; however, we did find difficulty in explaining the variability. This relates to the identification of the variables that best explains EE during strength training sessions. There are many factors that may contribute to this variation. Our model demonstrates that total session time can explain 61% of the variance observed ($R^2 = 0.61$). This means that 39% of the variation in energy expenditure cannot be explained solely by total session time. This suggests that there are other variables that influence EE. However, absolute-load did not prove to be an important variable in the prediction of EE as outlined in Table 4.

This study used a 75% load that may reflect some dependence on anaerobic metabolism instead of only aerobic energy cost. Therefore, this may explain part of the difference in the outcome found when compared with previous studies (Byrd et al., 1998, 1996; W. Phillips & Ziuraitis, 2003).

The remaining variability could be the result of undetected differences between individual’s body levers, segment size, and/or differences in technique (foot/hand/head positions).

It is worth mentioning that our equation loses its predictive value if it attempts to measure EE in strength training using different methodologies than those performed in this study. This includes
| Model | $R$ | $R^2$ | Adjusted $R^2$ | Autocorrelation | Statistic | $p$ | Muscle mass | Load volume | Absolute load | Time session |
|-------|-----|-------|----------------|-----------------|-----------|----|-------------|-------------|---------------|-------------|
| Model 1 | 0.83 | 0.69 | 0.56 | −0.04729 | 2.09 | 0.65 | 1.8060 | 1.8946 | 1.1552 | 1.4258 |
| Model 2 | 0.81 | 0.68 | 0.59 | −0.090 | 2.18 | 0.53 | 1.1362 | 1.0514 | 1.0847 | - |
| Model 3 | 0.82 | 0.66 | 0.61 | −0.053 | 2.10 | 0.68 | 1.0806 | - | 1.0806 | - |
“super slow” training, plyometric/explosive training, sessions consisting of fewer exercises (less than 6 exercises), or percentages below 60% of 1-RM.

An additional limiting factor in the present study and a possible contributor to the observed variability was the theoretical inability to completely measure EE during strength training using indirect calorimetry. Indirect calorimetry ignores the contributions of the phosphagen system and the glycolytic pathway (N. A. Ratamess et al., 2014; Robergs et al., 2004; Scott, 2011). In spite of this limitation, indirect calorimetry is still utilized as the preferred method of EE measurement during strength training (N. A. Ratamess et al., 2014; Reis et al., 2017).

Brown et al. (1994) analyzed the oxygen consumption associated with EE during the deadlift exercise. The regression equation developed (R = 0.90) was used to predict oxygen consumption (liters of oxygen) during exercise. Other studies have also used oxygen uptake converted to calories to predict EE. Byrd et al. (Byrd et al., 1998) examined the relationship between work done and EE during bench press exercise and the parallel squat exercise (Byrd et al., 1996). Oxygen consumption was measured by standard open-circuit spirometry, with conversion to caloric equivalents. The regression equation was calculated with external workload (kgm = multiplying the weight lifted (kg) x amount of repetitions (rep) x vertical distance of the bar). In summary, the prediction equation produced values of between R 0.91–0.95. Robergs et al. (2007) analyzed oxygen consumption using two exercises squat and bench press, in which a 5 minute steady-state per exercise set was performed and allowed for the development of 2 predictive equations, one for the bench press (R² = 0.72) and one for the squat exercise (R² = 0.65). Robergs et al. (2007) used intensities below 40% 1-RM with 21 repetitions and then extrapolated the values to higher intensities using the O₂ deficit method as repeated by Reis et al. (Reis et al., 2017).

We admit that comparisons are difficult because previous studies used very varied intensities, equipment and different exercises. In the present study, the strength training session consisted of eight exercises at an intensity of 75% of 1-RM. In addition, linear and angular exercises were performed in this study and in most other studies. For example, bench press and squat being linear and exercises, such as biceps curl and triceps extension being angular. Thus, it is not feasible to use the value of the vertical distance of the bar during the exercises and then calculate the kgm similar to previous studies (Byrd et al., 1998; Robergs et al., 2007).

Another limiting factor regards the recovery intervals between the sets and the exercises that increased the aerobic component of EE in the strength training session. In the present study, similar to previous studies (W. T. Phillips & Ziuraiteis, 2004), we used the values of oxygen consumption during the strength training session and converted them to energetic cost not
considering the values of non-mitochondrial metabolism. In addition, the relationship between work vs. oxygen consumption is not linear during the strength training session, consequently influencing EE.

Several mechanisms are related to the change in oxygen consumption associated with anaerobic and aerobic metabolic processes, such as 1) increase in activation of additional muscle groups; 2) respiratory muscle intensification activity; 3) recruitment of type II muscle fibers; 4) increases in muscle temperature; 5) increases in basal metabolic rate; 6) accumulation of lactate and protons; 7) leakage of protons from the inner mitochondrial membrane; and 8) decreases in potential cytosolic phosphorylation (Robergs et al., 2004, 2007; Scott, 2011).

Strength training presents demands on the phosphagen, glycolytic and mitochondrial systems of energy supply. It is not feasible to fully measure EE in strength training by applying indirect calorimetry during the training session since this method ignores the contributions of the phosphagen and glycolytic systems. Some studies have used lactate values to calculate the EE contribution of the glycolytic system and consumption oxygen after exercise to calculate the EE contribution of the phosphagen metabolic pathway contribution (Milioti et al., 2017; Reis et al., 2017, 2011; Reis & Scott, 2016; Robergs et al., 2004, 2007; Scott, 2006, 2011; Scott et al., 2011).

Some limitations should be addressed in this study such as analyzing EE only during effort (contribution from aerobic and anaerobic systems). Another limitation was the failure to obtain a predictive equation using anthropometric characteristics of the participants, such as body mass or fat percentage. Regression equations have been developed that predict \( \text{VO}_2 \) consumption, but \( \text{VO}_2 \) is a poor reflection of total EE during a resistance exercise session, and studies are lacking that can accurately predict EE using \( \text{VO}_2 \) during a strength training session as exercises involve different muscle groups with different muscle mass.

In our opinion, the results of this study indicate that the main variable is strength training, and to increase the energy cost, manipulations of volume and the session time need consideration. The explanation seems simple when we increase the intensity of exercise training time normally reduces. Therefore, training sessions that are of a high intensity normally result in short training periods.

For any individual who chooses to routinely monitor EE during strength training using regression equations, to calculate EE in the session, the practitioner will need the following values: a) load-volume (number of repetitions x sets x exercises); b) absolute-load (kilogram—kg); and c) time session (min). In order to increase the accuracy of our proposed equation, similar studies should be performed with other populations (e.g., women, untrained individuals), as well as, methods that incorporate other exercises and types of equipment. Comparisons with other studies are difficult because previous studies used very varied intensities, equipment, several exercises and different muscle groups. To our knowledge, the present study is the first to analyze a training session of eight exercises at an intensity of 75% of 1-RM. It is worth noting that a lower quantity of exercise during the strength training session may be enough to meet common guidelines (Faigenbaum et al., 2009; Fraga et al., 2019; Garber et al., 2011). The ACSM recommends 30 minutes of physical activity accumulation most days of the week comprising moderate and vigorous intensities. This will provide an EE of at least 8.0 kcal per minute for expending up to 2000 kcal-week\(^{-1}\) to optimize health and body composition parameters (Garber et al., 2011). Finally, individuals who wish to manage EE and performance during strength training sessions similar to those in the present study may find the regression equation listed here helpful.

4. Conclusion
Although our equations may have limited accuracy, our regression formula accounted for 51% of the variables in a strength training session at a moderate intensity of 75% of 1RM. The time of the session and total variability of EE in ST also need further consideration.
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