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Original Article

Effect of muscle strength at different intensities on resting energy expenditure

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ABSTRACT

Introduction: the regular practice of physical exercise is an important modulator of resting energy expenditure (REE), which depending on the intensity, duration, and type of exercise can increase the REE in an acute manner as well as long term. The effects of dynamic muscular strength exercises on the REE have been treated very little in literature. Objective: compare the effect of muscle strength exercise (MSE) at different intensities on the REE in young males. Methods: Intra-group design. Fourteen subjects aged 22,5±1,5 <active (IPAQ= MET≥3000 week), realized two sessions of strength exercises at 2 intensities (40% and 80%RM), in 3 types of exercises (90° Squats; Bicep Curls, and Upright Row). Each session evaluated the same number of sets (3), repetitions (6), and rest time between sets (2min.). The REE was measured beforehand, immediately after, and 24 hours after by indirect calorimetry. Results: The REEpost (kcal/day) increased after the MSE at 40%RM, ($p<0{,}05$; CI=1950,67-2215,62) and at 80%RM, ($p<0{,}001$; CI=1947,10-2154,62), for a high and moderate effect size respectively. Differences in the % of change for both intensities ($p<0{,}05$) and a high effect size for 40%RM and moderate for 80%RM were found. No differences were found in the comparison (kcal/day) between REEpre y REEpost 24h ($p>0{,}05$) after the exercise at 40%RM. The REEpost 24h was maintained according to the REEpre when the intensity was 80%RM. Conclusion: The REEpost exercise is independent of the intensity of the exercise and only is maintained after 24 hours when

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the MSE is at a high intensity. **Key words:** RESTING ENERGY EXPENDITURE, STRENGTH TRAINING, EXERCISE INTENSITY

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INTRODUCTION

The components of the total daily energy expenditure are; the thermogenic effect of food, the energy expenditure of physical activity, and the resting energy expenditure (Speakman & Selman, 2003). A decrease in the resting energy expenditure (REE) not compensated with a balanced diet influences in suffering overweight and obesity (Bonfanti et al., 2014; Schuenke, Mikat, & McBride, 2002), metabolic syndrome, and type II diabetes (Alexander, 2003; Cleland, Ingraham, Pitluck, Woo, & Ng, 2016; Grundy, Abate, & Chandalia, 2002). The regular practice of physical exercise is an important modulator of the REE, that depending on the intensity, duration, and type of exercise could increase the REE in an acute or chronic manner (Farinatti & Castinheiras Neto, 2011; Farinatti, Castinheiras Neto, & Amorim, 2016). The effects of aerobic type exercise on the metabolic states and health are well documented in literature (Frayn, 2010; Jiménez-Gutiérrez, 2007; Ulloa, Feriche, Barboza, & Padial, 2014; Wingfield et al., 2015), but there exists less comprehension of the effects of muscle strength exercise (MSE) on the REE.

The studies that have analyzed the acute effects of MSE on REE report a low energy expenditure during the activity, but an increase after the session (Benton, Anderson, Hunter, & French, 2016; Ormsbee et al., 2007) and for up to 72 hours (Heden, Lox, Rose, Reid, & Kirk, 2011; Schuenke et al., 2002), increments that are explained by a series of factors associated to homeostatic regulation, the increase of the bioenergetic requirements for the synthesis of muscle proteins, the translation of RNAm in response to the cellular damage (Bangsbo et al., 1990; Børsheim & Bahr, 2003), and the homeostatic reestablishment associated to these types of exercises (Børsheim & Bahr, 2003; Matsuura, Meirelles, & Gomes, 2006).

The studies that have analyzed the efficiency variables of MSE have been centered on the volume (Heden et al., 2011; Sedlock, Fissinger, & Melby, 1989), rest time between exercises (Vingren et al., 2009), type (Farinatti & Castinheiras Neto, 2011; Jamurtas et al., 2004), speed of execution (Benton et al., 2016; Mazzetti, Douglass, Yocum, & Harber, 2007) and intensity of the MSE (Olds & Abernethy, 1993; Roy, Hunter, & Blaudeau, 2006; Thornton & Potteiger, 2002; Vingren et al., 2009).

When the effects of the distinct intensities of MSE on REE were compared, the MSE with free weights were used as intervention protocols for a great variety of exercises, different muscle groups (Farinatti et al., 2016; Heden et al., 2011; Mazzetti et al., 2007), number of sets (Elliot, Goldberg, & Kuehl, 1992), repetitions (Elliot et al., 1992; Haddock & Wilkin, 2006) and recovery time between sets (Haltom et al., 1999; Elliot et al., 1992). The disparity between those intervention protocols and the use of theoretic models in order to determine the intensity of the MSE (number of repetitions per percentage of the maximum dynamic strength or a percentage of dynamic strength) make the studies unable to be compared to one another, which makes the determination of intensity of MSE, that to a larger extent influences the REE, difficult.

The systemization of the training methods and the control of the load components for the MSE is possible today due to the use of Functional Electromechanical Dynamometer Devices (FEDD) that permit the control, in an automated form, of the speed of execution, range of movement, work load, times and type of muscular contraction, and the intensity of the exercise, which permits the optimization of the MSE processes.

In the consulted literature, no studies were found that analyze the influence of MSE at distinct controlled intensities with a FEDD on REE, which could favor the prescription of the MSE intensity when the purpose is to modify the body composition or reduce the risk of suffering cardiometabolic diseases associated with a diminished REE. Therefore, the purpose of the study is to compare the effect of muscle strength exercises at distinct intensities with an automated control of the load over the resting energy expenditure in young active males.

MATERIAL AND METHOD

An intra-group design was employed with pre and post-test measures. The sample was composed of fourteen active (IPAQ ≥ 3000 METs) healthy male subjects (22,5 ±1,5 years of age; 70,6 ± 0,1 kg; 1,72 ± 0,1 m), with previous experience in training with heavy weights and/or free weights. The bioanthropometric characteristics of the sample are shown on Table 1. All the subjects participated in the study voluntarily and gave their written informed consent, a procedure that was adjusted to the rules established in the declaration of Helsinki and has the approval of the Ethics Committee of the University of Andrés Bello.

The subjects were asked to maintain their normal habits and that they limit the additional practice of physical exercise during the process of experimentation. The consumption of caffeine, alcohol, drugs, and diet supplements that could alter metabolism were considered as criteria for exclusion. In order to determine the acute effect of each intensity on the REE (kcal/day), the REE before the session (REEpre), immediately after (REEpost) and after 24 hours (REEpost 24h) were established through open-circuit indirect calorimetry.

One week before the experimentation process the participants realized three familiarization sessions with the excercises (90° Squats; Bicep Curl, and Upright Row) and the manipulation of the FEDD in the laboratory of the Sciences of Human Movement and Exercise Physiology of the University Andrés Bello, Chile.

A completely randomized strategy was used. The participants randomly carried out two sessions of MSE at distinct intensities (40% and 80% of RM), separated by 48 hours. In each of the strength sessions the same protocol was followed: after the standardized warmup, three sets of six repetitions of three different types of exercises were realized, in the same order of application (90° Squats; Bicep Curls, and Upright Row).

Table I Bioanthropometric characteristics of the sample (n=14)

Body Weight	(kg)	71,6 ± 0,1
Height	(m)	1,7 ± 0,1
%FM	(%)	15,1 ± 2,5
FM	(kg)	10,9 ± 2,8
%MM	(%)	43,4 ± 2,2
MM	(kg)	31,9 ± 3,8
IAM	(MM/FM)	2,1 ± 0,3

Data expressed as average ± SD; BMI=Body mass index in kilograms/m^2; %FM=Percentage of fat mass; FM=Fat mass; %MM=Percentage of muscle mass; MM= Muscle mass; IAM= Index of adipose muscle (Muscle Mass/Fat Mass).

Procedure

The participants, after the familiarization faze, were informed to meet at the laboratory of Sciences of Human Movement and Exercise Physiology of the University Andrés Bello, Chile. During 4 consecutive days. On the first day of visiting and before the first exercise session, the anthropometric variables of body composition, nutritional status, and physical level were determined. Posteriorly, the randomization of the intensities for the organization of the sessions was performed. The period of experimentation is shown in Figure 1.

PEP	S1			S2	S3			S4
$S_{1,2,3}$	CLpre	Set 1	CLpost	CLpost -24h	CLpre	Set 2	CL/post	CLpost – 2

Figure 1. PEP=Pre-experimetal period; $S_{1,2,3}$=Familiarization Sets; S=Experimentation Sets CLpre=Calorimetry pre-test; CLpost= Calorimetry post-test; CLpost-24= Calorimetry post 24 hours.

The homogeneity of the response to different strength exercises previous to the session was controlled. In all the exercise sessions the subjects presented homogeneous results in the peaks of maximum dynamic strength and in REE as is shown in Table 2.

Table II. Homogeneity of the peaks of maximum dynamic strength for each of the intensities and exercises before each session.

	40%RM	*p Value*	80%RM	*p Value*
Bicep Curls (N)	305,79 ± 121,86	0,332	474,00 ± 278,06	0,705
90° Squats (N)	627,64 ± 266,56	0,687	1002,36 ± 208,56	0,528
Upright Row (N)	1032,29 ± 294,64	0,167	1236,36 ± 248,86	0,724
REEpre (kcal/día)	2033,14 ± 142,84	0,322	2050,86 ± 179,70	0,413

Data expressed as average ± SD. N= Newton; 40%RM = Intensity of 40% of the maximum dynamic strength; 80%RM = Intensity of 80% of the maximum dynamic strength; REEpre=Resting Energy Expenditure before the session; *p* Value= Statistic significance.

Body Composition

The analysis of the body composition was realized through an anthropometric study following the standardized protocol of the International Society for the Advancement of Kinanthropometry (Marfell-Jones, Stewart, & de Ridder, 2006). Body weight (BW) and Height (H) were determined with a scale/measuring rod (Detecto® 2391, USA 2010) with a precision of 100g and 2mm respectively. The muscular perimeters (relaxed arm, flexed arm, maximum forearm, wrist, thorax circumference, minimum waist, hip, upper thigh, and calf) were obtained through the use of a metallic anthropometric Rosscraft® measuring tape, the skinfolds (biceps, triceps, subscapular, iliac crest, supraspinale, abdominal, front thigh, and medial calf) were triply measured with a skinfold caliper (Lange, Beta Technology Incorporated[MR]) later using the average value of the three measures. Muscle Mass (MM) was estimated according to the equation of Martin (1990) (Martin, Spenst, Drinkwater, & Clarys, 1990) and the fat mass (FM) through the formula of Durnin & Womersley (1974).

Exercise Sessions

Before the data collection the subjects realized three familiarization sessions with the three exercises and the use of the FEDD for the kinetic-tonic control of movement (0,10-1,5 m/s) with a sampling frequency processor of 1Ghz (Dynasystem, Symotech, Spain, 2014). The exercise sessions started with a standardized warm-up of 10 minutes, 5 minutes of continuous low intensity running hearth rate (HR)≤120 and 5 minutes of muscular activation at an intensity of 20%RM. Afterwards, the maximum dynamic strength was determined in (RM) in the concentric and eccentric (N) phases for the three types of exercises, which permitted the control of the load in each repetition and range of motion (ROM), in both the concentric phase as well as the eccentric phase of the exercises.

In each session the subjects realized 3 sets of 6 repetitions, with a 3-minute rest between sets and 5 minutes between assessment of the RM and the first sets of each of the exercises.

Three exercises were programed; one monoarticular (Bicep Curls 90°) and the other two polyarticular (Squats and Upright Row), in all of the exercises the ROM was tested with a goniometer. The Bicep Curl exercise was carried out standing in an upright position and consisted of completing elbow flexion extensions, going from a 20° to 110° flexion and a movement trajectory of approximately 50 cm. For the 90° squat exercise, a vest was used that was adapted with a system of rings on which the pulley of the FEDD was hooked. The exercise was carried out from a flexed position, with the feet at a separation of approximately 20 cm, with the hands placed on the trunk of the body, the movement considered the complete extension of the lower limbs maintaining the trunk upright, in order to return to the initial position against the resistance generated by the device. The Upright Row exercise began from the flexion of the lower limbs (hip, knee, ankle), the trunk of the body continued upright during the whole movement and the upper limbs operated the weight bar in pronation, the elbow started from a complete extension up to a maximum flexion, together with the abduction of the shoulder to 90°, until the bar reached the intermammary line. In order to guarantee that the load during the whole of the ROM of the exercises was consistent in the concentric and eccentric phases the FEDD was adjusted in an automated form in relation to the percentage of RM.

Resting Energy Expenditure

During all of the evaluations the conditions of the laboratory were standardized in illumination, temperature (21 to 22° C) and relative air humidity (60 to 65%). The REE was determined by open-circuit indirect calorimetry with a gas analyzer (Jaeger® MasterScreen CPX, Germany, 2014). The participants were instructed to meet at the laboratory in fasted conditions of more than 12 h, between 8:00 and 11:00 AM. It was recommended that they arrive in car (as the passenger) or in bus with the objective of compensating the rise in metabolic activity. Before beginning the measuring, the subjects remained lying back for 10 minutes with the purpose of normalizing the HR and reach the maximum level of rest. Once realized the calibration of the equipment (environmental conditions, volumes and determination of specific concentrations of CO_2 y O_2), a canopy type mask was put on the subjects and the measuring began. The participants remained laying down during an average period of 30 minutes, while the intake of O_2 (VO_2) and the production of CO2 (VCO_2) were registered with a recording of respiration to respiration, following the recommendations of da Rocha, Alves, & da Fonseca, (2006) and Haugen, Chan, & Li, (2007) for indirect calorimetry tests. In order to determine the time period for the calorimetric record, the criteria published by Capderou, Douguet, Losay, & Zelter, (1997) were considered. The first 10 minutes of the test, which were considered as the adaptation period, were eliminated and the analyses of the following 5 minutes were monitored for the determination of the REE. The values of VO_2 and VCO_2 were expressed in ml/min and were considered in order to determine the REE in accordance to the equation of Weir, 1990)

$$REE\ (kcal/min) = 3{,}94 \cdot VO_2\ (ml/min) + 1{,}106 \cdot CO_2\ (ml/min)$$

Where: VO_2 refers to the volume of oxygen inhaled and VCO_2 corresponds to the volume of carbon dioxide exhaled. The values of REE obtained were extrapolated to 24 hours (kcal/day).

Data Analysis

All the data were expressed as arithmetic averages, standard deviations, and percentages of change. The analysis of the distribution of frequencies was realized through the Shapiro and Wilk test. The homogeneity of variances for the peaks of maximum strength and REE were verified before the sessions through the Levene test. The effect of each intensity on the REE was measured through the Student or Wilcoxon T test of related samples. The comparison of both intensities on the REEpost and REEpost-24 were realized through the Student T test for paired samples. The effect size was established using Cohen's d, considering the relative differences of the REE. The magnitude of the effect size was established following the criteria of Hopkins. The statistics package SPSS 21.0 and GPower 3.1 were used for the analysis. A 95% interval of confidence and a 0,05 level of significance were used.

RESULTS

Table 3 reflects the comparative results of the intra-intensity analysis of the REEpost and REEpost 24-h in relation to the REEpre for the MSE at 40%RM and 80%RM in absolute (kcal/day) and relative (% of change) terms. The REEpost (kcal/day) incremented after the MSE at 40%RM (p<0,05; CI=1950,67-2215-62) and at 80%RM, (p<0,001; CI=1947,10-2154,62), for a high and moderate effect size, respectively. Differences were found in the % of change for both intensities (p<0,05) for a high effect size for 40%RM and for the moderate size for 80%RM. Differences were not found in the comparison (kcal/day) between REEpre and REEpost 24-h (p>0,05) for both intensities, though differences were found in the % of change for REEpost 24-h at 80%RM (p<0,05) and a moderate effect size.

Table III. Comparison inter-intensity for the REEpre vs. REEpost and REEpost 24h in absolute terms and % of change

	REEpre			REEpost			% change	ES	REEpost 24h			% change		ES
40%RM	2033,14	±	142,84	2128,36*	±	151,65	4,77**	1,1	2014,07	±	141,15	-0,84	4,99	0,5
80%RM	2050,86	±	179,70	2182,01*	±	222,79	6,36**	0,7	2105,71	±	196,37	2,79**	5,78	0,5

Data expressed as average ± SD. REEpre=Resting energy expenditure before the MSE; REEpost=Resting energy expenditure after exercise; REEpost 24h.= Resting energy expenditure after 24 hours of the MSE; %Change=Percentage of change; 40%RM = Intensity of 40% of the maximum dynamic strength; 80%RM = Intensity of 80% of the maximum dynamic strength; *p* Value= statistic significance; ES=Effect size.* = Statistic significance for REE in absolute terms; **=Statistic significance for the percent of change.

In Table 4, the absolute values of the changes in REE (Kcal/day) between REEpost and REEpost 24-h are shown. The REEpost 24-h, diminishes for both intensities, being greater at the intensity of 40%RM (Effect Size = high).

Table IV. Comparison between the REEpost vs. REEpost 24h for each intensity.

	REEpost	REEpost-24h	*p Value*	ES
40%RM	2128,36 ± 151,65	2014,07 ± 141,15	**0,001**	1,2
80%RM	2182,00 ± 222,79	2105,71 ± 196,37	**0,017**	0,7

Data expressed as average ± SD. REEpost= Resting energy expenditure after the MSE; REEpost 24h= Resting energy expenditure after 24 hours of the MSE; 40%RM = Intensity of 40% of the maximum dynamic strength; 80%RM = Intensity of 80% of the maximum dynamic strength; *p* Value= Statistic significance; ES=Effect size.

The comparative inter-intensities analyses of REEpost and REEpost-24, are presented in Table 5. Differences were not found (p>0,05) in REEpost comparing both intensities. In the comparison of REEpost-24h between both intensities a moderate effect size was found.

Table V. Comparisons inter-intensities for REEpost and REEpost 24h.

	40%RM			80%RM				
	Average		SD	Average		SD	*p* Value	ES
REEpost (kcal/día)	2128,36	±	151,62	2182,00	±	222,79	0,440	0,1
REEpost 24h (kcal/día)	2014,07	±	141,15	2105,71	±	196,37	0,086	0,5

Data expressed as average ± SD. REEpost=Resting energy expenditure after the MSE; REEpost 24h= Resting energy expenditure after 24 h of the MSE; 40%RM= Intensity of 40% of the maximum dynamic strength; 80%RM= Intensity of 80% of the maximum dynamic strength; *p* Value= Statistic significance; ES=Effect size.

DISCUSSION AND CONCLUSIONS

According to the literature consulted this is the first study to analyze the acute and after 24h effect of MSE, controlling the intensities with a FEDD (40% and 80%RM), for the concentric as well as the eccentric phases on the REE in young active males.

The results of this study suggest that MSE with automated control incremented the REE in an acute manner after the exercise sessions, an increment that is independent of intensity.

The increment of the REE after a session of MSE could be explained by the rapid and slow response of the intake of oxygen post exercise (Matsuura et al., 2006; Børsheim & Bahr, 2003) influenced by the rise in body temperature, the residual influence of certain hormones (Gaeser & Brooks, 1984), the resynthesis of muscle glycogen and repositioning of the phosphate substrates (Bangsbo et al., 1990), as well as by the reestablishment of the ion homeostatic processes and the energy expenditure of ventilation (Børsheim & Bahr, 2003).

The studies that analyzed the acute effects of distinct intensities of MSE on REE, for distinct muscle groups, number of repetitions, and times between sets present contradictory results (Farinatti & Castinheiras Neto, 2011; Haddock & Wilkin, 2006; Olds & Abernethy, 1993; Ratamess et al., 2007; Thornton & Potteiger, 2002). When Ratamess et al., 2007, compared the effects of the intensities of MSE (75% vs 85%RM) for only one type of exercise, same number of sets (5), and rest time between sets (30 sec), they did not find significant differences in the increases of REE between both intensities, results which coincide with what Roberg, Gordon, Reynolds, & Walker (2007) reported when they analyzed the effect of distinct intensities and number of repetitions on the REE.

Thornton & Potteiger (2002), when they compared two protocols of MSE to different intensities (45% vs 85%RM), with distinct volumes, number of repetitions by sets, and equal rest times between sets (60 sec), reported a greater increment of the energy expenditure when the intensity was of 85%RM, results that coincide with those reported beforehand by Roy et al. (2006). The disparity between the protocols make the studies non-comparable to eachother, the absence of the control of the variables that influence on the intensity, the difference in the volume of work assigned for each protocol of exercise and possibly the use of free weights as a training method, make it difficult to determine if it is the intensity of the exercise that determines the increments of the REE after the training session. The effects of the volume and muscle mass involved in the MSE on the REE were analyzed in a study recently published by Farinatti et al. (2016) in which the intensity of the MSE (15RM) was equalized. The FEDD results showed that both exercise protocols incremented the REE after the session, but were greater in the protocol that involved a greater muscle mass, which could explain the difference in the anterior results.

The design of our study, in which the automated control of intensity was performed by the FEDD for each of the exercises and the exercise protocol that considered the same number of sets, repetitions, and rest time between sets, permited the determination of the influence of the intensity of the exercise on REEpost and REEpost 24h.

Furthermore, it was established that after 24 hours the REE returned to the REEpre levels when the intensity of the exercise was 40% of the RM and was maintained over the REEpre (~2,6%) when the intensity of the exercise was 80% of the RM.

The increase of the REE after 24 hours was associated in response to the increment of the bioenergetics requirements associated to the increase of the synthesis of proteins, the residual effects of certain hormones (Dolezal, Potteiger, Jacobsen, & Benedict, 2000; Vingren et al., 2009), and various factors of growth (Nindl, 2009).

The studies that analyzed the effect of the MSE on the REE, reported increments of the exercise post oxygen consumption (EPOC) and of the REE that were maintained until 72 hours after the exercise session ended. When Heden et al. (2011) compared the changes in REE after 24, 48, and 72 hours in a group of young adults, after an exercise session of low volume muscular strength (1 set, 10 exercises, 10RM) versus another at a high volume (3 sets, 10 exercises, 10RM), reported an increase of REE after 24 hours (1 set p=0,003; 3 sets P=0,048), 48 hours (1 set p=0,024; 3 sets P=0,008) and 72 hours (1 set p=0,001; 3 sets P=0,008) independently of the volume of exercises. An increment that, according to the authors, could be explained by the number of exercises and muscle mass involved and not because of the intensity.

The use of a FEDD allow to maintain for a longer period of time the muscular contraction during the concentric as well as the eccentric phase of the exercises, which could favor in a greater measure of energy expenditure when the intensity of the exercise is greater in the MSE. If we consider that maintaining or overcoming a resistance of greater magnitude requires a greater recruitment of motor units, it could explain the greater energy expenditure associated with these types of exercises. Although the neuromuscular components associated with this type of exercise were not analyzed, they should be taken into account for future investigations because of the impact they could have on the REE.

Therefore, according to the results obtained in the conditions of the present study we can conclude that the MSE, when it is controlled with a DEMF, increments the REEpost independently of the intensity of the exercise. The increase of the REE by effect of the high intensity MSE (80%RM) is maintained after 24 h after the exercise sessions.

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