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Research Article

A single session of strength training changed plasma levels of resistin, but not leptin in overweight and obese men

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ABSTRACT

Obesity has a complex multifactorial etiology and is characterized by excessive accumulation of adipose tissue. Visceral adipose tissue has deleterious effects on health because it secretes large amounts of inflammatory cytokines. Nutritional calorie restriction associated with strength training may be useful in managing chronic systemic inflammation. This study aimed to evaluate the acute effect of a single strength-training session on plasma adipokine levels in sedentary, overweight, and obese young men. This study included twelve men (Age: [34.95 ± 9.77] years; Height: [174.16 ± 3.66] centimeter [cm]; Weight: [97.83 ± 12.87] kilogram (kg); body mass index [BMI]: [32.30 ± 4.51] kg/m^2), who performed a single strength training session. The strength training protocol consisted of 4 sets of 12 repetitions in the following six exercises, 45° leg press, bench press, leg extension, machine row, leg curl, and shoulder press. Blood samples were collected before, immediately after, and 1-h subsequent after strength training. The plasma levels of resistin and leptin were measured. A significant decrease in resistin levels were found 1 h after the strength training session if compared to levels before the training session (pre-[before] [2 390 ± 1 199] picograms per milliliter [pg/mL] vs post-1 h [1-h subsequent] [1 523 ± 798],6 pg/mL, $p = 0.002$ 8). The plasma leptin levels did not differ at any time point. In conclusion, a very well controlled single session of strength training significantly decreased the plasma levels of resistin without altering the concentration of leptin in overweight and obese individuals. This effect, at least in part, supports the benefits of exercise by reducing the low grade inflammation and insulin resistance in obesity.

1. Introduction

Obesity is a global health problem, with a prevalence of 30% in more than 70 countries.[1] An inadequate diet or excessive food intake associated with reduced or absent physical activity contributes to obesity.[2] Excess adipose tissue and high amounts of body fat are associated with certain types of cancer,[3] type 2 diabetes, depression, and other medical conditions.[4]

Adipose tissue is distributed throughout the body and plays important physiological roles, including regulation of energy balance, control of systemic metabolism, and modulation of immune responses.[5] An increase in energy balance can remodel adipose tissue by increasing the mass and number of adipocytes.[2] The role of the adipose tissue as a secretory source of molecules was described.[6] Adipocytes interact with the immune system and endothelial and stromal cells by secreting molecules

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List of abbreviations

1 RM	one-repetition maximum test
°C	degree Celsius
AM	antimeridian
BMI	Body mass index
BSA	Bovine serum albumin
cm	Centimeter
DXA	Dual-energy X-ray absorptiometry
EDTA	ethylenediaminetetraacetic acid
ELISA	enzyme-linked immunosorbent assay
IPAQ	International Physical Activity Questionnaire
kg	Kilogram
kDa	Kilodalton
M	molar mass
M1	Meeting 1
M2	Meeting 2
M3	Meeting 3
mL	milliliters
ml/kg	milliliters per kilogram
RM	Maximum repetitions
OMNI-RES	Perceived Exertion Scale for Resistance Exercise
PAR-Q	Physical Activity Readiness Questionnaire
PBS	Phosphate-buffered saline
pg/mL	Picograms per milliliter
RT	Room temperature
rpm	Revolutions per minute
ST	Strength training
TMB	3,3′,5,5′-tetramethylbenzidine

into the bloodstream. These molecules are called adipokines and interact with peripheral or adjacent cells.[5,7] Thus, exacerbated remodeling and disordered growth of adipocytes increases adipokine production, resulting in several metabolic changes and interactions with other organs.[8,9] Adipokines play a important role in this low grade inflammation scenario. Increased secretion of proinflammatory adipokines leads to a chronic inflammatory state that is accompanied by insulin resistance and glucose intolerance. Physical exercise is considered the best non-pharmacological approach for obesity since it can reduce insulin resistance, counteract the inflammatory state, and improve the lipid profile. There is growing body of evidence showing that exercise exerts its beneficial effects partly through alterations in the adipokines' profile by reducing inflammation and insulin resistance.

Leptin and resistin are adipokines with well-known biological functions. The leptin comprises 167 amino acids and has a molecular weight of 16 kDa.[10] The main biological function of this molecule is the inhibition of appetite through hypothalamic signaling. Furthermore, plasma levels of leptin are positively associated with adipose tissue size.[10,11] Resistin has a molecular weight of 12.5 kDa and 108 amino acids.[12] The main biological function of resistin is to reduce insulin sensitivity and establish a link between obesity and type 2 diabetes.[12,13]

Nutritional caloric restriction associated with physical exercise is a non-pharmacological strategy for reducing body fat.[14] Regular exercise controls chronic systemic inflammation.[15] Strength training (ST) is a physical exercise with several benefits. ST reduces the deleterious effects of chronic and metabolic diseases,[15,16] improves the health and functional capacity of elderly individuals,[17,18] promotes skeletal muscle hypertrophy,[19] and modulates adipose tissue metabolism by altering the fatty acid profile.[20] However, the effects of ST on plasma adipokine levels need to be investigated, particularly in overweight and obese individuals.

The experimental hypothesis of this study is that one single session of ST can modulate the circulating levels of leptin and resistin. Therefore, we aimed to investigate the acute effect of a single ST session on the plasma levels of resistin and leptin in overweight and obese sedentary young men.

2. Materials and methods

2.1. Ethical aspects and inclusion and exclusion criteria

This study was approved by the Ethics Committee of our institution (Resolution 466/2012). All participants provided informed consent before inclusion in the study.

The study included 12 men aged between 18 and 50 years who met the following inclusion criteria: (1) sedentary for at least six months, (2) non-smokers, (3) no associated comorbidity, (4) not using androgenic steroids or dietary supplements, and (5) body mass index (BMI) within the classification for overweight and obesity.

The exclusion criteria for volunteers were as follows: (1) refusal to participate in the study, (2) symptoms or signs of orthopedic alterations, (3) presence of acute or chronic disease; (3) failure to attend the study protocol.

2.2. Experimental design

The participants attended three meetings. Meetings 1 (M1) and 2 (M2) were held at the Physical Education School of Federal University of Ouro Preto. The meeting 3 (M3) was used to perform the body composition analysis using dual-energy X-ray absorptiometry (DXA) in a private clinical images center. A minimum interval of 72 h (h) was considered between the 1 repetition maximum (RM) test and the training sessions. The experimental design is illustrated in Fig. 1.

At M1, the participants received information about the study protocol and underwent an anthropometric assessment to determine body mass, height, and BMI. An anthropometric scale (FILIZOLA®, Brazil) with a precision of 0.1 kg was used to measure body mass. Height was measured using a stadiometer attached to a scale, with a precision of 0.5 cm (FILIZOLA®, Brazil). The Physical Activity Readiness Questionnaire (PAR-Q)[21] and the short version of the International Physical Activity Questionnaire (IPAQ)[22] were used to evaluate volunteer integrity and physical fitness and to determine the history and level of daily and weekly physical activity, respectively. After the anthropometric assessment, the participants were referred to the 1 RM test to estimate the maximum strength and quantify the load percentage of the training season in six weight machines: inclined 45° leg press, bench press, leg extension, row machine, leg curl, and shoulder press (Wellness®, Sterling Model, Brazil). To perform the test, the participants were familiarized with the mode of execution and range of motion of each piece of equipment. A pre-start warm-up was performed with a sets of 10 repetitions and a load of approximately 50% of the predicted 1 RM. The 1 RM test has high reliability in assessing muscle strength and is considered the gold standard in non-laboratory situations.[23,24]

In M2, the ST session was administered to all individuals in the morning. For the execution of each exercise, an intensity of 60% was applied, which was obtained using a 1 RM. Therefore, the volunteers performed four sets with a maximum of 12 repetitions. In addition, the time under tension was controlled by a metronome app (Korg®, MA2 Model, Brazil), with 4 s (s) of total execution for each repetition (2 s of concentric and 2 s of eccentric muscle action). The participants had a 90-s break to rest and recover between sets of repetitions and exercises.[25] At the end of each sets of repetitions, the subjective Borg scale was applied to all exercises (OMNI-RES = Perceived Exertion Scale for Resistance Exercise, 0–10).[26] The training load configuration was established based on previous studies.[27–29]

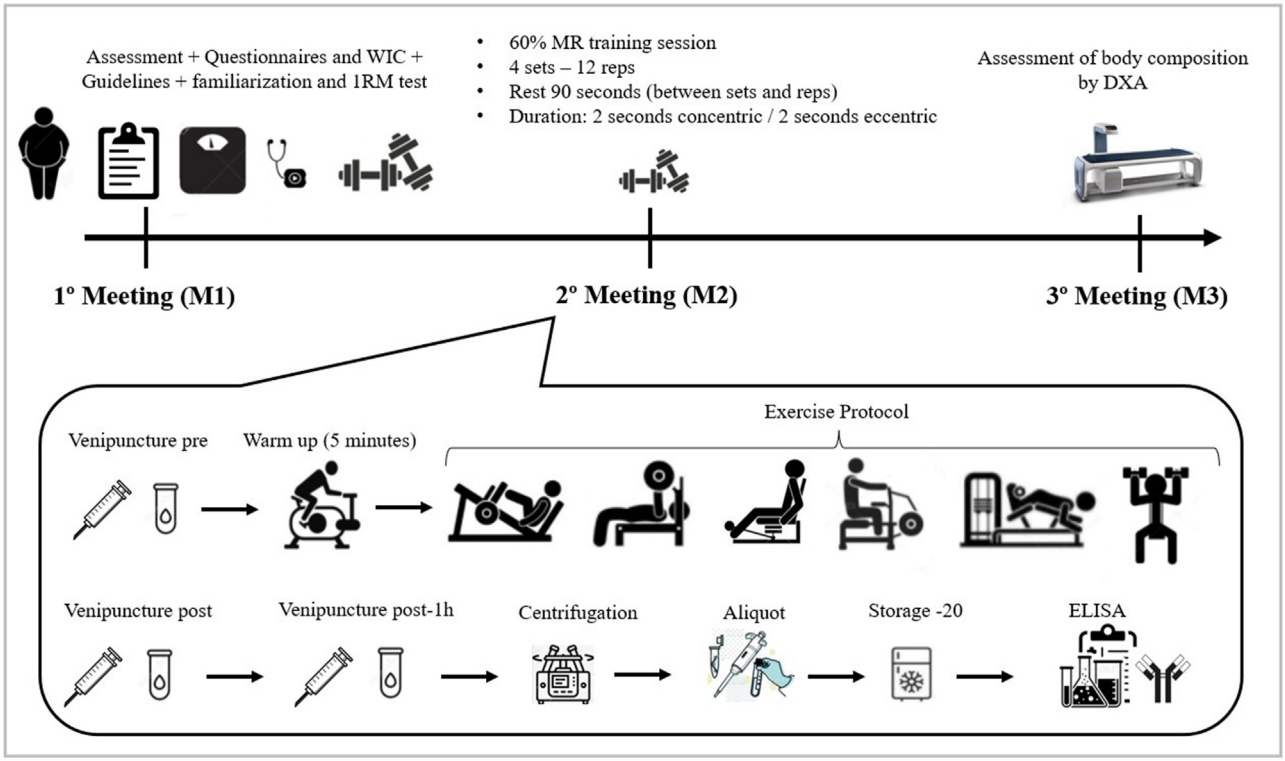

Fig. 1. Overview of the study protocol. Note. Meeting 1 (M1), the participants received information about the study protocol and were submitted to anthropometric assessment, 1 maximum repetition test for all exercises, and were instructed to answer the PAR-Q and IPAQ questionnaires; In Meeting 2 (M2), an strength training session was applied to all participants, and blood was collected before (pre), immediately after (post) and 1 h subsequent (1 h post) to strength training; In the Meeting 3 (M3), the participants were referred to the assessment of body composition using the DXA method. Abbreviations: **WIC** - Written Informed Consent; **MR** - Maximum Repetition; **ELISA** - Enzyme Linked Immuno Sorbent Assay; **DXA** - densitometry by dual-energy X-ray absorptiometry.

In M3, body composition was evaluated by densitometry using DXA[30] with the LUNAR PRODIGY ADVANCE equipment (GE®, Medical Systems, Madison, USA).

The participants received additional recommendations before the physical assessment and training sessions. The recommendations were as follows: (1) not to perform physical activities the day before, (2) not drink alcoholic beverages, (3) not consume caffeine, (3) not take medications, (4) sleep at least 8 h the night before, and (5) ingest 5–7 mL per kilogram (mL/kg) of water at least 4 h before exercise to ensure the state of hydration.[21] In the day of the ST session and blood collection, the volunteers were instructed to maintain their regular diet.

2.3. Sample collection

Blood samples were collected through venipuncture in the antecubital vein in three tubes with ethylenediaminetetraacetic acid (EDTA) + Fluoride (4 ml) and in six tubes with EDTA (4 ml) (Biocon®, Brazil), 2 tubes pre-(before), 2 tubes post-(immediately after), and 2 tubes post-1 h (1-h subsequent) to the ST session. The ST sessions were performed between 07:00 a.m. and 11:50 a.m. The blood samples were subsequently centrifuged to separate plasma (3 000 rpm at 4 °C for 10 min) and stored in eppendorf tubes (1.5 mL) in a freezer at −20 °C.

2.4. Measurement of adipokines

Adipokines (resistin and leptin) were analyzed using enzyme-linked immunosorbent assay (ELISA) sandwich kits (R&D Systems, Minneapolis, MN, USA). Briefly, the plates were incubated for 3 h at room temperature (RT) (20–25 °C) and washed three times (with phosphate-buffered saline [PBS]-Tween 0.1%). After washing, the plates were incubated with biotin-conjugated antibodies diluted in phosphate-buffered saline PBS- bovine serum albumin BSA 1% for 1 h at room temperature (RT). After washing (with 0.1%), peroxidase-conjugated streptavidin was added to all plates, which were then incubated for 30 min at RT. Finally, after further washing (with 0.1%), the chromogen 3,3′,5,5′-tetramethylbenzidine (TMB) was added to the plates in the absence of light. After 30 min, the reaction was stopped with a solution containing 1 M mass (M) of sulfuric acid. Marking intensity was measured at 450 nm using an ELISA reader (Agilent BioTek Epoch, Santa Clara, CA, USA). The detection limits for resistin and leptin are 6.59 and 7.8 pg/mL, respectively. All molecules were measured in a single assay to avoid inter-assay variability. The intraassay variability was < 3%.

2.5. Statistical analysis

GraphPad Prism 9 was used for statistical analysis. The Shapiro–Wilk test was used to analyze the distribution of the variables. For Gaussian variables, a one-way analysis of variance for repeated measures was used to assess the differences between the 3-time points. Tukey's post-hoc test was used to identify differences. Friedman's test and Dunn's post-hoc test were used to analyze non-parametric variables. The level of significance was set at $p < 0.05$. In addition, the Cohen's[31] criteria of $d < 0.1$ meaning trivial effect, $0.1 < d < 0.3$ meaning small effect, $0.3 < d < 0.5$ meaning medium effect, $d > 0.5$ meaning large effect, was used to analyze the effect size. The effects sizes for pre and post and post-1 h ST session were calculated.

3. Results

3.1. General characteristics and measurements

All 12 participants were male, 9 were obese, and 3 were overweight.

No acute or chronic diseases were detected or reported during the study. The other baseline characteristics and body compositions of the study participants are shown in Table 1.

3.2. Number of maximum repetitions performed in the exercise protocol

There was a reduction in the number of repetitions throughout the training sets, and this behavior was similar in all exercises performed. The results are shown in Fig. 2.

3.3. Plasma levels of leptin

Plasma leptin levels are shown in Fig. 3. There were no significant changes in the comparisons at different time points: pre vs. post (pre 105.9 [92.14–158.8] pg/mL vs. post 92.09 [83.24–117.3] pg/mL, $p = 0.056\ 7$, **Cohen's $d = 0.389\ 5$**), pre vs. post-1 h (pre 105.9 [92.14–158.8] pg/mL vs. post-1 h 94.90 [81.99–107.90] pg/mL, $p = 0.307\ 4$, **Cohen's $d = 0.320\ 7$**), post vs. post-1 h (post 92.09 [83.24–117.3] pg/mL vs. post-1 h 94, 90 [81.99–107.90] pg/mL, $p = 0.999\ 9$, **Cohen's $d = 0.049\ 9$**).

3.4. Plasma levels of resistin

Plasma levels of resistin are shown in Fig. 4. Plasma levels of resistin significantly reduced 1 h after the end of the ST session if compared to the concentrations before the training (pre [2 390 ± 1 199] pg/mL vs. post-1 h [1 523 ± 798.6] pg/mL, $p = 0.002\ 8$, **Cohen's $d = 0.850\ 8$**). No significant changes were detected when levels before ST were compared to those immediately after (pre [2 390 ± 1 199] pg/mL vs. post [2 073 ± 1 031] pg/mL, $p = 0.434\ 3$, **Cohen's $d = 0.282\ 8$**), as well in the comparison between levels immediately after and 1 h subsequent to ST (post [2 073 ± 1 031] pg/mL vs. post-1 h [1 523 ± 798.6] pg/mL, $p = 0.072\ 5$, **Cohen's $d = 0.596\ 9$**).

4. Discussion

The main objective of this study was to investigate the acute changes in the plasma levels of resistin and leptin after an ST session in overweight and obese individuals. We found a reduction in resistin levels 1 h after the end of the ST session compared with the levels before training. No significant changes were observed at other time points for either resistin or leptin.

It is necessary to highlight the characteristics of the training protocol and blood collection. Analysis from the IPAQ showed that this group of volunteers was classified as sedentary people, but they were not incapable to practicing physical exercise. None volunteer answered YES to one or more PAR-Q questions. This study applied a training load model previously used by our group.[27–29] The number of repetitions and exercise loads were equally established for all participants. This is important to ensure that metabolic changes occur similarly in all individuals and that the exercise load is adequate to interfere with body homeostasis. The number of repetitions significantly decreased in all exercises, indicating an adequate load to generate physiological stress in the participants. In addition, the time of each repetition was standardized and controlled using a metronome, and the subjective effort scale of the OMNI-RES was applied to verify compatibility with the maximum execution of repetitions at the end of each sets. Blood was collected at three time points to investigate the acute effects of a single ST session. Other studies have also investigated the acute effects of exercise on resistin and leptin levels but adopted different training protocols and time points for blood collection.[32–42]

Table 1
Characteristics of study participants ($n = 12$).

Variable	Mean ± *SD*
Age (years)	34.95 ± 9.77
Height (cm)	174.16 ± 3.66
Weight (kg)	97.83 ± 12.87
BMI (kg/m^2)	32.30 ± 4.51
Fat Mass (kg)	33.56 ± 9.17
% Fat Mass	35.07 ± 6.07
Lean Mass (kg)	59.74 ± 5.55
% Lean Mass	62.35 ± 5.81

n: numbers; *SD*: standard deviation.

A single ST session did not alter plasma leptin levels. Previous studies evaluating acute plasma leptin levels after ST have also shown divergent results.[32,33,35,36] A recent study by our group did not find acute changes in plasma leptin levels in healthy young men after the first ST session when compared to the pre- and immediately post-training values.[36] Rahmani-Nia et al.[37] did not detect significant changes in the plasma levels of leptin in samples from young obese women collected immediately after ST and 10 h later. However, studies evaluating the chronic effects of ST have shown contradictory results.[35,38–41] For example, Ataeinosrat et al.[35] compared the plasma levels of leptin before and after 12 weeks of 3 different ST protocols in obese men. The authors found a significant reduction in leptin levels after all ST protocols compared to non-trained individuals (control group). The decrease in plasma leptin levels may have been due to reduced body fat and increased energy expenditure during the 12-week training period.[35]

The main finding of this study was the significant reduction in the plasma levels of resistin 1 h after the ST session. Interestingly, this alteration was not observed immediately after ST. The reason for this slight delay in finding a reduction in plasma resistin levels as an acute response to ST in overweight and obese individuals remains unclear. Previous studies have obtained divergent results regarding plasma resistin levels after acute ST. However, the participants of the study differs from those from our study and included trained or sedentary men,[42] healthy young men[43] and elderly postmenopausal women.[44–46] The reduction in plasma resistin levels 1 h after a single ST session can be considered a beneficial effect since resistin contributes to insulin resistance and the pro-inflammatory state associated with some metabolic diseases.[12,43] If a single ST session decreases plasma resistin levels, it seems plausible to assume that repeated ST sessions chronically reduce the concentration and effects of resistin in obese and overweight individuals. Previous studies have confirmed this assumption but included different participants.[42,44–47]

This study has several important limitations. First, the sample size was relatively small and not completely homogeneous regarding age and BMI (overweight and obese). These factors may interfere with the responses observed after ST sessions. Second, we did not measure the levels of these molecules in normal weight individuals as a comparison group. Third, we did not investigate the mechanisms underlying acute ST effects or possible chronic responses. Nevertheless, the homogeneous ST protocol, three time points of blood collection, and rigorous measurements of leptin and resistin are the strengths of our study.

Despite these limitations, we investigated the acute effects of a single ST session on the plasma levels of resistin and leptin. Although leptin levels remained unchanged, plasma resistin levels were significantly reduced. Our study's exercise load imposed on participants likely affected their homeostasis. We believe that this paper showed two important novelties: 1) the volunteers performed a well-controlled ST session, while the previous studies investigated aerobic exercise protocols; 2) we investigated the role of intensity, volume, density, time under tension, and duration of pause of a single ST session in dynamic changes of circulating levels of resistin and leptin.

Nowadays, it is well known that acute and chronic physical exercise lead to many benefits for the health. This study showed that a single session of an specific type of exercise, the ST, was able to reduce the circulating levels of resistin. This molecule is associated with inflammation and insulin resistance. The effect of ST supports a potential benefit for this modality of physical exercise for individuals with overweight and obesity.

This supports the need to monitor several variables in chronic ST

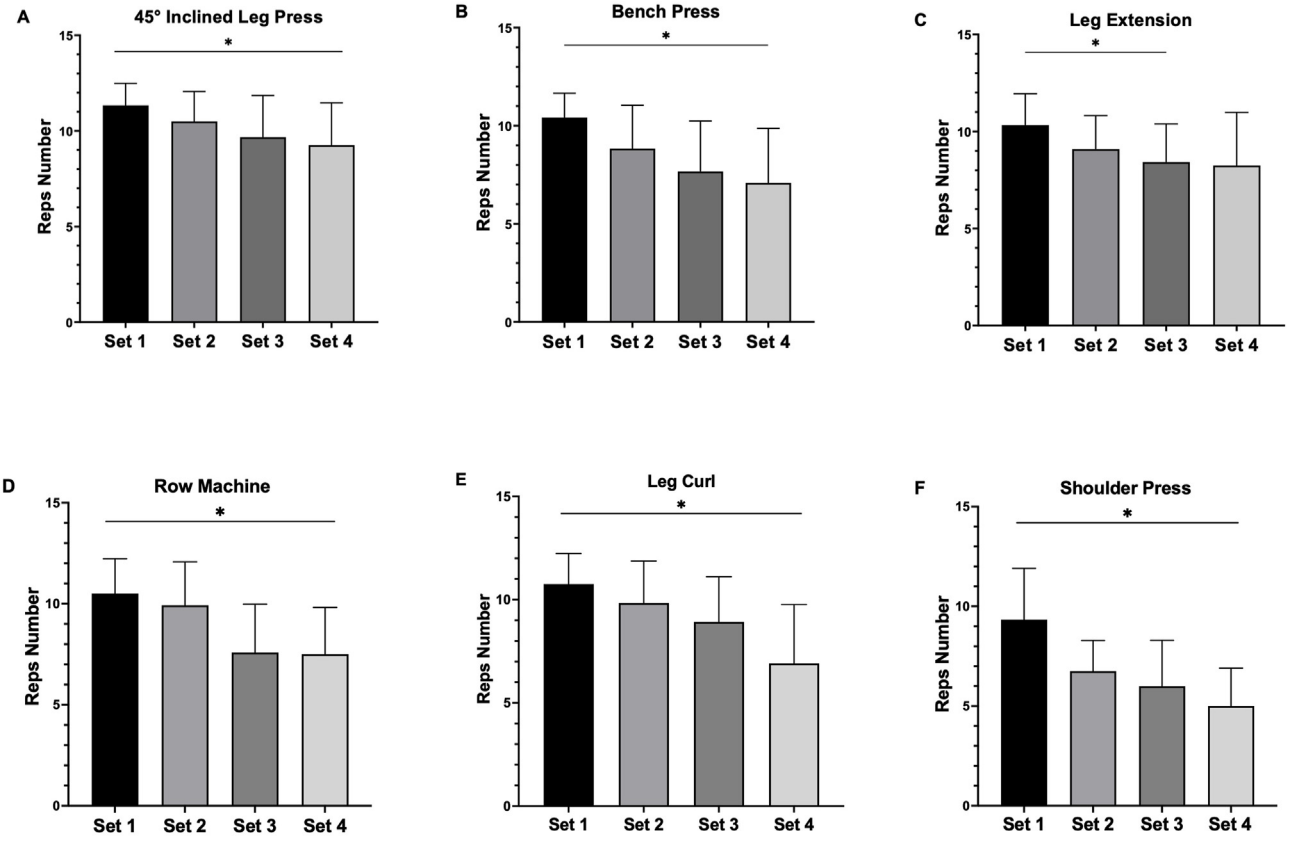

Fig. 2. Number of repetitions performed in each exercise sets: **45° Inclined Leg Press:** *$p < 0.04$ (Fig. 4A). **Bench Press:** *$p < 0.004$ (Fig. 4B). **Leg Extension:** *$p < 0.04$ (Fig. 4C). **Row Machine:** *$p < 0.000\ 9$ (Fig. 4D). **Leg Curl:** *$p < 0.000\ 7$ (Fig. 4E). **Shoulder Press:** *$p < 0.000\ 6$ (Fig. 4F). Values are represented as mean ± *SD*. Results were obtained by one-way analysis of variance followed by Tukey's multiple comparisons test. *SD*: standard deviation.

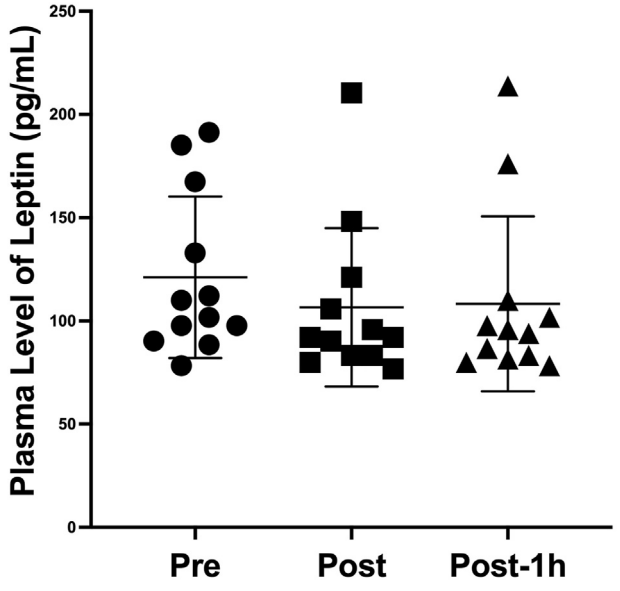

Fig. 3. Plasma level of leptin pre, post, and post-1h the acute strength training (ST) session. Values are represented as median and interquartile range. Results were obtained by Friedman's test and Dunn's post hoc test.

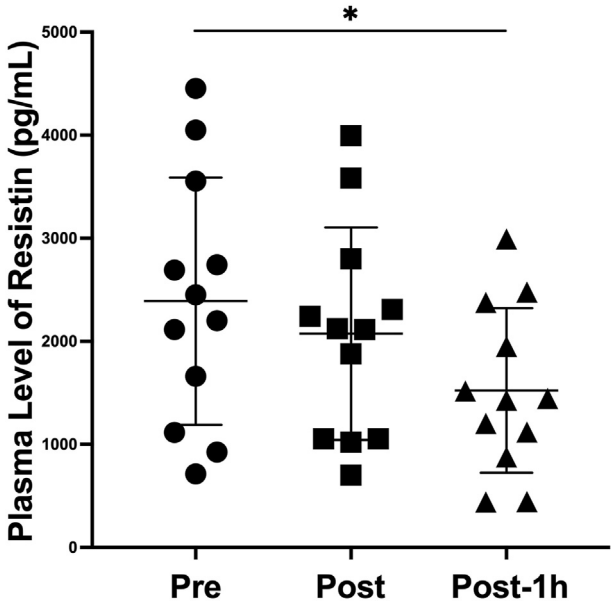

Fig. 4. Plasma levels of resistin before (pre), immediately after (post), and 1-h subsequent (post-1 h) to strength training (ST) session. Values are represented as mean ± *SD*. Results were obtained by one-way analysis of variance followed by Tukey's multiple comparisons test. *SD*: standard deviation.

protocols. The effects of exercise on adipokines depend on the training protocol and characteristics of the sample. The main physiological meaning of this finding is that a single session of ST was able to reduce the levels of a molecule related to inflammation and insulin-resistance. Thus, ST could be a nonpharmacological alternative to improve the health of overweight and obese individuals. Further larger-scale studies will be necessary to confirm our findings and elucidate the underlying mechanisms.

5. Conclusions

A very well controlled single session of ST significantly decreased the plasma levels of resistin without altering the concentrations of leptin in overweight and obese individuals. This finding might, at least in part, explain the benefits of exercise on low grade inflammation and insulin resistance in obesity. Further studies are necessary to explore the mechanisms underlying the acute effects of ST on plasma resistin levels and to investigate the responses to chronic training protocols.

Submission statement

The present manuscript has not been submitted, accepted, or published elsewhere and all authors have read and agree with manuscript content. While this manuscript is being reviewed for this journal, the manuscript will not be submitted elsewhere for review and publication.

Ethics approval statement

The study was approved by the Ethics Committee of Ouro Preto Federal University (CAAE no. 42886621.4.0000.5150 and approval no. 4.693.684) according to the criteria of the Brazilian legislation for studies on human beings and the resolution of the National Health Council 466/12. The informed consent was obtained from each participant, and the study was reviewed by the author's institution and received approval to implement the study. The informed consent was collected from each participant in this study.

Authors' contribution

Yago Martins Fortes: Conceptualization, Data curation. **Antonio Felipe Souza-Gomes:** Writing – original draft, Writing – review & editing. **Alessandro Roberto Silveira Moreira:** Data curation, Investigation. **Leo Nogueira Campos:** Formal analysis, Investigation. **Samara Silva de Moura:** Formal analysis. **Lucélia Scarabeli Silva Barroso:** Formal analysis. **Marcelo Henrique Salviano de Faria:** Writing – original draft. **Heliana de Barros Fernandes:** Formal analysis. **Aline Silva de Miranda:** Formal analysis, Funding acquisition, Writing – original draft. **Hugo César Martins-Costa:** Writing – original draft. **Ana Cristina Simões e Silva:** Conceptualization, Data curation, Formal analysis, Methodology, Writing – original draft, Writing – review & editing. **Janaina Matos Moreira:** Conceptualization, Data curation, Funding acquisition, Supervision, Writing – original draft, Writing – review & editing. **Albená Nunes-Silva:** Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing – original draft, Writing – review & editing.

Conflict of interest

Authors declare on conflict of interest.

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