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Research Article

Obesity, Associated Diseases and Potential Complications: Prevention and Treatment Strategy through Nutritional Intervention Combined with Physical Activity

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Abstract

Obesity modulate the production of hormones and adipokines such as leptin, adiponectin, and resistin, thereby favoring the development of chronic Noncommunicable Diseases (NCDs). Nutritional intervention is a strategy used for its prevention and/or treatment. We analyzed the benefits of a nutritional intervention program combined with the practice of physical activity on body composition and NCD markers. Eighteen people with a mean age of 58 ± 8 years, weight of 73.68 ± 16.57 kg, Body Mass Index (BMI) of 28.30 ± 4.88 kg/m^2, Waist Circumference (WC) of 95.72 ± 13.57 cm, waist/hip ratio of 0.80 ± 0.07, and body fat percentage of 35.22% ± 4.84% who practiced aquatic aerobics and/or swimming participated in a six-month nutritional intervention program with weekly meetings. Data collection was performed before and after the intervention. We evaluated BMI, body fat percentage, WC, and hip circumference as well as the levels of leptin, resistin, adiponectin, and insulin. Nutritional intervention combined with physical activity contributed to a reduction in weight by 1.47% ($p < 0.05$), BMI by 1.32% ($p < 0.05$), and the plasma concentration of leptin by 18.04% ($p < 0.05$) and resistin by 8.70% ($p < 0.05$). There was no significant change in the hormones adiponectin and insulin. Total cholesterol decreased by 22% ($p < 0.01$) and low-density lipoprotein cholesterol (LDL-c) by 51.80% ($p < 0.0001$). During the follow-up period we observed a reduction in weight, BMI, leptin, resistin, total cholesterol, and LDL-c. Therefore, we conclude that changes in eating habits along with the performance of physical activity assist in the treatment of overweightness and obesity and, thus, prevent associated diseases.

Keywords: Obesity; Adipokines; Nutritional intervention; Physical activity; Inflammation; Covid-19

Introduction

Each year, 2.8 million people die from obesity-related diseases such as hypertension, dyslipidemia, and metabolic syndrome. Economic burden is one of the various negative aspects of obesity because the expenditure on healthcare to meet the needs of individuals with chronic Noncommunicable Diseases (NCDs) is high both in developed countries, including the United States of America, and developing countries such as Brazil [1]. Studies show that in 2018, Brazil spent 3.45 billion reais in the Unified Health System for the treatment and follow-up of patients with obesity, hypertension, and diabetes [2].

Obesity is characterized by the accumulation of triacylglycerol inside adipocytes caused by an imbalance between food intake and total energy expenditure [3,4]. The accumulation of visceral fat leads to increased metabolic risk, causing problems such as diabetes and liver steatosis, in addition to the risk of developing triglyceride storage dysfunction, which contributes to the development of dyslipidemia [5]. Because white adipose tissue is the largest endocrine organ, obesity leads to an imbalance in the production of some adipokines such as IL-6, adiponectin, leptin, resistin, apelin, and visfatin [6].

Hypertrophy and hyperplasia of adipocytes result in local hypoxia leading to cell death and increased flow of fatty acids. These metabolic processes combined with the imbalance of adipokines, including IL-6, leptin, and resistin, which have proinflammatory properties, contribute to the development of subclinical inflammation in people with obesity and favor the development of comorbidities [7,8].

Leptin is one of the hormones responsible for the increased activity of the sympathetic nervous system, which in turn controls renal and vascular blood pressure. As a result, the increase in plasma leptin levels is associated with the occurrence of hypertension in people with obesity [9,10].

Resistin plays a role in the storage and use of energy in the form of triacylglycerol and has been associated with the development of chronic diseases linked to obesity, such as type 2 diabetes and cardiovascular diseases [11].

On the other hand, in addition to influencing insulin sensitivity, adiponectin has anti-inflammatory and antiatherogenic properties

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and is therefore considered as an antidiabetic hormone. Obesity, insulin resistance, diabetes, hypertension, coronary artery disease, and high risk for myocardial infarction are associated with low serum levels of adiponectin [12].

Since the beginning of 2020, obesity, along with NCDs, is a matter of increasing concern due to the COVID-19 pandemic, and several studies show that obese patients tend to have worse disease progression, a long period of hospitalization, and high morbidity and mortality [13]. Compared to eutrophic individuals and patients without comorbidities, obese individuals are in a subclinical inflammatory state, and the presence of another inflammatory stimulus, such as COVID-19 infection, facilitates an inflammatory burst that promotes complications [14]. In addition, individuals with obesity elicit a delayed and ineffective immune response [15].

Furthermore, the SARS-CoV-2 virus binds to target cells through the spike protein, which in turn comes into contact with the Angiotensin-Converting Enzyme 2 (ACE2). Both lung and adipose tissues have high expression of ACE2, which makes obese individuals highly vulnerable to infection [16].

Inadequate dietary choices, such as having a high intake of foods with high calorie, high sucrose, and low fiber levels, are closely related to obesity. Strategies that alter these behaviors can positively influence the nutritional status of the population and reduce the incidence of obesity and NCDs [17]. However, nutrition education has been shown to be more effective when it focuses on behavior/action and not just on knowledge acquisition by the individuals; therefore, any strategy needs to be based on three pillars-theory, research, and practice [18].

In addition to changes in food consumption and physical activity, aerobic exercises are strategies that especially contribute both to weight loss and the maintenance of this loss [19]. Aquatic exercise activities are shown to be effective for weight loss and anthropometric changes in previously sedentary adults, even in a short period of intervention [20]. However, a previous study by our group showed that aquatic exercises performed for a long period did not promote changes in body composition, despite improving the inflammatory subclinical state and NCD markers [21].

In this study, we evaluated the benefits of a nutritional intervention program on body composition and NCD markers in individuals who practice aquatic exercise.

Methods

Sample

The participants were screened and recruited in a structured aquatic physical activity program at a community-based health and fitness center at the Institute of Physical Activity and Sport Sciences of the Cruzeiro do Sul University. The study included 18 participants (16 women and 2 men) with a mean age of 58 ± 8 years, weight of 73.68 ± 16.57 kg, Body Mass Index (BMI) of 28.30 ± 4.88 kg/m2, Waist Circumference (WC) of 95.72 ± 13.57 cm, Waist/Hip Ratio (WHR) of 0.80 ± 0.07, and body fat percentage of 35.22 ± 4.84%.

The participants underwent a supervised 12-month nutritional intervention program which involved performing 60 min of exercise twice a week. The training sessions were supervised by trainers qualified in the modalities of swimming (x participants) and/or water aerobics (y participants), and the sessions were conducted in the Sports Center of the Institute of Physical Activity and Sports Sciences as described by Gondim [21].

With regard to the nutritional status, before the start of the nutritional intervention program, most participants (76%) were overweight (according to BMI) and 62% were classified as obese (according to body fat percentage). In addition, 19% of the participants were at a high risk and 76% were at a very high risk for developing Cardiovascular Diseases (CVDs) according to their WCs, and 43% participants were at a high risk for developing CVD according to their WHRs.

The participants were excluded from the study if they did not obtain at least 80% attendance in the training sessions and nutrition workshops, did not participate in the three steps proposed by our study (at baseline and after 6 and 12 months of regular exercise), and had not fasted for 8 h prior to blood collection.

With respect to medication, 11% of them had previously received a prescription for dyslipidemia, 38% for hypertension, 11% for diabetes mellitus, 22% for hypothyroidism, and 16% for anxiety and depression.

The nutrition workshops and data collection were conducted in the Sports Center of the Institute of Physical Activity and Sports Sciences. An informed consent form was obtained from all the participants before enrolling them in the study. Additionally, the study was approved by the Human Ethics Committee of the Cruzeiro do Sul University (approval number: 1179/CEPSH).

The study lasted for 10 months, and the nutritional intervention and data collection were performed in this period. Two data collections were performed in 2015, the first at the beginning of March before the nutritional intervention [pre-nutritional intervention (pre-NI)] and the last at the end of the nutritional intervention in early November (post-NI).

Anthropometric data (weight, height, hip circumference, WC, body composition, body fat percentage, and lean mass percentage) were recorded, and 10 mL blood samples were collected in sterile vacuum tubes by healthcare professionals. Nutritional anamnesis was performed using the Food Frequency and Habitual Diet Questionnaire.

Nutritional intervention

After the first data collection, the participants were recruited in a group nutritional intervention program that included nutrition workshops conducted for 50 min once a week before or after the practice of physical activity for a total duration of 6 months and a total of 16 nutrition workshops.

The nutritional intervention strategies included nutritional guidance (dietary choices, questions about specific food, adequate substitutes, etc.), assessment of food intake (by maintaining records in a food diary), and development of a dietary plan (on an individual basis).

The workshops addressed various topics and included a theoretical background and language appropriate to the public. The topics were addressed following a planned and consistent line of reasoning for the assimilation and understanding of the contents according to the Food

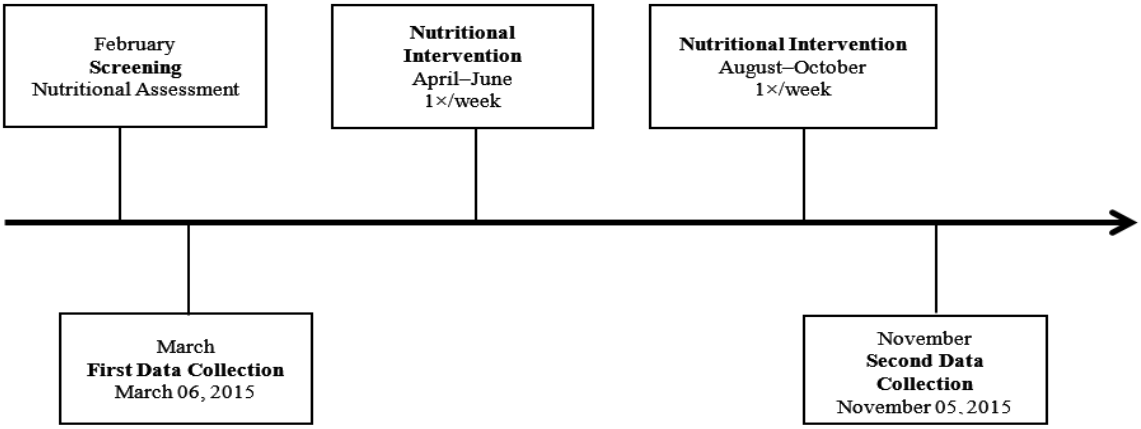

Figure 1: Experimental design.

Guide for the Brazilian Population and other recommendations [22-24]. To facilitate engagement and understanding, practical activities such as tastings, competitions, and games were carried out.

In the first 3 months, the topics covered general concepts of nutrition such as the classification of foods according to the food pyramid and correct food portioning and labeling. In the next 3 months, the workshops addressed topics related to illnesses resulting from inadequate nutrition with a sequence of meetings on NCDs, as shown in Table 1.

In addition to nutrition workshop participation, the participants received a food plan formulated based on each individual's dietary habits and caloric needs according to the nutritional recommendations of the World Health Organization (WHO) and taking into account the deficiencies of each individual as well as micronutrient requirements according to the technical regulations on the recommended daily intake of vitamins and minerals [32].

Dietary plans were developed according to the diet guidelines for weight loss, which establish an energy deficit of 500 kcal to 1000 kcal [30] in relation to the total energy requirement and taking into account the calculation of the basal metabolism rate and physical activity factor. The caloric value corresponding to the energy requirement was obtained through the standard calculation proposed by [33], which depends on gender, age, and nutritional status.

The structure of the food plan given to the participants included foods selected by the nutritionist and a list of three options for the replacement of each food so that the diet could be varied. Both the dietary plan and habitual diet analyses were performed using the DietPro® software.

The physical activity factor was evaluated according to the FAO [33] parameters, which stipulate the following levels for overweight men and women: sedentary (1.0/1.0), moderately active (1.12/1.16), active (1.29/1.27), very active (1.59/1.44). Because the activity modality was classified as moderate and had a short duration and a frequency of up to twice a week, the "moderately active" parameter was used.

Assessment of body composition

The anthropometric evaluations were conducted through the measurement of weight, height, and hip and WCs using an electronic scale, a stadiometer, and nonelastic tape measure, respectively [34,35]. The guidelines of the WHO [35] were followed to obtain these data.

The assessment of the nutritional status of each participant was performed by calculating their BMI and classifying them based on it. BMI was calculated using the following formula: weight divided by height squared. The participants were classified as adults (>20 to <60 years) and elderly (>60 years), this study included 10 elderly and 8 adult participants. For the risk factors of WC and WHR, the parameters established by WHO [36], were used.

The evaluation of body composition (fat mass in kg and percentage, muscle mass in kg) was performed using the bioimpedance test according to the manufacturer's standard recommendations. The Bioimpedance Biodynamics 310e® (Biodynamics Corporation USA and/or TBW Importadora Ltd.) was used for all participants. To perform the bioimpedance test, the participants had to refrain from consuming caffeinated foods for a period of 24 h and from performing physical exercise for 12 h.

Blood sampling

Blood samples were collected after 8 h of fasting and 24 h after the last training session for evaluating the biochemical markers of NCD. Blood samples (20 ml-10 ml in an EDTA-containing tube and 10 ml in a dry tube) were collected from the antecubital vein before the training session and 6 months and 12 months after the training began. The serum and plasma were separated by centrifugation for 10 min at 1000 ×g and were subsequently stored in aliquots at -80°C until further analysis.

Analysis of Risk Markers for NCDs

Lipid profile: The plasma samples were used for lipid profile analysis using the enzymatic colorimetric test. Bioclin® kits (Belo Horizonte, MG, Brazil) were used to determine total cholesterol, High-Density Lipoprotein Cholesterol (HDL-c), and Low-Density Lipoprotein Cholesterol (LDL-c) according to the manufacturer's instructions. The analysis was performed using a spectrophotometer at a wavelength of 500 nm (SpectraMax, Molecular Devices, CA, USA).

Hormonal assessment: The serum samples were used for

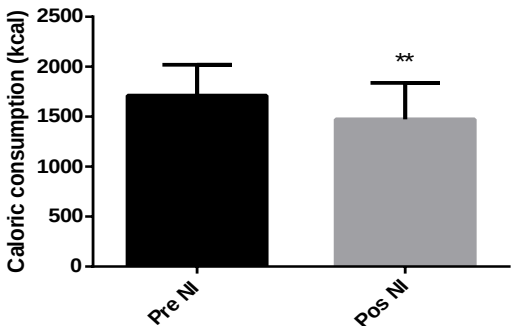

Figure 2: Evaluation of caloric intake before and after nutritional intervention.

determining the levels of the hormones adiponectin, leptin, resistin, and insulin using the enzyme linked immunosorbent assay method (Quantikine® Colorimetric Sandwich ELISAS or Duoset®, R&D Systems, Minneapolis, USA) according to manufacturer's instructions.

Statistical Analysis: All data were expressed as mean ± standard deviation. The statistical analysis was performed using the Prisma® software version 6 and Student's t-test. The significance level was set at $p < 0.05$ for all parameters. The Kolmogorov-Smirnov test was used for the analysis of normality between variables. The Holm-Sídák test was used for evaluating parametric data, and the Friedman test was used for evaluating nonparametric data.

Results

Assessment of food intake

We observed a 14% reduction in total energy intake post-NI ($p<0.01$), which promoted a negative energy balance when comparing the usual and proposed diets. There was no change regarding the distribution of macronutrients of the total caloric intake according to FAO [32].

Assessment of Body Composition

After the nutritional intervention, there was an increase of 9% (from 2 to 3 participants) in the percentage of eutrophic individuals (according to BMI) and a 19% reduction (from 9 to 5 participants) in obese individuals (according to body fat percentage). In addition, there was a 9% reduction in the percentage of participants at a very high risk for CVD according to WC and an increase of 14% in the percentage of participants without risk according to WHR.

The nutritional intervention program combined with the practice of physical activity contributed to a reduction in the weight of 1.47% participants (Figure 1A) and, consequently, to a reduction in the BMI of 1.32% participants (Figure 1B). However, there was no significant change in AC, body fat percentage, and WHR (Figure 1C, 1D and 1E).

Lipid profile assessment

There was a reduction in the plasma concentration of total cholesterol (22%) and LDL-c (51.80%) after the nutritional intervention (Figures 2A and 2B). With regard to the HDL-c fraction and triglyceride concentrations, the participants showed no changes (Figures 2 C and 2D).

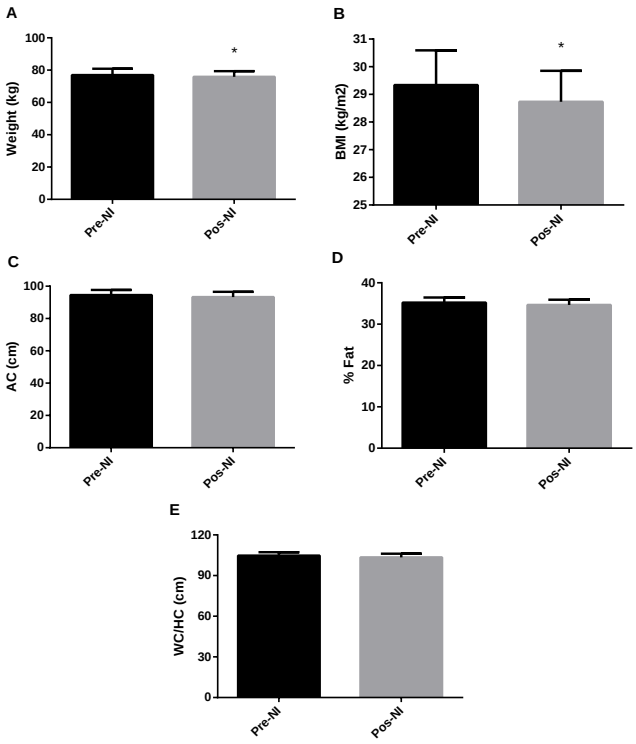

Figure 3: Evaluation of anthropometric parameters before and after the nutritional intervention.
We determined weight (A); body mass index, BMI (B); waist circumference, WC (C); body fat percentage (D); and hip circumference, HC (E). The values are presented as mean ± standard deviation for 18 participants. *$p < 0.05$ for comparison between values before and after the nutritional intervention.

Hormonal assessment

The nutritional intervention caused a significant decrease in the plasma concentrations of leptin (18.04%) and resistin (8.7%) (Figures 3A and 3B) in the participants who practiced aquatic exercise. There was no significant change in the participants in terms of the hormones adiponectin and insulin (Figures 3C and 3D).

Discussion

The nutritional intervention program in conjunction with the practice of physical activity reduced the risk factors for CVD and metabolic disease. It promoted the reduction in weight; BMI; body fat percentage; concentrations of the adipokines, leptin and resistin; and total cholesterol and LDL-c.

Andreyeva [37], in a longitudinal study conducted between 1996 and 2003, analyzed the changes obtained after weight loss attempts and strategies in all population groups and found that most individuals who tried to lose weight achieved this goal through caloric restriction. Figueroa [38] and Avila [39] suggest that a low-calorie diet and regular physical activity are effective methods for promoting weight loss. In our study we observed that caloric restriction promoted a negative energy balance, with a reduction in weight and body fat percentage.

To ensure adherence, the prescribed diets were developed following the FAO parameters [32] in relation to the intake of macronutrients. Hooper [40] and McManus [41] state that diets

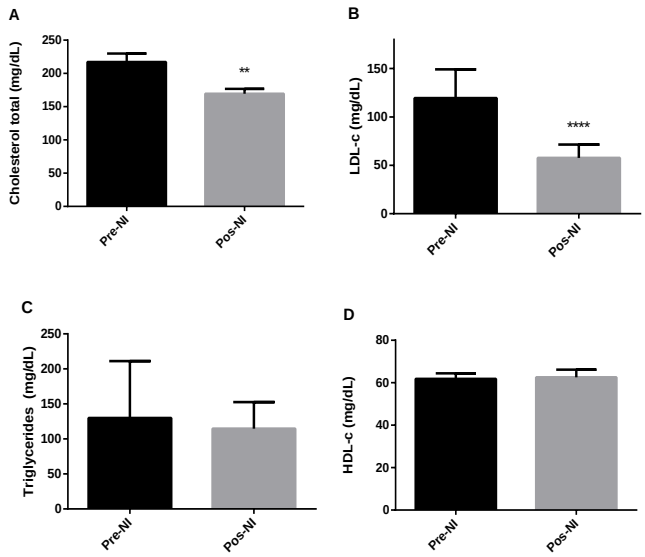

Figure 4: Evaluation of lipid profile before and after the nutritional intervention. We determined the total cholesterol (A); LDL-c: Low-Density Lipoprotein Cholesterol (B); triglycerides (C); and HDL-c: high-density lipoprotein cholesterol; (D) in plasma. The values are presented as mean ± standard deviation for 18 participants. **p < 0.01 and ****p < 0.001 for comparison between values before and after the nutritional intervention.

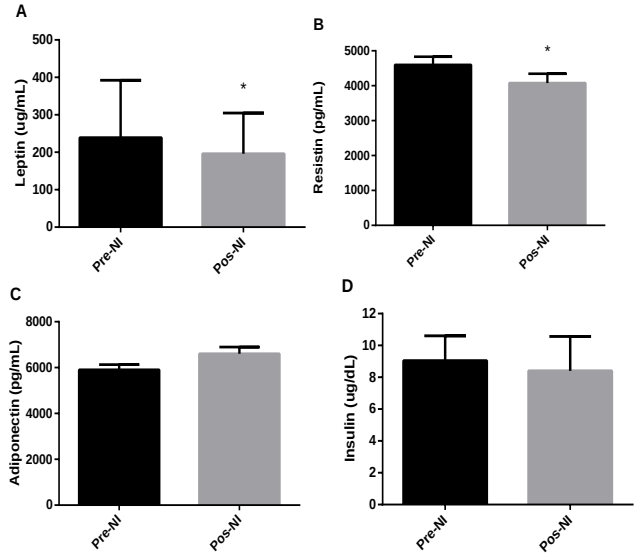

Figure 5: Evaluation of hormones before and after the nutritional intervention. We determined the concentration of leptin (A), resistin (B), adiponectin (C), and insulin (D) in the plasma. The values are presented as mean ± standard deviation for 18 participants. *p < 0.05 for comparison between values before and after the nutritional intervention.

prepared with adequate macronutrient percentages allow individuals to adhere to changes in eating habits in the long term.

Reduction in leptin levels was observed in studies that promoted caloric restriction and body weight loss (>10%) [42,43]. In the present study, a weight loss lower than that obtained in the aforementioned study (1.47%) was sufficient to promote an 18% reduction in leptin, which indicates that small proportions weight reductions may reflect hormonal changes, such as reduced leptin.

A nutritional intervention program combined with physical activity presents better results for weight loss and hormonal parameters than diet or exercise alone [44,45]. In our study we observed that the practice of physical activity for an average period of 6 months along with a nutritional intervention program resulted in a reduction of leptin levels.

In a comparison study involving diet and exercise intervention, Reseland [46] found that leptin concentrations were reduced among individuals in the group that had long-term participation in a

Table 1: Topics addressed in the nutrition workshops included in the study.

Workshop Topics	Methodology	Reference
Nonregulatory Eating Behavior. Food *vs.* Feelings	Oral explanation and group discussion	Aquino and Philippi [25]
Diet is More Than Nutrient Intake. Basic Guidelines for a Balanced Meal	Oral explanation and group discussion	Brazil [22]
Ideal Food Choice-Food Categories-Packaging	Video: "The farce of packaged juices"	Brazil [22] Brazil [26]
Understanding Food Labels	Oral explanation and label analysis through game	Brazil [26]
Knowing the Food Pyramid. Food Groups	Dynamic activity: building the food pyramid with real food	Philippi [27]
Knowing the Food Pyramid. Portions	Dynamic activity: identification of portions (daily quantity and caloric value of food)	Philippi [27]
Do you know what chronic noncommunicable diseases are?	Visual resource and oral explanation	Cuppari [28]
What is Diabetes?-Part 1	Dynamic activity: the relationship of sugar dosages with corresponding foods	SBD [24]
What is Diabetes?-Part 2 Diagnosis/Treatment/Control	Visual resource, oral explanation, and tasting light passion fruit mousse	SBD [24]
What is Hypertension?-Part 1 Causes/Treatment/Control	Visual Resource and Oral Explanation	SBC [23]
Knowing More About Sodium. Uses/Legislation/Risks	Visual resource and oral explanation Label analysis	BRAZIL [29] SBC [23]
Seasonings that Replace Salt	Dynamic activity: preparation of herbal salt. Tasting: ricotta paté with herbs	-----
The Fat in our Body and its Relationship with Atherosclerosis. Functions/Classifications/Risks	Visual resource and oral explanation	Cuppari [30]
The Fat in our Diet: Classifications	Dynamic activity: recognizing the types of fats	-----
What are Skimmed, Semi-Skimmed, Light, and Zero-Fat Products	Dynamic activity: recognizing low-fat products-tasting	Brazil [31]

nutritional intervention and physical activity program.

Experiments with rats confirmed that higher the level of resistin due to obesity, the higher will be the level of leptin and the more pronounced and faster will be the development of atherosclerosis [47]. In the present study, in addition to a reduction in leptin levels, there was a reduction in resistin levels after the proposed nutritional interventions.

Kusminski [48] showed that obese individuals who presented increasing weight loss, such as in cases of bariatric surgery, also had a significant reduction in resistin. A previous study with a 6-month period of intervention showed that weight reduction with the sustained use of medications, even if modest, led to significant metabolic benefits and a reduction in CVD risk [49]. In our study, the benefits were obtained without the use of medicines for weight loss, with a similar period of intervention. This shows that nutrition education and physical activity can be as effective as the drug therapies or surgical procedures used in the aforementioned studies.

In our study, resistin levels were correlated with BMI, and significant results were obtained. This indicated that a reduction in BMI is accompanied by a reduction in resistin level. Other studies also showed that resistin levels correlate with BMI, visceral adiposity, body fat percentage, and serum insulin concentration [11].

In the present study, dietary changes led to an increase in adiponectin during the interventions; however, these were not significant. In a study on weight loss after gastric balloon placement, Yang et al., [50] obtained a 21% reduction in mean BMI with a consequent 46% increase in the mean plasma adiponectin level. Our results may not be as significant as those mentioned above because the weight loss achieved through our method is lower than that obtained with surgical intervention.

Xydakis [51] described a reduction in some parameters such as leptin and triglycerides; however, they did not obtain a significant increase in adiponectin and concluded that other metabolic and cardiovascular risk parameters may improve regardless of the increase in adiponectin.

In our study, the low-calorie diet associated with exercise increased adiponectin by approximately 11%, a result that was not significant. Silva [52] found that the increase in adiponectin occurs with the use of three methods-intervention through a low-calorie diet, modified diet using a supplement, and diet associated with exercise. Weight loss achieved through a low-calorie diet combined with exercise in the aforementioned study was associated with an increase in adiponectin levels (from 18% to 48%). Intervention using physical exercise alone, i.e., without changing eating behaviors, does not seem to be effective for increasing adiponectin [53].

In the US, a survey analyzed approximately 13,000 people aged between 20 and 74 years between the years 1960 and 1991 and found that after the implementation of public health programs aimed at lifestyle changes, there was a consistent reduction in total cholesterol (especially LDL-c reduction). This reduction over the years was accompanied by a continuous decline in mortality caused by CVD [54]. Total cholesterol reduction, especially LDL-c reduction, was observed in our study after lifestyle-related interventions were implemented.

Weight loss may have contributed to the reduction of LDL-c; this was also described in studies conducted by Dattilo and Kris-Etherton [55] who observed an improvement in the lipid profile through weight reduction. These authors believe that with every kilogram of body weight that is eliminated, there is an increase of 0.009 mmol/L and a reduction of 0.007 mmol/L in the HDL-c of individuals who actively lose weight. A long-term reduction of 0.6 mmol/L in total cholesterol (corresponding to 10%) decreases the risk for ischemic heart disease in individuals by 50% for up to 40 years and by 20% for up to 70 years [56].

Vartiainen [57] report that reducing serum cholesterol through dietary changes is feasible in the physically active population. Varady and Jones [58] suggest that nutritional interventions mainly reduce total cholesterol and LDL-c, whereas exercise helps increase HLD-c and decrease triglycerides. The interventions proposed in our study did not promote an increase in HDL-c. In a study conducted by Zwald [59] on Americans between 2011 and 2014, it was found that the concentration of HDL-c was low even among individuals who practiced physical activity within the recommended minimum levels. Studies show that physical activity is able to promote an increase in HDL-c; however, this increase does not necessarily occur in all who engage in physical activity. Thus, the interventions proposed in the cited study and those in our study are complementary and contribute to the improvement of the lipid profile.

Conclusion

In conclusion, nutritional interventions involving the monitoring of an adequate dietary plan and participation in nutrition workshops along with the practice of physical activity proved to be effective for improving lipid and hormonal profile parameters related to obesity and its associated comorbidities. During the intervention period with caloric restriction, we observed a significant reduction in weight, BMI, leptin and resistin levels, and total cholesterol and LDL-c levels. Thus, changes in eating habits combined with the performance of physical activity can assist in the treatment of overweightness and obesity and, therefore, prevent the development of associated diseases.

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