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Effects of an interdisciplinary program to promote the health of overweight or obese adolescents on the consumption of inflammatory and anti-inflammatory foods

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ABSTRACT

Background: Being overweight is a significant public health problem. Due to the complexity of obesity in adolescence, the treatment in health recovery must be interdisciplinary.

Goals: the present study aimed to investigate the effects of an interdisciplinary intervention program in overweight adolescents on the consumption of inflammatory and anti-inflammatory foods.

Methods: the project lasted 14 weeks and was divided into three stages: recruitment of participants and initial assessments; interdisciplinary interventions, which included the simultaneous participation of their parents and, finally, the reassessments. Food intake was measured at the beginning and end of the interventions using a three-day food record. The average values of calories and nutrients were used to generate the Dietary Inflammatory Index (DII®), a numerical score that assesses a diet for its effect on several biomarkers linked to inflammation. For the categorization of the DII®, high values (+1) for the pro-inflammatory effect and lower values (-1) for the anti-inflammatory effect were considered. For all analyses, a $p<0.05$ was considered.

Results: The consumption of carbohydrates, lipids, total cholesterol, and saturated fat was reduced ($p<0.05$). On the other hand, there was an increase in the consumption of fiber, proteins, and vitamins A, D, E, B3, B6, B9, B12, and C, in addition to an increase in the consumption of iron, selenium, magnesium and zinc ($p<0.05$). The level of inflammation in IBD was significantly decreased for saturated fat, vitamins B6, B9, and C, as well as magnesium ($p<0.05$).

Conclusion: Based on the results, the interdisciplinary intervention promoted a positive response with reduced lipids, total cholesterol, saturated fat, and reduced inflammatory food. New interventions with large groups and different samples are recommended to encourage possible extrapolation of our findings.

KEYWORDS

Parental influence, lifestyle changes, nutritional education, eating patterns, family programs.

INTRODUCTION

Adolescence is a complex period of human development in which young people are susceptible to unhealthy behaviors, such as physical inactivity and an unbalanced diet[1]. Given the great vulnerability of this group, it is noteworthy that the prevalence of overweight has increased epidemically in the last four decades and currently represents a major public health problem in the world[2]. The 2021 Food and Nutrition Surveillance System revealed that 19.75% of adolescents in Brazil showed overweight and obesity[3]. Being overweight contributes to health and biopsychosocial complications both immediately and in the long term. Therefore, the prevention of obesity is a public health issue[4]. According to Neves *et al.*[5],

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the advancement of technology has allowed the time spent on social media, *games,* and in front of the television to skyrocket. Associated with this fact, the increase in hypercaloric diets and greater access to ultra-processed foods rich in fats and carbohydrates contributed to the worsening of the problem. In addition to being a crucial factor in perpetuating obesity, poor diet also influences inflammatory responses. Some nutrients are known to contribute to the development of chronic low-grade inflammation[6].

Dietary patterns characterized by higher consumption of red and processed meats, fried foods, and lower intake of whole grains contribute to higher rates of inflammatory markers. Meanwhile, a diet rich in fruits and vegetables has been recommended to combat oxidative stress, decrease pro-inflammatory mediators, and increase the spectrum of immune cells[7]. Cavicchia *et al.*[8], described the Dietary Inflammatory Index (DII®) to evaluate the inflammatory potential of diet. This index was improved and validated by Shivappa *et al.*[9] and aims to establish a quantitative classification of foods' anti-inflammatory and inflammatory potential, which are currently associated with a series of outcomes, including cancer, metabolic syndrome, and asthma[9,10].

To this end, in 2010, a literature search was conducted using 1,943 peer-reviewed articles to find nutrients and food bioactives that affect the levels of inflammation markers, such as interleukin-1b, interleukin-4, interleukin-6, iInterleukin-10, tumor necrosis factor-a, and C-reactive protein. Each of the 45 substances found was assigned a score. Negative values suggest that the meal or food intake may have anti-inflammatory effects, while positive values indicate inflammatory effects[9]. It should be noted that interdisciplinary intervention promotes adolescent health and improves psychological, nutritional, social, body composition, and biochemical parameters[11]. It is also noteworthy that the family exerts a primary influence on the formation of eating habits and can directly influence the choices of adolescents[12].

It is also known that studies using the DII® directed to adolescents are scarce[13]. In this sense, this study aimed to investigate the effects of an interdisciplinary intervention program on adolescents' consumption of inflammatory and anti-inflammatory foods in overweight adolescents.

METHODOLOGY

This is a pre-experimental, descriptive, analytical study with a non-probabilistic sample, and the interdisciplinary intervention project took place at Cesumar University (UniCesumar) on the premises of the Laboratory of Interdisciplinary Intervention in Health Promotion (LIIPS) and the institution's multi-sport complex. The population consisted of overweight adolescents enrolled in the Obesity Treatment Project, living in Maringa, Parana, Brazil. Adolescents enrolled in the Obesity Treatment Project who met the following inclusion criteria were invited to participate in the study: a) age greater than or equal to 10 years up to 19 years[14]; b) overweight as determined by the body mass index for age (BMI/A) when Z-score ≥ +1, cut-off point adapted from the Food and Nutrition Surveillance System - SISVAN[14] and c) availability to participate in theoretical-practical interventions 3x a week. The exclusion criteria were: a) use of glucocorticoids and/or psychotropic medications that can regulate appetite; b) attendance lower than 75% in the different theoretical-practical activities carried out; c) musculoskeletal limitations that would prevent the regular and systematic practice of physical exercises; d) participation in another nutritional orientation program or other physical exercise proposals, as well as the performance of a low-calorie, *low-carb* or *low-fat* diet. After the project was publicized on social media, 67 adolescents signed up to participate in it; however, 13 (19.40%) did not meet the inclusion criteria, and 33 (49.25%) had a frequency lower than 75% or dropped out of the project, resulting in 21 (31.35%) participants in the research (Figure 1).

Regarding the ethical issues, this study was approved by the Research Ethics Committee of UniCesumar, with opinion number 4.913.453/2021. The research followed all the recommendations proposed by resolution 466/2012 of the Ministry of Health of the Brazilian Government and the Declaration of Helsinki.

The project took place in the second half of 2021, on Mondays, Wednesdays, and Fridays, for 14 weeks, i.e., one week of assessments, 12 weeks of intervention, and one week of reassessments. The interventions were carried out in groups and simultaneously in the presence of adolescents and their parents/guardians. Physical education, nutrition, and psychology professionals participated. Physical exercises were performed three times a week for 60 minutes, nutrition education sessions twice a week, and cognitive-behavioral therapy sessions once a week lasting 20 minutes each. Figure 1 presents the flowchart diagram of the present study.

The adolescents were recruited through posters and pamphlets in schools and Basic Health Units (BHU) in Maringa and pediatric clinics. The study was disseminated on the social networks of Instagram and Facebook of health professionals and LIIPS, in addition to dissemination on websites, television, and radio programs. After recruiting the participants, an initial meeting was scheduled to explain the technical procedures of the research project to all those interested in participating, along with their guardians.

Nutritional status was assessed by calculating body mass index (BMI). Height was measured using a standard stadiometer (Sanny®, São Paulo, Brazil). Next, body weight was measured using a mechanical scale (Welmy®, São Paulo, Brazil) with a 150 kg capacity and an accuracy of 100 g. Subsequently, BMI was calculated, in which body weight (BW) in kilograms was divided by height (H) in meters squared ($BMI = BW/(H^2)$). For

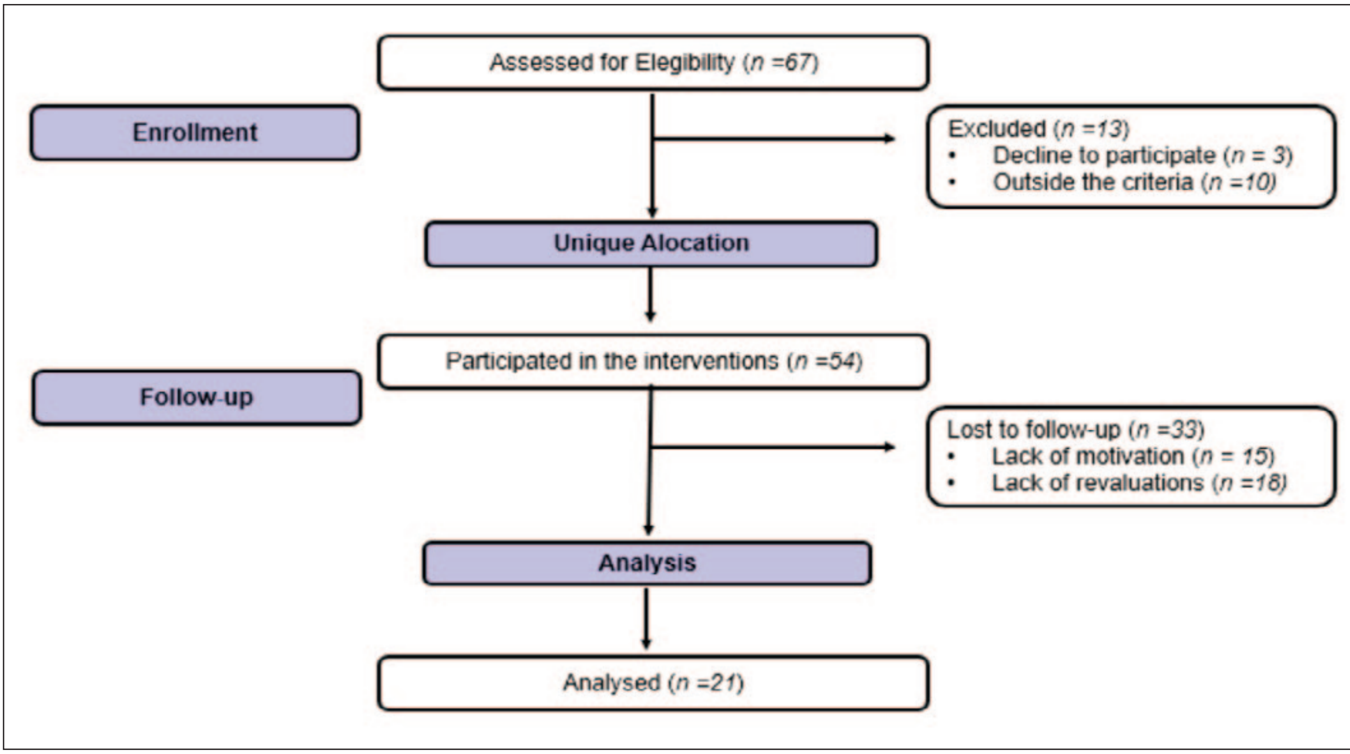

Figure 1. Flowchart diagram of the participants of the present study

adolescents, the World Health Organization (WHO) z-score tables for BMI/A were used[14,15]. Nutritional status was classified using the following cut-off points: Z-score ≥ +1 and < Z-score +2 (indicative of overweight), Z-score ≥ +2 (indicative of obesity). For analysis, overweight refers to the sum of the overweight and obesity classifications for the BMI/H index.

Food intake was measured in all adolescents at the beginning and end of the interventions using a three-day food record. The adolescents were instructed to write down all their meals during three non-consecutive days, two days during the week and one day on the weekend, and to fill in all the food and the appropriate quantities in detail (via home measurements), using measuring utensils, or to provide the best estimate of the portion size if they were away from home. In addition, all participants were told to specifically detail each food item, such as brand or restaurant names and labeling of specific items. To this end, support material was delivered for information on household measures and the correct completion of the food record. Finally, to help the adolescents, theoretical classes were held at the beginning of the project and in the final collections on how to fill in the material and what the homemade measurements are.

With the food records collected, the macro and micronutrients ingested were calculated using the Avanutri software (2004® version, Avanutri Equipamentos de Avaliação Ltda, Três Rios, Rio de Janeiro, Brazil). To estimate β-carotene and flavonoids (flavonol-3-ol, flavones, flavonols, flavonoids, anthocyanidins, and isoflavones), we used the Rodriguez-Amaya[16] and PhenolExplorer[17] databases, respectively.

The mean values of the three days of the food records were used in the pre- and post-intervention moments of the following nutrients: carbohydrates, proteins, total fats, fiber, cholesterol, saturated fat, monounsaturated fat (omega 9), polyunsaturated fats (omega 3 and omega 6), vitamins (A, B1, B3, B6, B9, B12, C, D, E), minerals (iron, magnesium, zinc, selenium) and flavonoids (flavonol-3-ol, flavones, flavanol's, flavonoids). The responses of the food registry, such as total intake of macronutrients, micronutrients, flavonoids, and calories, were subsequently tabulated in the Excel program (version 2013, Microsoft, United States of America.

The mean values of calories and nutrients consumed by each adolescent, found through the three-day food record, were used to create the DII® of the present study. The DII® was calculated using a scoring algorithm based on a review of 1,943 articles linking 45 dietary parameters and six inflammatory biomarkers (IL-1β, IL-4, IL-6, IL-10, TNF-α, and C-reactive protein). To calculate the IDI®, we used the global mean and the standard deviation developed for the global composition database, which was derived from 11 countries, including 4 Asian countries, mentioned in the study by Shivappa[9]. The calculation of the DII® is explained in Figure 2. Thus, the values obtained were used to create a DII® score for each participant. With the values found, the

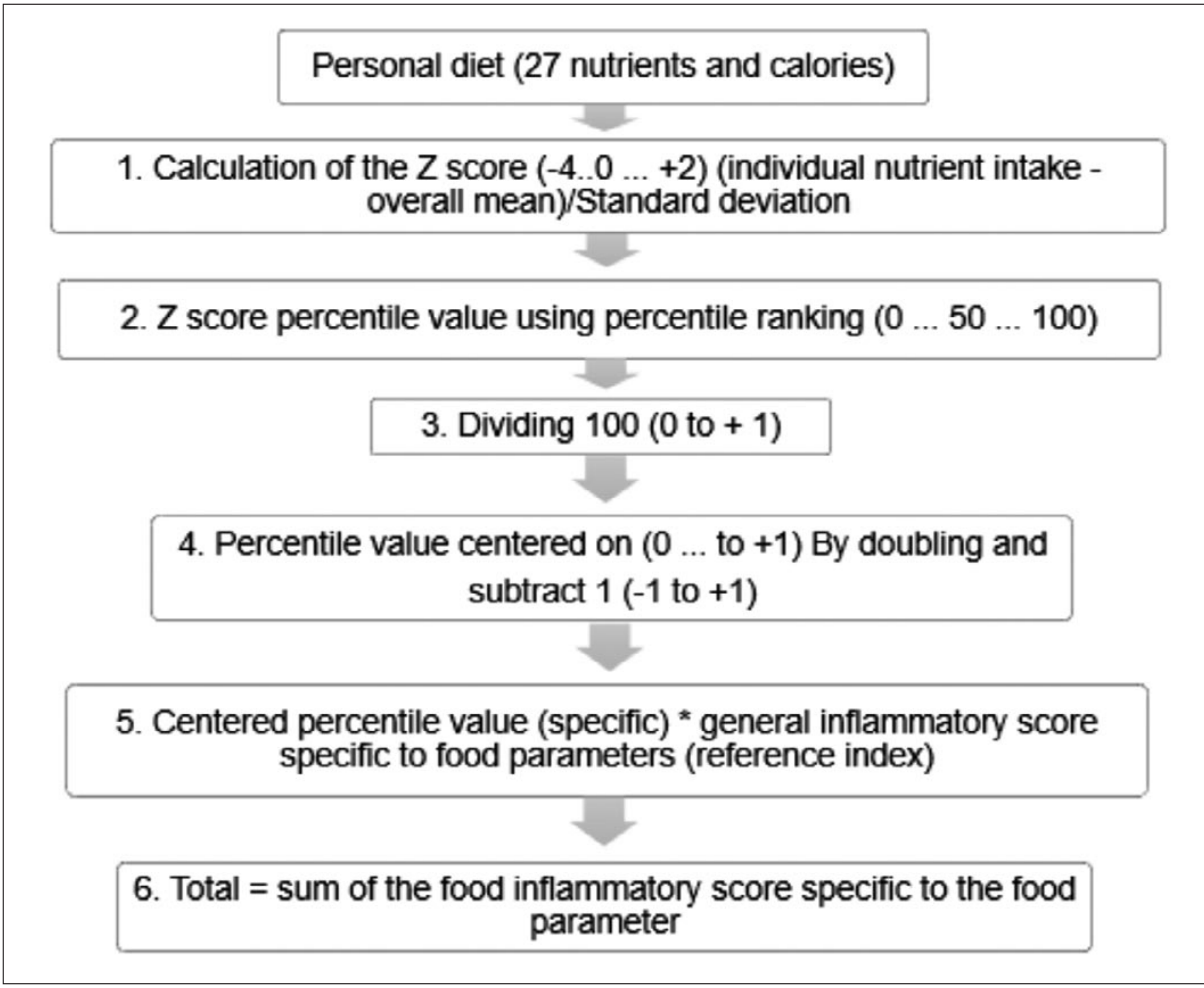

Figure 2. Flowchart of the stages of the calculation of the inflammatory index of the diet (DII®)

percentile value was converted to 10°, 25°, 50°, 75° and 90° in the SPSS statistical software.

Subsequently, the percentiles were divided by 100 to calculate the 0-1 score. After converting the centered percentile score, which ranged from -1 to +1 for each food parameter, it was multiplied by the overall food-specific inflammatory parameters of the worldwide effect score. The present study used the following 27 components: calories, carbohydrates, fiber, proteins, total lipids, cholesterol, saturated fat, monounsaturated fat, polyunsaturated fat, vitamins (A, D, E, B1, B2, B3, B6, B9, B12, C), minerals (iron, selenium, magnesium, zinc) and antioxidants (flavonol-3-ol, flavones, flavanol's, flavonoids). Figure 2 presents the flowchart of the stages of calculating the DII®.

Data were presented as mean and standard deviation (SD) after testing for normality using the Shapiro-Wilk test. A paired t-test was used to compare the pre- and post-intervention moments. All analyses assumed a significance level of 5%. Statistical analyses were performed using SPSS version 20.0 (IBM, United States of America).

RESULTS

Of the 21 adolescents evaluated, 11 (52.38%) were male. Regarding nutritional status, according to BMI/A, it is noteworthy that 12 (57.14%) adolescents were classified as obese and 9 (42.86%) as overweight, both in the pre- and post-intervention moments. When evaluating food intake, it was found that the intake of carbohydrates, total lipids, cholesterol, and saturated fat was significantly reduced in the post-intervention moment, and on the other hand, fiber, protein, vitamins A, D, E, B3, B6, B9, B12 and C and the minerals iron, selenium, magnesium, and zinc, increased significantly after the 12 weeks of intervention. Also noteworthy is the reduced calorie intake and increase in polyunsaturated fats, flavonol-3-ol, flavones, flavanol, and flavonoids in the post-intervention moment, but without statistical significance. Table 1 compares adolescents' dietary consumption of certain nutrients pre- and post-intervention moments.

Regarding the analysis of the DII®, according to Table 2, the general DII®, DII® for calories, DII® for cholesterol, and polyunsaturated fat did not present significant differences after the 12 weeks of intervention (*p*>0.05). However, they became less inflammatory. The DII® for calories, total lipids, and saturated fat was shown to be anti-inflammatory in the

Table 1. Comparison between adolescents' dietary consumption of certain nutrients pre- and post-intervention moments

Nutrient	Pre-intervention		Post-intervention		*p-value*
	Mean	Dp	Mean	Dp	
Calories (kcals)	1555.02	788.19	1394.11	632,09	0.1157
Carbohydrate (g)	180.77	101.53	164.50	79.38	0.0286*
Fibers (g)	10.88	8.80	15.43	9.90	0.0001*
Proteins (g)	76.89	42.33	80.88	29.49	0.0286*
Total lipids (g)	61.99	35.02	47.78	25.49	0.0013*
Cholesterol (mg)	442.39	384.15	346.12	181.36	0.0011*
Saturated fat (g)	23.60	11.31	16.31	7.67	0.0001*
Monounsaturated fat (g)	18.04	10.28	14.66	9.02	0.3008
Polyunsaturated fat (g)	10.05	7.01	10.65	8.27	0.0921
Vitamin A (mcg)	396.73	239.29	447.76	258.42	0.0187*
Vitamin D (mcg)	2.644	34.94	11.3	2.41	0.0421*
Vitamin E (mg)	5.40	4.38	8.55	7.21	0.0001*
Vitamin B1 (mg)	1.16	0.70	1.00	0.55	0.6742
Vitamin B2 (mg)	1.23	0.62	1.29	0.78	0.1152
Vitamin B3 (mg)	7.54	10.83	10.46	14.03	0.0001*
Vitamin B6 (mg)	1.00	0.58	1.33	0.66	0.0002*
Vitamin B9 (mcg)	106.67	83.89	228.28	232.16	0.0001*
Vitamin B12 (mcg)	2.29	2.00	5.36	8.15	0.0001*
Vitamin C (mg)	66.04	97.53	95.63	112.24	0.0001*
Iron (mcg)	10.48	4.53	14.20	6.59	0.0001*
Selenium (mcg)	49.94	27.52	64.03	34.92	0.0001*
Magnesium (mg)	136.69	71.25	194.69	98.52	0.0001*
Zinc (mg)	7.89	4.58	9.68	5.25	0.0061*
Flavonol-3-ol (mg)	4.50	5.87	10.35	18.58	0.3910
Flavones (mg)	2.43	3.59	7.27	17.39	0.9854
Flavonols (mg)	58.59	70.41	120.23	359.42	0.3591
Flavonoids (mg)	93.98	107.78	152.85	375.24	0.8469

kcals = calories; g = grams; mcg = micrograms; Dp = standard deviation; * = significant difference = p<0.05.

Table 2. General Dietary Inflammatory Index (DII®) in adolescents in pre- and post-intervention moments

DII® for Caloriesand macronutrients	Pre-intervention	Post-intervention	*p-value*
General DII®	2.25 ± 1.57	2.12 ± 1.89	0.5000
Calories	-0.08 ± 0.14	-0.12 ± 0.11	0.2708
Carbohydrate	-0.06 ± 0.06	-0.06 ± 0.06	0.5000
Fibers	0.44 ± 0.41	0.44 ± 0.41	0.5000
Proteins	0.00 ± 0.02	0.00 ± 0.02	0.2721
Total Lipids	-0.08 ± 0.25	-0.16 ± 0.19	0.0912
Cholesterol	0.02 ± 0.09	0.01 ± 0.09	0.3326
Saturated Fat	-0.12 ± 0.24	-0.27 ± 0.14	0.0076*
Monounsaturated fat	0.10 ± 0.13	0.14 ± 0.11	0.1313
Polyunsaturated fat	0.18 ± 0.22	0.17 ± 0.24	0.4649

DII®: Dietary Inflammatory Index; ± = standard deviation; * = significant difference = $p<0.05$.

Table 3. Dietary Inflammatory Index (DII®) for consuming vitamins, minerals, and antioxidants before and after the 12 weeks of intervention of the adolescents

DII® for Vitamins, Minerals and Antioxidants	Pre-intervention	Post-intervention	*p-value*
Vitamin A	0.28 ± 0.09	0.26 ± 0.10	0.2366
Vitamin D	0.35 ± 0.26	0.31 ± 0.20	0.4103
Vitamin E	0.25 ± 0.32	0.11 ± 0.39	0.0560
Vitamin B1	0.05 ± 0.05	0.06 ± 0.04	0.3436
Vitamin B2	0.02 ± 0.03	0.02 ± 0.04	0.4699
Vitamin B3	0.18 ± 0.11	0.15 ± 0.14	0.1360
Vitamin B6	0.14 ± 0.17	0.04 ± 0.20	0.0370*
Vitamin B9	0.16 ± 0.08	0.09 ± 0.15	0.0091*
Vitamin B12	-0.05 ± 0.09	-0,07 ± 0,05	0.0931
Vitamin C	0.24 ± 0.28	0,12 ± 0,32	0.0015*
Iron	0.01 ± 0.13	-0.01 ± 0.02	0.1814
Selenium	0.07 ± 0.31	0.05 ± 0.11	0.0594
Magnesium	0.25 ± 0.21	0.15 ± 0.21	0.0296*
Zinc	0.30 ± 0.01	0,07 ± 0.26	0.1181
Flavonol-3-ol	0.28 ± 0.61	0.15 ± 0.05	0.3983
Flavones	0.10 ± 0.46	-0.15 ± 0.61	0.4767
Flavonols	0.06 ± 0.25	-0.15 ± 0.61	0.2888
Flavonoids	0.01 ± 0.13	-0.09 ± 0.23	0.4124

DII®: Dietary Inflammatory Index; ± = standard deviation; * = significant difference = p<0.05.

pre-intervention moment. After 12 weeks, the DII® values became more anti-inflammatory, but only significantly for saturated fat ($p<0.05$). On the other hand, the DII® for monounsaturated fat became more inflammatory. Table 2 presents DII® in adolescents in pre- and post-intervention moments.

The data in Table 3 show that although the DII®s are still inflammatory after the intervention, there was an improvement for vitamins (A, D, E, B3, B6, B9, and C), minerals (selenium, magnesium, and zinc) and antioxidants (flavonol-3-ol), but significantly for B6, B9, C, and magnesium ($p<0.05$). There was an improvement in the DII® of vitamin B12, which has already started to be anti-inflammatory. The mineral iron and the antioxidants flavones, flavanol, and flavonoids started inflammatory and became anti-inflammatory, but without significance ($p>0.05$). The DII® for vitamin B1 became more inflammatory after the 12 weeks of intervention ($p<0.05$). Table 3 presents DII® for consuming vitamins, minerals, and antioxidants before and after the 12 weeks of intervention of the adolescents.

DISCUSSION

Regarding the analysis of the general DII®, it was found that it became less inflammatory after the 12 weeks of intervention, although without statistical significance. This finding is relevant because adolescents who are overweight and obese have a dietary pattern with high inflammatory potential[18]. It was also evidenced that nutritional education contributed to reduced caloric intake and a less inflammatory DII® of calories. Although not statistically significant, these results are positive since the recommended treatments for overweight people should include a healthy eating pattern promoting a calorie deficit associated with regular physical activity to induce weight loss[19].

As for carbohydrate intake, the significant reduction in the consumption of this macronutrient stands out. Soft drinks are among the main sources of simple carbohydrates in adolescents' diets. Due to their high caloric content, these beverages favor the development of obesity[20]. By inducing significant weight gain, sweetened beverages also contribute to the development of type 2 diabetes mellitus and a higher risk of cardiovascular disease. In addition, the high and habitual consumption of refined carbohydrates correlates with inflammatory stages and chronic diseases[21].

Twelve weeks of intervention contributed to a significant increase in protein intake. In the short term, a diet with higher protein levels helps more effectively with weight loss. It is believed that the mechanisms that support the effects of proteins on the efficacy of weight loss are related to increased satiety and resting metabolic rate[22]. Other favorable results after the interventions include significantly reducing total lipids, saturated fat, and cholesterol consumption. Saturated fatty acids induce greater insulin resistance and increased gene expression related to adipose tissue inflammatory pathways. Excessive consumption of saturated fat also elevates total cholesterol, *low-density lipoprotein,* and *high-density lipoproteins.* However, the observed elevation in HDL-c may not be sufficient to overcome the deleterious effects of LDL-c on cardiovascular risk. In addition, by modulating the transcription factors involved in the synthesis of lipogenic enzymes, saturated fatty acids favor the synthesis of triglycerides[23].

On the other hand, there was an increase in the consumption of omega-3 polyunsaturated fatty acids. This nutrient can potentially alter the production of pro- and anti-inflammatory cytokines, reducing inflammatory markers and platelet aggregation, improving endothelial function, and reducing blood pressure and triglyceridemia[23]. It is important to note that the results of the study by Pereira *et al.*[19], in overweight adolescents also showed a reduction in total caloric intake, carbohydrates, and lipids at the end of 20 weeks of intervention. The authors also showed that long-term interdisciplinarity, with therapy combined with education, contributed to reducing obesity and associated inflammatory processes.

Therefore, the increases in the intake of fiber, vitamins (A, D, E, B3, B6, B9, B12, and C), minerals (iron, selenium, magnesium, and zinc), and antioxidants (flavonol-3-ol, flavones, flavanol's and flavonoids) found in this study are considered favorable. Mendes *et al.*[7], state that eating habits rich in fruits and vegetables, as they are rich in fiber, vitamins, minerals, and antioxidants, help combat oxidative stress, being recommended to reduce the levels of pro-inflammatory mediators and improve immune cells. These authors conclude that a healthy lifestyle can modify oxidative stress and systemic inflammation.

Flieh et al.[24] report that ultra-processed foods are increasingly present in adolescents' diets. These foods, besides having high energy density and contributing to obesity, are low in vitamins, minerals, and fiber and are considered inflammatory foods. In addition, unhealthy eating patterns, such as the Western diet, high in fat and refined carbohydrates, are usually associated with higher concentrations of inflammatory markers, while healthy eating patterns, such as the Mediterranean diet, rich in fish, fruits, and vegetables, are associated with lower levels of inflammation[25].

Given the data exposed, it was found that the 12 weeks of interdisciplinary intervention contributed favorably to most of the nutrients evaluated, but regarding the DII® of the saturated fat, vitamins B6, B9, C, and magnesium became significantly less inflammatory. Pear tree *et al.*[18], argue that the results from the calculation of the DII® can be used to improve health conditions in obese adolescents. Borges *et al.*[26], also reaffirm the importance of using the DII® in research with obese adolescents, emphasizing that the higher the consumption of fast food, biscuits, and crackers, the more inflammatory the DII® is.

Finally, guidelines for preventing and treating childhood obesity must be based on lifestyle changes. Parental involvement and intensive follow-up are essential factors for a positive treatment outcome. Progress in combating childhood obesity has been slow and inconsistent. Investing in access and treatment possibilities and acting in prevention are necessary and urgent measures[27].

CONCLUSION

In conclusion, the interdisciplinary intervention performed for 12 weeks in overweight/obese adolescents reduced carbohydrate, lipid, total cholesterol, and saturated fat consumption after the intervention. Besides that, there was an improvement in vitamins A, D, E, B3, B6, B12, and C consumption and an improvement in iron, selenium, and zinc ingestion. After the interdisciplinary intervention, the DII® index reduced significantly for saturated fat, showing a positive impact on the adolescent's food consumption. It is well known that educating adolescents to consume anti-inflammatory foods can help maintain their health and well-being. Thus, it is hoped that this research will contribute to the increase of knowledge in the area and the interest of new studies, considering that few interdisciplinary projects with their respective heads have investigated inflammatory food consumption in adolescents. Thus, it is encouraged to invest in low-cost longitudinal intervention models to improve the quality of life of the young population through physical exercises and good choices for a healthy diet, reaching more and more adolescents who need a health promotion program. Finally, new studies with probabilistic samples, other age groups, and a control group could be relevant to driving assertive actions in health nutrition and health promotion.

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