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Interrelationship among body mass index, body composition, and biochemical profiles of overweight adolescents in south of Brazil: A cross-sectional study

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ABSTRACT

Introduction: Obesity in adolescence is associated with severe health complications.

Objective: To analyze possible associations among body mass index (BMI), body composition, and biochemical profiles of overweight or obese adolescents.

Methods: The study was carried out between 2017 and 2020 and included 132 adolescents aged 10 to 18 years. The following variables were analyzed: BMI, fat-free mass (FFM), body fat mass (BFM), skeletal muscle mass (SMM), body fat percentage (%BF), waist-to-hip ratio (WHR), lean mass index (LMI), fat mass index (FMI), and fat-to-lean mass ratio (FMR), as well as total cholesterol (TC), high-density lipoprotein (HDL-c), low-density lipoprotein (LDL-c) and glutamic-oxaloacetic transaminase (TGO). The variables were compared between the sexes, and correlated among them, assuming a $p<0.05$.

Results: Higher values were identified for height, LBM, FFM, and SMM in the male group ($p<0.05$). On the other hand, higher values were identified for the %BF and FMI in the female group ($p<0.05$). The female, male, and general groups showed significant correlations between BMI and FMR ($r = 0.69$, 0.74, and 0.69, respectively; all with $p<0.05$), BMI and FFM ($r = 0.44$, 0.67, and 0.49, respectively; all with $p<0.05$), BMI and SMM ($r = 0.44$, 0.68, and 0.50, respectively; all with $p<0.05$), and BMI and %BF ($r = 0.40$, 0.54, and 0.47, respectively; all with $p<0.05$). In the general group, BMI and HDL levels were correlated ($r = -0.18$; $p=0.04$). The BFM and WHR showed a predictive effect for TC; WHR and %BF showed a predictive effect for LDL concentrations, and %BF had a predictive effect for TGO ($p<0.05$).

Conclusions: The differences between the sexes was expected. It was possible to verify that BMI, body composition, and biochemical measures show an interrelationship between them, such as with a worsening of anthropometric and body composition indicators associated with worst biochemical parameters, e.g., lower HDL-c and higher TC, LDL-c, and TGO. Thus, public policies are indispensable for combating obesity and related comorbidities in the early phases of life.

KEYWORDS

Delivery of Health Care, Adolescent health, Obesity, Biomarkers, Cardiometabolic Risk Factors.

INTRODUCTION

Adolescence is the phase between childhood and adulthood; data from the 2010 Demographic Census showed that 17.9% of the Brazilian population are adolescents[1]. Overweight and obesity in the young population have tripled in the last three decades, becoming a public health concern[2]. The Food and Nutrition Surveillance System of 2021 in Brazil revealed that 19.75% of adolescents were overweight/obese[2]. Obesity is considered one of the biggest global health problems. Early in children and adolescents increase damage, and health problems in adulthood, such as

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systemic arterial hypertension (SAH), cardiovascular diseases, dyslipidemia, type 2 diabetes mellitus (T2DM), and non-alcoholic fatty liver disease (NAFLD)[3]. Therefore, obese adolescents will probably remain overweight in adulthood, exposing them to metabolic complications during aging[3]. The World Health Organization[4] defines obesity as a chronic disease characterized by the accumulation of body fat associated with health risks, whereby adolescents within the 85th to 95th percentile are classified as overweight, and those above the 95th percentile are classified as obese[4].

In fact, overweight and dyslipidemia are determining factors for developing cardiovascular diseases, accounting for 31% of deaths in Brazil[5]. Dyslipidemia is a metabolic disorder of lipoproteins characterized by increased levels of total cholesterol (TC), low-density lipoproteins (LDL-c), triglycerides (TG), and decreased levels of high-density lipoproteins (HDL-c)[6]. NAFLD, which has an estimated global prevalence of 25% in the general population and reaches 75% in the young obese population, depending on the method of diagnosis, is also associated with obesity[7]. This disease is characterized by excessive fat accumulation in the liver without alcohol consumption. To screen for this disease, ultrasonography and liver biomarker tests: pyruvic transaminase (TGP), and glutamic-oxaloacetic transaminase (TGO) are recommended[7]. Biomarkers are responsible for 70% of medical decisions. Therefore, laboratory tests can assist in diagnosing, prognosis, and preventing numerous diseases[8]. Because of this, the current study aimed to analyze the profile of adolescents undergoing a project to prevent obesity through understanding the correlation between body mass index, body composition variables, liver biomarkers, and cardiometabolic risk in overweight or obese adolescents.

METHODS

Study design

This analytical cross-sectional study was conducted between 2017 and 2020 and included 132 adolescents (71 females and 61 males) aged 10–18 years, entering an interdisciplinary program focused on health promotion, carried out by the Interdisciplinary Intervention Laboratory team in Health Promotion (LIIPS/UniCesumar) located in Maringá, Paraná, Brazil. The sample size was estimated at 98 participants utilizing the software G*power (Dusseldorf, Germany) and adopting a power of 80% (1-β = 0.80).

The participants were instructed about the research objective, and all agreed to participate voluntarily in the project and signed the consent form. Parents or guardians also signed an informed consent form. Data collections were carried out between March to May 2017 and 2020. The study was approved by the Ethics and Research Committee of the UniCesumar (number: 3.837.408). The inclusion criteria with the following: (i) aged between 10 to 18 years, (ii) enrolled in local or state school systems, and (iii) overweight or obese (BMI ≥ 85th percentile). The exclusion criteria were: the use of psychotropic drugs and/or appetite regulators. In addition, no adolescents presented with T2DM or SAH.

Anthropometry

Height was measured using a fixed stadiometer coupled to the wall (Sanny Standard®, São Paulo, Brazil). Waist circumference (WC, cm) and hip circumference (HC, cm) were measured using a flexible metal anthropometric tape (Cescorf®, Porto Alegre, Brazil). Waist and hip perimeters were used to calculate the waist-to-hip ratio (WHR) using the formula: WHR = WC / HC.

Body composition

Body composition was determined using eight tactile points through multi-frequency bioelectrical impedance analysis (Inbody® 570, Body Composition Analyzers, Seoul, South Korea). The study participants complied with the following protocol to obtain body composition measures: (i) fasting for four hours; (ii) not having used diuretic medications in the previous seven days; (iii) not having consumed alcoholic beverages in the previous 48 h; (iv) not having practiced intense physical exercise in the previous 24 h; (v) urinating at least 30 min before the examination, and (vi) remaining at absolute rest for 8 to 10 min before the measurement. The following variables were used: body weight (BW, kg), body mass index (BMI, kg/m^2), fat-free mass (FFM, kg), lean body mass (LBM, kg), body fat mass (BFM, kg), body fat percentage (%BF, %), and skeletal muscle mass (SMM, kg). Based on LBM and BFM, the following body variables were computed: lean mass index (LMI) [LBM (kg) / height (m)^2], fat mass index (FMI) [BFM (kg) / height (m)^2], and fat-to-lean mass ratio (FMR) [BFM (kg) / LBM (kg)][9].

Biochemical variables

Blood samples were collected, centrifuged, and Mhlab's automatic biochemistry and turbidimetry analyzer URIT 8021 was used to determine the following biochemical parameters: TGO, TGP, fasting glucose (GLU), TG, TC, HDL-c, and LDL-c. LDL-c levels were estimated by the Friedewald formula (LDL-c = TC HDL-c + TG/5). If the TG values were higher than 400 mg/dL, the formula of Martins or non-HDL cholesterol (LDL-c = TC HDL-c TG/x, where x oscillates from 3.1 to 11.9)[6] was used. The cut-off points used for lipid profiles were based on the values proposed by the Brazilian Society of Cardiology[6]. On the other hand, the cut-off values for liver enzyme levels were based on those proposed by the manufacturer of the Gold Diagnostic Analysis Kit[10]. Finally, the cut-off points for fasting blood glucose followed the guidelines of the Brazilian Society of Diabetes[11].

Statistical analysis

Initially, the data are presented as mean and standard deviation (SD). The normality test of Kolmogorov-Smirnov was realized to verify the distribution of data. The student's t-test was performed for independent samples to verify possible sex differences. Subsequently, Pearson's correlation was applied to body composition, anthropometric measurements, and biochemical markers (hepatic and cardiometabolic risk). The primary conditions for using multivariate data analysis techniques were tested: normality, linearity, homoscedasticity, and multicollinearity. After the tests, the violation of some premises (normality) was verified, and the data were adjusted using natural logarithms. After adjusting the data, the necessary conditions for using multiple linear regression techniques were achieved. We used the *enter* technique to force the most significant number of variables into the model and understand each relative and joint importance in explaining the phenomenon. The dependent variable was the serum biochemical parameters concentrations, as well as: GLU, TC, HDL, LDL, TG, VLDL, TGO, and TGP, and the independent variables included in the model were age, BMI, FFM, BW, BFW, SMM, WHR. These were not included in the model because they did not increase the percentage of variance determined for the model and LBM and BFM variables. The data showed the values of the predictive effect of the independent variable over the dependent variable on the angle of equation (β), values of hypothesis test (t), the significance of test (p), and interval confidence of 95% (IC95%). Statistical analyses were performed using SPSS® version 20.0, with a statistical significance of 5% ($p < 0.05$).

RESULTS

The analysis of results showed the mean age was 13.5 ± 2.6, 13.4 ± 2.4, and 13.6 ± 2.7 years old for the general, male, and female groups, respectively, with no significant sex differences in this regard ($p = 0.74$). As seen in Table 1, higher values were identified for height, LBM, FFM, and SMM in the male group than in the female group ($p < 0.01$). On the other hand, higher values were identified for the %BF and FMI in the female group than in the male group ($p < 0.01$). However, no significant differences were observed in the other variables, such as body weight ($p = 0.42$), BMI ($p = 0.47$), BFM ($p = 0.16$), WHR ($p = 0.53$), LMI ($p = 0.14$), and FMR ($p = 3.83$).

Biochemical examinations remained within normal ranges, although low HDL-c levels were found. In addition, no significant differences were observed between the sexes in fasting glucose, TC, HDL-c, LDL-c, triglycerides, TGO, and TGP levels, all with $p > 0.05$.

Regarding the correlations tested between BMI and body composition variables, it was verified correlations between BMI and FMR (general, $r = 0.69$; female, $r = 0.74$; male, $r = 0.69$), BMI and FFM (general, $r = 0.49$; female, $r = 0.67$; male, r = 0.44), BMI and SMM (general, $r = 0.50$; female, $r = 0.68$; male, $r = 0.44$), and BMI and %BF (general, $r = 0.47$; female, $r = 0.54$; male, $r = 0.40$; all with $p < 0.01$; Table 2).

Table 1. Comparison between anthropometric and body composition variables between males and females

	Male (n = 61) Mean and SD	Female (n = 71) Mean and SD	*p*-value
Height (cm)	166.4 ± 11.7*	159.5 ± 8.5	***p* < 0.001***
Body weight (kg)	88.6 ± 22.6	85.5 ± 21.3	$p = 0.42$
BMI (kg/m^2)	32.7 ± 9.7	33.9 ± 7.6	$p = 0.47$
LBM (kg)	49.2 ± 11.7*	43.4 ± 8.6	***p* < 0.01***
FFM (kg)	52.3 ± 12.4*	46.0 ± 9.1	***p* < 0.01***
BFM (kg)	36.2 ± 12.9	39.5 ± 13.6	$p = 0.16$
SMM (kg)	28.9 ± 7.4*	25.3 ± 5.5	***p* < 0.01***
BF (%)	38.6 ± 7.2	43.3 ± 8.0*	***p* < 0.01***
WHR	0.8 ± 0.2	0.85 ± 0.2	$p = 0.53$
LMI	17.5 ± 2.2	16.9 ± 2.2	$p = 0.14$
FMI	12.9 ± 4.0	15.4 ± 4.7*	***p* < 0.01***
FMR	0.7 ± 0.2	0.9 ± 0.2	$p = 3.83$

Note: SD = standard deviation. BMI = body mass index. LBM = lean body mass. FFM = fat-free mass. BFM = body fat mass. SMM = skeletal muscle mass. BF% = body fat percentage. WHR = waist-hip ratio. LMI = lean mass index. FMI = fat mass index. FMR = fat-to-lean mass ratio. *significant difference between sexes = $p<0.05$. In this table, the t-test for independent groups was applied.

Regarding the correlations between BMI and biochemical variables, the correlation observed between BMI and HDL-c in the general group (r = −0.18; $p = 0.04$) is highlighted (Table 3).

The multiple linear regression model presented an r value of 0.948 and an R^2 value of 0.899. This equation demonstrates the excellent predictive capacity of the model since 89.90% of the variance can be explained by the variables inserted in the model.

To evaluate the predictive effects of anthropometric and body composition variables over the biochemical parameters in a multiple linear regression model was possible to identify significant responses, as well as: BFM (r = -0.114, $p = 0.288$; β = 1.543; $p = 0.041$) and WHR (r = 0.320, $p < 0.05$; β = 0.312; $p = 0.026$) to predictive effect over total cholesterol; BF% (r = -0.160, $p < 0.05$; β = -1.371; $p = 0.021$) and WHR (r = 0.412, $p < 0.05$; β = 0.326; $p < 0.001$) to predictive effect

Table 2. Groups separated the correlation between body mass index and body composition variables (general, female, and male)

Tested correlations	Correlation coefficient	*p*-value
General (n = 132)		
BMI and FMR	r = 0.69	***p* < 0.01***
BMI and WHR	r = 0.12	*p* = 0.17
BMI and FFM	r = 0.49	***p* < 0.01***
BMI and SMM	r = 0.50	***p* < 0.01***
BMI and %BF	r = 0.47	***p* < 0.01***
Female (n = 71)		
BMI and FMR	r = 0.74	***p* < 0.01***
BMI and WHR	r = 0.20	*p* = 0.08
BMI and FFM	r = 0.67	***p* < 0.01***
BMI and SMM	r = 0.68	***p* < 0.01***
BMI and %BF	r = 0.54	***p* < 0.01***
Male (n = 61)		
BMI and FMR	r = 0.69	***p* < 0.01***
BMI and WHR	r = 0.05	*p* = 0.68
BMI and FFM	r = 0.44	***p* < 0.01***
BMI and SMM	r = 0.44	***p* < 0.01***
BMI and %BF	r = 0.40	***p* < 0.01***

Note BMI = body mass index. FMR = fat-to-lean mass ratio. WHR = waist-to-hip ratio. FFM = fat-free mass. SMM = skeletal muscle mass. %BF = body fat percentage. *significant difference between sexes = p <0.01. In this table, Pearson's correlation was used.

over LDL concentrations; and %BF (r = -0.325, $p < 0.05$; β = -1.692, $p < 0.01$) to predictive effect over TGO (Table 4).

DISCUSSION

The main results of this study indicated higher values of height, LBM, FFM, and SMM in the male group than in the female group. In contrast, the %BF and FMI were higher in the female group. However, no significant differences were observed for the other variables, such as body weight, BMI, BFM, WHR, LMI, FMR, and biochemical variables.

Table 3. The correlation between body mass index and biochemical variables was separated by group (general, female, and male)

Tested correlations	Correlation coefficient	*P*-value
General (n = 132)		
BMI and GLU	r = 0.02	*p* = 0.79
BMI and TC	r = - 0.07	*p* = 0.39
BMI and HDL-c	r = - 0.18	***p* = 0.04***
BMI and LDL-c	r = - 0.03	*p* = 0.71
BMI and TG	r = 0.12	*p* = 0.16
BMI and TGP	r = -0.04	*p* = 0.70
BMI and TGO	r = -0.01	*p* = 0.91
Female (n = 71)		
BMI and GLU	r = 0.05	*p* = 0.69
BMI and TC	r = -0.19	*p* < 0.01
BMI and HDL-c	r = -0.16	*p* = 0.17
BMI and LDL-c	r = -0.15	*p* = 0.22
BMI and TG	r = 0.06	*p* = 0.60
BMI and TGP	r = -0.01	*p* = 0.95
BMI and TGO	r = -0.10	*p* = 0.45
Male (n = 61)		
BMI and GLU	r = 0.02	*p* = 0.85
BMI and TC	r = 0.01	*p* = 0.95
BMI and HDL-c	r = -0.20	*p* = 0.11
BMI and LDL-c	r = 0.06	*p* = 0.66
BMI and TG	r = 0.20	*p* = 0.12
BMI and TGP	r = -0.04	*p* = 0.78
BMI and TGO	r = 0.19	*p* = 0.17

Note: BMI = body mass index. GLU = fasting glucose. TC = total cholesterol. HDL-c = high-density lipoproteins. LDL-c = low-density lipoproteins. TG = triglycerides. TGP = pyruvic transaminase. TGO = glutamic-oxaloacetic transaminase. *significant difference between sexes = p<0.05. In this table, Pearson's correlation was used.

Table 4. Linear multiple regression to the predictive effect of anthropometric and body composition variables over the biochemical parameters in overweight adolescents

TC	β	t	*P*-value	IC95%
BFM	1.543	2.062	**0.041***	0.062; 3.023
WHR	0.312	2.246	**0.026***	0.037; 0.587
LDL	**β**	**t**	***P*-value**	**IC95%**
%BF	-1.371	2.797	**0.021***	-2.535; -0.207
WHR	0.326	2.797	**0.006***	0.095; 0.557
TGO	**β**	**t**	***P*-value**	**IC95%**
%BF	-1.692	-2.508	**0.014***	-3.030; -0.354

Note: TC = total cholesterol. BFM = Body fat mass. WHR = waist-to-hip ratio. LDL = low-density lipoprotein. %BF = body fat percentage. TGO = glutamic-oxaloacetic transaminase. β = angle of the equation. t = values of the hypothesis test. IC95% = interval confidence of 95%. * = Significance of the test ($p < 0.05$).

Regarding the correlations, BMI was correlated with FMR, FFM, SMM, and %BF in the general, female, and male groups. Considering the correlations with the biochemical variables, only the general group presented a correlation between BMI and HDL-c levels. Friedemann et al.[12] highlighted that adolescents with a high BMI showed higher serum changes in TG and HDL-c levels than normal-weight adolescents. However, the present study demonstrated a negative correlation between BMI and HDL-c levels, decreasing high-density lipoprotein levels as BMI increased. Higher HDL-c is a negative risk factor for cardiovascular events, and its plasma level is inversely related to the incidence of cardiovascular events, overcoming the prevalence of hypercholesterolemia[6].

Studies have shown that BMI is the optimal anthropometric indicator for identifying risk factors for cardiovascular events in the young population[13,14]. However, it should be used with caution because it cannot distinguish the changes in body composition[15]. Therefore, determining the HDL-c level is a critical anti-atherogenic factor because this cholesterol fraction extracts LDL-c from the arteries to the liver, where it is metabolized and excreted[6]. Therefore, circulating HDL-c levels must be above the cut-off value of 45 mg/dL[6]. However, values lower than the established cut-off points were observed in the present study, corroborating the increase in the cardiometabolic risk affecting children and adolescents[16]. This demonstrates that, in overweight individuals, early identification of biochemical and body composition alterations should be prioritized to prevent the risk of developing cardiovascular diseases that can be aggravated in adulthood[8]. Thus, improving the different body composition variables (decrease in BFM and increase in LBM) has been an effective strategy in treating obesity because the amounts of FFM and FM vary with weight loss or gain[15].

The LBM values were higher in the male group than in the female group, which lower levels of physical activity may explain and a higher prevalence of a sedentary lifestyle among female adolescents, consistent with the findings reported by Galan-Lopez et al.[17]. Additionally, the sexual maturation process between the sexes possibly influences LBM due to the changes in the secretion pattern of some hormones, as affected by the activation of the gonadal–hypothalamic–hypophyseal axis. This triggers the secretion of sexual hormones, mainly testosterone in male adolescents and estrogen in female adolescents, leading to changes in the LBM level and an increase in FM, respectively[18]. According to Longo et al.[19], FFM may not be a reliable indicator of SMM in individuals with large amounts of body fat because it includes non-skeletal muscle components, such as internal organs, connective tissue, skin, and fat-free components of fat cells in adipose tissues. Therefore, FFM increases simultaneously with an increase in the amount of these components.

The higher %BF in female adolescents compared to male adolescents correlates with previous findings[17]. This result may be explained because %BF increases more slowly in male adolescents due to the simultaneous increase in FFM, influenced mainly by testosterone. In contrast, female adolescents tend to accumulate BFM. The abovementioned event is related to the sexual maturation process explained above, which triggers estradiol release in female adolescents, causing an increase in %BF[18]. Although FMI is rarely used to evaluate adiposity in adolescents, it can identify body fat changes faster than BMI and %BF[20]. The female group had a higher FMI value in the present study, which is justified because this variable was calculated from BFM and adjusted for height. This result was directly proportional to the BFM value and in-

versely proportional to height. Therefore, the shorter the individual or the lower the BFM, the higher the FMI[21].

The difference in body weight between the sexes was already expected since the higher %SMM in the male group suggests a higher total body mass than in the female group. However, no significant differences in body weight were found between the sexes. In contrast to previous studies that frequently report higher body weight in male adolescents[22,23], male adolescents presented a higher %SMM than female adolescents[24]. Similarly, the higher the BMI and maturational stage in the female group, the higher the %BF. In the present study, the female group had a higher %BF and BMI than the male group, indicating the probability of female adolescents being in a maturational stage favorable to this result. However, this point was not evaluated, indicating a limitation to be addressed in future research.

The distribution of %BF may vary considerably between individuals[25]. Adolescents who stored more fat in the abdominal region showed significantly higher central obesity, and fat accumulation in this region is related to the development of cardiometabolic diseases and excessive deposition of visceral, intra-abdominal, and hepatic fat[26]. Therefore, the WHR measurement has been used to evaluate abdominal fat as a predictor of the etiology of cardiometabolic diseases[27].

Thus, a higher BMI is associated with a higher probability of developing cardiometabolic diseases[28]. However, in our study, the results did not demonstrate a correlation between BMI and WHR. Therefore, the adolescents in this study did not demonstrate a higher likelihood of developing cardiometabolic diseases based on the correlation between BMI and WHR. This correlation needs to be analyzed with caution since WHR is neither a good predictor of cardiometabolic risk nor a reliable anthropometric measure.

The high prevalence of overweight in adolescence has demonstrated an increase in dyslipidemia among the young population. Adolescents with increased body mass indices have increased total cholesterol and LDL-c values and decreased HDL-c values[29]. The present study presented BMI and WHR as a predictive effect on TC and %BF and WHR as a predictive effect on LDL-c. With this increase in childhood obesity, NAFLD has become the most common cause of chronic liver disease in this age group[30]. The result of this study evaluates the %BF as a predictive effect on AST. Although the AST values are below the proposed cut-off point (<40 U/L), changes in feeding litter through healthy food choices are recommended.

A limitation of this study is that analyses of the adolescents' pubertal staging and sex hormone (testosterone and estrogen) levels were not performed. The stage of sexual maturation influences anthropometric and body composition variables since BMI differs significantly during sexual maturation, especially in female adolescents[18]. On the other hand, the levels of male sex hormones (testosterone) and female sex hormones (estrogen), as already explained during the study, are correlated with increased body fat in female adolescents[18]. As recommendations for future investigations, a more thorough evaluation of the relationships between sexual maturation and the quantification of sex hormones is needed. Based on the results of the current study, higher %BF and FMI were observed in the female group than in the male group, suggesting a higher risk of decline in health and quality of life.

Another point that could be highlighted is the multi-professional approach to combat obesity in adolescence. Recent study by Branco et al.[31] used a multi-professional intervention with physiologists, nutritionists, and psychologists to promote health in overweight or obese adolescents, evaluated through anthropometric measurements, body composition, physical tests, and mental health. Thus, considering the complexity of obesity, i.e., multifactorial disease, a trained team should organize the intervention to improve success in obesity treatment interventions.

In conclusion, we analyzed the profile of adolescents overweight or obese through body composition, hepatic biomarkers, and cardiometabolic risk. It was possible to observe some characteristics, that is, values that are not normal for the variables analyzed, which compromise the health of adolescents and increase the risk of developing cardiovascular diseases later in adulthood. The female group had higher values of %BF and FMI compared to the male group, but there was no difference in gender when correlated with FMI and HDL-c levels. Where individuals with higher FMI have lower levels of HDL-c, improving body composition through multidisciplinary intervention programs may be relevant for treating obesity and its associated comorbidities.

It is hoped that this research will contribute to the increase of knowledge in the area and the interest of new research, considering that few interdisciplinary projects investigate the interrelationships between body mass index, body composition, and biochemical profiles of overweight adolescents. Thus, it provides data for developing models of low-cost longitudinal interventions to improve the young population's quality of life through physical activity and good choices for a healthy diet, reaching more people who need a health promotion program.

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