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Research Article

Physical Exercise for Overweight/Obese Adolescents: Impact on Metabolic and Anthropometric Variables

Maria Tereza Nicolau Santos[1], Paulo Pimenta Figueiredo Filho[2], Ana Lúcia Pimenta Starling[2], Ennio Leão[2], Adriana Reis Brasil[2], Adriana Márcia Silveira[2], Valéria Tassara[2], Viviane Cássia Kanufre[2], Rocksane de Carvalho Norton*[2]

[1] Escola de Fisioterapia da Universidade Católica de Minas Gerais, Brazil

[2] Faculdade de Medicina da Universidade Federal de Minas Gerais, Brazil

Abstract

Introduction: Overweight and obesity are acquiring epidemic proportions in childhood and adolescence. Among many organic disorders found in obese adolescents, metabolic syndrome (MS) is a condition that has generated concern. Prevention seems to be an important tool to avoid these problems. Physical activity is an accessible intervention to prevent overweight and MS. This study aims to evaluate the results of a 12-week aerobic exercise program on the metabolic and anthropometric variables related to metabolic syndrome in overweight and obese adolescents.

Methods: We developed a longitudinal clinical study with 32 overweight or obese adolescents, 15 in a test group (TG) and 17 in a control group (CG). Subjects of TG (7 boys, 8 girls; 12.73 ± 2.37 years of age) were enrolled in a supervised program of aerobic exercise (moderate intensity, 12 weeks, 60 min. sessions, 3x/week) and in a biweekly interdisciplinary assistance control. The adolescents allocated in the CG (6 boys, 11 girls; 13.29 ± 2.22 years of age) participated only in the biweekly meetings during 12 weeks. Anthropometric variables, total cholesterol (TC) and fractions were obtained before and after the 12 weeks intervention period.

Results: The TG displayed a reduction in BMI, in waist circumference and systolic blood pressure (SBP) and an increase in height and in TC ($p<0.05$). The CG displayed an increase in weight, height, BMI, waist circumference, triglycerides, TC and VLDL ($p<0.05$). The difference between the two groups was significant for the alterations in weight, height, BMI, weight circumference and SBP ($p<0.05$).

Conclusion: A 12 weeks program of aerobic exercises could have positive effects on the metabolic and anthropometric variables related to metabolic syndrome in overweight or obese adolescents, optimizing the interdisciplinary approach. Physical activity should be encouraged so as to contribute towards a healthier future.

Key words: *obesity, adolescents, metabolic syndrome, physical exercise.*

Introduction

Obesity in childhood and adolescence emerges as a prevalent global condition, representing contemporary society imbalances. Obesity is considered the most common chronic disease in childhood [1] and its prevalence threatens to undermine all the recent advances in the prevention and control of chronic diseases [2]. Childhood prevalence of obesity has almost tripled in the last twenty years in the country [3].

Obesity causes many organic disorders affecting health from childhood to adult life. Metabolic syndrome, although not well established in children and adolescents has been reported in association with obesity, meaning that early atherosclerotic lesions may be found in the first decades of life [4,5].

Adipose tissue, as a dynamic tissue, secretes many substances, among which the adipokines that are involved in atherogenic, thrombogenic and inflammatory processes responsible for metabolic disorders that results in high blood pressure, insulin resistance, type 2 diabetes and dyslipidemias [4-6].

The American Heart Association and the American Diabetes Association highlight lifestyle changes as strategies to prevent and reduce the alarming picture of weight excess in the world [2]. Inactive lifestyle contributes heavily towards weight gain, which in turn becomes an obstacle to the establishment of a physically active behavior pattern [7]. Low cost and easily accessible, regular physical exercise has a protective effect shown to be an important tool for breaking this vicious cycle [8], as it has various benefits for health in general and helps the prevention and treatment of high blood pressure, insulin resistance, diabetes, dyslipidemia and obesity [4,5].

In contrast with adult population, studies that relate physical exercise with atherosclerosis risk factors and health promotion in the pediatric age groups are scarce and contradictory [9-16]. Thus, new studies to evaluate the benefits of physical activity in the preventions and control of obesity and metabolic syndrome in pediatrics are necessary [16].

The American College of Sports Medicine preconizes a life-long commitment to regular exercise beginning in childhood, which can result in a reduction of healthcare costs and better quality of life [17].

Objective

This study aimed to evaluate the results of a program of physical activity during 12 weeks on anthropometric and metabolic variables of a group of overweight/obese adolescents.

Corresponding author: Rocksane de Carvalho Norton, Faculdade de Medicina da Universidade Federal de Minas Gerais, Brazil, Tel: +55 31 34098940; Fax: +55 31 34098940; E-mail: rocksane.norton@gmail.com

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Methodology

Forty-two overweight or obese adolescents of both sexes were invited to participate in a longitudinal clinical 12 weeks' study. They were monitored at the Nutritional Diseases Clinic of *Hospital das Clínicas* of the Federal University of Minas Gerais (HC-UFMG) and agreed to participate by a Term of Free and Informed Consent signed by the adolescent and their parents/guardians.

The test group (TG) participated both in the aerobic exercise program and in the monitoring program conducted by an interdisciplinary team of nutritionist, pediatrician, psychologist and physiotherapist. The control group (CG) participated in the monitoring program but not in the aerobic exercise program.

Anthropometric data for both groups were obtained prior to and following the interventions, in accordance with the research protocol at the Nutritional Diseases Clinic at HC–UFMG: weight, height, waist circumference, blood pressure. Body weight and height were obtained with patients barefooted and wearing light clothes.

Adolescents with a BMI (weight/height^2) between the 85th and 95th percentiles were classified as overweight and those with a BMI above the 95th percentile were classified as obese.

Waist circumference was measured at the midpoint between the costal arch and the iliac crest, at the end of a normal exhalation, utilizing a non-elastic measuring tape.

Blood pressure was measured after the individuals had remained sitting for at least 5 minutes using the indirect auscultatory method, using a calibrated sphygmomanometer, with the right arm supported at the height of the precordium. The cuff was firmly positioned approximately 2cm or 3 cm above the brachial artery. The stethoscope was then placed over the brachial artery and the cuff inflated to 30 mmHg above the disappearance of the radial pulse and the pressure slowly released. The first Korotkoff sound was considered for the systolic blood pressure (SBP) reading and the last for the diastolic blood pressure (DBP) reading [18].

The laboratory exams were performed at the Central Laboratory at the HC–UFMG, following a 12 hours fast period. Blood samples were collected to determine blood glucose, insulin, triglycerides, total cholesterol (TC) and LDL, HDL and VLDL fractions. The HOMA-IR (Homoeostasis Model Assessment for Insulin Resistance) was utilized to evaluate insulin resistance by the formula [19]:

$$\text{HOMA-IR} = \frac{\text{Fasting blood sugar (mmol/L)} \times \text{fasting insulin } (\mu\text{UI/ml})}{22.5}$$

Physical and laboratory exams were performed a maximum of one week prior to the beginning of the intervention and a maximum of one week following the end. The adolescents allocated to the test group (TG) underwent the laboratory exams after 72 hours from the end of the physical exercise program.

The interdisciplinary monitoring was conducted bi-weekly, in a group setting, at UFMG Movement Laboratory.

The aerobic exercise program was conducted at the PUC Minas Sports Complex, 3 times a week during 12 weeks, supervised by a physiotherapist and 15 graduate students. The program was composed of recreational and playful aerobic exercises (40 minutes), preceded by a warm-up and stretching (10 minutes), followed by a cool-down and stretching (10 minutes), for a total duration of 60 minutes. The effort intensity was moderate, or that is, the heart rate at peak effort was 75% of the maximum heart rate expected for the age of the adolescent, with heart rate monitoring by a frequency counter. Full extension movements and the use of multiple joints favored the use of large muscle groups, always taking into account the anatomical, physiological and psychological immaturity of adolescence, and respecting the individual limits and tolerance of participants [20]. Individual preferences were respected, thus fostering a greater enjoyment of the activities undertaken as these must always be pleasing for the adolescent so as to maintain their continued participation.

The heart rate and the blood pressure of the adolescents were monitored four times: at rest, warm-up, peak effort and recovery. The subjects received a chronogram of the activities scheduled during the 12 weeks. In this chronogram, which they carried with them at all times, their attendance was recorded, so that the individuals themselves had a control of their regular attendance and also of the correct dates so that they could plan their schedules.

The characteristics of participants were described using means and standard deviations (SD). For the evaluation of the normality of the distributions the Shapiro-Wilk test was used. To compare the differences between the means respective of each of the groups the single Student's T-test was used, following an evaluation of the variances. Student's T-test was utilized to compare means obtained before and after the intervention. The significance level admitted was up to 5% for type I error probability.

The study was approved by the UFMG Ethics Research Committee and had the consent of PUC Minas.

Results

The control group (CG) and the test group (TG) were initially shown to be equal for all the parameters ($p>0.05$), as shown in (Table 1,2).

In the CG group 17/21 adolescents concluded the activities: 14 (82.35%) were classified as obese and only 3 (17.65%) as overweight. In the TG 15/21 adolescents concluded the activities: 13 (86.66%) were classified as obese and only 2 (13.34%) as overweight.

After the 12 weeks period TG group had BMI, waist circumference and SBP reduction and height increase ($p<0.05$), as shown in (Table 3,4). On the other hand, CG had weight, height, BMI, waist circumference, plasmatic concentrations of triglycerides, TC and VLDL gain ($p<0.05$) as demonstrated in (Table 5,6).

A comparison of the CG and TG results shows significant differences among the two groups ($p<0.05$) (Figure 1). The alterations observed in the CG and in the TG, in the laboratory exams, presented no statistical significance when the two groups are compared (Figure 2).

Discussion

Overweight and obesity in adolescence are challenging conditions as they can have a lifelong impact on human health. Prevention seems to be the best strategy to minimize the consequences of these conditions. Regular physical activity has been shown to be an effective measure of control, but not always attractive to adolescents. In this

Table 1: Comparison between the initial data obtained from the physical exams of the CG and of the TG.

Variables	CG		TG		
	Mean	SD	Mean	SD	p Value
Weight (kg)	76.629	16.824	80.4	28.512	0.6585
Height (m)	1.59	0.101	1.556	0.126	0.4071
BMI (kg/m²)	30.064	4.578	32.494	8.017	0.3125
Waist (cm)	98.194	12.274	103.466	19.394	0.3596
SBP (mmHg)	106.823	13.947	119.6	22.868	0.0626
DBP (mmHg)	70.117	11.346	73.066	12.232	0.4848

Table 2: Comparison between the initial data obtained from the laboratory exams of the CG and of the TG.

Variables	Before - CG		Before - TG		
	Mean	SD	Mean	SD	p Value
Blood Sugar (mg/dL)	77	7.491	81.866	10.411	0.1363
Insulinemia (μUI/mL)	14.605	12.219	15.966	13.454	0.7664
HOMA	2.751	2.125	3.368	3.205	0.5218
Triglycerides (mg/dL)	89.176	18.944	98.4	59.868	0.5751
TC (mg/dL)	161.647	23.2	171.866	32.091	0.3061
HDL (mg/dL)	46.117	9.512	49.866	14.749	0.3940
LDL (mg/dL)	97.705	16.069	102.2	21.331	0.5029
VLDL (mg/dL)	17.823	3.626	19.8	11.935	0.5460

Table 3: TG anthropometric measures and blood pressure before and after the intervention.

Variables	Before		After		
	Mean	SD	Mean	SD	p Value
Weight (kg)	80.4	28.512	80.12	28.572	0.6540
Height (m)	1.556	0.126	1.576	0.130	**0.0001**
BMI (kg/m²)	32.494	8.017	31.55	7.671	**0.0005**
Waist (cm)	103.466	19.394	96.966	19.621	**0.0000**
SBP (mmHg)	119.6	22.868	110.4	20.230	**0.0010**
DBP (mmHg)	73.066	12.232	69.066	13.603	0.1329

Table 4: TG glucose, insulin, HOMA, triglycerides, and cholesterol results before and after the intervention.

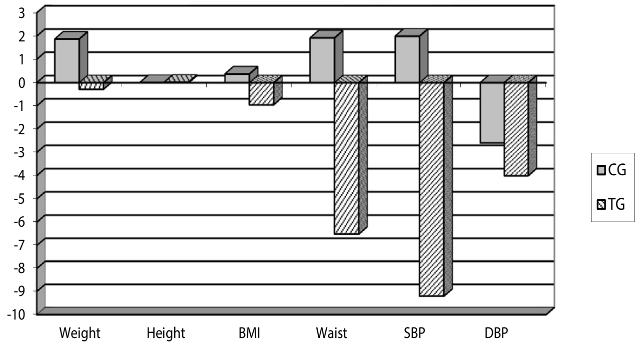
Variables	Before		After		
	Mean	SD	Mean	SD	p Value
Blood Sugar (mg/dL)	81.866	10.411	80.733	4.949	0.6214
Insulinemia (μUI/mL)	15.966	13.454	15.766	12.971	0.8560
HOMA	3.368	3.205	3.194	2.734	0.5153
Triglycerides (mg/dL)	98.4	59.868	104.133	37.498	0.6829
TC (mg/dL)	171.866	32.091	181.6	32.299	**0.0461**
HDL (mg/dL)	49.866	14.749	50.533	16.478	0.8002
LDL (mg/dL)	102.2	21.331	110.133	26.070	0.1361
VLDL (mg/dL)	19.8	11.935	20.933	7.382	0.6823

Table 5: CG anthropometric measures and blood pressure before and after the intervention

Variables	Before		After		
	Mean	SD	Mean	SD	p Value
Weight (kg)	76.629	16.824	78.505	16.610	**0.0002**
Height (m)	1.59	0.101	1.599	0.097	**0.0005**
BMI (kg/m²)	30.064	4.578	30.442	4.437	**0.0135**
Waist (cm)	98.194	12.274	100.117	11.815	**0.0024**
SBP (mmHg)	106.823	13.947	108.823	9.593	0.4251
DBP (mmHg)	70.117	11.346	67.529	8.704	0.2368

Table 6: CG glucose, insulin, HOMA, triglycerides, and cholesterol results before and after the intervention.

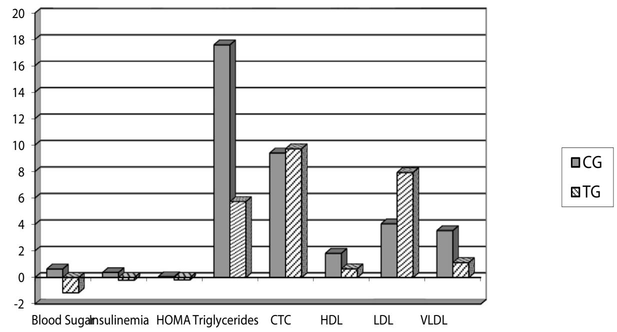
Variable	Before		After		
	Mean	SD	Mean	SD	p Value
Blood Sugar (mg/dL)	77	7.491	77.647	4.768	0.7258
Insulinemia (μUI/mL)	14.605	12.219	14.988	15.887	0.8318
HOMA	2.751	2.125	2.811	2.728	0.8781
Triglycerides (mg/dL)	89.176	18.944	106.764	36.923	**0.0406**
TC (mg/dL)	161.647	23.2	171.058	27.065	**0.0414**
HDL (mg/dL)	46.117	9.512	47.9411	9.717	0.2456
LDL (mg/dL)	97.705	16.069	101.764	18.853	0.2075
VLDL (mg/dL)	17.823	3.626	21.352	7.432	**0.0405**



* $p < 0.05$

Note: weight in kg, height in m, BMI in kg/m², waist in cm, SBP and DBP in mmHg.

Figure 1: Comparison between the means of the differences (before-after) obtained in the physical exams of the CG and of the TG.



* $p < 0.05$

Note: blood sugar, triglycerides, TC, HDL, LDL and VLDL in mg/dL; insulinemia in μUI/mL.

The databank for this study is available from the author upon request.

Figure 2: Comparison between the means of the differences (before-after) obtained in the laboratory exams of the CG and of the TG.

study our intention was to demonstrate that, besides a monitoring dietetic program, light and playful physical activities, adjusted to the desires of the patients, can have benefits.

The CG, monitored bi-weekly by a multidisciplinary team had a mean weight gain over 12 weeks, as well as an increased BMI and waist circumference, denoting the remarkable difficulty in controlling this chronic disease. The increase in height was not taken advantage, given the significant weight gain. The literature points out that obesity accelerates maturation, and consequently the increase in height and in weight is always accelerated [21], contributing to a progressive increase in the BMI observed in the CG in this study. This results are worrying, since cardiovascular risk increases with BMI [22] and since waist circumference, indicative of an accumulation of abdominal fat, is strongly associated with metabolic alterations. In abdominal adiposity, lipolytic cellular activity is increased and there is a release of free fatty acids (FFA) in the portal vein, exposing the liver to an increased quantity of FFAs. This reduces the hepatic extraction of insulin, contributing further to the systemic hyperinsulinemia condition. Excessive quantities of FFAs contribute towards less utilization of glucose as an energy substrate, in addition to increasing the hepatic release of lipoproteins rich in triglycerides, VLDL and apolipoprotein B into circulation [23]. The weight excess and the abdominal distribution of fat have been associated with an increase in triglycerides in children and adolescents in various studies. The weight gain is a high-risk factor for potentially lethal atherosclerotic lesions and the accumulation of abdominal fat is the most important predictor of these alterations [22-31].

The TG, in contrast with the CG, presented a reduction in BMI. By engaging in regular physical exercise for 12 weeks, in addition to receiving interdisciplinary monitoring, the TG was able to take advantage of the increase in height, demonstrating only a non-significant reduction in weight, which is already an excellent result, as it factored positively in a reduction in BMI. The increase in energy demand with the physical effort managed to outpace the daily energy acquisition, resulting in a negative energy balance.

In children and adolescents, any reduction in BMI must be considered a good therapeutic result. Therefore, the prolonged maintenance of weight levels, which allows for a gradual decline in BMI as the child or adolescent grows taller, may be sufficient as an objective for many [9]. Also satisfactory was the reduction in waist circumference among the TG, which is a beneficial result for the cardiovascular health of these individuals in view of the intense metabolic role that abdominal fat exerts on an organism: it is more sensitive to lipolysis, via catecholamines and adrenoreceptors; more resistant to the action of insulin; secretes larger concentrations of adipokines linked to the pro-inflammatory processes [6].

Concomitant to the reduction in BMI and in waist circumference, a reduction in the systolic BP was observed, which is a coherent result, since it is associated with weight gain and since a reduction in adiposity, with a probable consequent reduction in FFA, may positively affect the production of nitric oxide, vascular reactivity and endothelium-dependent vasodilatation, preventing endothelial dysfunction.

Physiological mechanisms that could explain the results of the physical exam of the TG may include, besides the physical exercise inherent effects, increase of parasympathetic and decrease in the sympathetic tonus, increase of endothelial nitric oxide, reduction of peripheral vascular resistance, and in plasma concentrations of catecholamines and renin - the modulation of the factors that link adiposity with blood pressure levels. The renin-angiotensin system is related to the accumulation of adipose tissue and involved in the inflammatory and atherogenic processes, stimulating the production of adhesion molecule-1 and of macrophage-colony stimulating factor on the endothelial wall, thus increasing the metabolism of nitric oxide into free radicals, platelet activity and the level of PAI-1. Therefore, its elevated concentration links obesity, high blood pressure and cardiovascular diseases [28-30,32].

As weight gain is associated with cardiovascular diseases, the BMI and waist circumference reduction of TG subjects with the concomitant reduction in SBP, is a very satisfactory and strong motivating result, which reflects the achievement of a more successful approach.

In this study, physical exercise led to weight loss. However, it is difficult to know whether the inotropic benefits observed are related to the exercise itself or to the weight loss, in accordance with what many other researchers have reported [33-37].

Despite the fact that the Kelley et al meta-analysis has demonstrated that short term physical exercise does not reduce resting systolic and diastolic blood pressure in children and adolescents, the authors point out a series of factors that may have interfered in this result and the National high blood pressure education program working group on high blood pressure in children and adolescents [18] affirms that regular physical exercise brings inotropic benefits to children and adolescents, which is corroborated in this study, in that of Leary et al [38] and that of Bouziotas et al [15].

The laboratory exams conducted on the TG pointed to an increase in plasma concentrations of TC. However, this result should not be attributed to physical exercise, in view of the fact that, in addition to the CG also presenting an increase in TC, the comparative analysis (CG × TG) did not indicate a significant difference between the groups in this regard. The increase in TC plasma concentrations in this study challenged both approaches. However, the TG did not have a significant alteration in contrast with the CG, possibly do to the significant increase in the VLDL fraction.

The significant differences in weight, BMI, waist circumference and SBP between the two studied groups should be attributed to the regular physical exercise that was added to the interdisciplinary approach. Despite the increase in height that occurred in both groups, there was a significant difference between the CG and TG possibly related to maturational differences among the adolescents. Although increases of physical activity are associated with an improvement in the lipid and in glycemic metabolism, such evidence was not corroborated in this study. A comparison of the data from this study with those from other studies is difficult, due to the different methodologies employed [39-42]. Caution must be present to analyze the results of blood pressure in adolescents, due to the large degree of oscillation in the values of this variable in individuals in the pediatric age group [18]. This aspect may be considered a limitation of this study, since it was not possible to produce a mean of multiple blood pressure measurements in the CG. In the TG, which was monitored three times per week, producing a mean of the multiple measurements would in fact be possible, utilizing the resting data from the first week of intervention and comparing it with those from the last week. However, as that was not possible with the CG, a decision was made to not utilize such data to compose the analyses of the TG, with the goal of having the approaches being equal and thus allowing comparison between the groups.

Conclusion

Moderate intensity aerobic exercise has positive effects on the metabolic and anthropometric variables related to metabolic syndrome in overweight or obese adolescents, most certainly optimizing the multi-family interdisciplinary approach. These results are obtained even in the short term, which is highly motivating for the adolescents, who are able, with regular physical exercise, to accelerate their progress towards the defined objectives. On the other hand, overweight or obese adolescents who do not engage in physical exercise tend to see their conditions worsen.

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