

Effects of a multidisciplinary program on autonomic modulation in overweight or obese children and adolescents

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Abstract

Purpose: this study evaluated the effects of a multidisciplinary program on autonomic modulation in overweight or obese children and adolescents.

Methods: fifteen individuals with $10,93 \pm 2,28$ years were submitted to autonomic evaluation using heart rate variability before and after a program based on physical exercises for three months, three times a week, 60 minutes per session and psychological and nutritional counseling. Data was analyzed using the paired t-test or Wilcoxon test and the level of significance was set at $P < 0.05$.

Results: multidisciplinary program was able to promote benefits in autonomic modulation observed thought temporal (SDNN: $39,96 \pm 10,33 \times 49,44 \pm 12,31$; $p = 0,019$; rMSSD: $28,97 \pm 11,50 \times 37,26 \pm 11,17$; $p = 0,018$), spectral (LFnu: $64,49 \pm 12,21 \times 56,74 \pm 11,18$; $p = 0,014$; HFnu: $35,50 \pm 12,21 \times 43,25 \pm 11,18$; $p = 0,014$) and geometrical (SD1: $20,51 \pm 8,13 \times 26,36 \pm 7,90$; $p = 0,018$ SD2: $52,31 \pm 13,04 \times 64,58 \pm 16,33$; $p = 0,031$) indices in overweight and obese children and adolescents. Also, after the intervention there was a reduction on resting heart rate ($88,53 \pm 9,24 \times 83,09 \pm 7,93$; $p = 0,023$) and there were changes in the classification of overweight 26,67% \times 46,66% and obesity 73,33% \times 53,33%, although not significant changes in body mass index.

Conclusions: exercise program together with nutritional and psychological counseling is able to promote benefits in autonomic modulation in children and adolescents who are overweight or obese.

Key words: autonomic nervous system, physical exercise, nutritional state, psychological counseling.

INTRODUCTION

Obesity is characterized as a major public health problem in children, as will be seen in the next generation¹. It has a multifactorial etiology influenced by genetic, behavioral and environmental factors^{2,3} and tends to persist into adult life⁴. It is also associated with a number of complications such as some types of cancer⁵, hypertension and dyslipidemias⁶.

Autonomic changes in obese children and adolescents are described in the literature⁷⁻⁹, as representing an

important negative condition, since such changes are related to an increased risk of morbidity and mortality from several conditions¹⁰.

In this context, treatment of obese children and adolescents is of fundamental importance and physical activity, associated with a hypocaloric diet, is a tool that can promote a positive impact on this condition¹¹. In this population, the practice of physical activity and nutritional intervention present evidence of benefits such as reduced adiposity, maintenance of stable weight and improvement of metabolic disorders and lipid use during maximum exercise^{12,13}.

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Some studies focusing on children have stressed the beneficial effects of physical activities on autonomic modulation. Gutin et al.¹⁴, after a program of physical exercise with 7- to 11-year-old obese children, saw an improvement in autonomic modulation, characterizing the program as capable of promoting an adequate stimulus for the cardiovascular system. Moreover, Nagai et al.¹⁵ observed that physical activity levels are related to autonomic changes in obese children and suggested that physical activity programs could contribute to the improvement of autonomic modulation in these children.

However, no studies were found that evaluate the effects of multidisciplinary treatments involving physical activity and nutritional and psychological counseling on autonomic modulation of children and adolescents above normal weight. The hypothesis is that this type of intervention could promote beneficial effects on the autonomic modulation of this population.

In order to insert new elements on this theme into the literature, this study aimed to evaluate the influence of a multidisciplinary program, combining exercise and nutritional and psychological counseling, on autonomic modulation in overweight or obese children and adolescents.

METHODS

Subjects

This study is a longitudinal clinical trial that evaluated a program based on physical exercises and nutritional and psychological counseling. It involved 38 overweight and obese children and adolescents of both genders, between 6 and 17 years of age, who reported no use of medicine or cardiorespiratory and metabolic diseases. Among them, 23 (60.52%) were excluded because they abandoned the three month exercise protocol, the final sample thus consisted of 15 volunteers, seven males (46.66%) and eight females (53.33%). The characteristics of the final sample are presented in table 1

Ethical procedures

The volunteers and their parents/guardians received an explanation of the objectives and procedures of the study and signed an informed consent form. The procedures used in this study were approved by the Research Ethics Committee of the Faculty of Sciences and Technology, Paulista State University, Presidente Prudente, São Paulo, Brazil, (Protocol n° 259/2008) and followed resolution 196/96 of the National Health Council.

Study design

The experimental protocol consisted of an initial evaluation, a multidisciplinary program and a final evaluation. During the initial evaluation, anamnestic, anthropometric and autonomic evaluations were conducted. Following this, the participants took part in the multidisciplinary program and, on completion, the final evaluation, including anthropometric and autonomic evaluations, was conducted. The structure of these methods was based on the Consolidated Standards of Reporting Trials (CONSORT) guidelines which can be found at: www.consort-statement.org/.

Medical history and anthropometry

Personal information on the volunteers, together with their complete medical history, were recorded, with questions regarding the use of medicine and cardiorespiratory and metabolic diseases in order to determine whether they fulfilled the inclusion criteria. Anthropometry measurements were performed to determine their compliance with the targeted population. Body weight and height were measured and the body mass index (BMI) was calculated using the following formula: weight (kilograms-Kg)/height² (meters-m). Weight was measured on a digital scale (Welmy, R/I 200, Brazil), with a maximum capacity of 180kg and a precision of 0.1kg, with the volunteers in an orthostatic position, barefoot and wearing light clothing. Height was measured using a stadiometer (Sanny, Brazil), with a precision of 0.1cm and a maximum length of 2.20m¹⁶. From the BMI, the volunteers were classified as overweight or obese according to sex and age following the criteria proposed by Cole et al.¹⁷.

Autonomic modulation

Autonomic modulation was assessed in the morning between 8.00 and 12.00 to minimize the influence of circadian rhythm, in a temperature-controlled room of between 21 °C and 23 °C and humidity between 40% and 60%. The volunteers were instructed to avoid stimulant drinks such as coffee, tea and soft drinks and/or food containing chocolate for a period of 12 hours prior to the autonomic evaluation.

During the autonomic evaluation, the volunteers were instructed to remain awake, in silence, breathing spontaneously while resting in the supine position for 20 minutes on a couch. After receiving an explanation of the data collection procedures, an electrode was placed on the volunteer's chest next to the xiphoid process using an elastic strap, and a heart rate receiver (Polar Electro, model S810i, Finland) was attached to the participant's wrist. The equipment had been previously validated to record beat-to-beat heart rate and for use in collecting heart rate variability (HRV) data for analysis¹⁸.

The behavioral pattern was registered beat-to-beat with a sampling rate of 1000Hz for HRV analysis. Thousand intervals of consecutive cardiac beats were used to analyze HRV indices, selected after digital filtering, complemented by manual filtering to eliminate artifact and ectopic beats, and only series with more than 95% sinus beats were included in the study.

The HRV analysis was performed through the linear indices of the time (rMSSD and SDNN) and frequency domains (LF, HF, LF/HF) and the geometric indices: triangular index (RRtri), TINN and Poincaré plot (SD1, SD2, SD1/SD2). In the time domain, the following indices were used: rMSSD (the root mean square of successive differences between normal intervals of consecutive cardiac beats in an interval of time expressed in milliseconds [ms]) and SDNN (the standard deviation of normal-to-normal intervals in an interval of time expressed in ms)¹⁹.

In the frequency domain, the spectral components of low frequency (LF:0.004 to 0.15 Hertz [Hz]) and high frequency (HF: 0.15 to 0.40Hz) were used, expressed in

ms² (ms squared) and normalized units (nu), which represent the relative value of each spectral component at the total potency minus the very low frequency, and the ratio between them (LF/HF)¹⁹. These analyses were calculated using the Fast Fourier Transform algorithm.

The following geometric indices used were: RRtri, TINN and Poincaré plot. RRtri was calculated from the density histogram of iRR and consisted of the integral of the histogram (i.e., the total number of iRR) divided by the maximum of the density distribution (modal frequency of iRR), measured on a discrete scale with 7.8125ms boxes (1/128 seconds). The TINN index consisted of the base width of the distribution measured as the base of a triangle, approximating the distribution of all iRR, the minimum square difference being used to determine the triangle. The Poincaré plot allowed each iRR to be plotted against the previous interval. The duration of an interval (RRn) was represented on the “x” axis, and the length of the next interval (RRn+1) on the “y” axis, so each point on the graph (RRn, RRn+1) corresponded to two successive heart beats. For quantitative analysis of the plot, the indices calculated were: SD1 (standard deviation of instantaneous beat to beat variability), SD2 (standard deviation of long term continuous iRR) and the SD1/SD2 ratio¹⁹.

The qualitative analysis of the plot was performed by analyzing the figures formed by its attractor, based on the description in Tulppo et al.²⁰, as: I) a figure with a greater dispersion of the iRR beat-to-beat featuring a plot with greater variability in the long term and II) a figure with small overall dispersion beat-to-beat without increasing the dispersion of iRR in the long term, featuring a plot with less variability.

The analysis was processed using Kubios software (Biosignal Analysis and Medical Image Group, Department of Physics, University of Kuopio, Finland)²¹.

Intervention program

The developed program, entitled Super-Action, aims to treat children and adolescents through physical activities associated with psychological and nutritional counseling. The activities were conducted over a period of three months with a frequency of three times a week, 60 minutes per session. The volunteers were divided into two groups: children from 6 to 11 years and adolescents from

12 to 17 years, in order to ensure they carried out activities appropriate to their age group.

In relation to physical activity, each session consisted of five minutes of stretching at the beginning and end, 50 minutes of predominantly aerobic activities and exercises to stimulate the development of strength and resistance of large muscle groups (arms, legs, chest, shoulder, back and hip) in the form of walking and circuit activities. The activities had a playful and dynamic profile.

The nutritional and psychological interventions were carried out biweekly through group meetings at which instructions about healthy eating habits and psychological aspects of care were transmitted simply and clearly to the children together with their parents. This was done through tips on daily living and counseling in order to stimulate beneficial changes in lifestyle.

Statistical analysis

Characteristic data of the population were described as mean, standard deviation, median, minimum, maximum or absolute values and percentages. Data distribution was checked using the Shapiro-Wilk test to compare HRV indices before and after the intervention program, and, depending on the data distribution, the paired t-test or Wilcoxon test was used. Statistical analysis was performed using the SPSS statistical software package, version 13.00 (SPSS, Inc. Chicago, IL, USA). The level of statistical significance was set at P<0.05 for all analyses.

RESULTS

The characteristics of the sample before and after the intervention are presented in Table 01. There were changes, although not significant in BMI, but in the classification of overweight and obesity. At the beginning of the protocol, 4 volunteers (26.67%) were considered overweight and 11 (73.33%) obese and at the end of the protocol three volunteers from the obese group had moved to the overweight group, totaling, seven volunteers overweight (46.66%) and eight obese (53.33%).

The values of the temporal indices of HRV are presented in Table 02

Table 1: Sample feature before and after the intervention at mean, standard deviation, median, minimum and maximum.

Feature	Pre (n = 15)	Post (n = 15)	p
Age (years)	10,93 ± 2,28 (11,00) [7,00 - 15,00]	11,33 ± 2,19 (11,00) [8,00 - 15,00]	0,0086
Body mass (kg)	69,80 ± 34,26 (58,20) [39,70 - 154,90]	70,66 ± 32,79 (58,90) [42,10 - 148,90]	0,2676
Height (m)	1,51 ± 0,14 (1,46) [1,31 - 1,76]	1,55 ± 0,14 (1,58) [1,32 - 1,76]	0,0234
BMI (kg/m ²)	28,95 ± 8,32 (26,37) [21,79 - 49,84]	28,15 ± 8,37 (24,13) [21,19 - 48,01]	0,4212

Legend: p = significance level, BMI = body mass index, kg = kilograms, m² = squared meters.

Table 2: Temporal indexes of heart rate variability express at mean, standard deviation, median and confidence interval.

Indexes	Pre (n = 15)	Post (n = 15)	p
MeanRR(ms)	685,98 ± 74,10 (677,30) [644,94 – 727,02]	730,74 ± 74,55 (41,50) [689,45 – 772,03]	0,024
MeanHR(bpm)	88,53 ± 9,24 (88,98) [83,41 – 93,65]	83,09 ± 7,93 (83,01) [78,70 – 87,48]	0,023
SDNN (ms)	39,96 ± 10,33 (41,50) [34,14 – 45,58]	49,44 ± 12,31 (47,80) [42,62 – 56,26]	0,019
rMSSD (ms)	28,97 ± 11,50 (29,20) [22,59 – 35,34]	37,26 ± 11,17 (37,60) [31,07 – 43,45]	0,018

Statistically significant difference by Student t test for paired data ($p < 0.05$). Legend: p = significance level, MeanRR = mean of intervals between consecutive heart beats, MeanHR = mean of heart rate, SDNN = standard deviation of all normal to normal intervals, rMSSD = the square root of the mean of the sum of the squares of differences between adjacent normal to normal intervals, ms = milliseconds, bpm = beats per minute.

A significant increase in iRR mean, SDNN and rMSSD and a significant reduction in heart rate value were observed after the intervention.

The autonomic modulation data verified by the spectral indexes are presented in Table 03. There was a significant increase in LH and HF obtained in ms^2 . When

Table 3: Spectral indexes of heart rate variability express at mean, standard deviation, median and confidence interval

Indexes	Pre (n = 15)	Post (n = 15)	p
LF (ms^2)	592,26 ± 288,10 (613,00) [432,71 – 751,83]	762,26 ± 376,65 (656,00) [553,67 – 970,87]	0,081
HF (ms^2)	392,33 ± 325,23 (283,00) [212,21 – 572,46]	617,66 ± 365,37 (486,00) [415,31 – 820,02]	0,018
LF (nu)	64,49 ± 12,21 (63,20) [57,72 – 71,26]	56,74 ± 11,18 (55,70) [50,55 – 62,94]	0,014
HF (nu)	35,50 ± 12,21 (36,80) [28,74 – 42,2]	43,25 ± 11,18 (44,30) [37,05 – 49,44]	0,014
LF/HF	2,22 ± 1,36 (1,60) [1,47 – 2,98]	1,48 ± 0,73 (1,26) [1,07 – 1,89]	0,020 [†]

Statistically significant difference by Student t test for paired data ($p < 0.05$). [†]Statistically significant difference by Wilcoxon test ($p < 0.05$). Legend: p = significance level, LF = low frequency component, HF = high frequency component, ms^2 = squared milliseconds, nu = normalized units.

measured in nu, there was a reduction in LF and an increase in HF. There was also a reduction in the LF/HF ratio.

The quantitative analysis of geometric indices of HRV is presented in Table 04 and the qualitative analysis in Figure 01. Regarding the quantitative analysis of geometric indices, there was a significant increase in TINN, SD1 and SD2. There were no changes to the RRtri and SD1/SD2 indices. There was greater dispersion of beat-to-beat iRR in the qualitative analysis and in the long term after the multidisciplinary program compared with the pattern observed initially. Figure 01 demonstrates a pattern example of a Poincaré plot before (Figure 1A) and after (Figure 1B) the intervention.

DISCUSSION

The results of this study suggest that a program of physical exercise associated with nutritional and psycho-

logical counseling can have a positive influence on autonomic modulation in children and adolescents who are overweight or obese. Additionally, there was a reduction in resting heart rate and changes in the classification category of some children after the intervention from obese to overweight, although there was no significant difference in BMI.

Regarding the temporal and spectral indices of HRV which represent the parasympathetic autonomic nervous system (rMSSD, HF (ms^2), and SD1)¹⁹, there was an increase in values when comparing the moments before and after the intervention. There is evidence that obese children demonstrate reduced parasympathetic activity^{7,22}, which is an important negative factor as this reduction is associated with the development of risk factors and an increase in morbidity and mortality²³. Thus, the increase in parasympathetic activity induced by the applied intervention program represents an important aspect for these children.

Table 4: Geometric indexes of heart rate variability express at mean, standard deviation, median and confidence interval

Indexes	Pre (n = 15)	Post (n = 15)	p
TINN(ms)	188,33 ± 45,65 (190,00)	225,33 ± 45,01 (220,00)	0,014
	[163,05 – 213,62]	[200,40 – 250,27]	
RRtri	10,87 ± 2,91 (11,11)	11,97 ± 3,02 (12,05)	0,170
	[9,25 – 12,49]	[10,29 – 13,64]	
SD1(ms)	20,51 ± 8,13 (20,70)	26,36 ± 7,90 (26,60)	0,018
	[16,00 – 25,01]	[21,98 – 30,74]	
SD2(ms)	52,31 ± 13,04 (55,10)	64,58 ± 16,33 (62,10)	0,031 [†]
	[45,08 – 59,53]	[55,53 – 73,62]	
SD1/SD2	0,38 ± 0,10 (0,37)	0,40 ± 0,08 (0,42)	0,364

* Statistically significant difference by Student t test for paired data ($p < 0.05$). † Statistically significant difference by Wilcoxon test ($p < 0.05$). Legend: p = significance level, TINN = baseline width of the minimum square difference triangular interpolation of the highest peak of the histogram of all normal to normal interval, RRtri = total number of all normal to normal intervals divided by the height of the histogram of all normal to normal intervals measured on a discrete scale with bins of 7•8125 milliseconds (1/128 seconds), SD1 = standard deviation of normal to normal intervals in short term, SD2 = standard deviation of normal to normal intervals in long term, ms = milliseconds.

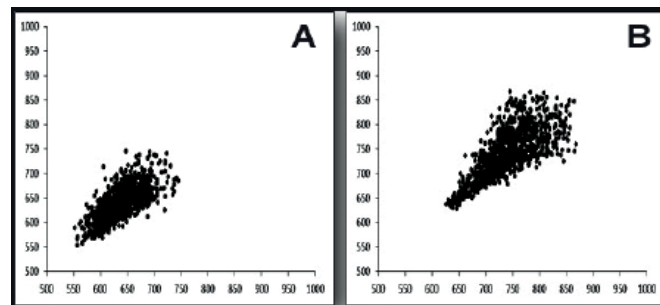


Figure 01. Visual pattern of Poincaré plot before (1A) and after (1B) intervention.

The temporal and spectral indices of HRV which represent overall variability (SDNN, SD2, TINN and RRtri), and the LF (ms^2) index which shows the sympathetic component of the autonomic nervous system¹⁹, also increased after implementing the intervention program. The literature highlights evidence of reduced sympathetic activity in obese children^{7,22} which could represent another negative aspect in these children as the sympathetic nervous system participates in the modulation of glucose and lipid metabolism²⁴ and, thus, a reduction in sympathetic activity is associated with less energy expenditure and consequent weight gain²⁵.

Regarding the analysis of the spectral indices expressed in nu, there was an improved balance in the ratio between the sympathetic and parasympathetic components of the ANS, with an increase in parasympathetic activity relative to sympathetic activity. The normalization process could minimize the effects of changes in the very low frequency band of the power spectrum and is determined by

the division of the low frequency or high frequency power components by the total power spectrum, minus the very low frequency component, multiplied by 100¹⁹.

Regarding the SD1/SD2 ratio, no significant differences were observed between the pre- and post-intervention moments, which could be explained by the increase in both SD1 and SD2 indices after the completion of the intervention program.

The qualitative analysis of the Poincaré plot suggests that the applied program promoted an increase in HRV and hence improved autonomic modulation. After the intervention, the figure of the Poincaré plot showed higher dispersion of beat-to-beat and long term, featuring a plot with more variability when compared to the pre-intervention.

Additionally, the program positively influenced the classification of children according to BMI, since some of the children went from being obese to being overweight. Kelley & Kelley et al.²⁶, showed that exercise is effective

in reducing the percentage of body fat in obese children and adolescents, although not sufficiently to suggest that exercise reduces other measures of adiposity.

In this study, there was an average reduction of five beats per minute (6.14%) in heart rate after the intervention. Reduction in heart rate in obese adolescents aged 13 to 16 years after three months of interval aerobic training has been reported in the literature²⁷ and, independent of obesity, adolescent athletes have a bradycardia response resulting from physical exercise when compared to non-athletes²⁸.

As reported above, obese children and adolescents demonstrated changes in autonomic behavior of the nervous system characterized by reductions in both sympathetic and parasympathetic activity^{7,22}, which is associated with higher risks of morbidity and mortality²³. Given this and the epidemiological importance of obesity¹, any intervention capable of inducing improved autonomic modulation is fundamental and should be implemented.

The physiological mechanisms responsible for these changes have not yet been described and studies are needed in order to understand them. Regarding exercise, it is known that a program of physical activity performed three times a week, for three months in obese pre-pubertal children can decrease blood pressure, arterial stiffness and abdominal fat; increase cardiorespiratory functional capacity and delay arterial wall remodeling²⁹; and can even promote improved autonomic modulation in both obese¹⁵ and healthy children¹⁴.

Evidence regarding the benefits of nutritional counseling¹⁹, and psychological treatments³⁰ pointed to positive influences on obesity in children, but information about the effects of such interventions on autonomic modulation are unknown.

The association of physical exercise and a hypocaloric diet together are known to produce a positive impact on obesity¹⁹, and in obese children, there is evidence of benefit in reduced adiposity, maintenance of stable weight and improvement in metabolic disorders and lipid use dur-

ing maximum exercises¹²⁻¹³.

Among the limitations of this study, it is worth pointing out that 60.52% of the subjects did not complete the three-month program, thus reducing the sample size and as a result, the analyses of gender, age and influence of maturational stage were not carried out in relation to the HRV. Furthermore, the intervention time (12 weeks) may have been insufficient to promote reduction in the body weight of the participants.

It is therefore concluded that an exercise program together with nutritional and psychological counseling is able to promote benefits in autonomic modulation in children and adolescents who are overweight or obese, which reinforces the importance of multidisciplinary treatment of childhood obesity, as an efficient tool for reversing the physiological changes caused by obesity.

Contribution in public health

It is known that childhood obesity will be the major public health problem to be seen in the next generation. Also, an important fact is that this disease is likely to persist into adult life and be associated with a number of complications such as cardiovascular diseases, which remain a leading cause of death in Brazil and in the world, hypertension; dyslipidemias; diabetes and even cancer. In consequence, this leads to a social and economic burden. This study is about a multidisciplinary treatment, based on nutritional and psychological guidance along with a physical exercise program in children and youth who are overweight or obese. Interventions contributing to the treatment of obesity may, in the future, contribute to reducing the cost of treating the health complications as well as the social burden related to obesity.

Author Disclosures

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Resumo

Objetivo: avaliar a influência de um programa multidisciplinar na modulação autonômica de crianças e adolescentes com sobrepeso e obesidade.

Método: quinze indivíduos com $10,93 \pm 2,28$ anos foram submetidos a avaliação da modulação autonômica por meio da variabilidade da frequência cardíaca antes e após um programa de atividades físicas conduzido por três meses, com frequência de três vezes na semana por 60 minutos cada sessão, associado com aconselhamento nutricional e psicológico. Para análise estatística foi utilizado teste T para dados pareados ou teste de Wilcoxon com significância de $p < 0,05$.

Resultados: o programa multidisciplinar foi capaz de influenciar positivamente a modulação autonômica o que pode ser observado por índices temporais (SDNN = $39,96 \pm 10,33$ vs. $49,44 \pm 12,31$; $p = 0,019$; rMSSD = $28,97 \pm 11,50$ vs. $37,26 \pm 11,17$; $p = 0,018$), espectrais (LFnu = $64,49 \pm 12,21$ vs. $56,74 \pm 11,18$; $p = 0,014$; HFnu = $35,50 \pm 12,21$ vs. $43,25 \pm 11,18$; $p = 0,014$) e geométricos (SD1 = $20,51 \pm 8,13$ vs. $26,36 \pm 7,90$; $p = 0,018$; SD2 = $52,31 \pm 13,04$ vs. $64,58 \pm 16,33$; $p = 0,031$) de variabilidade em crianças e adolescentes com sobrepeso e obesidade. Adicionalmente, após a intervenção houve redução da frequência cardíaca de repouso ($88,53 \pm 9,24$ vs. $83,09 \pm 7,93$; $p = 0,023$) e mudanças na classificação da obesidade dos indivíduos para sobrepeso 26,67% vs. 46,66% e obesidade 73,33% vs. 53,33%. Apesar disso, não houve diferença significativa no índice de massa corporal.

Conclusões: um programa de exercícios associado com aconselhamento nutricional e psicológico foi capaz de promover benefícios na modulação autonômica em crianças e adolescentes com sobrepeso e obesidade.

Palavras-chave: sistema nervoso autônomo, exercício físico, estado nutricional e aconselhamento psicológico.