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Associations between Health Risk Indicators and Heart Rate Variability in Adolescents: a Cross-Sectional Study

Associações Entre Indicadores de Risco à Saúde e Variabilidade da Frequência Cardíaca em Adolescentes: um Estudo Transversal

Juliano Casonatto*[a]; Raphael Gustavo Testa[a]

[a]Unopar, Programa de Pós-Graduação Stricto Sensu em Exercício Físico na Promoção da Saúde. PR. Brasil.
*E-mail: juliano2608@hotmail.com

Abstract

Several studies have shown relationships between different health risk factors, such as hypertension, obesity, trunk adiposity and low physical activity and adaptations in the autonomic response, however, the largest body of knowledge is established for adults. Thus, the aim of the present study was to analyze the possible associations between health risk indicators and heart rate variability in adolescents. The sample was composed of adolescents of both sexes, ages ranging from 12 to 17 year-old , regularly registered in public elementary schools. Data collection began with physical activity practice questionnaire, followed by anthropometric measures (height, body mass, and waist circumference). Next, heart rate variability was assessed. Then, the adolescents were carefully positioned in the sitting position for blood pressure measurement. The chi-square test was used to assess associations between blood pressure (dependent variable) and other variables. Those that were significantly associated were submitted to Poisson regression to identify the association magnitude. Obese adolescents were 76% more likely to have high LF/HF ratio values (PR=1.76 [IC95% 1.02-2.75] *P*<0.001). Abdominal obesity adolescents presented 4.32 times more prevalence of high LF (PR=4.32 [IC95% 1.07-8.17] *P*=0.046) and adolescents with elevated blood pressure had 60% more prevalence of high LF (PR=1.60 [IC95% 1.13-2.29] *P*=0.008). The heart rate variability was not associated with physical activity practice. Adolescents with high blood pressure, obesity and truncal adiposity have a higher prevalence of exacerbated autonomic activity. The physical activity practice is not associated with heart rate variability in adolescents.

Keywords: Autonomic Nervous System. Blood Pressure. Cardiometabolic Risk Factors. Exercise.

Resumo

Vários estudos têm mostrado relações entre diferentes fatores de risco à saúde (como hipertensão, obesidade, adiposidade de tronco e baixa atividade física) e adaptações na resposta autonômica. Contudo, o maior corpo de conhecimento está estabelecido para adultos. Assim, o objetivo do presente estudo foi analisar as possíveis associações entre indicadores de risco à saúde e a variabilidade da frequência cardíaca em adolescentes. A amostra foi composta por adolescentes de ambos os sexos, com idades entre 12 e 17 anos, regularmente matriculados em escolas públicas de ensino fundamental. A coleta de dados iniciou-se com questionário de prática de atividade física, seguido de medidas antropométricas (estatura, massa corporal e circunferência da cintura). Em seguida, a variabilidade da frequência cardíaca foi avaliada. Em seguida, os adolescentes foram cuidadosamente posicionados na posição sentada para a aferição da pressão arterial. O teste qui-quadrado foi utilizado para avaliar as associações entre a pressão arterial (variável dependente) e outras variáveis. Aquelas que se associaram significativamente foram submetidas à regressão de Poisson para identificação da magnitude da associação. Adolescentes obesos demonstraram 76% mais propensão a elevados valores de razão LF/HF (RP=1,76 [IC95% 1,02-2,75] P<0,001). Adolescentes com obesidade abdominal apresentaram 4,32 vezes mais prevalência de LF elevado (RP=4,32 [IC95% 1,07-8,17] P=0,046) e adolescentes com pressão arterial elevada tiveram 60% mais prevalência de LF elevado (RP=1,60 [IC95% 1,13-2,29] P=0,008). A variabilidade da frequência cardíaca não foi associada à prática habitual de atividade física. Adolescentes com hipertensão, obesidade e adiposidade abdominal apresentam maior prevalência de atividade autonômica exacerbada. A prática de atividade física não está associada à variabilidade da frequência cardíaca em adolescentes.

Palavras-chave: *Sistema Nervoso Autonômico. Pressão Arterial. Fatores de Risco Cardiometabólico. Exercício.*

1 Introduction

Heart rate variability is characterized by a set of mathematical techniques aimed at analyzing the activation and control pattern of the heart's beat-to-beat time interval (SASSI *et al.*, 2015). This analysis has been very useful as it relates to the activity of the autonomic nervous system (SHAFFER; GINSBERG, 2017). The different indexes and components of the analysis of heart rate variability are directly related to sympathetic and parasympathetic modulations originating from the autonomic nervous system (Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Thus, heart rate variability can be considered a tool for indirect assessment of autonomic nervous behavior.

Several studies have confirmed the relationship between heart rate variability and risk for development in a disease, especially cardiovascular diseases (KLEIGER; STEIN; BIGGER, 2005). It is currently known that greater variability in heart rate parameters associated with parasympathetic activation is related to a lower incidence of health problems (ERNST, 2017). Studies have also shown that greater heart rate variability is associated with greater quality (LEHRER *et al.*, 2020) and life expectancy (ERNST, 2017).

This entire context is well known in adult populations, however in recent decades there has been great interest in analyzing pediatric populations, since the prevalence of health risk factors has increased exponentially in this population group (JARDIM *et al.*, 2018). The associations between the different physiological and behavioral variables related to health are not always similar between the adult and adolescent population. Thus, the present study analyzed different indices and components of heart rate variability as a dependent variable. The scientific literature demonstrates that age can modify the indices of heart rate variability (FINLEY; NUGENT, 1995) and, therefore, specific studies need to be conducted to improve the understanding of these possible relationships.

Thus, the aim of the present study was to analyze the possible associations between health risk indicators (blood pressure, nutritional status, truncal adiposity, and physical activity practice) and heart rate variability in adolescents.

2 Material and Methods

2.1 Participants

The sample was composed of 138 adolescents of both sexes, ages ranging from 12 to 17 year-old, regularly registered in public elementary schools. The minimum sample size was estimated taking into account an elevated blood pressure prevalence of 10% (MOURA *et al.*, 2004), statistical power of 80%, and error of 5%. The required sample was 100 subjects. Considering the conglomerate sampling, the sample was increased by 20%.

Parents signed a written consent form as the inclusion criteria. The study was approved by the Ethical Research Board of the University (CAAE Nº 0281.0.268.000-07 – Report Nº 295/07).

2.2 Blood pressure

Blood pressure was assessed through the use of an automatic device (Omron HEM 742) previously validated for adolescents (CHRISTOFARO *et al.*, 2009). Adolescents remained seated for 10 minutes prior to the assessment. The procedures adopted for blood pressure measurement have been previously published (PICKERING *et al.*, 2005). The criteria to classify adolescents as "normotensive" or "hypertensive" were those established by the National High Blood Pressure Education Program (NHBPEP, 2005). Adolescents ≥95 percentile for systolic and/or diastolic blood pressure were classified as "high blood pressure".

2.3 Anthropometry

All anthropometric measures were taken with the subjects wearing light clothing and no shoes. Body mass was measured using a digital scale with a maximum capacity of 150kg, and height using a portable stadiometer. Body mass index was calculated dividing the body mass by the height squared. The cutoffs proposed by Cole *et al.* (2000) were used to identify the nutritional status.

2.4 Truncal adiposity

The truncal adiposity was assessed by waist circumference, defined as the minimum circumference between the iliac crest and last rib using a metallic tape measure to the nearest millimeter (mm). The cutoffs adopted to identify truncal adiposity (normal or elevated) were proposed by Taylor *et al.* (2000).

2.5 Physical activity practice

Physical activity practice was assessed using a questionnaire (BAECKE; BUREMA; FRIJTERS, 1982) previously validated for the Brazilian pediatric population (GUEDES *et al.,* 2006). The questionnaire generates a score considering the physical activity performed at school, sport practice, leisure-time, and overall physical activity (school, sport, and leisure-time). The adolescents who were ranked in the lowest quartile for physical activity score were classified as "low physical activity practice" (categorical variable).

2.6 Heart rate variability measures

Heart rate variability was measured using a previously validated heart rate monitor (Polar - RS800CX) (QUINTANA; HEATHERS; KEMP, 2012). The measures were taken in a calm, quiet, and thermoneutral (22 °C to 24 °C) environment. The adolescents remained in the supine position. The R-R intervals were recorded by the device for 10 minutes and subsequently uploaded to a computer using the software *Polar Precision Performance* (release 3.00, Polar Electro Oy), considering only the final five minutes of measurement. Indicators of heart rate variability were calculated using the *Kubios* heart rate variability software, version 2.2 (Kuopio, Finland). Fourier's transformation was performed to quantify the very low, low, and high frequency bands, following the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). The quantitative analysis "beat-by-beat" was performed using the Poincaré plot. The analyzed variables were "root mean square of successive differences among normal heartbeats" (RMSSD) [time domain], low-frequency power (LF_{nu}), high-frequency power (HF_{nu}), and LF/HF_{nu} ratio in normalized units [frequency domain]. Heart rate variability was classified according to the cutoff points suggested by Sharma *et al.* (2015).

2.7 Experimental design

Initially, the Municipality Department of Education provided a list of all school units in the city and their geographical location. Considering the geographical regions (north, south, east and west), a random process was used to select one school unit per geographical region, totalizing four. The selected school units provided a list of all the schoolchildren of the target age range and from this list the students were randomly selected of each school. Following the previously established minimum sample size, a minimum of 25 adolescents were assessed in each school unit. Only adolescents whose parents/legal guardians signed the written consent form were assessed.

Data collection began with physical activity practice questionnaire, followed by anthropometric measures (height, body mass, and waist circumference). Next, the adolescents received guidance and help (if necessary) on how to wear the heart rate monitors used to assess the heart rate variability. The adolescents were requested not to speak and to avoid movements. After the heart rate variability measures, the adolescents were carefully positioned in the sitting position for blood pressure measures.

2.8 Statistical analysis

Descriptive data are presented in frequency and percentage. The Chi-square test assessed the associations among heart rate variability (dependent variable) and blood pressure, nutritional status, truncal adiposity, and physical activity practice (independent variables). Significant associations (P<0.05) were analyzed in the Poisson regression to determine the magnitude of the associations between the dependent and independent variables (prevalence ratio [PR]). Statistically significant associations in the univariate model were inserted in the adjusted multivariate model. Statistical significance was established at P<0.05. Statistical analysis was performed using the statistical software SPSS version 20.0 and STATA version 8.

3 Results and Discussion

The distribution of absolute and relative frequency is shown in Table 1. Schools "1, 2, 3 and 4" refer to those located in the north, south, east, and west, respectively. Besides the schools, the absolute and relative frequencies of gender, blood pressure, nutritional status, truncal adiposity, physical activity practice and heart rate variability indices are shown (RMSSD, LF_{nu}, HF_{nu}, and LF/HF_{nu}).

Table 1 - Absolute and relative frequency distribution

		Frequency	Percent (%)
School	1	34	24.6
	2	29	21.0
	3	37	26.8
	4	38	27.5
Total		138	100.0
Sex	Male	54	31.1
	Female	84	60.9
Blood pressure	Normal	76	55.1
	Elevated	62	44.9
Nutritional status	Normal/ Overweight	133	96.4
	Obese	5	3.6
Truncal adiposity	Normal	127	92.0
	Elevated	11	8.0
Physical activity practice	Low	100	72.5
	High	62	27.5
RMSSD	Low	109	79.0
	High	29	21.0
LF	Low	101	73.2
	High	37	26.8
HF	Low	132	95.7
	High	6	4.3
LF/HF	Low	61	44.2
	High	77	55.8

Schools "1, 2, 3 and 4" refer to those located in the north, south, east, and west, respectively. RMSSD = root mean square of successive differences between normal heartbeats; LF = low-frequency power; HF = high-frequency power; LF/HF = LF/HF ratio.
Source: Authors.

Table 2 presents the associations among heart rate variability (dependent variable) and blood pressure, nutritional status, truncal adiposity, and physical activity practice (independent variables). Table 2 also shows the association degree (Phi).

Table 2 - Associations among heart rate variability indices (dependent variables) and blood pressure, nutritional status, truncal adiposity, and physical activity practice (independent variables)

		Blood Pressure		Likelihood Ratio		Phi	
		Normal	Elevated	χ^2	*P*-value	Value	*P*-value
		N (%)	N (%)				
RMSSD	Low	60 (55)	49 (45)	0.000	0.990	-0.001	0.990
	High	16 (55)	13 (45)				
$LF_{(nu)}$	Low	62 (61)	39 (39)	6.072	0.014	0.210	0.014
	High	14 (38)	23 (62)				
$HF_{(nu)}$	Low	73 (55)	59 (45)	0.065	0.799	0.022	0.798
	High	3 (50)	3 (50)				

		Blood Pressure		Likelihood Ratio		Phi	
		Normal	**Elevated**	χ^2	***P*-value**	**Value**	***P*-value**
		N (%)	**N (%)**				
$LF/HF_{(nu)}$	Low	37 (61)	24 (39)	1.382	0.240	0.100	0.241
	High	39 (51)	38 (49)				
		Nutritional Status		**Likelihood Ratio**		**Phi**	
		Normal	**Obese**	χ^2	***P*-value**	**Value**	***P*-value**
		N (%)	**N (%)**				
RMSSD	Low	105 (96)	4 (4)	0.003	0.955	-0.005	0.955
	High	28 (96)	1 (4)				
$LF_{(nu)}$	Low	100 (99)	1 (1)	6.426	0.011	0.233	0.006
	High	33 (89)	4 (11)				
$HF_{(nu)}$	Low	127 (96)	5 (4)	0.453	0.501	-0.041	0.627
	High	6 (100)	0 (0)				
$LF/HF_{(nu)}$	Low	61 (100)	0 (0)	5.983	0.014	0.173	0.043
	High	72 (93)	5 (7)				
		Truncal Adiposity		**Likelihood Ratio**		**Phi**	
		Normal	**Elevated**	χ^2	***P*-value**	**Value**	***P*-value**
		N (%)	**N (%)**				
RMSSD	Low	100 (92)	9 (8)	0.060	0.807	-0.020	0.810
	High	27 (93)	2 (7)				
$LF_{(nu)}$	Low	98 (97)	3 (3)	11.102	0.001	0.305	<0.001
	High	29 (78)	8 (22)				
$HF_{(nu)}$	Low	121 (92)	11 (8)	1.020	0.312	-0.063	0.461
	High	6 (100)	0 (0)				
$LF/HF_{(nu)}$	Low	60 (98)	1 (2)	7.074	0.008	0.208	0.015
	High	67 (87)	10 (13)				
		Physical activity practice		**Likelihood Ratio**		**Phi**	
		Low	**High**	χ^2	***P*-value**	**Value**	***P*-value**
		N (%)	**N (%)**				
RMSSD	Low	81 (74)	28 (26)	0.888	0.346	0.080	0.346
	High	19 (65)	10 (35)				
$LF_{(nu)}$	Low	75 (74)	26 (26)	0.607	0.436	0.066	0.436
	High	25 (68)	12 (32)				
$HF_{(nu)}$	Low	95 (72)	37 (28)	0.371	0.542	0.371	0.542
	High	5 (83)	1 (17)				
$LF/HF_{(nu)}$	Low	47 (77)	14 (23)	1.152	0.283	0.091	0.283
	High	53 (69)	24 (31)				

RMSSD = root mean square of successive differences among normal heartbeats; LF = low-frequency power; HF = high-frequency power; LF/HF = LF/HF ratio.
Source: Authors.

The LF_{nu} component was associated with blood pressure. A higher relative frequency of adolescents with high blood pressure was observed among those with high LF_{nu} (62% vs 69% [*P*=0.014]), and the degree of association was 21% (*P*=0.014). There was no significant association between blood pressure and the other components of heart rate variability.

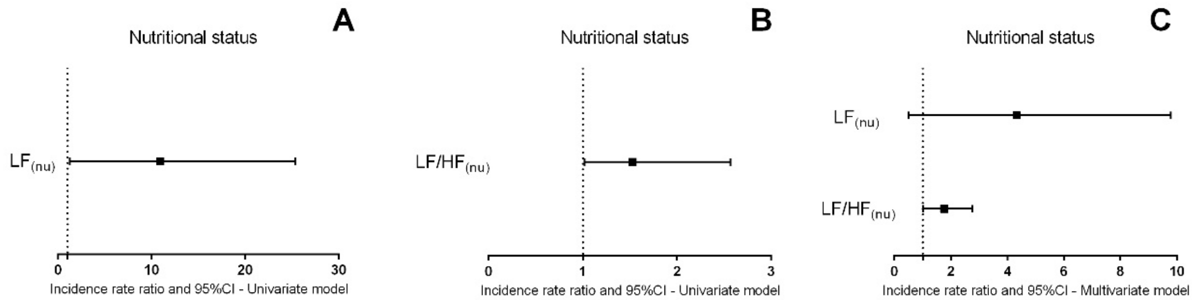
Obese adolescents were associated with high LF_{nu} and LF/HF_{nu} components (11% vs 1% [*P*=0.011] and 7% and 0% [*P*=0.014], respectively). The degree association was 23% [*P*=0.006] (LF_{nu}) and 17% [*P*=0.043] (LF/HF_{nu}). The other components of heart rate variability were not associated with nutritional status.

In the same sense, the LF_{nu} and LF/HF_{nu} components were associated with abdominal obesity. A higher relative frequency of adolescents with abdominal obesity showed high values for LF_{nu} (22% vs 3% [*P*=0.001]) and LF/HF_{nu} (13% vs 2% [*P*=0.008]). The associations degree were 30% [*P*<0.001] and 21% [*P*=0.015] for LF_{nu} and LF/HF_{nu}, respectively. No significant associations were observed among other heart rate variability components.

The heart rate variability components were not associated with physical activity practice.

Figure 1 shows the univariate regression model for LF_{nu} (A) and LF/HF_{nu} ratio (B), as well as the multivariate model (C) in relation to the nutritional status (independent variable). Obese adolescents had ten times more prevalence of high LF_{nu} (Graph A - PR=10.9 [IC95% 1.25-25.30] *P*=0.031) and 53% more prevalence of high LF/HF_{nu} (Graph B - PR=1.53 [IC95% 1.02-2.57] *P*<0.001) compared to non-obese ones. No significant prevalence ratio for LF_{nu} was identified between obese and non-obese adolescents in the multivariate model (Graph C - PR=4.32 [IC95% 0.50-9.78] *P*=0.183). On the other hand, obese adolescents were 76% more likely to have high LF/HF_{nu} ratio values (Graph C - PR=1.76 [IC95% 1.02-2.75] *P*<0.001).

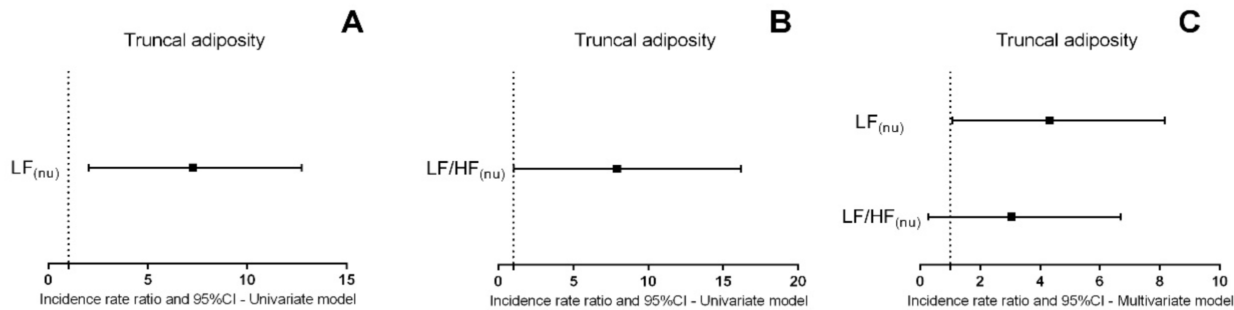
Figure 1 - Regression models for nutrition status (independent variable) and LF and LF/HF (dependent variables). Graph (A) = Univariate model for $LF_{(nu)}$; Graph (B) = Univariate model for $LF/HF_{(nu)}$; Graph (C) = Multivariate model for $LF_{(nu)}$ and $LF/HF_{(nu)}$. LF_{nu} = low-frequency power in normalized units; HF_{nu} = high-frequency power in normalized units; LF/HF_{nu} = LF/HF ratio in normalized units.



Source: Authors.

Likewise, univariate analysis (Figure 2) showed that adolescents with truncal obesity had seven times more prevalence of LF_{nu} (Graph A - PR=7.27 [IC95% 2.03-12.74] *P*=0.002) and LF/HF_{nu} (Graph B - PR=7.92 [IC95% 1.03-16.22] *P*=0.046) compared to non-truncal obese adolescents. On the other hand, in the multivariate model the LF/HF_{nu} lost significance (Graph C - PR=3.05 [IC95% 0.28-6.69] *P*=0.358), while LF_{nu} maintained (Graph C - PR=4.32 [IC95% 1.07-8.17] *P*=0.046).

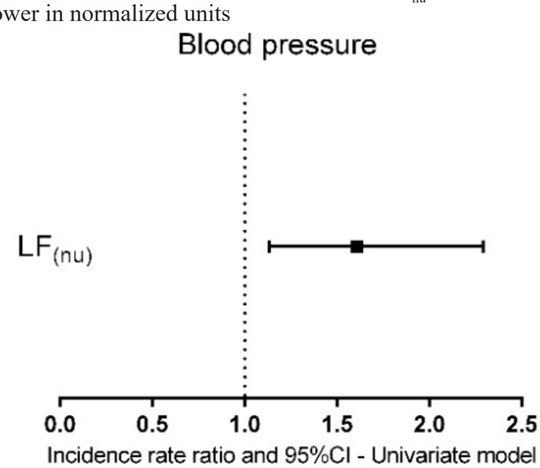
Figure 2 - Regression models for truncal adiposity (independent variable) and LF and LF/HF (dependent variables). Graph (A) = Univariate model for $LF_{(nu)}$; Graph (B) = Univariate model for $LF/HF_{(nu)}$; Graph (C) = Multivariate model for $LF_{(nu)}$ and $LF/HF_{(nu)}$. LF_{nu} = low-frequency power in normalized units; HF_{nu} = high-frequency power in normalized units; LF/HF_{nu} = LF/HF ratio in normalized units



Source: Authors.

Finally, adolescents with elevated blood pressure had 60% more prevalence of high LF_{nu} (Figure 3 - PR=1.60 [IC95% 1.13-2.29] *P*=0.008).

Figure 3 - Regression model for blood pressure (independent variable) and LF (dependent variable). LF_{nu} = low-frequency power in normalized units



Source: Authors.

The present study investigated the association among health indicators (blood pressure, nutritional status, truncal adiposity, and physical activity practice) with indices and components of heart rate variability (RMSSD, LF, HF and LF/HF). In the present analysis model, it was firstly determined whether there were significant differences between the observed and expected frequencies of the dependent (heart rate variability) and independent (blood pressure, nutritional status, and truncal adiposity) variables. Statistically significant associations were subjected to analysis of the magnitude of the association (prevalence ratio).

Thus, except for physical activity, the other variables were associated, at least in part, with heart rate variability in adolescents. Interestingly, among adolescents with high blood pressure, there was a 60% higher prevalence of subjects with a high LF_{nu} value. Importantly, the LF component refers to global variability, being sensitive to both sympathetic and parasympathetic modulations (Heart rate variability: standards of measurement, physiological interpretation and clinical use. Task Force of the European Society of Cardiology and the

North American Society of Pacing and Electrophysiology, 1996). Thus, it is possible to hypothesize that adolescents with high blood pressure tend to have greater autonomic activation. In adults, it is well known that higher blood pressure values are also associated with greater sympathetic branch action (IZZO; TAYLOR, 1999). However, in the LF/HF component (essentially sympathetic) no significant associations were identified, demonstrating that the autonomic response of adults and adolescents may be different since hypertensive adults usually have reduced parasympathetic tone indicators of heart rate variability (SAITO *et al.*, 2018).

Obese adolescents were associated with higher LF and HF/LF values, suggesting more exacerbated sympathetic activity and lower vagal tone in these subjects. The relationship between obesity and reduced vagal tone in childhood and adolescence has been identified in previous studies (DANGARDT *et al.*, 2011). Considering that heart rate variability naturally tends to reduce with age (ALMEIDA-SANTOS *et al.*, 2016), it is possible to hypothesize that reduced early parasympathetic activity tends to increase risks in adulthood, specially from the fourth decade of life which tends to be the period of time when the autonomic-metabolic aging process starts manifesting its cardiac autonomic dysregulation on obese people (RASTOVIĆ *et al.*, 2019). Furthermore, the present study demonstrated in the multivariate analysis model that the LF/HF ratio remained statistically significant, reinforcing the relationship between obesity and high sympathetic activity.

Unlike other researchers (SANTOS-MAGALHAES *et al.*, 2015), reductions were not identified in parasympathetic modulation in time (RMSSD) or frequency-domain heart rate variability. This fact can be attributed, at least in part, to the specific characteristics of the sample. In the present study, few participants were classified as having high parasympathetic activity (RMSSD or HF). Thus, future studies must be conducted to clarify this aspect in this reference population.

Trunk adiposity has been widely studied, especially in pediatric populations, since this characteristic has been associated with several risk factors, especially related to cardiovascular disease (KELISHADI *et al.,* 2015). In the present study, higher scores in the LF component and in the LF/HF ratio were associated with abdominal obesity. As in general obesity, adiposity in the trunk has been characterized as a modulator of heart rate variability (FARAH *et al.,* 2013). Studies have shown that central fat is associated with a decrease in parasympathetic indices, such as RMSSD and HF, as well as an increase in the components most associated with sympathetic activation, such as the LF/HF ratio (YADAV *et al.*, 2017).

In the present study, associations were not identified between the habitual practice of physical activities and the analyzed heart rate variability indicators. In fact, previous studies have shown that the practice of physical activities in pediatric populations promotes greater direct benefits in motor and morphological abilities (ALVES; ALVES, 2019; HALLAL *et al.,* 2006). However, a study involving only adolescents with abdominal obesity showed that higher leisure-time physical activity levels were associated with better heart rate variability profile (FARAH *et al.*, 2018).

In general, it is important to highlight that in the present study, no significant associations were found with primarily parasympathetic indices, which may be related to the specific characteristics of pediatric populations. Hypothetically, children and adolescents do not have an autonomic profile that is highly linked to morpho-functional characteristics (ALVES; ALVES, 2019; HALLAL *et al.,* 2006).

Some limitations of this essay must be considered. This is a cross-sectional study, for this reason it is not possible to identify cause-effect relationships. The present sample has relatively few obese adolescents, so it is recommended that in future studies, strategies be adopted to prevent obese individuals from refusing to participate in the surveys. It is also recommended that more accurate assessment strategies be used to assess the practice of physical activities.

Despite the limitations, it is important to emphasize that the present investigation was carried out with a local sample representative of all regions, as well as in an adequate size. In addition, all assessments were performed using validated methods.

4 Conclusion

Adolescents with high blood pressure have a higher prevalence of exacerbated autonomic activity. Additionally, obesity and truncal adiposity, are associated with greater expression of sympathetic activity indicators. Finally, the practice of physical activities is not associated with heart rate variability in adolescents.

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