Original article (short paper)

Blood pressure and cardiac autonomic modulation at rest, during exercise and recovery time in the young overweight

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Abstract—This study aimed to assess the blood pressure (BP), cardiac autonomic modulation at rest, in physical exercise and in the recovery in untrained eutrophic (E) and overweight (O) youth. The body mass index (BMI), waist circumference (WC), systolic BP-SBP (E: 109.80 ± 10.05; O: 121.85 ± 6.98 mmHg) and diastolic BP – DBP (E: 65.90 ± 7.28; O: 73.14 ± 12.22 mmHg) were higher in overweight and the heart rate recovery (%HRR) was lower as compared with E volunteers. The BMI was associated with SBP (r= 0.54), DBP (r= 0.65), load on the heart rate variability threshold - HRVT (r= -0.46), %HRR $^{2'}$ (r= -0.48) and %HRR $^{5'}$ (r= -0.48), and WC was associated with SBP (r= 0.54), DBP (r= 0.64) and HRR $^{2'}$ (r= -0.49). The %HRR was associated to SBP, DBP and HRVT. In summary, the anthropometric variables, BP and cardiac autonomic modulation in the recovery are altered in overweight youth.

Keywords: obesity, heart rate variability, aerobic fitness, heart rate recovery.

Introduction

Obesity is considered a public health problem and currently reaches 17.5% in Brazilian population, while the prevalence of overweight people has already reached 50.8% (Brasil, 2013). The excess body mass predisposes to a lower life expectancy by early development of cardiovascular disease in adulthood, likely beginning in childhood and adolescence (Altuncu *et al.*, 2012).

In Brazil, the frequency of people diagnosed as hypertension is 24.1%, reaching over 50% in the population over 55 years old. However, the young adult population is already constituted by 11.1% of hypertensive subjects (Brazil, 2013). It is estimated that by 2025, the prevalence of hypertension in adult population worldwide will be 26.8% in the male population (20 to 29 years old) (Kearney *et al.*, 2005).

Monitoring cardiovascular parameters allows for an early prevention and/or treatment of the development of cardiovascular diseases. Due to the simplicity of measurement, heart rate behavior is widely studied in diverse health conditions associated to the resting rate (Cambri, DE Olivera, & Gevaerd, 2008; Fronchetti, Nakamura, Aguiar & Oliveira, 2006), as well as during physical exercise (Laursen, Shing, Peake, Coombes, & Jenkins, 2005; Lima & Kiss, 1999; Lucía *et al.*, 2000; Tulppo *et al.*, 2003;) and on a smaller scale, in the recovery time after exercise (Cambri *et al.*, 2009; Cole, Blacktone, Pashkow, Snader, & Lauer, 1999; Fernandes, Adam, Costa, Silva & De-Oliveira, 2005; Kannankeril, Le, Kadish & Goldberger, 2004). Indeed, the heart rate at rest and during recovery time after exercise are utilized as indicators of aerobic fitness, monitoring cardiovascular adaptations and the autonomic function since the maintenance of heart rate values is a consequence of a balance between vagal tone and sympathetic activity. Therefore, heart rate variability (HRV) - interval temporal variability between successive heartbeats, measured by R-R interval are important approaches to detect cardiac autonomic dysfunction, degenerative chronic diseases and the higher mortality risk (Almeida & Araújo, 2003).

Other aerobic fitness predictors are the metabolic transition thresholds, which may be determined by HRV, also known as HRV threshold (HRVT) (Lima & Kiss, 1999). It is associated with the transition between the effort intensity where the parasympathetic influence in heart rate control is reduced, and with predominant participation of sympathetic activity, also associated with the lactate, ventilatory and glycemic thresholds (Fronchetti *et al.*, 2006; Lima, Kiss, 1999; Tulppo *et al.*, 1998).

The heart rate at rest, HRV, HRVT and heart rate recovery are non-invasive measurements, allowing analysis of the cardiac autonomic nervous system (Vanderlei *et al.*, 2009). Most studies assessing the heart rate and HRV at rest, associated with obesity, involve middle-aged adults (Karason, Mølgaard, Wikstrand, & Sjostrom,1999; Laederach-Hofmann, Mussgay, & Ruddel, 2000; Singh *et al.*, 1998) and elderly, both with associated diseases such as hypertension (Grassi *et al.*, 2000; Singh *et al.*, 1998) and diabetes mellitus (Cambri *et al.*, 2008; Cambri *et al.*, 2009; Jarczok, Mauss, Fischer & Thayer, 2012). In addition, the pathological changes are already considered established and in some conditions more pronounced, due to time of exposure to the excess body mass and properties of the aging process, which makes the isolation of obesity's effects difficult. Furthermore, studies assessing the HRV in physical exercise usually involve eutrophic physically active youth or athletes (Fronchetti *et al.*, 2006; Lima & Kiss, 1999; Peçanha, Mattos, Silva, Rezende & Lima, 2013). Given that apparently healthy young subjects that are overweight are not being assessed, especially when considering the autonomic nervous system responses during the recovery after physical exercise. This study was carried out to understand the associated factors with cardiac autonomic control in young overweight subjects.

Thus, the present study aimed to compare the anthropometric variables, blood pressure and cardiac autonomic modulation indexes at rest, during physical exercise, and in active recovery time after maximum progressive tests between eutrophic and overweight youth, as well as verifying the association between these variables.

Methods

Participants

We assessed 21 university students between the ages of 18 and 25 years old (21.51 ± 1.81 years), all apparently healthy males. Considered untrained by not practicing any kind of physical exercise in the four months prior to the study, there being 10 eutrophic individuals (BMI ≤ 24.9 kg.m^{-2}) and 11 overweight individuals (BMI ≥ 25 kg.m^{-2}). The Ethics in Research Committee approved the study procedures under the advice nº 19109213.2.0000.5541, and all the volunteers signed an Informed Consent Form. The exclusion criteria were morbid obesity, smoking, use of medications that interfere in the studied variables, articular problems which prevents physical exercise and other pathologies.

Procedures

The participants were instructed not to perform vigorous activities and not to consume alcohol or caffeinated drinks within 24 hours prior to the evaluations. They were also advised to eat the final meal two hours before the data collection started.

The body mass (CAMRY® balance, 100 g) and height (SANNY® stadiometer, 0.1 cm) were utilized to determine the BMI. The waist circumference was measured in the smallest region between the xiphoid process and the umbilical scar (anthropometric tape SANNY®, 0.1 cm), to evaluate the cardiometabolic risk.

The systolic and diastolic blood pressure were determined in sitting position after ten minutes of rest (MICROLIFE®, BP 3BT0-A model). Following the procedures established in the *IV Brazilian Guidelines of Hypertension (2010)*, the heart rate and HRV were measured for a period of five minutes after five minutes of rest, using a portable heart rate monitor (POLAR®, RS800CX model) that records beat to beat by R-R intervals.

The R-R intervals were treated in *Kubios HRV* software with the artifacts filtered at a moderate level. The HRV indexes utilized were related to time domain as standard deviation of the instantaneous R-R intervals (SD1); standard deviation of R-R intervals analyzed at long-term (SD2); square root of the successive differences means to be squared between adjacent R-R (RMSSD); the percentage of successive difference between R-R intervals that are < 50 ms (pNN50).

Exercise protocol

A maximum progressive test was performed on an ergometer cycle (INBRASPORT®, CG-04 model), with initial load of 15 W, adding 15 W and 60 rpm every minute until voluntary exhaustion. All participants reaching at least 90% heart rate of the maximum predicted by age (220 - age) considered as the test limit. The SD1 index (by Poincaré plot) was determined for HRV analysis during testing, which represents the parasympathetic tonne, associated to each load. The HRVT was defined by Lima & Kiss (1999) criterion, which is the first exercise intensity to present the SD1 index less than 3 ms. At the end of the incremental test, the recovery period was actively performed for five minutes with 15 W. The HRR was determined every minute in relation to the peak heart rate which reached at full load test in percentage. The evaluations always occurred in the afternoon between 2 and 4 pm with temperature of 25 ± 4.14 °C and relative humidity of 45.07 ± 5.95%.

Statistical Analysis

A descriptive statistic was utilized with mean determination and standard deviation. The Shapiro Wilk test was utilized to analyze the data normality. The T-test non-paired for parametric data and the U-test of Mann-Whitney for non-parametric data were utilized for comparison of the groups. The Pearson's linear correlation and Spearman's rank were utilized to determine the relation between the variables analyzed for parametric and non-parametric data, respectively. The significance level was 5% ($p < .05$).

Results

Table 1 shows the mean values and standard deviation of anthropometric variables, blood pressure and cardiac autonomic modulation indexes at rest.

From eleven overweight individuals evaluated 54% were obese. The data indicate that the overweight youth showed higher values of BMI, waist circumference, systolic and diastolic blood pressure when compared with the eutrophic group ($p < .05$). Moreover, the overweight youth also showed higher resting heart rate and lower HRV (measured by diverse indexes), although non-significant.

All volunteers performed the maximum test, since they reached 100.16 ± 5.09% of the maximum heart rate predicted for their age. Table 2 shows the comparison between groups regarding the variables of maximum progressive test and of the active recovery period. Showing that overweight youth tend to present lower absolute and relative load in HRVT (p = 0.08), indicating low aerobic fitness. Besides, post-exercise they normalized the heart rate later (p < .05), when compared with the eutrophic group of the same age (Table 2).

Table 3 shows a significant correlation (p < .05) between systolic blood pressure and BMI, waist circumference and SD2, as well as diastolic blood pressure with BMI, waist circumference and HRVT. Additionally, significant correlations were observed (p < .05) in heart rate with SD1, SD2, RMSSD, pNN50 and HRVT load; and the load of HRVT with SD1, SD2, RMSSD and pNN50.

Table 4 shows a negative correlation between HRR, blood pressure and HRVT, with significant correlations (p < .05) between HRR in the second and third minutes with systolic and diastolic blood pressure, and in the fifth minute with systolic blood pressure and additionally of HRR in the third, fourth and fifth minutes with HRVT. In addition, significant correlations were observed (p < .05) between HRR_{2}, with BMI (r = - 0.48) and waist circumference (r = - 0.49), and between HRR_{5}, with BMI (r = - 0.48) and pNN50 (r = 0.48).

Discussion

The main results of this study demonstrate that resting blood pressure was increased and the %HRR was reduced after physical exercise in overweight youth. In addition, BMI, waist circumference and %HRR are correlated to higher blood pressure and lower load of HRVT.

The most interesting finding is that cardiovascular changes due to excess body mass in young people, seem to be more detectable during recovery time and in some variables at rest, without affecting the response to the physical exercise between the two groups. This underlines the importance of evaluation at different physiological moments in this population. The importance of this study is that we assessed apparently healthy overweight untrained youth, since the most studies examined obesity associated with cardiac autonomic modulation at rest in middle-aged individuals with other pathologies already installed (Laederach-Hofmann *et al.*, 2000; Karason *et al.*, 1999; Singh *et al.*, 1998). Furthermore, the cardiac autonomic modulation has been examined eutrophic and physically active youth during exercise only (Fronchetti *et al.*, 2006; Lima & Kiss, 1999).

In this study, the overweight group had higher systolic and diastolic blood pressure values, although still in normotensive status. Accordingly, it was demonstrated that 85.2% of public servants considered hypertensive showed to be overweight or obese (Sabry, Sampaio & Silva, 2002). Confirming, thus, that excess body mass is one of the most important factors associated with increased blood pressure in adults (Commitee, 1997; Rahmouni, Correia, Haynes & Mark, 2005). Corroborating these results in a group with heterogeneous ages, significant associations of BMI, and waist circumference with blood pressure were found (Silva, Barbosa, Oliveira & Guedes, 2006).

The increase of blood pressure represents an independent risk factor for cardiovascular disease and its complication whereas its reduction decreases the prevalence of cardiovascular events. Indeed, the reduction of 2 mmHg in systolic blood pressure decreased the risk of mortality around 10% as well as to develop other vascular complications in middle age patients nearly by 7% (Lewingdon, Clarke, Qizilbash, Peto & Collins, 2002).

Thus, the HRV analysis has been used as a tool for better understanding of cardiovascular behavior, as well as its relation with blood pressure levels (Grassi *et al.*, 2000; Singh *et al.*, 1998; Thiyagaraja *et al.*, 2012).

Table 1. Anthropometric variables, blood pressure and heart rate variability indexes at rest.

	Eutrophic (n=10)	**Overweight (n=11)**
Age (years)	21.34 ± 1.90	21.66 ± 1.81
BMI ($kg.m^{-2}$)	22.46 ± 1.83	30.03 ± 2.78*
Waist circumference (cm)	76.02 ± 3.04	95.83 ± 6.41*
Systolic blood pressure (mmHg)	109.80 ± 10.05	121.85 ± 6.98*
Diastolic blood pressure (mmHg)	65.90 ± 7.28	73.14 ± 12.22#
Heart rate (bpm)	73.65 ± 10.11	78.05 ± 12.72
SD1 (ms)	27.33 ± 10.41	22.72 ± 15.67
SD2 (ms)	75.47 ± 22.82	65.26 ± 28.56
RMSSD (ms)	38.59 ± 14.71	32.08 ± 22.13
pNN50 (%)	17.31 ± 13.09	13.01 ± 17.29

*Statistically significant difference by Student's t-test's to parametric data (p< .05).

Statistically significant difference by Mann Whitney U Test for nonparametric data (p < .05).

Table 2. Absolute and relative intensity in heart rate variability threshold (HRVT) and heart rate recovery (HRR).

	Eutrophic (n=10)	Overweight (n=11)
Peak load (W)	198.43 ± 32.10	210.00 ± 20.64
HRVT (W)	103.50 ± 34.96	71.67 ± 42.94
HRVT (%)	52.98 ± 17.64	37.79 ± 20.67
Peak heart rate (bpm)	196.40 ± 10.88	199.80 ± 10.30
Heart rate HRVT (bpm)	138.90 ± 13.80	131.89 ± 8.91
Heart rate HRVT (%)	70.97 ± 8.57	66.24 ± 5.34
HRR_1 (%)	15.16 ± 3.19	10.64 ± 4.88*
HRR_2 (%)	23.79 ± 3.24	18.31 ± 4.38*
HRR_3 (%)	28.65 ± 3.64	23.64 ± 5.96*
HRR_4 (%)	31.55 ± 3.34	26.77 ± 6.56
HRR_5 (%)	36.05 ± 10.94	27.67 ± 6.44#

* Statistically significant difference by Student's t-test's to parametric data ($p < .05$).

Statistically significant difference by Mann Whitney U Test for nonparametric data ($p < .05$).

Table 3. Correlation coefficients (r) between anthropometric variables, blood pressure, heart rate variability indexes at rest and heart rate variability threshold (HRVT).

n=21	Systolic blood pressure (mmHg)	Diastolic blood pressure (mmHg)	Heart rate (bpm)	HRVT (W)
BMI ($kg.m^{-2}$)	0.54†	0.65†	0.26	-0.46†
Waist circumference (cm)	0.54†	0.64†	0.34	-0.38
Heart rate (bpm)	0.34	0.37	-	-
SD1 (ms)	-0.35	-0.39	-0.64‡	0.66‡
SD2 (ms)	-0.46†	-0.42	-0.56†	0.60†
RMSSD (ms)	-0.34	-0.39	-0.62‡	0.65‡
pNN50 (%)	-0.38	-0.43	-0.59‡	0.67‡
HRVT (W)	-0.34	-0.46†	-0.57†	-

† Significant correlation coefficient by Pearson's linear correlation ($p < .05$).

‡ Significant correlation coefficient by Spearman's Rank linear correlation ($p < .05$).

Table 4. Correlation coefficients (r) between heart rate recovery (HRR), resting blood pressure (mmHg) and heart rate variability threshold - HRVT (W).

n=21	Systolic blood pressure	Diastolic blood pressure	HRVT
HRR_1 (%)	-0.45	-0.34	-0.17
HRR_2 (%)	-0.63†	-0.60†	-0.34
HRR_3 (%)	-0.51†	-0.53†	0.52†
HRR_4 (%)	-0.20	-0.33	0.48‡
HRR_5 (%)	-0.43	-0.54‡	0.47‡

† Significant correlation coefficient by Pearson's linear correlation ($p < .05$).

‡ Significant correlation coefficient by Spearman's Rank linear correlation ($p < .05$).

Higher values of heart rate at rest reflect a lower parasympathetic activity, suggesting worse cardiac autonomic control combined with a less favorable health status and increased risk for cardiovascular disease (Greenland *et al.*, 1999). As observed in a previous study evaluating sedentary youth of both genders, in which heart rate at rest, as well as the sympathetic nervous activity were higher in the overweight group compared with the eutrophic group (Oliveira & Bassini, 2013). Differently, in the present study, no differences were observed between the groups for the heart rate at rest, although the values in the overweight group were higher.

Middle age individuals that are overweight, as compared with eutrophic, tend to show differences in sympathovagal balance consisting in lower activity of the parasympathetic tone, resulting in increase of heart rate at rest and decrease of HRV index (Karason *et al.*, 1999). On the other hand, high fitness level would cause a greater parasympathetic activity and hence lower values of heart rate at rest (Almeida & Araújo, 2003; Cambri *et al.*, 2009; Fronchetti *et al.*, 2006). Our results indicated a trend in young overweight individuals, showing a smaller load in HRVT, with a moderate correlation of HRV indexes at rest. The HRVT load (0.60 to 0.67) indicates that the higher load in the HRVT was associated with higher parasympathetic tone. Overweight volunteers seem to show lower parasympathetic tone as well as lower aerobic fitness. This occurs due to the fact that overweight individuals show an early vagal withdrawal followed by a large participation of sympathetic activity (Brunetto, Rosseguini, Hirai, & Guedes, 2005). We believe that if our group was constituted only by obese individuals these differences would be more statistically significant. Since increased body mass is associated with cardiac autonomic, metabolic and morphophysiological dysfunctions and these deep changes may occur only in the installed obesity, and not in the overweight, which constituted 46% of our group.

Furthermore, correlations that show that the increased body mass and waist circumference negatively affects the blood pressure, aerobic fitness and %HRR, as well as the HRV indexes at rest associated to the HRVT load were verified in the present study. The latter associations were also demonstrated by Cambri *et al.* (2008), in type 2 diabetics, and by Fronchetti *et al.* (2006) for eutrophic youth. Additionally, in a study of type 2 diabetic of middle-aged, it was verified that the morphological variables such as body mass, BMI, waist circumference, body fat percentage, were associated significantly with the lipids and glycemic profile (Cambri & Gevaerd, 2006). This suggests that young individuals with higher levels of adiposity may present other cardiovascular risk factors such as changes in lipid and glycemic profile.

In the present study, the negative correlation (r = - 0.63) was observed between heart rate at rest and the load corresponding to HRVT, suggesting that decreasing in heart rate at rest is associated with changes in aerobic fitness determined by HRVT. These results corroborate the literature showing that aerobic training reduces the heart rate at rest and improving sympathovagal balance, and during physical exercise parasympathetic is blunted resulting in higher loads of HRVT, lactate and ventilatory threshold (Fronchetti, Nakamura, De-Oliveira, Lima-Silva, & Lima, 2007; Laursen *et al.*, 2005; Lucía *et al.*, 2000; Tulppo *et al.*, 2003 (Yamamoto, Miyachi, Saitoh, Yoshioka & Onodera,2000).

Besides controlling the heart rate at rest, the autonomic nervous system has a key role in controlling blood pressure, and may be related to an important pathophysiological factor in the development of hypertension (Julius, 1991; Menezes Júnior, Moreira & Daher, 2004). The literature has shown that in obese and non-obese individuals, a higher sympathetic activity has been constantly associated with hypertension (Grassi *et al.*, 2000; Singh *et al.*, 1998), due to peripheral vasoconstriction and other associated factors, where individuals with hypertension show a reduced HRV. Furthermore, a negative correlation was found between diastolic blood pressure and the load in HRVT, also between the blood pressure and %HRR, indicating that the morphophysiological changes are related with cardiac autonomic modulation in young individuals.

Thus, the HRVT identification is an important parameter because it may be used for training prescription within a safe range associated with an improved aerobic capacity, as well as other morphophysiological variables. The protective effect of exercise was demonstrated through aerobic training of 30 minutes in lactate threshold load, highlighting improvement in blood pressure values of university professors (Ribeiro *et al.*, 2011). It is also suggested that the load increase in HRVT in maximum test after high intensity interval training of three weeks reflects the delay in parasympathetic withdrawal, due to improvements in cardiac autonomic modulation in sedentary individuals. Reinforcing the use of HRV analysis at rest and during exercise, in exercise prescription and monitoring of their responses (Fronchetti *et al.*, 2007).

After exercise, the heart rate decreased exponentially, and it is controlled by the autonomic nervous system, through vagal tone reactivation and sympathetic tone withdrawal. Moreover, the literature shows an inverse relation between the HRR and mortality risk; thus, the smaller reduction of the heart rate in recovery time, a higher prevalence of autonomic dysfunction, especially in its parasympathetic area, seen in patients with coronary disease, chronic cardiac insufficiency, hypertension, myocardial infarction and mellitus diabetes (Cole *et al.*, 1999; Cole, Foody, Blackstone, & Lauer, 2000; Imai *et al.*, 1994; Lima, Oliveira & Ferreira-Júnior, 2012; Nishime, Cole, Blackstone, Pashkow & Lauer, 2000; Perini, Orizio, Comand, Castellano & Beschi, 1989). Accordingly, the HRR measurement provides information about the integrity and functioning of the autonomic nervous system, as well as the hemodynamic variables behavior in the recovery phase, and also showing clinical and sporting applications.

In the present study, the overweight individuals showed a delay in normalizing the the heart rate post-exercise as compared with eutrophic individuals. The HRR is decreased in diverse pathological conditions such as obesity, mellitus diabetes, severe coronary artery disease, chronic cardiac insufficiency, chronic renal disease, myocardial infarction (Ghaffari, Kazemi, Aliakbarzadeh, 2011; Imai *et al.*, 1994; Sarmiento *et al.*, 2013; Tavares, Nunes,& Santos, 2010). In addition, Nishime *et al.* (2000) verified that individuals with unusual HRR have lower functional capacity and that HRR values in the first minutes less than 10 to 12 bpm were associated with higher mortality risk in adults in middle age. Previous study show the percentage fall of HRR in the first and in the fifth minute was 17.8 and 38.2%, respectively in eutrophic youth (Peçanha *et al.*, 2013). In agreement, our study shows similar percentages in the eutrophic group.

Post-exercise cardiac autonomic recovery may be divided into fast and slow phases (Coote, 2014; Imai *et al.*, 1994; Perini *et al.*, 1989). In the fast phase, the central command stimulus closure, present in skeletal muscle after exercise, allows the vagal reactivation which produces a rapid fall of the heart rate (Carter, Watenpaugh, Wasmund, Stenphen & Smith, 1999; Ogoh *et al.*, 2002). A fact that was verified in the Carter et al (1999) study, where there was a smaller decrease in heart rate in active recovery protocol than in the passive recovery, indicating that the central command stimulus closure to muscles is a determining factor in the early heart rate decrease.

The mechanisms that explain the decrease in heart rate in recovery after maximum progressive test are still controversial.

In this regard, Peçanha *et al.* (2013) verified vagal reactivation absence during 5 minutes after a maximum progressive test due to the mean values of RMSSD index, which reflects vagal predominance, every 30 seconds of the recovery, not being different from those obtained in the first 30 seconds. As for the average SDNN index every 30 seconds, which reflects sympathetic and parasympathetic activity, significantly increased, probably due to a slight sympathetic withdrawal, suggesting that sympathetic withdrawal and not vagal reactivation was the main cause of HRR in the first five minutes, diverging from the results found in the literature (Cole *et al.*,1999, 2000; Nishime *et al.*, 2000; Perini *et al.*,1989; Pierpont & Vohtoh, 2004). As a result, more research is required for a better understanding of the sympathovagal balance during post-exercise recovery and its influence on heart rate.

It is possible that the small number of individuals in the group studied, as well as no subdivision between overweight and obese, have interfered in the observation of a large number of differences and significant associations between the analyzed variables constituting the limitations of this study.

In summary, waist circumference, systolic and diastolic resting blood pressure, and the HRR in the early stages of active recovery after maximum progressive test are altered in overweight youth. In addition, the BMI and waist circumference negatively affect the blood pressure, the aerobic fitness and the HRR, and the diverse indexes of HRV at rest are associated to aerobic fitness determined by heart rate at rest and the load in HRVT. Furthermore, the HRR was associated to resting blood pressure and the load in HRVT, highlighting that excess body mass negatively implies on morphophysiological variables of these young individuals and reflects in lower levels of aerobic fitness.

Thus, a lifestyle change requirement is observed, in order to reduce BMI and waist circumference, and aerobic fitness improvement. This will result in a better hemodynamic and cardiac autonomic control, both at rest and in physical exercise, and in post-exercise recovery, reducing the risk of developing chronic diseases and cardiovascular complications precociously, and its many associated with better outcomes.

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