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Cardiac Autonomic Modulation in Preadolescents Following 4 and 8 Weeks of Play-based Summer Activity

M Meucci[1], C Baldari[2], L Guidetti[2], C Cook M.S[1], J Prestes[3] and SR Collier[1*]

[1]Department of Health and Exercise Science, Appalachian State University, Boone, North Carolina, USA

[2]Department of Movement, Human, and Health Sciences, University of Rome "Foro Italico", Rome, Italy

[3]Graduate Program on Physical Education, Catholic University of Brasilia, Brasilia, Brazil

[*]**Corresponding author:** Scott R. Collier, Department of Health and Exercise Science, Appalachian State University, Boone, North Carolina, USA, **Tel**: 828-262-7145; **Fax**: 828-262-3138; **E-mail**: colliersr@appstate.edu

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ABSTRACT

Pediatric obesity is associated with a decrease in cardiac autonomic modulation and baroreflex sensitivity. Physical activity increases heart rate variability in adults, yet no study has elucidated the mode and intensity of exercise for beneficial effects on cardiac autonomic modulation in children.

Objective: The purpose of our study was to examine the effectiveness of 4 and 8 weeks of supervised, play-based activity on blood pressure, heart rate variability and baroreflex sensitivity in preadolescents.

Methods: Twenty-two recreationally active overweight, 8 to 12 year-old children were randomly divided into a 4- and 8-week activity group and an unsupervised control group (4w, n = 6, 8w, n = 6, and C, n = 10). 4w and 8w groups performed play-based activities 5 days per week, 4 hours a day while C group were instructed to maintain a regular summer break with no supervised intervention. Heart rate variability and baroreflex sensitivity were tested before and after exercise with a heads-up tilt test.

Results: Systolic blood pressure was significantly lower in all three groups in post conditions (P = 0.02, eta2 = 6.86). Normalized low and high frequencies reported a significant group-by-time difference in both supine resting conditions and after heads-up tilt (P = 0.04, eta2 = 0.28 and P = 0.05, eta2 = 0.28, respectively) and total power in supine position (P = 0.04, eta2 = 0.29) between the 8w, and the 4w and C groups, while baroreflex sensitivity increased by only 3 ms/mmHg in the 8w group (P = 0.09).

Conclusion: 8 weeks of supervised, play-based physical activity improved autonomic nervous system activation with favorable changes in sympathovagal balance in recreationally active overweight preadolescents during summer break.

Keywords: Preadolescents; Autonomic nervous system; Physical activity; Summer break; Heart rate variability; Cardiac autonomic modulation; Baroreflex sensitivity

Introduction

The adoption of a sedentary lifestyle has become a serious epidemic in adults and children and it is increasingly disconcerting since it is associated with an increase in the clinical manifestation of cardiovascular disease. Previous studies shown that overweight/obese children have lower heart rate variability (HRV) than their normal weight counterpart and that HRV is positively correlated with physical activity levels [1]. Low HRV is indicative of reduced cardiac autonomic modulation (CAM), which is commonly used as a clinical tool to predict cardiac morbidity and mortality [2,3]. Chronic sympathetic activity will lead to the erosion of parasympathetic dominance of cardiac control which in turn increases myocardial stress leading to early cardiovascular diseases (CVD) [4] and related heart failure [5]. It has been shown that reduced CAM is associated with a variety of conditions such as myocardial infarction, myocardial transplant, diabetic neuropathy, and tetraplegia [2].

Exercise is an important factor in the prevention and treatment of CVD through all stages of growth and development [6]. It is well known that fit individuals have greater CAM compared to the sedentary counterpart [7,8] and studies in obese adolescents have demonstrated that physical activity augments cardiovascular autonomic function [1,9,10] lending clinical utility to a population that is at-risk for cardiovascular and metabolic disorders [11]. However, the most appropriate type of physical activity for preadolescents has yet to be established.

It is well known that structured, endurance exercise can enhance autonomic function in children [12-16]. Yet, studies have shown that physical activity is more likely to be repeated if it is obtained during play-based activities using skill-based games, which evolves into habitual practice [17,18]. Our laboratory has recently shown the positive benefits of play-based activity on cardiac function [19]. However, to our knowledge, there are no studies documenting the effects of short term, play-based physical activity on autonomic function in children.

The aim of this study was to examine the effectiveness of a 4 and 8 week play-based, supervised physical activity program on cardiac autonomic modulation and baroreflex sensitivity (BRS) over summer break.

Materials and Methods

Subjects

Only healthy, recreationally active preadolescents were recruited for this study. Exclusion criteria included previous CVD, renal disease, diabetes or any use of medications. Participants were recruited via flyers during from the local community. Twenty-two overweight children (13 males and 9 females), ages 8-12 years old and BF% equal to 25.1 ± 11.0% in males and 27 ± 5.7% in females (75th percentile) [20], were recruited from the local community. They were randomly assigned to three different groups based on the four or eight week camp their parents enrolled them into: an 8-week (8w, n = 6) and a 4-week (4w, n = 6) activity groups, which performed a supervised play-based activity program, and an unsupervised age matched control group (C, n = 10) where subject (and parents) had no plans of changing typical activity levels throughout the summer.

During the initial screening, cardiovascular risk and history were assessed and exclusion criteria included previous CVD, renal disease, diabetes, or any use of medications. Parents reported their child's health history and current activity status through a questionnaire and seated peak height velocity (cm) was measured to check for maturational stage [21]. Only healthy, recreational active preadolescents from 8 to 12 years old were chosen. Procedures were approved by the University's Institutional Review Board. All subjects and parents read and signed informed consent and assent forms to show their understanding and willingness to participate in the study.

Experimental design

Subjects were required to report to the Vascular Biology and Autonomic Studies Laboratory on two separate occasions, before and after the study period. To obtain more reliable data between pre and post conditions and attenuate inter-individual variability in measurements, external influences were controlled by testing the children at the same time of day between 6:30 a.m. and 8:00 a.m. following a 12 hour overnight fast [22,23]. All subjects reported to the laboratory prior to starting the summer camp for CAM and BRS testing prior to randomization to one of the three groups. Following 4 or 8 weeks of supervised or 8 weeks of unsupervised activity, subjects reported back to the laboratory within 48 hours for post measurements. Both visits included anthropometrics, and electrocardiogram recordings (ECG) in supine resting condition (SRC) (0°) and after heads-up tilt (HUT) (+80°).

Anthropometric and body composition assessment

Weight was assessed using a calibrated beam scale and mass was recorded in kilograms (kg). Height was measured using a stadiometer and recorded within 0.5 cm. Body mass index (BMI) is calculated as: weight (kg) divided by height (m) squared. Body fat was assessed using the estimate given from the bioelectrical impedance analysis (BIA; Tanita TBF-300A, Arlington Heights, IL, USA). Seated peak height velocity (cm) was measured while subjects were seated with erect trunk from the surface of the floor to the right knee (leg peak height velocity, PHVl), and from the surface of the chair to the apex of the head (trunk peak height velocity, PHVt) to check for upper and lower body growth changes over the study time [21,24].

Blood pressure

Blood pressure was measured manually at the left brachial artery after 5 minutes of rest while the subjects relaxed in a seated position with feet on the floor and the left arm rested with the elbow parallel at the heart level. Measures were taken using a standard stethoscope and a sphygmomanometer by the same trained investigator to control for systolic (SBP) and diastolic (DBP) blood pressure. The value of SBP was considered as the first appearance of the Korotkoff sound and DBP by the disappearance of the sound.

Signal acquisition and analysis

Beat-to-beat blood pressure was ascertained using a non-invasive, finger plethysmograph (Finometer; FMS, Amsterdam, the Netherlands) and heart rate (HR) (Biopac Systems, Santa Barbara, CA, USA) was measured using a modified, CM5 electrode configuration in both supine resting condition (SRC) and heads up tilt (HUT) conditions to evaluate HRV and BRS. Three electrodes were used for this analysis: 1) the right arm electrode was placed on the right manubrium sterni, 2) the left arm electrode was placed at the 5th intercostal space in the anterior axillary line, and 3) the left electrode was placed on the right manubrium sterni functioning as a ground electrode. The electrocardiogram was collected at a sampling rate of 1,000 Hz for 20 min, including 10 min in the SRC position and 10 min in HUT position. All files were stored off-line and were analyzed at a later time. Data files were manually inspected for ectopy, arrhythmic events, and noise and each file was linearly interpolated to provide a continuous data stream. R waves of the QRS complex were detected via an automatic QRS detection algorithm and generated an R-R interval time event series (Kubios HRV Analysis Software, Biosignal Analysis and Medical Imaging Group, University of Eastern Finland, Kuopio, Finland). The continuous data stream was resampled through a low-pass impulse response filter with a 0.5 Hz cut off frequency.

HRV analysis was made on the last 5 minutes of steady state in both SRC and HUT positions. The high frequency (HF) and low frequency (LF) were used as frequency domain measures. The total power (TP) was calculated by measuring the area under the power spectra density curve. Three peaks were revealed and their corresponding bandwidths are defined as follows: a very low frequency (VLF) domain < 0.04 Hz, a LF domain 0.04 - 0.15 Hz, which is considered a marker of sympathetic modulation [25,26], and a HF domain 0.15-0.40 Hz, which is thought to represent efferent parasympathetic activity [2,27]. The power spectra during supine and head-up conditions were calculated in absolute values (LF and HF) and in normalized units (nLF and nHF) to reflect the relative value of each power in relation to the TP minus the VLF component, emphasizing the balance of the parasympathetic and sympathetic branches of the autonomic nervous system. TP is a value of overall variability and it is used as a marker of vagal modulation and the low frequency to high frequency ratio (LF:HF) as an indicator of sympathovagal balance. All data acquisition and analysis were conducted in accordance with standards presented by the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [2].

Cardiovagal BRS was collected at a sampling rate of 1000 Hz and evaluated shortly after the +80° head-up tilt from the time point in which R-R intervals start to lengthen until the point of maximal systolic BP. Data were recorded and stored onto a PC computer for later offline analysis using the WINCPRS software (Absolute Aliens, Ooulu Finland). The slope of the linear regression between the SBP and the corresponding R-R intervals was used as measure of cardiovagal BRS. The up–up (upup) and down–down (dndn) sequences were identified over three or more consecutive beats for at least 4 ms and 1 mmHg respectively. Only sequences with correlations ≥ 0.80 were accepted. BRS was also determined using the transfer function technique, using the SBP and R–R interval spectra in the LF band (0.04–0.14 Hz) with a coherence above 0.5.

Supervised activity

The 4w and 8w supervised activity groups were involved in supervised play based activities throughout their summer program. Children attended the summer camp five days a week, from 8:30a.m. to 4:00 p.m. performing play-based physical activity intermittently, in which both sport and recreational activities were utilized.

This program intended to let children experiment with a variety of moderate-intensity activities, including hiking, canoeing, soccer, swimming, running, group sports and games, and resistance-band training to increase their strength, flexibility and cardiovascular fitness and to teach new skills through lifetime sport and recreational activities with the main objective of increasing the time spent in PA and minimize inactivity.

Children were supervised by exercise physiologists to maintain children active during the entire exercise sessions. The C group was asked to follow their usual summer break schedule without any intervention from the study coordinators.

Treatment of data

Statistical analysis of the data was completed with SPSS v19 (IBM, Chicago, IL, USA). Group differences were measured using a 2x2x3 repeated measures analysis of variance (RmANOVA; time [pre vs post] by factor [rest vs tilt] by group [8w vs 4w vs C]).

To identify the differences in BRS between the three groups, a 3x2 (group by time) RmANOVA was used. A Bonferroni post hoc test was conducted to determine where the significance lied between the group comparisons.

A priori significance was set at $P \leq 0.05$ and all data are reported as mean ± standard deviation (SD). Due to the relatively small sample size, the authors have shown effect sizes following the power data to aid the reader in determining the level of significance.

Results

Anthropometric and cardiovascular data in pre and post conditions are reported in (Tables 1 and 2). The statistical analysis showed no group differences at baseline in any of the analyzed parameters.

Body weight and body fat percentage did not change significantly in all groups after the 4 and 8-week period (P = 0.1, eta2 = 0.06).

However, body fat in the 4-week and 8-week groups showed a decreasing trend after the intervention decreasing by 7.3% and 6.7%, respectively, whereas no changes in body fat were observed in the control group (Table 1).

Table 1: Anthropometric characteristics at baseline (Pre) and after (Post) 4 and 8 weeks of activity (4w and 8w), and an unsupervised 8-week control period (C).

	Pre			Post		
	8w	4w	C	8w	4w	C
Height (cm)	139.2 ± 11.2	145.7 ± 11.7	145.3 ± 11.0	140.2 ± 11.1	146.4 ± 11.5	146.0 ± 11.6
Weight (kg)	43.4 ± 10.9	48.1 ± 14.9	41.7 ± 10.0	43.7 ± 11.8	47.7 ± 14.7	42.3 ± 9.9
BMI (kg/m^2)	22.2 ± 4.0	22.5 ± 3.4	19.5 ± 3.4	22.0 ± 3.9	22.3 ± 3.4	19.6 ± 3.7
PHt (cm)	76.0 ± 8.1	76.7 ± 8.4	72.1 ± 7.8	76.4 ± 9.5	77.0 ± 8.2	72.5 ± 8.4

PHl (cm)	39.4 ± 6.6	39.1 ± 6.2	38.4 ± 5.6	39.5 ± 7.2	39.2 ± 7.7	38.6 ± 5.9
%BF (%)	28.5 ± 12.8	27.4 ± 8.4	23.7 ± 8.0	26.6 ± 7.0	25.4 ± 6.7	23.6 ± 7.1

PHl leg peak height velocity, PHt trunk peak height velocity, BMI body mass index, %BF body fat percentage.
Values are mean ± SD; Significance was set at P ≤ 0.05.

Systolic BP was significantly lower in post conditions in all groups (P = 0.02, eta2 = 6.86) while DBP did not significantly change in any of them after intervention. The 8w group showed a tendency in increasing BRS following the exercise intervention (18 ± 6 to 21 ± 5 ms/mmHg, P = 0.09) however, the increase was not significantly different that the 4w and C groups (8w, 18 ± 6 to 21 ± 5, 4w, 19 ± 8 to 19 ± 7 and C, 20 ± 10 to 19 ± 9 ms/mmHg) (Table 2).

Table 2: Cardiovascular parameters at baseline (Pre) and after (Post) 4 and 8 weeks of activity (4w and 8w), and an unsupervised 8-week control period (C).

	Pre			Post		
	8w	4w	C	8w	4w	C
RHR (beat/min)	75 ± 17	75 ± 11	77 ± 13	73 ± 9	75 ± 13	74 ± 13
SBP (mmHg)	95 ± 5	93 ± 6	97 ± 10	89 ± 8*	89 ± 5*	92 ± 8*
DBP (mmHg)	66 ± 7	64 ± 7	67 ± 9	57 ± 9	64 ± 5	64 ± 9
BRS (ms/mmHg)	18 ± 6	19 ± 8	19 ± 7	21 ± 5	19 ± 7	19 ± 9

RHR resting heart rate, SBP systolic blood pressure, DBP diastolic blood pressure, BRS baroreflex sensitivity.
Values are mean ± SD. *Significant time P ≤ 0.05 compared to pre.
Significant time differences in SBP in all three groups (P = 0.02).

Heart rate parameters in both SRC and HUT positions are reported in (Table 3). No significant time-differences were found in absolute parameters but a significant group-by-time difference was observed in nLF and nHF in both supine and head-up positions (P = 0.04, eta2 = 0.28 and P = 0.05, eta2 = 0.28, respectively) and in TP in supine position (P = 0.04, eta2 = 0.294) between the C and 8w group. The 8w group increased nHF and TP and decreased nLF, while both 4w and C groups lowered nHF and TP and increased nLF after the intervention. No significant differences were obtained from the LF:HF ratio analysis between any of the groups following the intervention.

Table 3: Frequency domain HRV data in supine resting condition (SRC) and after heads-up tilt (HUT) in pre and post conditions after 4 and 8 weeks of activity (4w and 8w), and an unsupervised 8-week control period (C).

	pre			Post		
	8w	4w	C	8w	4w	C
LF (ms^2/Hz)						
SRC	2514 ± 1214	3810 ± 1214	2510 ± 1051	2013 ± 1179	3535 ± 1179	2626 ± 1021
HUT	1734 ± 1355	3173 ± 1355	848 ± 1173	1333 ± 582	1847 ± 582	1108 ± 504
HF (ms^2/Hz)						
SRC	2866 ± 968	3417 ± 1118	1973 ± 1118	2739 ± 973	3418 ± 1123	1022 ± 1123
HUT	442 ± 877	2336 ± 1013	1019 ± 1013	743 ± 251	646 ± 289	449 ± 289
TP (ms^2/Hz)						
SRC	7480 ± 2326	9322 ± 2686	6670 ± 2686	12008 ± 3393*	9268 ± 3917	4353 ± 3917
HUT	2183 ± 851	1789 ± 982	4715 ± 982	2938 ± 1122	4642 ± 1295	2815 ± 1295
nLF (nu)						
SRC	0.49 ± 0.07	0.48 ± 0.08	0.59 ± 0.08	0.47 ± 0.06*	0.54 ± 0.07	0.64 ± 0.07

HUT	0.77 ± 0.05	0.64 ± 0.06	0.67 ± 0.06	0.64 ± 0.08*	0.72 ± 0.08	0.71 ± 0.09
nHF (nu)						
SRC	0.49 ± 0.06	0.50 ± 0.07	0.39 ± 0.07	0.51 ± 0.06*	0.45 ± 0.07	0.34 ± 0.07
HUT	0.22 ± 0.05	0.34 ± 0.06	0.31 ± 0.06	0.30 ± 0.06*	0.27 ± 0.07	0.28 ± 0.07
LF:HF						
SRC	1.2 ± 0.6	1.2 ± 0.7	2.6 ± 0.7	1.2 ± 0.8	1.6 ± 0.9	2.0 ± 0.9
HUT	5.2 ± 1.3	3.7 ± 1.5	2.5 ± 1.5	4.8 ± 2.2	6.5 ± 2.5	3.2 ± 2.5

LF: low frequency, HF: high frequency, TP: total power, nLF: normalized low frequency, nHF: normalized high frequency, LF: HF low frequency to high frequency ratio. All data are represented as mean ± SD. *Significant group by time interaction, P ≤ 0.05.

Group-by-time difference (between C and 8w, pre vs post) in nLF (P = 0.043) and nHF (P = 0.05) in SRC and HUT, and in TP (P = 0.04) in SRC.

Discussion

The major finding of this study was the increased sympatho-vagal balance (nHF and nLF) in the 8w group in comparison with the unsupervised control group. Yet, after 8 weeks of play-based physical activity children showed augmented vagal tone, and reduced sympathetic activity together with a higher TP and a tendency in increasing BRS. Differently, after 4 weeks of intervention or 8 weeks of unsupervised summer camp, children showed no differences or an opposite trend in HRV or BRS parameters when compared to the 8-week exercise group. Thus, supervised play-based physical activity has shown to be beneficial for parasympathetic modulation and increasing baroreflex activity during the summer break period.

It is well known that physical activity can increase HRV and BRS in adults, and that these parameters are also positively related to the duration, frequency, intensity and type of exercise stimulus [28,29]. However, the effect of physical activity on HRV and BRS in children is not well established. Blom et al. reported significant correlations between self-reported physical activity and HR, time and frequency domain parameters of HRV in adolescents [30] in parallel with a previous study of Nagai and Moritani that observed lower resting HR and higher TP, LF, and HF power in lean-active children compared to obese-inactive and lean-inactive counterparts [11]. In a 1-year intervention study, Nagai et al. showed that a moderately intense exercise training program is enough of a stimulus to increase autonomic function in healthy children that presented with initially low HRV [15].

Conflicting results have been reported when studying an adolescent and preadolescent population, yet obese children are less likely to maintain an exercise regimen and their responsiveness to a short-term exercise intervention has shown some controversial results. Mandigout and colleagues, observed that 13 weeks of an endurance training program increased aerobic capacity and positively influenced nocturnal HRV in healthy prepubertal children without obtaining sympathetic and parasympathetic modifications [16]. Gamelin et al. reported that 7 weeks of high intensity intermittent exercise training significantly increased aerobic performance and peak capacity without any significant change in HRV parameters [13]. In another study, Gutin et al. reported that 4 months of physical training increased vagal tone and lowered the ratio of low- to high-frequency power in obese children together with a reduction in body fat and submaximal heart rate [31]. Moreover, it has been shown that low fat mass and high fat-free mass in children are associated with time-domain parameters of HRV and regular physical training positively affects fitness and body composition, which may also augment parasympathetic activity in obese subjects [32].

Our study has shown that eight weeks of supervised, play-based physical activity performed for 4 hours/day, 5 days/week improved sympathovagal balance increasing vagal tone (nHF) and TP and decreasing sympathetic activity (nLF) in SRC and HUT conditions independently of significant body weight or body composition alterations. However, 4 weeks of activity, or 8 weeks of no intervention lowered nHF and TP and a increased nLF in both conditions. However, no significant time differences were obtained in HRV parameters after the 8 weeks of exercise. It may be surmised that a longer exercise intervention that changes body composition and body weight, was needed to obtain significant changes in HRV.

The analysis of BRS revealed a 3 ms/mmHg increase in the 8w group while the 4w and C groups did not show any changes in the average value. Although we did not observe any significant differences, BRS and markers of autonomic modulation (nLF, nHF, and TP) showed a favorable increase following 8-weeks of supervised play-based activity. Our results also showed no significant group changes in resting heart rate and DBP after intervention while SBP dropped in all groups. Previous studies report that BRS is lower in children with high BP [33,34] since chronic high blood pressure model the carotid arterial wall reducing its distensibility and that systolic blood pressure is positively related to carotid intima-media thickness as an index of endothelial function [35]. This hypothesis is supported by recent findings of our laboratory showing that arterial distensibility can improve after play-based activity in preadolescents [19]. Baroreceptors are stimulated by the distension of the carotid wall, therefore, less compliance of the carotid artery results in lower BRS. However, our study resulted in all of the exercise groups decreasing their SBP but the 8w cohort showed increases in BRS and frequency domain parameters of HRV after the play-based intervention. These results could be attributed to the augmented autonomic nervous system activity. Both HRV and BRS are based on the analysis of the ECG recording but they explore different aspects of the autonomic control of the HR. Therefore, the augmented BRS in the 8w group could be the result of increased parasympathetic dominance observed by the higher HRV in the 8w group.

We recognize a limitation of this study is the small sample size by group that prevented us from performing additional statistical analysis and maybe from identifying additional effects induced by the exercise intervention. Future studies with a greater sample size will be needed to confirm our results. However, the significant group-by-time interactions coupled with the related effect sizes help us determine the changes stemming from the intervention. The lack of monitoring of physical activity levels during the exercise sessions and in the controls is another limitation of this study. However, children in the control group did not participate in any structured physical activity during the intervention period and the three groups reported no differences at baseline. It is important to remember that this is an exploratory study and our results show that play based activity is a sufficient stimulus to make beneficial changes to the autonomic nervous system. To our knowledge, no studies have shown the effects of supervised, play-based physical activity on HRV and BRS in preadolescents, yet this area may help us combat pediatric and adolescent obesity and the resulting disease.

In conclusion, our data showed that 8 weeks of play-based activity lends beneficial outcomes to the sympathovagal balance and increases BRS producing cardioprotective benefits in children during summer vacation, while no supervised activity does not change CAM or BRS in preadolescents.

References

1. Chen SR, Chiu HW, Lee YJ, Sheen TC, Jeng C, et al. (2012) Impact of pubertal development and physical activity on heart rate variability in overweight and obese children in Taiwan. The Journal of school nursing: the official publication of the National Association of School Nurses 28: 284-290.
2. [No authors listed] (1996) Heart rate variability. Standards of measurement, physiological interpretation, and clinical use. Eur Heart J 17: 354-381.
3. Colhoun HM, Francis DP, Rubens MB, Underwood SR, Fuller JH, et al. (2001) The association of heart-rate variability with cardiovascular risk factors and coronary artery calcification - A study in type 1 diabetic patients and the general population. Diabetes Care 24: 1108-1114.
4. Zahorskamarkiewicz B, Kuagowska E, Kucio C, Klin M (1993) Heart-rate-variability in obesity. Int J Obes 17: 21-23.
5. Vanravenswaaijarts CMA, Kollee LAA, Hopman JCW, Stoelinga GBA, van Geijn HP, et al. (1993) Heart-rate-variability. Ann Intern Med 118: 436-447.
6. Strong WB, Malina RM, Blimkie CJ, Daniels SR, Dishman RK, et al. (2005) Evidence based physical activity for school-age youth. J Pediatr 146: 732-737.
7. Boutcher SH, Cotton Y, Nurhayati Y, Craig GA, McLaren PF, et al. (1997) Autonomic nervous function at rest in aerobically trained and untrained older men. Clinical Physiology 17: 339-346.
8. Sloan RP, Shapiro PA, DeMeersman RE, Bagiella E, Brondolo EN, et al. (2009) The effect of aerobic training and cardiac autonomic regulation in young adults. Am J Public Health 99: 921-928.
9. Kaufman CL, Kaiser DR, Steinberger J, Kelly AS, Dengel DR, et al. (2007) Relationships of cardiac autonomic function with metabolic abnormalities in childhood obesity. Obesity 15: 1164-1171.
10. Tonhajzerova I, Javorka M, Trunkvalterova Z, Chroma O, Javorkova J, et al. (2008) Cardio-respiratory interaction and autonomic dysfunction in obesity. J Physiol Pharmacol 59: 709-718.
11. Nagai N, T. Moritani (2004) Effect of physical activity on autonomic nervous system function in lean and obese children. International journal of obesity 28: 27-33.
12. Winsley R (2002) Acute and chronic effects of exercise on heart rate variability in adults and children: A review. Pediatric Exercise Science 14: 328-344.
13. Gamelin FX, Baquet G, Berthoin S, Thevenet D, Nourry C, et al. (2009) Effect of high intensity intermittent training on heart rate variability in prepubescent children. European journal of applied physiology 105: 731-738.
14. Hedelin R, Wiklund U, Bjerle P, Henriksson-Larsén K. (2000) Pre- and post-season heart rate variability in adolescent cross-country skiers. Scandinavian journal of medicine & science in sports 10: 298-303.
15. Nagai N, Hamada T, Kimura T, Moritani T (2004). Moderate physical exercise increases cardiac autonomic nervous system activity in children with low heart rate variability. Child's nervous system: ChNS: official journal of the International Society for Pediatric Neurosurgery 20: 209-214.
16. Mandigout S, Melin A, Fauchier L, DN Guyen L, Courteix D, et al. (2002) Physical training increases heart rate variability in healthy prepubertal children. European Journal of Clinical Investigation 32: 479-87.
17. Gately PJ, Cooke CB, Barth JH, Bewick BM, Radley D, et al. (2005) Children's residential weight-loss programs can work: A prospective cohort study of short-term outcomes for overweight and obese children. Pediatrics 116: 73-77.
18. Torrance B, McGuire KA, Lewanczuk R, McGavock J (2007) Overweight, physical activity and high blood pressure in children: A review of the literature. Vasc Health Risk Manag 3: 139-49.
19. Meucci M, Curry CD, Baldari C, Guidetti L, Cook C, et al. (2012) Effect of play-based summer break exercise on cardiovascular function in adolescents. Acta Paediatrica.
20. Laurson KR, Eisenmann JC, Welk GJ (2011) Body fat percentile curves for U.S. children and adolescents. Am J Prev Med 41: S87-92.
21. Busscher I, Kingma I, de Bruin R, Wapstra FH, Verkerke GJ, et al. (2012) Predicting the peak growth velocity in the individual child: validation of a new growth model. Eur Spine J 21: 71-76.
22. Leicht AS, GD Allen (2008) Moderate-term reproducibility of heart rate variability during rest and light to moderate exercise in children. Braz J Med Biol Res 41: 627-633.
23. Winsley RJ, Armstrong N, Bywater K, Fawkner SG (2003) Reliability of heart rate variability measures at rest and during light exercise in children. Br J Sports Med 37: 550-522.

24. Mirwald RL, Baxter-Jones AD, Bailey DA, Beunen GP (2002) An assessment of maturity from anthropometric measurements. Medicine and science in sports and exercise 34: 689-694.

25. Kamath MV, Fallen EL (1993) Power spectral-analysis of heart-rate-variability - a noninvasive signature of cardiac autonomic function. Critical Reviews in Biomedical Engineering 21: 245-311.

26. Montano N, Ruscone TG, Porta A, Lombardi F, Pagani M, et al. (1994) Power spectrum analysis of heart-rate-variability to assess the changes in sympathovagal balance during graded orthostatic tilt. Circulation 90: 1826-1831.

27. Goldsmith RL, Bigger JT, Steinman RC, Fleiss JL (1992) Comparison of 24-hour parasympathetic activity in endurance-trained and untrained young men. J Am Coll Cardiol 20: 552-558.

28. Buchheit M, Simon C, Charloux A, Doutreleau S, Piquard F, et al. (2005) Heart rate variability and intensity of habitual physical activity in middle-aged persons. Medicine and science in sports and exercise 37: 1530-1534.

29. Collier SR, Kanaley JA, Carhart R Jr, Frechette V, Tobin MM, et al. (2009) Cardiac autonomic function and baroreflex changes following 4 weeks of resistance versus aerobic training in individuals with pre-hypertension. Acta physiologica 195: 339-348.

30. Henje Blom E, Olsson EMG, Serlachius E, Ericson M, Ingvar M, et al. (2009) Heart rate variability is related to self-reported physical activity in a healthy adolescent population. European journal of applied physiology 106: 877-883.

31. Gutin B, Owens S, Slavens G, Riggs S, Treiber F, et al. (1997) Effect of physical training on heart-period variability in obese children. J Pediatr 130: 938-943.

32. Gutin B, Barbeau P, Litaker MS, Ferguson M, Owens S, et al. (2000) Heart rate variability in obese children: Relations to total body and visceral adiposity, and changes with physical training and detraining. Obes Res 8: 12-19.

33. Fitzgibbon LK, Coverdale NS, Phillips AA, Shoemaker JK, Klentrou P, et al. (2012) The association between baroreflex sensitivity and blood pressure in children. Applied physiology, nutrition, and metabolism = Physiologie appliquee, nutrition et metabolisme 37: 301-307.

34. Honzikova N, Fiser B (2009) Baroreflex sensitivity and essential hypertension in adolescents. Physiological research / Academia Scientiarum Bohemoslovaca 58: 605-612.

35. Ciccone MM, Faienza MF, Altomare M, Nacci C, Montagnani M, et al. (2016) Endothelial and Metabolic Function Interactions in Overweight/Obese Children. J Atheroscler Thromb.