Heart Rate Variability and Cardiovascular Risk Factors in Adolescent Boys

Breno Q. Farah, MS[1], Mauro V. G. Barros, PhD[1], Babu Balagopal, PhD[2], and Raphael M. Ritti-Dias, PhD[1]

Objective To establish reference values of heart rate variability (HRV) measures in a cohort of adolescent boys and to determine the relationship between HRV and the clustering of risk factors (RFs) for cardiovascular disease.
Study design This cross-sectional study included 1152 adolescent boys (age: 16.6 ± 1.2 years old). Demographic data, health-related habits, obesity indicators, and blood pressure were evaluated. HRV measures of time (SD of all RR intervals, root mean square of the squared differences between adjacent normal RR intervals, and the percentage of adjacent intervals over 50 ms) and frequency domains were assessed (low [LF] and high [HF] frequency).
Results The components of HRV were RR interval (827 ± 128 ms), SD of all RR intervals (61.9 ± 23.5 ms), root mean square of the squared differences between adjacent normal RR intervals (54.5 ± 29.4 ms), percentage of adjacent intervals over 50 ms (29.4 ± 20.4%), LF (53 ± 16 nu), HF (47 ± 16), and LF/HF (1.44 ± 1.08). Greater sympathetic and lower parasympathetic modulation at rest were associated with higher adiposity, higher blood pressure and physical inactivity. Adolescents with 2 or more RFs also presented lower HRV than subjects with no RFs ($P < .001$).
Conclusions The study has provided descriptive indicators that help the interpretation of HRV results in adolescents. Lower HRV measures are associated with the clustering of cardiovascular RFs. *(J Pediatr 2014;165:945-50)*.

The autonomic nervous system plays a major role in the regulation of the cardiovascular system.[1] Cardiac autonomic modulation can be assessed based on heart rate variability (HRV),[2] defined as the variability between consecutive beats. HRV is considered a potent marker of cardiovascular risk in different groups,[2-7] providing information about early changes in cardiac autonomic control.[1,2] HRV is commonly assessed by analyzing the heart beat intervals using time and frequency domain techniques.[2] Although time domain measures either the heart rate at any point in time or the intervals between successive normal complexes, the frequency domain analysis describes the periodic oscillations of the heart rate signal decomposed at different frequencies and amplitudes.[2]

A low HRV is indicative of reduced parasympathetic cardiac control and has been associated with various conditions such as cardiovascular disease, diabetes, sleep disorders, and emotional issues.[2,8] Although the relationship between low HRV and compromised health has been extensively studied in adults, such studies are scarce in adolescents. The reference values of HRV in children (5-10 years old)[9] and adults (mean age 41 ± 9 years old)[10] have been established, but surprisingly, they are not available in adolescents. Given the broad array of health issues associated with lowered HRV and the challenges involved in the interpretation of such issues in the youth, it is important to fill this gap and establish reference standards for HRV in adolescents.

Previous studies have shown that being overweight,[11,12] abdominal obesity,[13] and physical inactivity[13,14] affect HRV measures in adolescents. However, the impact of blood pressure on HRV remains unclear. In a subsample of the Bogalusa Heart Study, Urbina et al[15] found a trend toward higher sympathetic and lower parasympathetic measures occurring in adolescent males with higher diastolic blood pressure. Prior studies[11-16] that analyzed the association between cardiovascular risk factors (RFs) and HRV in adolescents typically had small samples and considered the RFs separately, and it is known that clustering of RFs is an important determinant of cardiovascular risk.[17-19] The potential impact of clustering of cardiovascular RFs on HRV in adolescents has not been previously reported.

The aims of the current study were to establish reference values of HRV measures in a large cohort of adolescent boys and to determine the relationship between HRV measures and the clustering of RFs for cardiovascular disease.

Methods

The cross-sectional study protocol was approved by the ethics committee of the University of Pernambuco in compliance with the Brazilian National Research Ethics System Guidelines. The target population was limited to high school students between 14 and 19 years old. The participants were sampled from the students of the

HF	High frequency
HRV	Heart rate variability
LF	Low frequency
PNN50	Percentage of adjacent intervals over 50 ms
RFs	Risk factors
RMSSD	Root mean square of the squared differences between adjacent normal RR intervals
SDNN	SD of all RR intervals

From the [1]Associate Graduate Program in Physical Education, University of Pernambuco, Recife, PE, Brazil; and [2]Nemours Children's Clinic and Mayo Clinic College of Medicine, Jacksonville, FL

Supported by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (grant 481067/2010-8) and Coordenação de Aperfeiçoamento de Pessoal de Nível Superior. The authors declare no conflicts of interest.

http://dx.doi.org/10.1016/j.jpeds.2014.06.065

Table I. General characteristics of adolescents (n = 1152)

Variables	Values
Age (y)	16.6 ± 1.2
Weight (kg)	63.7 ± 12.6
Height (cm)	171.6 ± 7.1
WC (cm)	76.6 ± 9.4
BMI (kg/m^2)	21.6 ± 3.8
SBP (mm Hg)	121.6 ± 12.4
DBP (mm Hg)	67.8 ± 8.6
Race (% non-whites)	72.0
Place of residence (% urban)	79.2
Abdominal obesity (%)	15.4
Overweight (%)	16.6
High blood pressure (%)	9.7
Physical inactivity (%)	64.4

BMI, body mass index; *DBP*, diastolic blood pressure; *SBP*, systolic blood pressure; *WC*, waist circumference.

Public School System in the State of Pernambuco (northeast Brazil). Volunteers with known diabetes mellitus, cardiovascular disease, and neurologic or mental disabilities were excluded. Exclusion criteria also included consumption of caffeinated beverages 12 hours prior to the HRV evaluation; use of alcohol, any form of tobacco, and/or other illicit drugs; and participation in any physical exercise training 24 hours before evaluations.

Data collection was performed between May and October in 2011 and the period of the day that the adolescents were in class (morning, afternoon, and evening). Age, ethnic background, place of residence, and physical activity level were obtained using the Global School-based Student Health Survey, as proposed by the World Health Organization for similar epidemiologic studies in children and adolescents, which is available at www.who.int/chp/gshs/en. Physical activity level was assessed by the question "During the past 7 days on how many days were you physically active for a total of at least 60 minutes per day?" Adolescents were classified as active (if the answer was 5 or more days per week with at least 60 minutes per day of moderate to vigorous physical activity) or physically inactive.[20] Reproducibility indicators (ie, test retest consistency, 1-week apart) ranged from moderate to high for the majority of the items, with kappa coefficient of 0.77 for physical activity level.

Adolescents were weighed without shoes and coats on an automatic scale, and the height was measured using a stadiometer. Waist circumference was measured in the standing position at the level of the umbilicus using a constant tension tape. Overweight was determined by body mass index above the 85th percentile for their age.[21] Abdominal obesity was determined by waist circumference above the 80th percentile for their age.[22]

Blood pressure was measured using the Omron HEM 742[23] (Omron, Shangai, China) after the adolescents rested and remained seated with legs uncrossed for 5 minutes. Appropriate cuff size was used for each adolescent. All blood pressure measurements were performed 3 times in the right arm placed at heart level in a seated position. The mean value of the last 2 measurements was used for analysis. High blood pressure was defined as systolic and/or diastolic blood pressure equal or higher than the reference sex-, age-, and height-specific 95th percentile.[24]

HRV was assessed from the RR intervals obtained by a heart rate monitor (POLAR, RS 800CX; Polar Electro Oy Inc, Kempele, Finland). Adolescents remained in the supine position for 10 minutes, after approximately 30 minutes at rest. All analyses were performed with Kubios HRV software (Biosignal Analysis and Medical Imaging Group, Joensuu, Finland) by a single evaluator blinded to the other study variables, following the recommendations of the Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology.[2]

The time-domain variables, such as SD of all RR intervals (SDNN), root mean square of the squared differences between adjacent normal RR intervals (RMSSD), and the percentage of adjacent intervals over 50 ms (PNN50) were obtained. The frequency-domain variables were analyzed using the spectral analysis of HRV. Stationary periods of the tachogram, with at least 5 minutes, were broken down into bands of low (LF) and high (HF) frequencies, using the autoregressive method with a fixed model order of 12. Frequencies between 0.04 and 0.4 Hz were considered as physiologically significant, where the LF component was represented by oscillations between 0.04 and 0.15 Hz and HF was represented by oscillations between 0.15 and 0.4 Hz. The power of each spectral component was normalized by dividing the power of each spectrum band by the total variance, minus the value of very low frequency band (<0.04 Hz), and

Table II. Mean ± SD and percentile values for HRV parameters in adolescents (n = 1152)

		Percentile								
Parameters	Mean ± SD	1	5	10	25	50	75	90	95	99
RR interval (ms)	827 ± 128	571	637	670	736	815	905	997	1062	1165
SDNN (ms)	61.9 ± 23.7	21.3	29.4	34.9	44.5	58.4	76.5	92.9	103.7	138.7
RMSSD (ms)	54.5 ± 29.4	10.1	18.2	22.6	33.2	49.6	68.9	94.2	113.0	153.6
PNN50 (%)	29.4 ± 20.4	0.0	1.10	3.0	11.0	28.1	45.1	58.3	66.2	75.0
Variance (ms^2)	3992 ± 3138	411	792	1090	1849	3092	5388	7687	9821	17 222
LF (ms^2)	1268 ± 1024	94	242	349	614	990	1644	2465	3023	5357
HF (ms^2)	1377 ± 1424	51	127	201	422	937	1801	3219	4137	7232
LF/HF	1.44 ± 1.08	0.23	0.36	0.47	0.71	1.14	1.80	2.82	3.49	5.37
LF (nu)	53.0 ± 15.6	18.9	26.7	32.2	41.6	53.2	64.3	73.8	77.7	84.3
HF (nu)	47.0 ± 15.6	15.7	22.3	26.2	35.7	46.8	58.4	67.8	73.3	81.1