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Authors: Iwona Walecka, Jakub S Gąsior, Piotr Wieniawski, Bożena Werner

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Elite HRV smartphone application using Polar H10 is valid for short-term heart rate variability analysis in pediatric cardiac patients

Short title: Elite HRV app validity for HRV analysis in pediatric cardiac patient

Iwona Walecka[1], Jakub S Gąsior[2], Piotr Wieniawski[2], Bożena Werner[2]

[1]Department of Pediatric Cardiology and General Pediatrics, Doctoral School Medical University of Warsaw, Warszawa, Poland
[2]Department of Pediatric Cardiology and General Pediatrics, Medical University of Warsaw, Warszawa, Poland

Correspondence to:
Prof. Bożena Werner, MD, PhD,
Department of Pediatric Cardiology and General Pediatrics,
Medical University of Warsaw,
Żwirki i Wigury 61, 02–091 Warszawa, Poland,
e-mail: bozena.werner@wum.edu.pl

INTRODUCTION

Patients with congenital heart disease/defects (CHDs) present cardiac autonomic dysfunction [1]. Heart rate variability (HRV) is a non-invasive method to evaluate cardiac autonomic responsiveness [2]. Nevertheless, pediatric cardiologists have rarely considered HRV analysis in the setting of CHDs [3]. The gold standard for obtaining RR intervals (RRi) for HRV is electrocardiography (ECG) [2]. Over last decades, devices like heart rate monitors (HRM) or mobile applications have been used for measuring HRV [4–6]. To use a new device in clinics, it must be validated against the gold standard. HRM with smartphone application/smartwatch have been validated against ECG for measuring HRV among healthy and obese children [6–8]. The objective of this study was to assess the validity of short-term RRi obtained using Elite HRV with Polar H10 for analysis of HRV against ECG in pediatric cardiac patients.

METHODS

The inclusion criteria were: age 3–17 years, lack of infection or acute cardiac condition or mental disability. The study was approved by the University Bioethical Committee (KB/24/2020). All parents/caregivers and patients older than 16 years old gave written consent for their participation in the study. In a hospital setting, RRi were recorded simultaneously (rest, supine) using a portable PC with an integrated ECG (Custo cardio 100 PC ECG; Custo med GmbH, Ottobrunn, Germany, sampling frequency 1000 Hz) and the Polar H10 (RR mode — sampling frequency 1000 Hz) with Elite HRV according to methodological recommendations for short-term recordings [9] between January 2022 and April 2022. Breathing pattern was video-recoded. Respiratory rate was determined from the counted number of video-observed respiratory cycles. Short-term (5 min) RRi series were checked to identify and correct (interpolation of degree zero) aberrant beats and then imported into Kubios HRV Standard 3.5 software to calculate time-, frequency-domain and nonlinear HRV parameters (Table 1). Smoothness priors based detrending approach was applied (Lambda value = 500), RRi series were transformed to evenly sampled time series (4-Hz resampling rate). The detrended and interpolated RRi series were used to compute HRV spectra (fast-Fourier-transform, Welch's periodogram; 300 s window width without overlap). Low frequency (0.04–0.15 Hz) and high frequency (0.15–0.50 Hz) bands were distinguished based on respiratory rate between 9 and 32 breaths per min.

Statistical analysis

Bland-Altman plot with limits of agreement (LoA) and intraclass correlation coefficient were used. An agreement sufficient for the interchangeable use of two methods is suggested when a lower 95% confidence interval >0.75 [10]. The smallest worthwhile change (SWC) was calculated by multiplying the between-subject ECG standard deviation values by 0.2. Two methods are considered in agreement if the LoA do not exceed the SWC. After the normality assumptions were verified (Kolmogorov–Smirnov test), Student's t-test for paired samples was employed to compare changes between parameters calculated based on RRi from 2 devices. The threshold probability of P <0.05 was used as the level of significance for all tests. Statistical analyses were performed using PQStat Software (v.1.8.4.138, PQStat Software, Poznan, Poland).

RESULTS AND DISCUSSION

Results of 23 patients (17 without confirmed diagnosis, 6 due to non-stationary RRi signal) out of 92 were excluded. The results of 69 (31 girls) pediatric cardiac patients (n = 40 CHD:

tricuspid valve anomaly n = 2, mitral regurgitation n = 2, idiopathic dilatation of pulmonary trunk n = 2, pulmonary stenosis n = 1, ventricular septal defect n = 6, atrial septal defect n = 10, atrioventricular septal defect n = 4, aortic coarctation n = 7, aortic valve stenosis n = 3, patent ductus arteriosus n = 2, tetralogy of Fallot n = 1; n = 21 cardiac arrhythmia; n = 8 cardiomyopathy/myocarditis were analyzed. Patients had a history of the comorbidities: perinatal diseases n = 46, pregnancy complications n = 14, digestive system diseases n = 7, endocrine diseases n = 5. The median (range) age, stature, body mass and body mass index were: 12 years (3–17), 155 cm (100–198), 51 kg (15–104) and 19 kg/m^2 (11–45). There were 111 technical artifacts recorded using ECG and 130 using Polar H10 with Elite HRV application which gave an error rate of 0.3% in ECG, 0.4% for Elite HRV.

There were no significant differences between parameters calculated based on RRi from both devices in the whole group (P >0.05) nor in the diagnosis subgroups, i.e. CHD, cardiac arrhythmia and cardiomyopathy/myocarditis (P-value between 0.19 and 0.95). Table 1 presented results of agreement statistics for analyzed HRV parameters. The 95% confidence interval of intraclass correlation coefficient ranged between 0.95 and 1.00 for all parameters. The SWC was for: mRR: 29 ms, HR: 3 bpm, SDNN: 4.8 ms, RMSSD: 5.9 ms, pNN50: 4.1%, low frequency: 307 ms^2, high frequency: 288 ms^2, SD1: 4.2, SD2: 5.5, SD2/SD1: 0.09, ApEn: 0.02, SampEn: 0.05, DFAα1: 0.05. For SD2/SD1, ApEn, SampEn and DFAα1 LoA exceeded the defined SWC.

Short-term HRV parameters calculated based on preprocessed RRi recorded using Polar H10 with Elite HRV in resting supine presented sufficient agreement with gold standard ECG in pediatric cardiac patients. Results presented here are in line with those presented for healthy children aged 8–11 years for 10 min HRV analysis obtained using the Polar T61™ HRM with Smartwatch Polar S810 [7] also with those for adolescents with obesity for HRV from the Polar RS800cx [8]. Interestingly, Polar H10 sensor was used as gold standard to assess validation of finger photoplethysmography for measuring HRV in healthy children aged 3 to 5 years [6]. Worse results of agreement statistics for non-linear parameters may suggest that HRV indices calculated based on counting statistics (e.g. HR asymmetry) without sophisticated preprocessing procedures (like detrending) may be biased when using RRi from HRM.

Elite HRV is commonly accessible on smartphone operating systems which in connection with HRM provides reliable raw RRi for calculation of linear and selected non-linear HRV indices. There are now more adults living with a history of CHD than there are children [11]. Valid HRV assessment may be helpful to detect arrhythmias in children [12] and, importantly, in adults as rhythm disorders are common in adults living with a history of CHD

and are accompanied by significant morbidity, mortality, and decreased quality of life [13]. Differences in HRV parameters between the measurements are associated with the changes in respiratory rate [14]. In presented study, respiratory rate was video-recorded. Pneumonitors — portable devices recently validated in children with heart disease [15] are better solution as they record breathing patterns using impedance pneumography along with single-lead ECG, subject motion, and/or pulse oximetry (saturation, pulse wave) and can be used during e.g. physical activity. This examination was performed in the rest condition. It is encouraged to verify HRM validity for pediatric cardiac patients also during the activity and for other family of nonlinear parameters.

Article information

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Table 1. Results of agreement of short-term parameters obtained from ECG and Elite HRV App in the resting position

Parameters	ECG	EliteHRV App + H10	Bias (95% CI)	LoA	95% CI lower; upper LoA
mRR, ms	789.5 (143.8)	786.9 (143.5)	2.6 (2.3–2.9)	0.1; 5.2	–0.5–0.6; 4.7–5.7
HR, bpm	79 (15)	79 (15)	–0.3 (–0.4 to –0.2)	–1.2; 0.6	–1.4 to –1.0; 0.4–0.8
SDNN, ms	48.4 (23.6)	48.0 (23.5)	0.4 (0.1–0.6)	–1.7; 2.5	–2.1 to –1.3; 2.0–2.9
RMSSD, ms	53.7 (29.5)	52.9 (29.4)	0.8 (0.3–1.3)	–3.4; 4.9	–4.3 to –2.5; 4.1–5.8
pNN50, %	27.5 (20.2)	26.8 (20.3)	0.6 (0.3–0.9)	–2.2; 3.4	–2.7 to –1.6; 2.8–3.9
LF, ms^2	1052 (1525)	1038 (1499)	14 (7–22)	–44; 72	–56 to –32; 60–85
HF, ms^2	1449 (1429)	1425 (1399)	24 (5–43)	–128; 176	–160 to –96; 144–208
SD1, ms	38.0 (20.9)	37.5 (20.8)	0.6 (0.2–0.9)	–2.4; 3.5	–3.0 to –1.8; 2.9–4.1
SD2, ms	56.3 (27.2)	56.0 (27.1)	0.3 (0.1–0.6)	–1.7; 2.4	–2.2 to –1.3; 1.9–2.8
SD2/SD1	1.62 (0.45)	1.65 (0.47)	–0.02 (–0.05–0.0)	–0.22; 0.17	–0.26 to –0.17; 0.13–0.21
ApEn	1.16 (0.10)	1.16 (0.10)	0.0 (–0.0–0.01)	–0.04; 0.04	–0.05 to –0.03; 0.03–0.05
SampEn	1.70 (0.22)	1.69 (0.21)	0.01 (0.0–0.03)	–0.09; 0.12	–0.12 to –0.07; 0.10–0.15
DFAα1	0.87 (0.24)	0.87 (0.24)	0.00 (–0.01–0.01)	–0.10; 0.10	–0.12 to –0.08; 0.08–0.12

Abbreviations: ApEn, approximate entropy; CI, confidence interval; DFAα1, detrended short-term fluctuations; ECG, electrocardiogram; HF, high-frequency; HR, heart rate; HRV, heart rate variability; LF, low-frequency; LoA, limits of agreement; mRR, mean RR interval; pNN50, percentage of RR intervals differing >50 ms from the preceding one; RMSSD, root mean square of successive R-R interval differences; SampEn, Sample Entropy; SD1, in Poincaré plot short term variability, the standard deviation perpendicular to the line-of-identity; SD2, in Poincaré plot long term variability, the standard deviation along the line-of-identity; SD2/SD1, ratio between SD2 and SD1; SDNN, standard deviation of RR intervals