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

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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 the last decades, devices like heart rate monitors (HRMs) or mobile applications have been used for measuring HRV [4–6]. A new device must be validated against the gold standard in clinical practice. HRMs with smartphone applications/smartwatches have been validated by comparison with ECG for measuring HRV in 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 in comparison with ECG in pediatric cardiac patients.

METHODS

The inclusion criteria were age 3–17 years, the absence 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.RRi were recorded simultaneously in a hospital setting (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. The breathing pattern was video-recoded. The 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). The smoothness priors-based detrending approach was applied (Lambda value = 500), and RRi series were transformed into 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 the respiratory rate between 9 and 32 breaths per minute.

Statistical analysis

Bland-Altman plot with limits of agreement (LoA) and intraclass correlation coefficients were used. An agreement sufficient for the interchangeable use of two methods is suggested when a lower 95% confidence interval is greater than 0.75 [10]. The smallest worthwhile change (SWC) was calculated by multiplying the between-subject ECG standard deviation values by 0.2. Two methods were considered in agreement if the LoA did not exceed the SWC. After the normality assumptions were verified (Kolmogorov–Smirnov test), Student's t-test for paired

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

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 out of 92 were excluded (17 without confirmed diagnosis, 6 due to non-stationary RRi signal). We analyzed 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). Patients had a history of 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, respectively,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% for ECG and 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 presents the results of agreement statistics for the analyzed HRV parameters. The 95% confidence interval of the intraclass correlation coefficient ranged between 0.95 and 1.00 for all parameters. The SWC was 29 ms for mean RR interval, 3 bpm for heart rate, 4.8 ms for standard deviation of RR intervals, 5.9 ms for root mean square of successive R-R interval differences, 4.1% for percentage of RR intervals differing >50 ms from the preceding one, 307 ms2 for low frequency, 288 ms2 for high frequency, 4.2 for in Poincare plot short term variability, the standard deviation perpendicular to the line-of-identity (SD1), 5.5 for in Poincare plot long term variability, the standard deviation along the line-of-identity (SD2), 0.09 for SD2/SD1, 0.02 for approximate entropy, 0.05 for sample entropy, 0.05 for detrended short-term fluctuations, SD2/SD1, approximate entropy, sample entropy, and detrended short-term fluctuations LoA exceeded the defined SWC.

Short-term HRV parameters calculated based on preprocessed RRi recorded using Polar H10 with Elite HRV in the resting supine position presented a 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] and also with those for adolescents with obesity for HRV from the Polar RS800cx [8]. Interestingly, the Polar H10 sensor was used as the gold standard to assess the 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 help detect arrhythmias in children [12] and, importantly, in adults as rhythm disorders are common in adults with a history of CHD and are accom-

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

Article information

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