Proceeding

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Accuracy and reliability of a free mobile HRV application in measurement of heart rate variability

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ABSTRACT

Background: This study aimed to investigate the accuracy and reliability of a free mobile heart rate variability (HRV) application in measuring HRV. Methods: Twelve females and 12 males underwent five-minute simultaneous HRV recording from electrocardiogram (ECG) and chest strap connected to a free mobile HRV application (HRVapp) in a supine position. HRV data from ECG and HRVapp were used to examine accuracy and reliability via relative error and intraclass correlation coefficient respectively. Results: The natural log of the square root of the mean of the sum of the squares of differences between adjacent normal to normal intervals (lnRMSSD) exhibited accuracy and high reliability in HRVapp. Conclusion: lnRMSSD in HRVapp can serve as an alternative, low-cost technology for measurement of autonomic activity. **Keywords**: Heart rate variability; Mobile application; Autonomic health; Parasympathetic nervous system; Sympathetic nervous system; Autonomic activity.

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INTRODUCTION

Heart rate variability (HRV) refers to fluctuation in heartbeat intervals reflecting autonomic health (Bernston et al., 1997; Task Force, 1996). In athlete settings, practitioners utilize HRV in monitoring autonomic recovery and training load quantification (Janssen et al., 1993; Kylosov et al., 2009; Mal'tse et al., 2010; Plews, et al., 2012; Saboul et al., 2018; Schneider et al., 2018). The 'gold standard' for measuring HRV is through a laboratory electrocardiogram (ECG). However, the previous method is costly and require technical expertise. Recently, numerous low-cost HRV equipment are available. Among these is a smartphone with an HRV mobile application (HRVapp) (Boos et al., 2017; Flatt and Esco, 2013; Perrotta et al., 2017).

Equivocal findings in the validity of HRVapp exist. For example, Flatt and Esco (2013) found out that ultra-short term HRV using the log-transformed square root of the mean of the sum of the squares of differences between adjacent normal to normal intervals (lnRMSSD) from an HRVapp is valid when compared with lnRMSSD obtained from ECG. Conversely, Perrotta and colleagues (2017) discovered that an HRVapp presented poor validity when used for 14-day monitoring.

The aforementioned HRVapp studies use RMSSD which is a time-based HRV index (Bernston et al., 1997; Task Force, 1996). Implications for autonomic health can be better understood using frequency derived HRV indices (Malliani et al., 1991; Malliani et al.,1994; Montano et al., 2009; Sassi et al., 2015; Schneider et al., 2018). However, there seems to be a void in literature examining the accuracy and reliability of frequency-based HRV from an HRVapp. Thus, the purpose of this study was to examine the accuracy and reliability of time and frequency HRV indices from an HRVapp.

METHODS

Participants

Twelve females (age: 20.3 ± 0.97 yrs.; height: 170 ± 5.51 cm; weight: 64.5 ± 8.16 kg; body mass index: 22.2 ± 2.36) and 12 males (age: 21.3 ± 1.48 yrs.; height: 181 ± 4.80 cm; weight: 80.9 ± 6.47 kg; body mass index: 24.6 ± 1.60) volunteered to participate in the study. All participants were physical education students who have no known clinical disease. At the time of the study, participants reported at least 10 hrs of physical activity per week. All participants were informed of the purpose, benefits, risks of the study, and right to withdraw at any time without explanation. Before commencing the study, participants signed a written informed consent. The study was performed in accordance with the Declaration of Helsinki for Human Experimentation and was approved by the local institutional ethical board.

Procedures

Experimentation occurred for a single session between 08.00 – 12.00 hrs at the Tuzla University Exercise Science Laboratory. Upon arrival, participants were asked to a seated rest for 5 minutes. After, anthropometric data were collected. Body height was measured to the nearest 0.01 m from a portable stadiometer (Astra 27310; Gima, Italy). Body mass was identified using a portable scale (Tanita TBF-300, increments 0.1%; Tanita, Tokyo, Japan). Anthropometric measurements were followed by placement an elastic strap with a heart transmitter (Polar H10, Polar Electro Oy, Kemple, Finland) around the upper thorax at the level of xiphoid process. A free HRVapp (Pulse Express Pro, Philippines) operating on an android smartphone (Xperia XA, Sony, UK) was utilized for HRV recording. Then, surface electrodes from a portable ECG (CONTEC8000G, Qinhuangdao Contec Medical Systems Co., Ltd, China) were attached using lead II configuration with a sampling rate of 1000 Hz. After ECG electrode attachment, participants underwent a 7-minute supine rest with eyes closed on an examination bed. Simultaneous HRV recording from HRVapp and

ECG was administered in the last 5 minutes of supine rest. Prior to recording, participants were asked to breathe normally and remain still during the entire test.

Data displayed on ECG and HRVapp were encoded on a spreadsheet. For time-based HRV, the standard deviation of normal to normal intervals (SDNN), RMSSD, pNN50 (number of pairs of adjacent NN intervals differing by more than 50 ms in the entire recording divided by the total number of NN intervals) were utilized (Task Force 1996). Further, RMSSD from ECG and HRVapp were transformed to natural log to address non-uniformity of error (Flatt et al., 2013; Perotta et al., 2017). Low frequency (LF: 0.04 – 0.15 Hz; ms2), high frequency (HF: 0.15 – 0.4 Hz; ms2), and LF/HF ratio were examined in frequency HRV domains. Normalized low frequency (LFnu = LF/LF+HF *100) and normalized high frequency (HFnu = HF/LF+HF *100) were also computed for comparison. Researchers suggested that LFnu and HFnu are reliable markers for quantifying autonomic function (Burr, 2007; Malliani et al., 1991; Malliani et al., 1994; Montano et al., 2009; Reyes del Paso et al., 2015).

Data analysis

Data are expressed as mean ± standard deviation (SD). Relative error (%RE) was used to identify the accuracy the HRV parameters in HRVapp (Abbiss et al., 2009). Equipment reliability of HRVapp was determined utilizing intraclass correlation coefficient (ICC) from the reliability spreadsheet by Hopkins (Atkinson and Nevill, 1998; Koo and Lee, 2016; Hopkins, 2000; Weir, 2005).

RESULTS

Table 1 displays the HRV parameters in ECG and HRVapp. Results showed that HRVapp SDNN posted %RE = -6.326 ms and %RE SDNN ICC = 0.941. %RE for HRVapp RMSSD was -6.326 ms with RMSSD ICC of 0.931. HRVapp lnRMSSD %RE = -0.667 ms and lnRMSSD ICC = 0.941. %RE PNN50 for HRVapp was 34.38 while PNN50 ICC = 0.760. For HRV frequency parameters, %RE of HRVapp LF = -139.5 ms2 and LF ICC = .778. HRVapp LFnu %RE = -3.074 with LFnu ICC of 0.555. HRVapp %RE HF was -180.9 ms2 and HF ICC = 0.632. %RE HFnu of HRVapp = 12.69 while HFnu ICC = 0.554. Lastly, HRVapp %RE LF/HF = -589.8 with LF/HF ICC = 0.534.

Table 1. HRV Indices in ECG and HRVapp (mean ± SD)

	ECG	HRVapp	% RE	ICC
SDNN (n = 24)	60.16 ± 25.14	63.45 ± 26.60	-6.326	0.941
RMSSD (n = 24)	56.32 ± 32.95	59.93 ± 36.41	-6.326	0.931
lnRMSSD (n = 24)	3.854 ± 0.655	3.886 ± 0.732	-0.667	0.941
PNN50 (n = 22)	12.64 ± 7.146	27.79 ± 15.69	34.38	0.760
LF (n = 24)	700.8 ± 681.8	1447 ± 1270	-139.5	0.778
LFnu (n = 24)	54.70 ± 17.69	54.24 ± 19.59	-3.074	0.555
HF (n = 24)	661.1 ± 839.7	1411 ± 1454	-180.9	0.632
HFnu (n = 24)	45.30 ± 17.69	45.76 ± 19.59	-12.69	0.554
LF/HF (n = 24)	1.632 ± 1.313	5.674 ± 5.544	-589.8	0.534

ECG - electrocardiogram; HRVapp - Pulse Express Pro mobile application; %RE - relative error; ICC - intraclass correlation coefficient; SDNN – standard deviation of normal to normal intervals (ms); RMSSD – square root of the mean of the sum of the sum of the squares of differences between adjacent normal to normal intervals (ms); lnRMSSD – natural log of RMSSD (ms); PNN50 – number of pairs of adjacent normal to normal intervals different by more than 50 ms in the entire recording divided by the total number of normal to normal intervals (%); LF - low frequency ms^2; LFnu - normalized low frequency; HF - high frequency ms^2; HFnu - normalized high frequency; LF/HF - low frequency to high frequency ratio.

DISCUSSION

The aim of this study was to establish the accuracy of a free HRVappn measuring HRV parameters when compared to the ECG criterion. Accuracy was assessed using %RE interpreted from the following criteria: < 0.50 % - accurate; 1.50 – 2.50 % - moderately accurate; > 2.50 % - inaccurate (Abbiss et al., 2009). Results showed that only lnRMSSD was an accurate HRV measure. This finding coincides with the results posted by previous researchers (Boos et al., 2016; Flatt et al., 2013). Further, other HRV parameters such as SDNN, RMSSD, LF, LFnu, HF, HFnu, LF/HF were found to be inaccurate. The observed inaccuracies from the HRVapp can be attributed to equipment variability from signal processing and artefact correction.

Another objective of this study was to examine the reliability of HRV indices from HRVapp. ICC was utilized for reliability which is interpreted as: ICC > 0.90 - 'excellent'; 0.80 - 0.90 - 'good'; < 0.80 - 'questionable' (Vincent, 2005). Findings demonstrated that ICC for SDNN, RMSSD, lnRMSSD were 'excellent'. The results were in line with previous research (Flatt et al., 2013; Perotta et al., 2017). Further, ICC of PNN50 and LF are relatively 'good'. Reliability was seen to be 'poor' in LFnu, HF, HFnu, and LF/HF.

Limitations in this current study should be noted. Firstly, raw data from both ECG and HRVapp were not available. Extraction of raw data from both equipment may allow standardization of artefact correction and possibly increase the accuracy and reliability of HRV indices from HRVapp (Perotta et al., 2017). Also, computation of HRV in HRVapp did not undergo artefact correction. This may have contributed to large 'noise' in HRV frequency parameters. Additionally, lnRMSSD was not displayed in HRVapp. Inclusion of lnRMSSD display feature after HRV recording in HRVapp can increase the utility of HRVapp. Lastly, equipment functionality and other reliability measures (e.g. intra/inter day) were not analysed in this study (Weir, 2005; Pyne et al, 2004). Carrying out such analyses may increase practitioner confidence in using the HRVapp. Thus, future studies addressing the limitations of this study should be warranted.

In conclusion, lnRMSSD is an accurate and highly reliable index in measuring autonomic modulation in HRVapp. On the other hand, the high reliability demonstrated by SDNN and RMSSD in HRVapp suggest that these measures can be utilized in monitoring autonomic activity over time.

PRACTICAL IMPLICATIONS

Practitioners can use the HRVapp as a low-cost alternative to measure autonomic health via lnRMSSD.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare. No funding was used for this study.

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