Clin Auton Res (2003) 13 : 99–102
DOI 10.1007/s10286-003-0085-7

RESEARCH ARTICLE

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Agreement of two different methods for measurement of heart rate variability

Received: 25 April 2002
Accepted: 6 January 2003

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Abstract *Background* The widespread use of affordable devices with sufficient precision for measurement of heart rate variability (HRV) might lead to early detection of abnormalities in a large number of high-risk patients and athletes. The purpose of this study was to determine the limits of agreement of two devices for measuring HRV parameters differing in price and assumed precision. *Subjects and methods* 36 healthy subjects (22 men and 14 women) with a mean age of 27.4 (SD 11.1) years were included. The two devices used for comparison were PowerLab® with Chart® software as the reference golden standard, and Polar® Transmitter®/Advantage® with Precision Performance® software, respectively. Measurements included the following heart rate variability parameters: heart rate, range of R-R-interval duration, SDNN, rMSSD, total Power, VLF power, LF power, and HF power. Measurements were taken during metronomic respiration over a total period of 3 minutes. Statistical analysis was performed according to Bland and Altman and by means of scatterplots and Spearman correlation coefficients. *Results* Good agreement was found for heart rate (95 % CI of limits of agreement: –0.7–0.6 bpm; r = 0.999), range of duration of R-R-intervals (95 % CI: –18.9–17.0 ms; r = 0.997), rMSSD (95 % CI: –1.5–2.5 ms; r = 0.999), and SDNN (95 % CI: –3.0–3.1 ms; r = 0.997). Correlation of measurements was high for the variables total Power, VLF power, LF power, and HF power. Analysis of method agreement for frequency domain variables was statistically not feasible. *Conclusion* The level of agreement for the analyzed time domain variables between the reference golden standard and the inexpensive device is sufficient to permit initial screening by family doctors, and self-administration by high-risk patients and athletes.

Key words heart rate variability · method agreement

Introduction

The measurement and analysis of heart rate variability (HRV) has been established during the past few decades as a valuable tool for risk stratification in a variety of medical disorders including acute myocardial infarction, sudden cardiac death, and congestive heart failure [2–4, 6, 8, 10]. Other authors have pointed out the association of HRV-related parameters with the overall health status of individuals without cardiovascular disorders [5, 7, 9].

A number of devices have been developed for measuring HRV. It is of interest to determine the agreement

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between expensive, precision devices built for medical application, on the one hand, and affordable devices developed for heart rate control during sport activities, on the other hand. If it can be shown that measurements made with affordable devices have an acceptable agreement with measurements made with expensive devices, a recommendation could be made for the use of inexpensive devices. We therefore decided to compare an affordable, simple-to-use heart rate measurement device (Polar® T31® Transmitter with Advantage® receiver and Precision Performance® software for Windows Version 2.1, Polar Electro, Kempele, Finland) with an expensive, ECG-based HRV measurement device (PowerLab® with Chart® software Version 6.3, AD Instruments, Castle Hill, Australia). The latter was considered the reference golden standard for the purpose of this study.

Subjects and methods

Thirty-six healthy volunteers (22 men and 14 women) with a mean age of 27.4 (SD 11.1) years were included. Written informed consent was obtained from all volunteers prior to participation. The following two devices are compared.

PowerLab® (high fidelity ECG measuring device, "golden standard")

A conventional ECG is registered using PowerLab® (ADInstruments, Castle Hill, Australia), a measuring device routinely used worldwide for multimodal monitoring of biosignals. Three self-adhesive ECG electrodes are administered in the left and right infrajugular fossa and close to the heart apex, respectively. PowerLab® is equipped with an analog-digital converter (ADC) used to digitalize all signals. The digital signals are then transferred to a PC and analyzed using the Chart® software (Version 6.3). A full continuous ECG can be viewed and saved for later analysis, and software-based filters are used for exclusion of movement artifacts and ectopic beats prior to HRV analyses.

Polar transmitter/advantage (inexpensive R-R-interval measuring device)

For registration of R-R-intervals using the Polar® system, an elastic belt (Polar T31™ transmitter, Polar Electro, Kempele, Finland) is fixated to the chest of the volunteer at the level of the lower third of the sternum. The belt contains a stable case with heart rate electrodes, electronic processing unit, and electromagnetic field transmitter. The heart rate signals are continuously transmitted to the receiver unit Polar® Advantage® via an electromagnetic field. The required distance between transmitter and receiver for successful signal registration is 10–90 cm. The receiver is connected to a PC. The digitally coded R-R-interval length is continuously submitted to the software Polar® Precision Performance® which in turn displays a heart tachogram on the monitor. In addition, HRV parameters can be calculated using the analysis software (with or without applying software filters in order to exclude movement artifacts and ectopic heart beats from the analysis).

HRV measurements included the following cardiovascular parameters:

- Mean heart rate (beats per minute, bpm).
- Range of duration of RR-intervals (milliseconds, ms).
- SDNN: Standard deviation of the duration of all normal R-R-intervals (ms).
- *rMSSD (root mean square of successive differences)*: Square root of the mean sum of squared differences between the duration of all normal successive R-R-intervals (ms).
- High frequency (HF) power.
- Low frequency (LF) power.
- Very low frequency (VLF) power.
- Total power (TP).

Measurements

On presentation in the lab, the volunteer was asked to sit comfortably in an armchair. The basic medical history was recorded and arterial blood pressure was measured non-invasively. ECG electrodes and thoracic belt were fixated as described above and the room was darkened to support the process of relaxation.

The volunteers were instructed and asked to breathe metronomically at a rate of 6 breaths per minute. This was followed by the simultaneous registration of R-R-intervals with both devices for three minutes. The duration of measurements was written down in a protocol. Prior to measurement analysis, movement artifacts and ectopic beats were removed if necessary by means of software filters available for each system. Furthermore, by analysis of breathing pattern and ECG waveforms, we made sure that exactly the same time periods were analyzed for both devices.

Statistical methods

Approximately normally distributed variables (age, heart rate, range of R-R interval duration, SDNN, rMSSD) are described using mean values with standard deviation (SD). Variables without assumption of normal distribution (total power, VLF power, LF power, HF power) were described using the median with lower and upper quartile. Scatterplots and Spearman correlation coefficients with respective p values were used for analysis of the linear association between measurements based upon the two devices. The method agreement analysis was performed according to Bland and Altman [1]. Additionally, the ratio of half the range of limits of agreement (LA) and the mean of the pairwise measurement means (MPM) was computed. A ratio of up to 0.10 was considered as good agreement. All statistical analyses were carried out using the software StatsDirect Version 1.9.8 (Camcode, Ashwell, England, http://www.statsdirect.com).

Results

Numerical results are given in Tables 1 and 2. Good agreement was found for heart rate (95% CI of limits of agreement: –0.7–0.6 bpm), range of duration of R-R-intervals (95% CI: –18.9–17.0 ms), rMSSD (95% CI: –1.5–2.5 ms), and SDNN (95% CI: –3.0–3.1 ms). The scatterplots (Fig. 1 a–d) describe the strong linear association between the two devices. Correlation coefficients were equal to or close to 1 in the four analyzed time domain variables. Correlation coefficients were considerably lower for all frequency domain variables and ranged between 0.84 and 0.93. Due to the fact that pairwise measurement differences were not approximately normally distributed, Bland-Altman analysis was not feasible for all four frequency domain variables.

Table 1 Analysis of time domain variables (n = 36)

Parameter	Mean (SD)		Correlation coefficient (p value)	Limits of agreement (LA), 95% CI	Mean of pairwise means [MPM] (SD)	Ratio 0.5* range(LA)/MPM
	PowerLab device	Polar device				
Heart rate (bpm)	78.7 (11.4)	78.8 (11.5)	0.999 (< 0.001)	−0.7–0.6	78.7 (11.4)	0.009
Range of R-R interval (ms)	391.0 (151.8)	392.0 (151.5)	0.997 (< 0.001)	−18.9–17.0	391.5 (151.6)	0.046
rMSSD (ms)	58.0 (33.9)	57.5 (33.4)	0.999 (< 0.001)	−1.5–2.5	57.8 (33.6)	0.034
SDNN (ms)	95.3 (43.6)	95.3 (43.0)	0.997 (< 0.001)	−3.0–3.1	95.3 (43.3)	0.032

Table 2 Analysis of frequency domain variables (n = 36)

Parameter	Median (25th percentile; 75th percentile)		Correlation coefficient (p value)
	PowerLab device	Polar device	
Total power	3352 (1834; 8149)	7499 (3752; 15994)	0.93 (< 0.001)
VLF power	263 (139; 378)	1133 (478; 2270)	0.84 (< 0.001)
LF power	2663 (1242; 6690)	4951 (2684; 11628)	0.92 (< 0.001)
HF power	266 (141; 946)	337 (126; 2004)	0.92 (< 0.001)

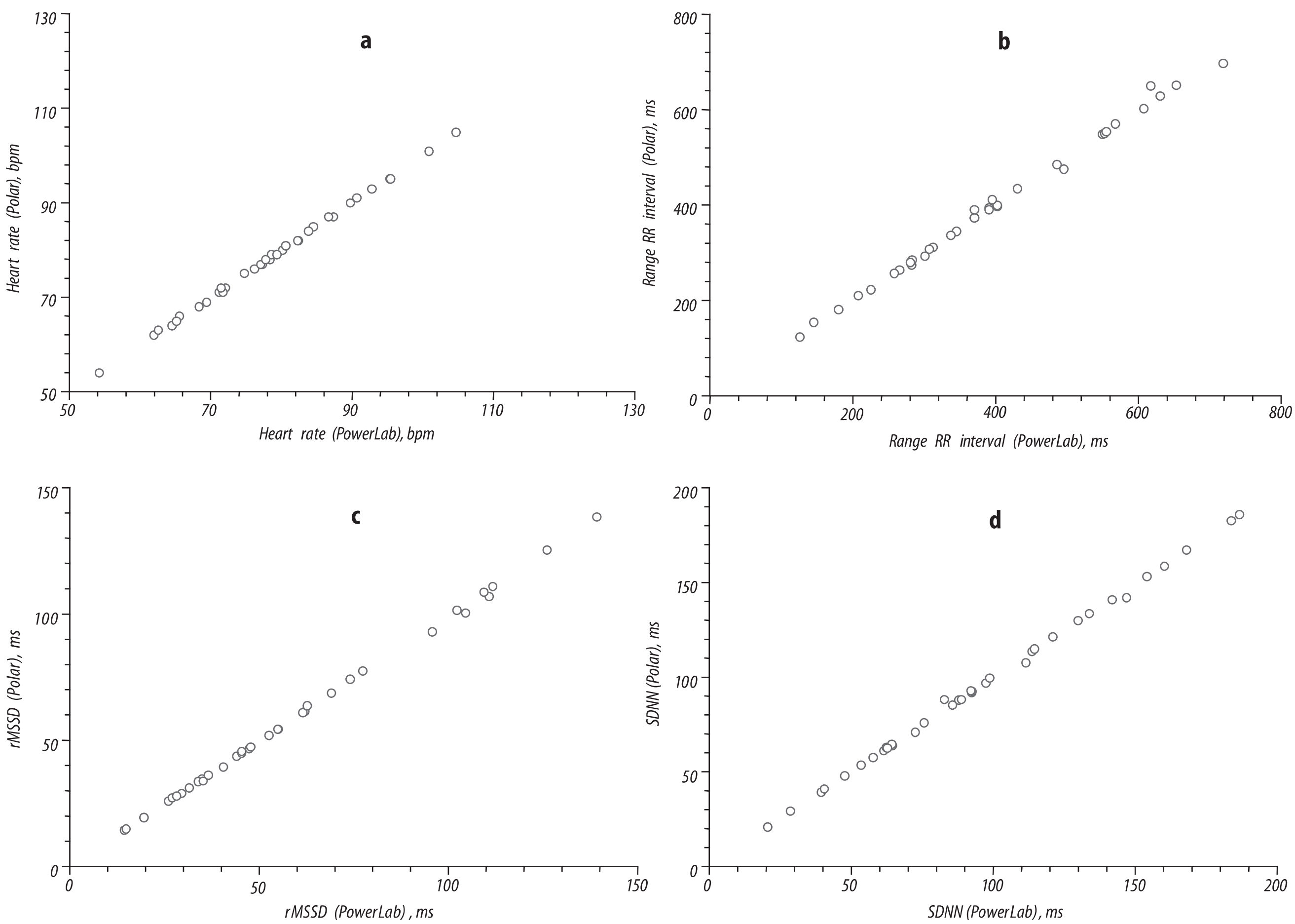

Fig. 1 Scatterplot of mean heart rate (**a**), range of R-R interval (**b**), rMSSD (**c**), and SDNN (**d**) measured by PowerLab versus Polar

Discussion

This study was performed to evaluate the usefulness of an affordable device (Polar T31 transmitter and Advantage receiver, Polar Electro, Finland) for the measurement of heart rate variability compared to a high fidelity measurement device (PowerLab, ADInstruments, Australia). Good method agreement could be demonstrated for heart rate, duration of R-R-intervals, SDNN, and rMSSD. We, therefore, recommend the use of the inexpensive device for screening of high-risk patients by family doctors and for self-administration by athletes. There is a definite potential for early detection of HRV-related abnormalities and for early referral of patients to specialized medical diagnostic procedures. We are convinced that a considerable number of subjects at risk for serious cardiovascular events could potentially benefit from the widespread use of the inexpensive HRV measuring device.

In contrast, results of frequency domain analyses obtained by means of different mathematical methods are obviously not comparable. It is well known that different mathematical methods for the analysis of frequency domain variables lead to different results. This does not only apply to low-cost devices, but also to comparisons of different high fidelity devices. We therefore suggest that patients should always be measured with the same device during the course of HRV studies. Provided that the autonomic tone of an individual is similar, repeated HRV measurements in this person with subsequent spectrum analyses using autoregressive modelling will lead to comparable results. While looking for frequency domain variable reference values in the published literature, one should keep in mind the algorithm used for their calculation. Without expert knowledge and specific experience, however, results of spectrum analysis should not be interpreted for medical purposes. Therefore, in screening studies performed by family doctors or athletes, only time domain variables should be used.

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