วารสารเทคโนโลยีทางการแพทย์และสหเวชศาสตร์
Journal of Medical Technology and Allied Health Sciences (JMAS)
ปีที่ 1 ฉบับที่ 1 มกราคม - เมษายน 2568
Vol. 1 No.1 January - April 2025

รหัสบทความ e2893
นิพนธ์ต้นฉบับ

Validity and Reliability of Two Smartphone Applications on Heart Rate Variability in Healthy Subjects

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Abstract

Heart rate variability (HRV) parameters represent the body's autonomic activity. The approach to obtaining these parameters needs special equipment. Interestingly, smartphone applications (apps) have recently become more friendly. With Polar H10, Elite app has good validity and reliability. HRVlogger is another fascinating app with more sophisticated in functionality. This study aims to determine the validity and reliability between Elite HRV and HRV logger application implementing the same chest strap, Polar H10, on heart rate variability parameters in healthy subjects. Twenty-six healthy adults performed three consecutive five-minute HRV recordings with one minute rest in both app during sitting. There were three correlations with the highest strength, natural log of the root mean square of successive differences between normal heartbeats (LnRMSSD) (r = 0.95, *p*-value < 0.01), the percentage of adjacent normal to normal intervals that differ from each other by more than 50 ms (pNN50), (r = 0.94, *p*-value < 0.01), and RR interval (r = 0.93, *p*-value < 0.01). The excellent correlation was root mean square of successive differences between normal heartbeats (RMSSD), heart rate (HR), and standard deviations of all the NN intervals (SDNN). The values were 0.88, 0.86, and 0.84, respectively (*p*-value < 0.01). Moreover, the low frequency/high frequency (LF/HF) ratio had moderate correlation (r = 0.59, *p*-value < 0.01). Reliability was excellent. RMSSD is 0.93 (0.84, 0.97), LnRMSSD is 0.97 (0.94, 0.99), HR is 0.97 (0.94, 0.99), RR interval is 0.97 (0.92, 0.94), SDNN is 0.90 (0.78, 0.96), and pNN50 is 0.94 (0.87, 0.97). The LF/HF ratio is poor to moderate, 0.38 (-0.39,0.72). HRV logger has moderate to excellent validity and reliability.

Keywords: Smartphone application, Heart rate variability, Polar H10, Validity, Reliability

Received date 14/03/25; Revised date 12/04/25; Accepted date 28/04/25

Introduction

Heart rate variability (HRV) parameters, the time interval between consecutive heartbeats, define the autonomic nervous system (ANS) of the body (Shaffer & Ginsberg, 2017). HRV is generally recorded using an electrocardiogram (ECG) by the gold standard 12-channel Holter. The ECG is complicated and requires a specialist to operate this device. The chest strap accompanied by an analysis program is more functional; an example includes the Polar chest strap accompanied by its program (Shaffer & Ginsberg, 2017; Rajendra et al., 2006). A previous study examined the correlation between the Medilog® AR12plus Holter device and Polar H10. The results found a high correlation of Polar H10 compared to the gold standard. Therefore, a simple chest strap is recommended for RR interval assessments (Gilgen-Ammann et al., 2019).

The surge in bearable technology and mobile applications (apps) allows anyone, regardless of expertise, to record these variables (Dobbs et al., 2019; Perrotta et al., 2017). This enhances compliance with daily HRV measurements, owing to their ease of use, efficiency, and user-friendly interface. There are smartphone apps able to analyze HRV parameters. The Elite HRV app with chest strap Polar H10 was investigated for validity and reliability. As validated by the ECG gold standard, the investigations showed strong to almost perfect validity. The intraclass correlation coefficient reported good to excellent reliability. These mobile apps can be employed for assessing HRV (Moya-Ramon et al., 2022).

To date, many individuals can assess their daily ANS for general health. However, exported raw data from Elite HRV need to be better located in the time interval. This is not convenient for scientific research with a larger sample size. On the other hand, the HRV logger is another smartphone app that further reports HRV data every minute in an Excel file, which is unchallenging to export. Even though smartphone apps like Elite HRV and HRVlogger, paired with the Polar H10 chest strap, are gaining popularity for HRV measurements, but their validity and reliability have not been extensively compared. Regarding ECG, the gold standard also needs special training, and Elite HRV has undergone validation in comparison to the gold standard ECG for precise measurement.

Objective

This study was designed to investigate the validity and reliability of Elite HRV in relation to the HRV Logger app implementing the same chest strap, Polar H10, on HRV parameters in healthy subjects.

Research Methodology

Experimental design

In a session, three consecutive five-minute HRV recordings with one minute rest between each were performed in a sitting position. The sequence of app was randomized as shown in **Figure 1**. This study employed Bluetooth-connected smartphone apps (Elite HRV and HRV logger) with the chest strap (Polar H10, Polar Electro Oy, Kempele, Finland). The smartphone was identical for each app (iPhone, Apple Inc., USA).

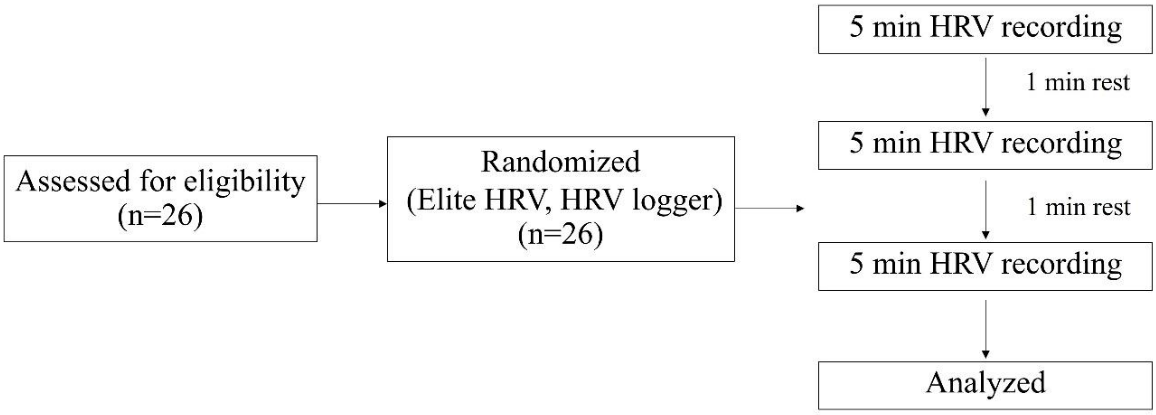

Figure 1 Protocol of the study

Population and Sample

Twenty-six healthy adults were recruited from Chulalongkorn University, Thailand. A recruitment announcement, in the form of a digital poster, was distributed via social media to the student community. Interested individuals contacted the researcher directly for initial screening. Individuals were included if they were aged above 18 - 40 years old. They can be both males and females. Exclusion criteria were the participants with fever, colds, cardiovascular or respiratory disease, autoimmune conditions, and systemic infection. If the participants had a history of lung infection (within six weeks before enrolling in the study), lung cancer, bronchiectasis, and cystic fibrosis, the participants would have been excluded. Another exclusion criterion was smoking, as it can significantly influence ANS function and alter HRV, which may confound the interpretation of study outcomes. All exclusion criteria were assessed based on self-reported health history obtained during the initial screening interview with the researcher.

HRV assessment methods

The Polar H10 chest strap was securely fitted on the participants, positioning the HR sensor over the xiphoid process of the sternum. The chest strap size is adjustable for proper fit around the sternum. The sensor is positioned over the center of the sternum, just below the rib cage, to avoid ambiguity. The HRV measurements were acquired through the detection of the electrical signals generated by the heart. Through Bluetooth 4.0 signals, the Polar H10 linked wirelessly to the Elite HRV and HRV logger apps and downloaded the data onto the iPhones. Once the device connections were verified, the data collection process began by selecting the "start" button on the Elite HRV app (Speer et al., 2020). The recording time for the HRV logger app started after the "record" button was pressed. Both apps were launched after verifying stable Bluetooth connectivity. The recording was initiated immediately after starting. Then, HRV parameters will be reported on the app. During data collection, the researcher monitored real-time data on the application interface throughout each session to ensure continuous signal reception. Any connectivity issues that occurred were promptly identified and addressed in real time, ensuring data accuracy.

Experiment protocol

Then, participants were fitted with the polar chest strap and asked to sit on a chair comfortably (head, neck, shoulder, hand relax, and feet on the floor) for ten minutes. Before recording, the researcher randomized one of two smartphone apps by simple random sampling. After connecting via Bluetooth, three consecutive five-minute HRV recordings were performed with one minute rest between each. Later, the second app was also connected via Bluetooth. The participants repeated the same three consecutives with one minute rest. Therefore, participants used both the Elite HRV and HRVlogger apps during the recordings (**Figure 1**). The data were extracted from both apps. There were RR interval and time-domain indices, mainly root mean square of successive RR intervals (RMSSD), which was chosen to reflect changes in vagal modulation and was preferred due to its superior reliability in demonstrating parasympathetic activity, compared to other power spectral density indices (Moya-Ramon et al., 2022). Natural log of the root mean square of successive differences between normal heartbeats (LnRMSSD). Other factors were also presented, including heart rate (HR), standard deviations of all the NN intervals (SDNN), and the percentage of adjacent NN intervals that differ from each other by more than 50 ms (pNN50). Frequency-domain accesses by program analysis on separating HRV into components based on frequency range, particularly the ratio of LF to HF (LF/HF), were also included in the study to provide a broader view of autonomic balance. The LF/HF ratio originated to estimate the ratio between sympathetic and parasympathetic activity contributions and is essential for interpreting shifts in autonomic modulation. This combination of time- and frequency-domain parameters allowed for a more comprehensive assessment of autonomic function (Shaffer & Ginsberg, 2017).

Statistical analysis

The descriptive data are shown as mean ± standard deviation (SD), and statistical analyses were conducted using SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA) for validity and reliability. A Shapiro-Wilk test was conducted to assess data normality, with statistical significance set at $p < 0.05$. The strength of the association between HRV measurements in different apps was assessed by Pearson's correlation coefficient and Spearman correlation in normal distribution and non-normal distribution data, respectively. To interpret these results, the correlation coefficient was set as follows: negligible (< 0.09), week (0.10 – 0.39), moderate (0.40 – 0.69), strong (0.70 – 0.89), and very strong (> 0.90) (Schober et al, 2018). The intraclass correlation coefficient (ICC) with a 95% confidence interval (CI) was calculated to identify the reliability of the Elite HRV and HRV logger. ICC values were interpreted as poor to moderate (< 0.75), good (0.75 to 0.90), and excellent (> 0.90) (Moya-Ramon et al., 2022).

Research Ethics

All participants were thoroughly informed of the study's objectives and provided written informed consent. The study has been executed in accordance with the Belmont Report 1979, the Declaration of Helsinki 2013, and the Council for International Organizations of Medical Sciences (CIOM) 2016 for human experiments. The committee approved the protocol and methodology (COA No.216/65).

Results

Descriptive data

Initially, 26 healthy participants were recruited. Participation was kept from being dropped out during the session. **Table 1** displays the descriptive data of all participants (mean ± SD). The participants consisted of 11 males and 15 females. Their age was 26.9 ± 5.7 years old. Their average weight was 63.7 ± 15.1 kg, and height was 165.9 ± 9.1 cm. The average BMI was 23.0 ± 4.1 kg/m^2. All participants were undergraduate students.

Validity of two different smartphone applications

The outcome of the validity studies is shown in **Table 2** and **Figure 2**. The correlations between the two apps' measurements were excellent for several HRV parameters including LnRMSSD (r = 0.95, *p*-value < 0.01), pNN50 (r = 0.94, *p*-value < 0.01), and RR interval (r = 0.93, *p*-value < 0.01). The strong correlation was parameters RMSSD, HR, and SDNN. The values were 0.88, 0.86, and 0.84, respectively at *p*-value < 0.01. These were significant. Moreover, the LF/HF ratio had a moderate correlation (r = 0.59, *p*-value < 0.01). The HRV logger has a moderate to excellent correlation compared to Elite HRV.

Table 1 Descriptive data of healthy participants (Mean ± SD).

Characteristics	Mean ± SD	n (%)
Age (years)	26.9±5.7	
Weight (kg)	63.7±15.1	
Height (cm)	165.9±9.1	
BMI (kg/m^2)	23.0±4.1	26 (100.0)
Sex		
- Male		11 (42.3)
- Female		15 (57.7)
Level of education		
- Undergraduate		26 (100.0)

Table 2 Comparison of HRV parameters between Elite HRV and HRV logger apps, including correlation values and intraclass correlation coefficients (ICC) with 95% confidence intervals (CI)

	Elite HRV (Mean ± SD)	HRV logger (Mean ± SD)	Correlation, *p*-value	ICC (95%CI)
HR (bpm)	78.88 ± 11.54	79.13 ± 11.35	0.86, <0.01	0.97 (0.94, 0.99)
RR interval (ms)	777.93 ± 104.24	773.72 ± 100.93	0.93, <0.01	0.97 (0.92, 0.94)
RMSSD (ms)	34.35 ± 16.58	32.36 ± 13.77	0.88, <0.01	0.93 (0.84, 0.97)
LnRMSSD	3.44 ± 0.55	3.37 ± 0.51	0.95, <0.01	0.97 (0.94, 0.99)
pNN50 (%)	14.81 ± 14.46	14.27 ± 13.80	0.94, <0.01	0.94 (0.87, 0.97)
SDNN (ms)	49.69 ± 13.76	43.14 ± 10.79	0.84, <0.01	0.90 (0.78, 0.96)
LF/HF ratio	2.81 ± 2.91	1.29 ± 0.50	0.59, <0.01	0.38 (-0.39,0.72)

ICC: intraclass correlation coefficient, HR: heart rate, LnRMSSD: natural log of the root mean square of successive differences between normal heartbeats, RMSSD: the root mean square of successive differences between normal heartbeats, pNN50: the percentage of adjacent NN intervals that differ from each other by more than 50 ms, SDNN: standard deviations of all the NN intervals, The *p*-value < 0.01 is significant.

Reliability of two different smartphone applications

Reliability across HRV parameters was high, with intraclass correlation coefficients (ICCs) ranging from 0.84 to 0.99 for most variables. However, the LF/HF ratio showed a poor-to-moderate reliability (ICC = 0.38). These results suggest that apps provide comparable HRV measurements, which may allow for interchangeable use in research and practice.

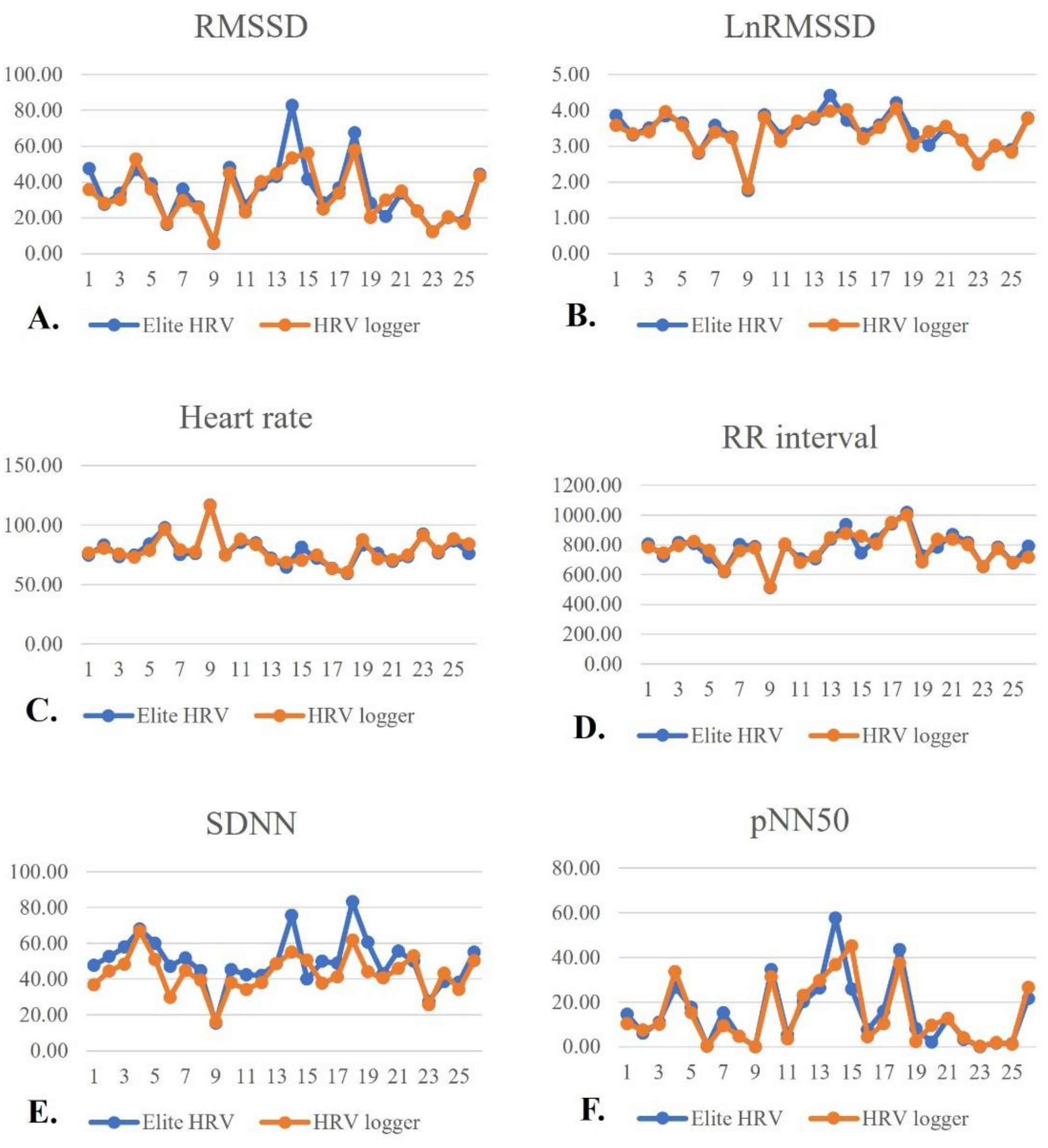

Figure 2 Illustrates the validity of the HRV parameters measured by the two smartphone apps in comparison (A-F).

Discussion and Conclusion

This study aimed to evaluate the validity and reliability of two smartphone apps for HRV measurement using the Polar H10 chest strap. The results found that validity ranged from moderate to excellent, depending on the parameters. Moreover, regarding reliability, most HRV measurements found an excellent ICC value.

The validity of the Elite HRV and HRV logger apps was interpreted by intraclass correlation coefficient after performing both apps. The previous research by Gambassi et al. (2020) measured RR interval from Elite HRV compared to ECG standard in asymptomatic adults. The results found excellent validity and consistency. However, this study had small sample size as well as data collection needs expertise during the process (Gambassi et al., 2020) To be useful with the technology and its convenience, the finding of the RR interval from the HRV logger was excellent as compared to Elite HRV. Moreover, a study evaluated Elite HRV's validity on RMSSD and LnRMSSD. The findings were excellent (Perrotta et al., 2017; Moya-Ramon et al., 2022). Like this current investigation in HRV logger, RMSSD and LnRMSSD were also excellent. However, the LF/HF ratio’s moderate correlation potential. The reasons for this discrepancy, including the sensitivity of the LF/HF ratio to signal noise, artifacts, and differences in spectral analysis methods across the two apps (Shaffer & Ginsberg, 2017). Therefore, the LF/HF ratio may be less reliable than time-domain measures when using different mobile applications. So far, the validity range of this current study was moderate to excellent. Therefore, the HRV logger can provide a valid HRV measurement.

A prior study attempted to analyze smartphone apps' reliability. The implementation differs in technology for measuring HRV reported that Elite HRV and Welltory had an exceptionally strong to nearly perfect correlation with the gold standard on RMSSD and LnRMSSD (Moya-Ramon et al., 2022). In this study, the reliability from the HRV logger was excellent on RMSSD and LnRMSSD as compared to Elite HRV. Since the validity range of this current study was moderate to excellent. Therefore, the HRV logger can provide reliable HRV measurement. The reliability of the LF/HF ratio was poor, which may be due to the same factors affecting its correlation. These findings suggest that the LF/HF ratio may be less stable and less suitable for comparative purposes when using different mobile HRV apps.

Finally, the smartphone app has been making profits and offering convenience. Interestingly, a smartphone app is effective in assessing HRV. However, this study had some limitations. Ectopic beats and artifact waveforms must be corrected. Further research could investigate the impact of various artifact correction methods used by smartphone apps to ensure accurate signal analysis processing as well as explore whether certain types of activities or environmental factors (e.g., time of day, stress levels) influence the accuracy of HRV measurements. Additionally, examining how daily activities and various exercise conditions influence HRV measurements would provide valuable insights for both clinical and wellness applications.

In conclusion, both HRVlogger and Elite HRV demonstrate moderate to excellent validity and reliability in measuring HRV using the Polar H10 chest strap. Due to its convenience, inexpensive, and easy-to-use data export, this study suggested that HRV logger smartphone apps can be implemented to register HRV measurements among researchers and practitioners investigating the ANS function.

Acknowledgments

We wish to convey our heartfelt appreciation for the scholarship granted by the Graduate School of Chulalongkorn University, in honor of the 72nd anniversary of His Majesty King Bhumibol Adulyadej. We appreciate our participants who kindly agreed to participate in this study. Finally, we thank Dr. James M. Brimson (Research Unit for Innovation and International Affairs, Faculty of Allied Health Sciences, Chulalongkorn University) for proofreading and editing the English of this manuscript.

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