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Short Communication

Accuracy of Pulse Rate Variability Parameters Obtained from Finger Plethysmogram: A Comparison with Heart Rate Variability Parameters Obtained from ECG

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Two spectral components of heart rate variability, respiratory sinus arrhythmia (RSA) and Mayer wave-related sinus arrhythmia (MWSA), respectively provide noninvasive indices of cardiac vagal activity and systemic sympathetic activity with vagal modification[1–3]. Their amplitudes are usually obtained from spectral analysis of R-R intervals measured on an electrocardiogram (ECG). In the present study, it was examined whether peak-to-peak intervals measured on a finger plethysmogram (FPG) can be alternative data to the ECG R-R intervals for the same analysis. If we can substitute the FPG for the ECG, this provides an advantage in a routine physical examination at a work site, because the FPG is often easier to be applied to many subjects than the ECG.

Subjects and Methods

Thirty-two healthy volunteers (6 men and 26 women aged 20.2 ± 1.7 (mean ± S.D.)) who gave written informed consent participated in this experiment. Following a rest period of 120 min after a meal, they lay quietly for 5 min in a sound-insulated and electrically shielded room, after which their ECGs (standard lead I), reflective-type FPGs (Model TL612-T, Nihon-Kohden Co., Ltd., Tokyo) on the left index finger, and pneumatogram (PMG: Model TR762-T, Nihon-Kohden Co., Ltd., Tokyo) were simultaneously recorded for 5 min in each of the following positions: supine rest, sitting rest (90° tilt), and standing rest in this order. The time constant for the FPG was set at 0.3 sec in order to minimize spontaneous baseline fluctuation, according to Minami *et al.*[4]. The recording started after the heart rate became stable. The subjects were instructed to breathe regularly without deep breaths and to change their posture actively. Data analysis was carried out following the method previously reported[1,2,5,6]. Autoregressive spectral analysis and component wave analysis were applied to the 200 successive R-R intervals measured on the ECG with a tachograph (Model TM55, CERX Co., Ltd., Tokyo). Following the formula proposed by Hayano[1], component coefficients of variation and center frequency of RSA (C-CV$_{RSA}$, %, and f$_{RSA}$, Hz) and those of MWSA (C-CV$_{MWSA}$, %, and C-CV$_{MWSA}$, Hz) were calculated. From the peak-to-peak intervals measured on the FPG for the same time period as the above ECG, similar variables were calculated in the same way. Since the above two C-CV$_{RSA}$ values were obtained in the same breathing condition, respiratory modification of C-CV$_{RSA}$[4,5] was neglected. Mean breathing frequency (BF, Hz) was calculated from the PMG for the same time period.

Results

The pulse rate based on the FPG always agreed with the heart rate based on the ECG. Figure 1 shows a typical power spectrum of HRV based on the ECG and that based on the FPG both of which were simultaneously obtained for the same subjects at supine rest. Similar spectral components, MWSA and RSA, were extracted from both of them by component wave analysis. C-CV$_{RSA}$ and C-CV$_{MWSA}$ values obtained from the FPG agreed well with those obtained from the ECG regardless of the posture (Fig. 2). f$_{RSA}$ values obtained from the FPG agreed well with BF obtained from

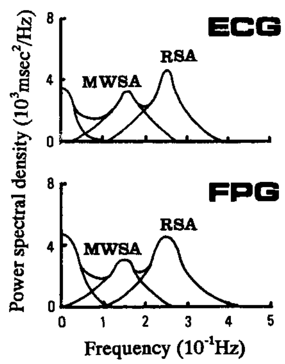

Fig. 1. Representative example of autoregressive power spectrum of R-R interval variability based on the ECG and of pulse interval variability based on the FPG. Representative example of power spectrum of heart rate variability obtained from the ECG and the FPG which were simultaneously used for the same subject at supine rest. The upper figure shows the power spectrum of R-R interval variability obtained from the ECG, in which two major spectral components present MWSA and RSA (mean R-R interval, 820 msec; total power 2,300 msec^2; MWSA power, 670 msec^2; center frequency of MWSA, 0.10 Hz; RSA power, 1,005 msec^2; and center frequency of RSA, 0.21 Hz). The lower figure shows the power spectrum of pulse interval variability obtained from the FPG (mean pulse interval, 820 msec; total power 2,450 msec^2; MWSA power, 648 msec^2; center frequency of MWSA, 0.10 Hz; RSA power, 980 msec^2; and center frequency of RSA, 0.21 Hz).

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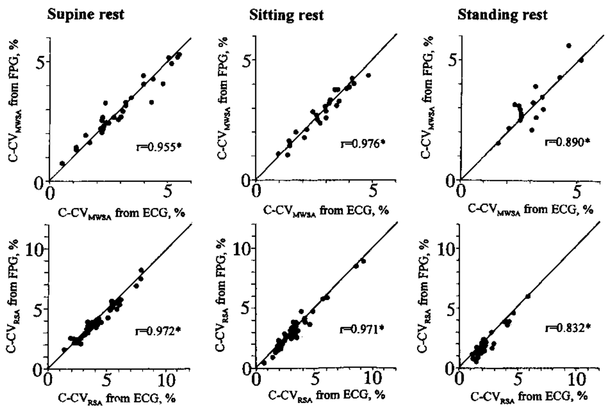

Fig. 2. Comparison of C-CV$_{MWSA}$ and C-CV$_{RSA}$ obtained from the FPG with those obtained from the ECG by postures. C-CV$_{MWSA}$, component coefficient for MWSA; C-CV$_{RSA}$, component coefficient for RSA; ECG, electrocardiogram; FPG, finger plethysmogram; and r, Pearson's correlation coefficient (*p<0.001).

the PMG (Fig. 3) as well as f_{RSA} obtained from the ECG. No sex difference was observed in these results.

Discussion

The results obtained from the FPG were somewhat inconsistent with those obtained from the ECG for some subjects, especially at standing rest (Figs. 2 and 3). This seems to be caused by the errors in peak-to-peak intervals measured with a tachograph because of the baseline fluctuation in the FPG. Although the time constant for the FPG was set short to minimize spontaneous baseline fluctuation[4], the FPG baseline sometimes fluctuated mainly due to minor body movement or slipping of the FPG sensor on the finger, especially at standing rest. In a practical situation such as physical examination at a work site, there is a need to watch the FPG records to exclude these artifacts from data analysis.

But the above results show on the whole that the C-CV$_{RSA}$, C-CV$_{MWSA}$, and f_{RSA} obtained from the FPG can be substitutes for those obtained from the ECG, at least for young healthy subjects. This means that respiratory modification of the C-CV$_{RSA}$ can be standardized based on the f_{RSA} following the method previously reported[5,6]. We are applying this easy, alternative method with the FPG to many subjects in a routine physical examination at a work site. The above results also suggest that the cardiac autonomic test based on HRV can be carried out in combination with other physiological tests using the FPG: e.g. an acceleration plethysmogram test[7] for assessment of peripheral circulation, a test of sound-induced decrease response in wave height of the FPG which indicates sympathetic function[4,8], and so on. These combinations may enable us to collect two kinds of information at a time, that for cardiac autonomic function or activity and that for peripheral circulation or sympathetic vasomotor control.

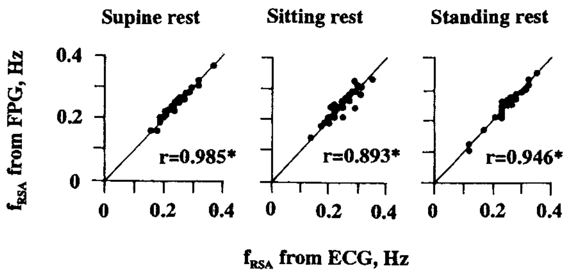

Fig. 3. Comparison of f_{RSA} obtained from the FPG with that obtained from the ECG. f_{RSA}, center frequency of RSA; ECG, electrocardiogram; FPG, finger plethysmogram; and r, Pearson's correlation coefficient (*p<0.001).

But it remains to be determined whether the above method can be applied to the aged, to vibrating-tool operators, or to those with a peripheral circulation disorder such as arteriosclerosis, because it is possible for a severe peripheral circulation disorder decrease the wave height of the FPG and to increase the errors in peak-to-peak intervals with a tachograph.

References

1) Hayano J. Quantitative assessment of autonomic function by autoregressive spectral analysis of heart rate variability: Effect of posture, respiratory frequency, and age. Jiritsu-Shinkei 1988; 25: 334–344 (in Japanese).
2) Murata K, Araki S, Maeda K. Autonomic and peripheral nervous system dysfunction in workers exposed to hand-arm vibration: A study of R-R interval variability and distribution of nerve conduction velocities. Int Arch Occup Environ Health 1991; 63: 205–211.
3) Araki S, Murata K, Yokoyama K, Kawakami N. Subclinical neuro-psychobehavioral effects in occupational, environmental and community health: Methodology and recent findings. Nippon-Eiseigaku-Zasshi 1995; 50: 713–729.
4) Minami M, Kabuto M. Individual differences of sympathetic response to white-noise-induced plethysmogram. Nippon-Eiseigaku-Zasshi 1993; 48: 646–653.
5) Kageyama T, Imai H, Kabuto M. A standardization method for respiratory sinus arrhythmia as an index of cardiac parasympathetic activity using breathing frequency. J Occup Health 1996; 38, 20–24.
6) Kageyama T, Imai H, Kabuto M. A standardization method for respiratory sinus arrhythmia using breathing frequency (the 2nd report): Efficiency for assessing change in cardiac parasympathetic activity with posture. J Occup Health 1996; 38, 107–112.
7) Katsuki K, Yamamoto T, Yuuzu T, et al. A new index of acceleration plethysmogram and its clinical physiological evaluation. Nippon-Seirigaku-Zasshi 1994; 56: 215–222 (in Japanese).
8) Matoba T, Mizobuchi H, Ito T, Chiba M, Toshima H. Further observations of the digital plesthysmography in response to auditory stimuli and its clinical applications. Angiology 1981; 32: 62–72.