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Relative influence of age, resting heart rate and sedentary life style in short-term analysis of heart rate variability

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Abstract

In order to assess the relative influence of age, resting heart rate (HR) and sedentary life style, heart rate variability (HRV) was studied in two different groups. The young group (YG) consisted of 9 sedentary subjects aged 15 to 20 years (YG-S) and of 9 nonsedentary volunteers (YG-NS) also aged 15 to 20. The elderly sedentary group (ESG) consisted of 16 sedentary subjects aged 39 to 82 years. HRV was assessed using a short-term procedure (5 min). R-R variability was calculated in the time-domain by means of the root mean square successive differences. Frequency-domain HRV was evaluated by power spectrum analysis considering high frequency and low frequency bands. In the YG the effort tolerance was ranked in a bicycle stress test. HR was similar for both groups while ESG showed a reduced HRV compared with YG. Within each group, HRV displayed a negative correlation with HR. Although YG-NS had better effort tolerance than YG-S, their HR and HRV were not significantly different. We conclude that HRV is reduced with increasing HR or age, regardless of life style. The results obtained in our short-term study agree with others of longer duration by showing that age and HR are the main determinants of HRV. Our results do not support the idea that changes in HRV are related to regular physical activity.

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Key words
- Heart rate variability
- Short-term analysis
- Autonomic nervous system
- Aging
- Sedentary life style

Introduction

The analysis of heart rate variability (HRV) is a simple noninvasive technique used to assess the instantaneous beat-to-beat variations in terms of R-R interval length. HRV has been considered as a suitable marker for the estimation of autonomic nervous system function (1,2).

HRV is reduced in many pathological conditions. Diabetes (3,4), coronary artery disease (5,6) and heart failure (7,8) are the most extensively studied. In all of these cases, there is a reduction of parasympathetic activity and an increase in sympathetic outflow. Nevertheless, the "normality" concept for HRV is a difficult task; the diagnosis of normal or reduced HRV requires the definition of the conditions prevailing during HRV measurement and even before it (9).

In a normal population without any pathological interference, HRV shows broad limits because autonomic outflow is labile. Modifications in age, postural changes, emotions, or time of the day can induce changes in HRV (10-13). In healthy subjects, an “alert” response increases the sympathetic outflow and reduces the parasympathetic one. We can say that the alert HRV response reproduces the behavior observed in a pathological situation. Studies of situations in which mental or physical stress induces a reduction of HRV give support to this point of view (11,14). On the contrary, interventions that reduce the sympathetic outflow may induce an increase in HRV; this is the case for pharmacological maneuvers (15), some relaxation techniques (16-18) and, hypothetically, physical training (19). Conversely, a sedentary life style may induce a reduction in parasympathetic outflow paralleled by an increase in sympathetic outflow (20).

HRV can be analyzed during daily activities (including sleeping hours) by Holter monitoring (21,22). On the other hand, short-term analysis can also be used (23). This type of study usually lasts a few minutes and can be performed under controlled laboratory conditions. In the present study we used a short-term technique involving similar conditions for all subjects.

Our main goal was the evaluation of the relative influence of age, resting heart rate (HR) and sedentary life style on HRV. In order to assess age effect, we chose two groups of healthy people of different mean age. The effect of HR on HRV was analyzed within each group. The influence of sedentary life style was studied in the younger group which included sedentary and nonsedentary subjects.

We show that age and HR are the main determinants of HRV. These results agree with others based on longer recordings than those used here (24). Our results do not support the point of view that regular physical activity modifies HRV.

Material and Methods

Subjects

We studied 34 healthy volunteers divided into two groups. The first group (YG) consisted of 18 young subjects (12 men and 6 women) aged 15 to 20 years. Nine of them (6 men and 3 women) engaged in physical activities (running, playing soccer or basketball) at least five days a week and are referred to as nonsedentary subjects of the YG group (YG-NS). The remaining persons were sedentary ones matched with the others for age and gender and are referred to as sedentary subjects of the YG group (YG-S).

Another group of elderly sedentary subjects (ESG) consisted of 16 sedentary volunteers (2 men and 14 women) aged 39 to 82 years (see Tables 1 and 2 for mean age values).

Heart rate variability study

A standard recorder (Fukuda FJC7110) was used to obtain an ECG. The ECG signal was connected to an electronic device which triggers a square wave pulse when the signal amplitude reaches an adjustable voltage threshold. A standard ECG lead was chosen to obtain a good R wave shape. The detection threshold was set according to the voltage of this particular R wave.

The pulses were fed to a computer through a parallel port. A specifically designed software (25) measured the time between successive R waves and stored them as ASCII files (values in ms).

In a previous study, the sensitivity and specificity of this method were found to be similar to those of Holter monitoring (26).

All tests were performed between 10 am and 1 pm. Each subject had taken a light breakfast two or more hours earlier. After a detailed explanation of the routine and aims, volunteers were placed in a quiet room in the supine position. For the chosen recording period of 10 to 15 min, an initial 15-min delay was included to allow the reduction of heart rate to a minimum level.

Stress test

After the acquisition of data for HR and HRV measurement, each subject in the YG group underwent a stress test based on a continuous bicycle protocol for assessment of training rank. Tests were initiated with a load of 50 watts and an additional 50-watt load was added every 3 min. The tests were stopped when maximal HR (calculated according to age) was achieved or when muscular fatigue occurred. In each case we recorded workload, time of effort and maximum HR achieved.

The ESG group did not perform the stress test.

Data analysis

To correct false R-R intervals due to detection of noise or non-sinusal R waves, we used a digital filtering routine (27). Briefly, the filter removes R-R intervals which are below or above a specified threshold (in this case 20%) of either the last compared interval or the mean value of all the intervals included up to that point. As usual for short-term analysis (28), we used the same sample interval (5 min) for all cases.

As mentioned above, our records lasted 10-15 min but we only used the 5 min of the central segment of the entire record. In this segment, conditions were more stable as we avoided operator influences during connection and disconnection of the equipment.

The average HR measured during this period was considered to be the resting HR.

The variability between R-R intervals was assessed in the time-domain by means of the square root of the mean of the sum of squares of successive differences between adjacent normal-to-normal intervals (rMSSD) (29). This index is considered to be a good marker for the fast changes in R-R duration (6,28) which is useful for parasympathetic activity evaluation.

Frequency-domain measurements were assessed by spectral analysis. For the purposes of the present study, only two bands of the spectrum were considered, i.e., a low frequency band (LF, 0.03 to 0.15 Hz) and a high frequency band (HF, 0.15 to 0.40 Hz). Very low and ultralow (28) frequencies should not be taken into consideration in a short-term analysis like ours. The values for the bands are reported as power spectrum density units (ms^2/Hz)[1].

For statistical analysis, the unpaired nonparametric Mann-Whitney test was used. Data are reported as means ± standard deviation. Results were considered significant when $P<0.05$ and P values are reported.

Results

Influence of age

Influence of age was analyzed by comparing the HRV between the elderly group (ESG) and the young group (YG). As seen in Table 1, rMSSD, HF and LF were significantly lower in ESG than YG.

Sedentary life style

Stress tests were applied only to YG. Most subjects performed submaximal tests, but all of them reached HR levels above 85% of the maximal HR calculated for their ages. Table 2 shows the average values of achieved workload for the sedentary (YG-S) and nonsedentary (YG-NS) subjects within YG. YG-NS reached significantly higher work-

[1]The original software for calculation of HRV indices was developed by R. Canetti and M. Hackas from Instituto de Ingeniería Eléctrica, Facultad de Ingeniería, Montevideo, Uruguay.

loads than YG-S. This result agrees with the regular physical activity which defines the YG-NS. Nevertheless, rMSSD, HF and LF were not significantly different between the two YG subgroups, as shown in Table 2.

Influence of resting heart rate

Mean HR values did not differ significantly between YG and ESG or between YG-S and YG-NS in YG (Tables 1 and 2).

There was a negative exponential correlation between the three calculated indices of HRV and HR for both groups. Figures 1-3 show a semi-logarithmic data transformation for a linear regression analysis. The correlation coefficients obtained were statistically significant in all cases.

Discussion

The aim of our study was to analyze the relative influence of age, sedentary life style and HR on HRV, measured with a short-term procedure.

Influence of heart rate

The HRV values depend on R-R interval duration. The shorter the interval, the smaller the range of variability that can be measured (30). This agrees with the widespread observation that an increase in sympathetic drive, which reduces the duration of R-R intervals, also reduces HRV. Conversely, the reduction of HR by an increase of parasympathetic activity leads to an increase of the duration of R-R intervals and an enhancement of HRV. Accordingly, we showed a negative correlation between rMSSD and HR within each group (Figure 1).

It should be pointed out that YG, whose mean HR was similar to that of ESG, showed higher mean rMSSD values (Table 1). Such observation indicates that HR influence should be considered together with other

Table 1 - Mean values of age, HR and HRV indices (rMSSD, HF and LF) for YG and ESG.

Values are reported as mean ± SD. All values but HR differed significantly between groups (see P values). n.s., Not significant. HR, Heart rate; HRV, heart rate variability; rMSSD, square root of the mean of the sum of squares of successive differences between adjacent normal-to-normal intervals; HF, high frequency band; LF, low frequency band; YG, young group; ESG, elderly sedentary group.

	Age (years)	HR (bpm)	rMSSD (ms)	HF (ms^2/Hz)	LF (ms^2/Hz)
YG (N = 18)	17.3 ± 1.7	66.1 ± 10.8	60.9 ± 31.0	1418.0 ± 1143.0	1891.5 ± 2224.7
ESG (N = 16)	54.2 ± 11.9	68.3 ± 7.3	30.1 ± 14.4	334.7 ± 311.2	467.1 ± 390.0
P value	<0.0001	n.s.	0.0018	0.0009	0.0018

Table 2 - Mean values of age, HR, achieved workload and HRV indices (rMSSD, HF and LF) for sedentary (YG-S) and nonsedentary (YG-NS) subjects of the young group (YG).

Values are reported as mean ± SD (N = 9). The only parameter that showed a statistically significant difference was the achieved workload (see text for discussion). For abbreviations, see legend to Table 1.

	Age (years)	HR (bpm)	Workload (watts)	rMSSD (ms)	HF (ms^2/Hz)	LF (ms^2/Hz)
YG-NS	17.3 ± 1.7	65.1 ± 13.2	1266.7 ± 250.0	49.9 ± 29.0	1122.7 ± 1047.5	1031.7 ± 807.7
YG-S	17.2 ± 1.8	66.9 ± 30.4	866.7 ± 235.0	66.4 ± 28.8	1713.8 ± 1217.4	2587.3 ± 2930.1
P value	n.s.	n.s.	0.0001	n.s.	n.s.	n.s.

HRV determinants such as age (see below).

Physiological increases of HR are related to a rise in sympathetic drive with the concomitant reduction of the parasympathetic one. In the frequency-domain analysis of HRV, there is general agreement that the HF band reflects parasympathetic activity, whereas the LF band has been related to sympathetic drive (28). However, the association between sympathetic activity and LF band is not as clear as in the case of HF and the parasympathetic drive (31).

In our study, the negative relationship between HR and the HF band found in both groups (Figure 2) agreed with a reduction of parasympathetic drive with increasing HR. On the other hand, HR increases when sympathetic tone is higher, and therefore we can expect a positive relationship between HR and LF. The negative relationship between LF and HR observed here (Figure 3) may reflect the previously mentioned contribution of the parasympathetic branch to this band.

Tsuji and co-workers (24) showed a negative correlation between HRV and HR in 2-h ECG recordings. Our short-term analysis supports the same relationship within each group.

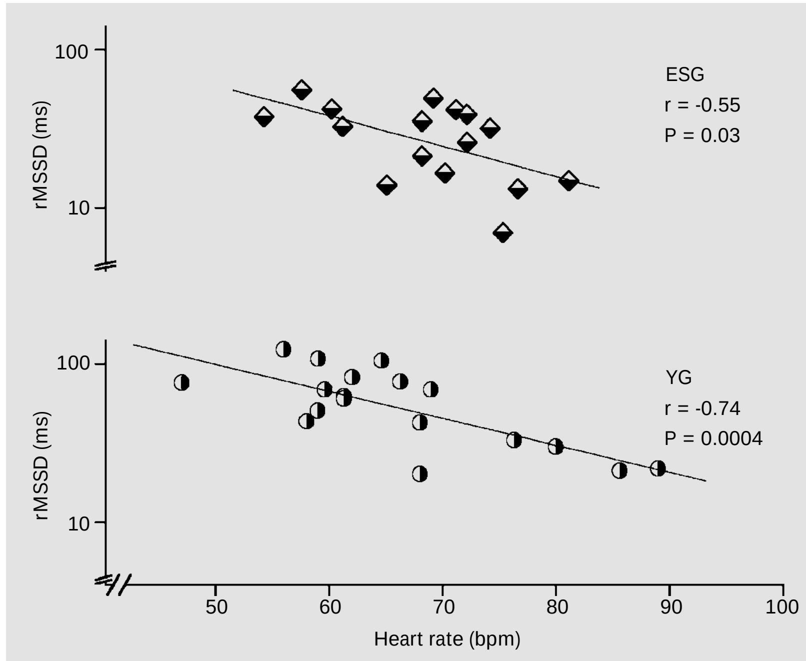

Figure 1 - Fitted regression line of natural log transformation of rMSSD (in ms) as a function of resting heart rate (bpm) for ESG (N = 16) and YG (N = 18). For abbreviations, see legend to Table 1.

Influence of age

Age was pointed out as one of the most important determinants of HRV in the above mentioned longer study (24). In our short-term HRV analysis, the group of older people (ESG) had reduced HRV when compared with the young group (YG) (Table 1). Aging of the autonomic nervous system, specifically of its parasympathetic branch (32), could explain this observation, showing that the evaluation of age is essential when considering HRV for clinical or research purposes.

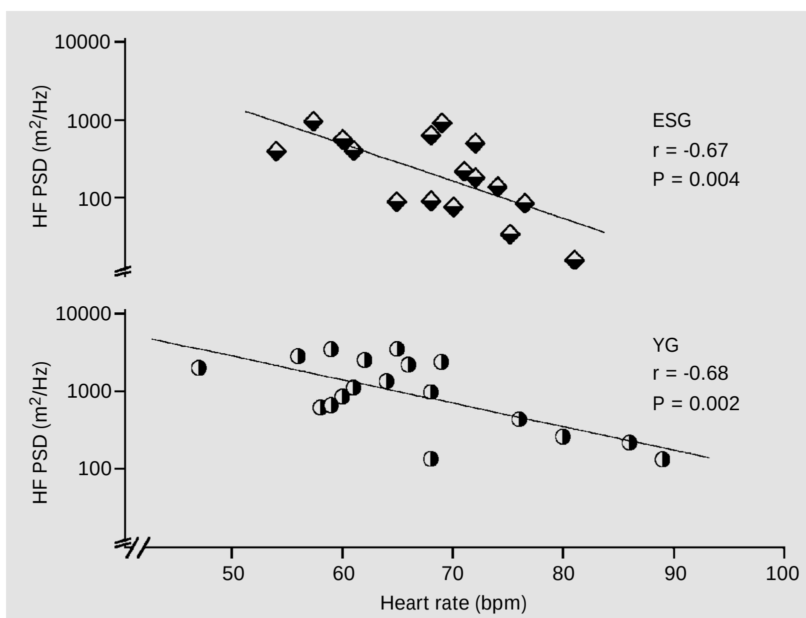

Figure 2 - Fitted regression line of natural log transformation of the power spectrum density (PSD) of the HF band (in ms^2/Hz) as a function of resting heart rate (bpm) for ESG (N = 16) and YG (N = 18). For abbreviations, see legend to Table 1.

Effect of sedentary life style

The effects of maintained physical activity have been related to an increase in para-

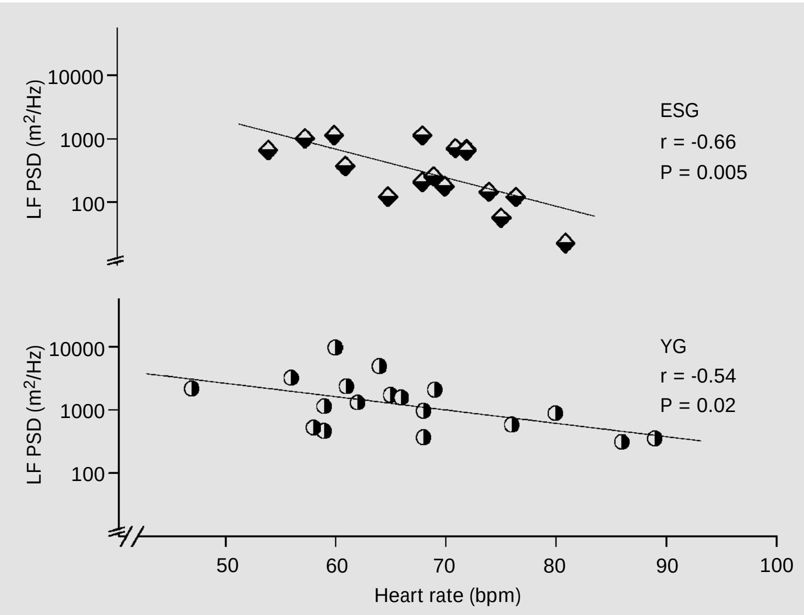

Figure 3 - Fitted regression line of natural log transformation of the power spectrum density (PSD) of the LF band (in ms^2/Hz) as a function of resting heart rate (bpm) for ESG (N = 16) and YG (N = 18). For abbreviations, see legend to Table 1.

sympathetic response with a concomitant reduction in sympathetic outflow (33). As expression of such adaptations, nonsedentary individuals are supposed to have lower HR (34) and blood pressure at rest (35). As mentioned earlier, since parasympathetic activity increases HRV we could expect reduced HRV in sedentary people (36,37). However, the influence of programmed exercise on HRV is an open issue (20). Some reports show differences in HRV between trained and nontrained groups (9,36,38), whereas others do not show such differences (35,39) or describe more complex results (40,41).

In the present study we recruited a group of young people including sedentary (YG-S) and nonsedentary (YG-NS) individuals. We could expect a lower HR in the YG-NS than in the YG-S. However, it should be pointed out that the simple measurement of HR is a labile parameter when measured in wakeful conditions. HR can be altered by the influence of the quality and duration of previous rest (42) and also by anxiety (14) or other psychological influences. To avoid these influences, for comparative purposes some authors considered HR during sleep even in athletes (18). Taking into account these considerations, we prefer to assess the differences in sedentary life styles by means of a bicycle effort test.

Our results confirmed the validity of this reasoning since YG-NS and YG-S are clearly differentiated by the stress test (YG-S had less tolerance to effort). However, they have similar HR and HRV.

We may conclude that in our short-term analysis, age and HR are the most powerful determinants of HRV. The same conclusion was reached by other authors (24) using longer recording periods. Among individuals with similar HR, HRV depends mainly on age. Conversely, for similar age, HR becomes the variable for differentiation. In such case physical activity does not seem to affect HRV.

On the basis of our results, HRV should not be referred to as an “index” without considering age or HR.

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