Heart Rate Variability and Intensity of Habitual Physical Activity in Middle-Aged Persons

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ABSTRACT

BUCHHEIT, M., C. SIMON, A. CHARLOUX, S. DOUTRELEAU, F. PIQUARD, and G. BRANDENBERGER. Heart Rate Variability and Intensity of Habitual Physical Activity in Middle-Aged Persons. Med. Sci. Sports Exerc., Vol. 37, No. 9, pp. 1530–1534, 2005. Purpose: In the middle-aged, it has been shown that moderate physical activity is associated with increased global HR variability (HRV) and vagal-related HRV indexes. However, the relative effect of quantity and intensity of physical activity on HRV is still unknown. The purpose of this study was to compare HRV indexes in three groups of subjects presenting different long-term physical activity profiles: sedentary subjects (SED) with low-energy expenditure (PAEE) and two groups of subjects with equivalent moderate PAEE, but differing in terms of intensity of physical activity (active (ACT) and sportive (SP) individuals). Methods: Forty-three middle-aged subjects (61.2 ± 4.3 yr) were divided into the three groups on the basis of a physical activity questionnaire (Modified Baecke Questionnaire for Older Adults). Physical activity was evaluated by accelerometry for 1 wk. Time and frequency domain HRV indexes were determined during quiet periods in the morning on 5-min stationary R–R interval segments under controlled breathing. Quality of life was evaluated using the SF-36 Health Survey Questionnaire. Results: SP spent more time in moderate to very high activities than ACT (2.1 ± 0.1 vs 0.6 ± 0.1 h wk⁻¹; P < 0.05) and less time in very light to light activities (62.8 ± 2.0 vs 73.7 ± 1.7 h wk⁻¹; P < 0.05). SP presented higher vagal-related HRV indexes than SED (P < 0.05), whereas increases in ACT were less marked. ACT and SP had similar health status scores, which were higher than for SED (P < 0.05). Conclusions: In older adults with different lifestyles, habitual moderate PAEE is associated with better self-estimated overall health status and higher vagal-related HRV indexes compared with subjects with low PAEE, especially when moderate- to very high-intensity physical activities are undertaken. Key Words: PARASYMPATHETIC CONTROL OF THE HEART, ENERGY EXPENDITURE, EXERCISE, AGING.

HR variability (HRV) holds increasing interest because low HRV levels and low vagal-related indexes have been associated with greater cardiovascular risk and mortality prognostics in the elderly (11,21). Global HRV can be assessed by the SD of normal R–R intervals (SDNN), and it has been proposed that vagal activity can be determined from the root mean square of successive normal R–R interval differences (RMSSD) and high-frequency (HF) power (20). Low-frequency (LF) power, usually considered an index of sympathetic activity with a parasympathetic component, has been a subject of debate (9,10). Finally, the more reliable marker of sympathovagal balance at rest appears to be the normalized LF/ (LF+HF) ratio (or its complement the HF/(LF+HF) ratio) (13,20).

Several studies have established that aging is associated with a decline in global HRV (16) and a predominant decline of parasympathetic activity (4,6), and thus a loss of the cardioprotective effect through cardiac electrical stability (2). The influence of physical training on vagal-related HRV indexes has been widely investigated in young subjects. Except for some inconsistencies, increased vagal-related indexes have been reported in active or moderately trained subjects (1,7). In older adults, the effect of habitual physical activity on autonomic function is less documented. Most investigations concern longitudinal endurance training programs, and little information on the influence of long-term physical activity profiles on HRV is available (1,7,24).

In a recent study, we reported that elderly subjects (75.7 ± 0.2 yr) presenting a long-term sportive lifestyle displayed higher global HRV and vagal-related HRV indexes than sedentary controls (8). However, as this lifestyle is associated with both increased daily physical activity energy expenditure (PAEE) and increased physical activity intensity, we could not know which of the two parameters has more influence on HRV.

The present study was designed to determine the relative influence of intensity and quantity of physical activity on HRV. We compared HRV indexes of sedentary middle-aged subjects with low PAEE and two groups of active individuals presenting different long-term physical activity profiles characterized by equivalent moderate PAEE, but differing in terms of intensity of physical activity. These lifestyles were characterized by either light activities of long duration or
activities of higher intensities and shorter total duration. Time and frequency domain HRV indexes were measured during supine resting periods under controlled breathing, and the data were confronted with self-estimated quality of life and overall health status evaluated through the SF-36 Health Survey Questionnaire (5).

METHODS

Subjects. Forty-three nonsmoking, nonobese, middle-aged adults (23 women, 20 men, aged 61.2 ± 4.3 yr (mean ± SEM), body mass index (BMI) 25.6 ± 0.3 kg·m⁻²), with no history or clinical signs of cardiovascular or pulmonary disease, volunteered for this study. Candidates were not taking any kind of medication and did not show abnormal blood pressure or electrocardiographic patterns. Because the accelerometers used for physical activity assessment could not be in contact with water, subjects reporting activities like swimming were not selected. The participants gave their informed consent to participate in this experiment, which had been approved by the local ethics committee.

Physical activity assessment by questionnaire. The Modified Baecke Questionnaire for Older Adults (MBQOA) (23) was used to evaluate the physical activity profiles of the subjects. The MBQOA gives a total activity score, which is the sum of a household score, a sporting activity score, and a leisure time activity score. The total score reflects overall PAEE, whereas the sport score gives insight into the intensity of physical activity. The scores are obtained from activity duration (h·wk⁻¹), frequency (months·yr⁻¹), and intensity at which the activity is performed. Intensity codes are unitless and were originally based on energy costs (23). An additional questionnaire developed especially to identify long-term habits was used to verify that a subject’s physical activity has remained roughly similar for about the past 10 yr without major interruption.

Physical activity groups. With regard to the distribution of scores given by the MBQOA, cutoff scores were determined to divide the subjects into three groups: the subjects considered sedentary (SED) presented a total score below 9 (seven women, six men). Active (ACT) and sportive (SP) groups were both composed of subjects displaying a total score higher than 12.5. However, to be classified as ACT, subjects had to have a sport score below 6 and a sum of household and leisure time scores higher than 6 (eight women, seven men). Conversely, the SP group gathered subjects with a sport score higher than 10 and a sum of household and leisure time scores lower than 5 (eight women, seven men). (For example, subjects having a total score of 10 or presenting a sport score of 8 were rejected.)

Physical activity assessment by accelerometry. Physical activity parameters were assessed by triaxial accelerometers (RT3, Stayhealthy, Monrovia, CA) (19). Participants were instructed to wear the small (2.8 × 2.2 × 1.1 inch) lightweight (2.8 oz) monitor at their right hip during waking hours for 1 week, which is the measurement period generally recommended for obtaining representative data (3), excluding sleep time and periods of bathing or washing. When the device is attached to clothing, it measures acceleration (counts·min⁻¹) in the anteroposterior, mediolateral, and vertical directions and summarizes the information as a vector magnitude (Vmag). This vector is calculated as the square root of the sum of the squared accelerations in each direction. PAEE was calculated by converting the Vmag data into energy expenditure (EE) (kilocalories) via the manufacturer’s proprietary equations, taking into consideration the subject’s body mass, sex, and age. PAEE is defined as the mean activity EE deduced from the week-long recordings, whereas total daily EE represents the PAEE plus the individual resting metabolic rate (RMR) calculated by the accelerometer software on the basis of a subject’s anthropometric data and age. Total activity time was the time over the full week during which movements had been recorded by the accelerometer. A threshold activity (15 counts·min⁻¹) was arbitrarily set in order to detect only substantial body movements and to eliminate artifacts (shocks and slight vibrations of the recorder detected in the absence of appreciable body movements). The EE measured by the accelerometer was converted into metabolic equivalents (Mets). Physical activities were then scored as a function of intensity range: time spent at ≤2.5 Metts (very light activities), between 2.6 and 4.4 (light), 4.5 and 5.9 (moderate), 6.0 and 8.4 (high), and ≥8.5 Metts (very high). The cutoff points were chosen taking into account the age of the participants (22). Times spent at these different intensities are reported in absolute values (h).

Autonomic control assessment protocol. These measurements were performed between 10:00 a.m. and 12:00 p.m. in an air-conditioned room with ambient temperature maintained at 21°C. The subjects were requested to avoid strenuous exercise for 2 d before the experiments. They had their usual breakfast at least 3 h before the beginning of the experiment, avoiding coffee. After 30 min of rest, subjects were asked to remain quietly supine for 10 min without speaking or making any movements. Subjects breathed at 15 cycles·min⁻¹ (0.25 Hz) by synchronizing their breathing pattern with an electronic metronome rhythm, so that the respiratory rate would influence the HRV indexes of each subject in the same way.

HR and breathing frequency measurements. ECG was continuously monitored during the 30 min of rest using a Holter with a sampling frequency of 256 Hz (Ela Medical, Paris, France) for determination of HR and HRV. Thoracic and abdominal movements were recorded using a Crystal Trace Piezo Respiration Sensor (Astro-Med EEG System, Grass Instruments, West Warwick, RI) to monitor the breathing frequency.

HRV analysis. The R–R intervals, that is, the time between the R peaks of consecutive QRS complexes recorded by the Holter, were calculated and checked for artifacts. Occasional ectopic beats were identified and replaced with R–R interval values interpolated from adjacent values. HRV analyses were performed on the last 5 min of the 10-min controlled breathing period, which ensures stationarity of the data. The mean of R–R intervals (mR–R),
SDNN, and RMSSD were calculated for the 5-min period. Power frequency analysis of the 5-min recordings was performed sequentially with a fast Fourier transform based on a nonparametric algorithm with a Welsh window after the ectopic-free data were detrended and resampled. A fixed linear resampling frequency of 1024 equally spaced points per 5-min period was used. The power densities in LF band (0.04–0.15 Hz) and the HF band (>0.15–0.50 Hz) were calculated from each 5-min density spectrum by integrating the spectral power density in the respective frequency bands. The HF/(LF+HF) ratio was also calculated.

Quality of life. The Short Form Health Survey Questionnaire is a multipurpose health survey with 36 questions (SF-36) (5). It comprises an eight-step scale of functional health and well-being scores as well as psychometrically based physical and mental health summary estimates and a preference-based health utility index. It is a generic measure, as opposed to one that targets a specific age, disease, or treatment group. Accordingly, the SF-36 has proven useful in surveys of general and specific populations by comparing the relative burden of diseases and in differentiating the health benefits produced by a wide range of different treatments (5).

Statistical analysis. The distribution of each variable was examined with the Kolmogorov–Smirnov and Shapiro–Wilk normality tests. Because absolute spectral indexes were skewed, these data were transformed by taking the natural logarithms of LF and HF power indexes to allow parametric statistical comparisons that assume normal distributions. Data for both sexes were analyzed together because we observed no differences in any HRV measurements. Interaction factors were considered in order to evaluate a possible heterogeneity of the associations across levels of the other factors. A one-way ANOVA with Tukey’s post hoc test were used to compare HRV and SF-36 health index distributions of the three physical activity groups, which were adjusted for potential confounders (gender, BMI, and age). Physical activity data are presented as means (±SEM), and HR and HRV data are presented as adjusted least-square means (±SEM). Spearman’s coefficient correlations were used to test the relationship between HRV indexes and health status. The level of significance was set at $P < 0.05$.

RESULTS

Accelerometry-determined physical activity. Table 1 presents the age and BMI for each group of subjects plus estimated RMR, PAEE, and EE. There were no significant differences in age, height, body mass, or RMR among the three groups of subjects. ACT and SP had similar PAEE and EE, both of which were significantly higher ($P < 0.001$) than for SED. Times spent at specific activity intensities are shown in Table 2. ACT spent significantly more time in very light and light activities than SED ($P < 0.05$). SP spent significantly more time in light, moderate, high, and very high intensities than SED. Compared with ACT, SP spent significantly less time in very light activities ($P < 0.05$) and more time in moderate and high activities ($P < 0.05$).

Summarizing these results, time spent in very light to light activities (≤4.4 METs) was significantly higher in ACT than in SED (73.3 ± 1.4 vs 59.4 ± 4.4 h wk⁻¹; $P < 0.01$). SP spent less time in very light to light activities compared with ACT (62.8 ± 2.0 vs 73.7 ± 1.7 h wk⁻¹; $P < 0.05$) and significantly more time in moderate to very high activities (>4.4 METs) than SED and ACT (2.1 ± 0.1 vs 0.7 ± 0.2 and 0.6 ± 0.1; $P < 0.01$).

HR and HRV indexes. Figure 1 illustrates the main HRV results for the three groups of subjects. HR was significantly lower in ACT and SP than in SED ($P < 0.05$). SDNN tended to be higher in ACT and SP compared with SED, but not significantly. ACT and SP showed significantly higher RMSSD ($P < 0.05$) than SED. SP tended to have higher RMSSD than ACT, but not significantly. HF/(LF+HF) was significantly higher in SP than in ACT ($P < 0.05$) and in SED ($P < 0.001$), but it was not significantly higher in ACT compared with SED. Concerning absolute spectral HRV indexes, ACT and SP showed significantly higher than SED (2.49 ± 0.2 vs 73.3 ± 1.4 h wk⁻¹; $P < 0.01$ and $P < 0.001$ for ACT and SP, respectively). Although SP tended to have higher HF values than ACT, the difference was not significant. Finally, LF power did not vary significantly among the three groups.

Quality of life. SF-36 scores are given in Figure 2. It appears that overall health status scores were similar for ACT and SP and significantly lower in SED ($P < 0.05$). The relationship between SF-36 scores and the HF/(LF+HF) ratio was significant (r = 0.48, $P < 0.05$).

DISCUSSION

Based on the evaluation of physical activity parameters from questionnaires and accelerometry, this study reveals two main findings in middle-aged individuals with distinct physical activity profiles: 1) Moderate PAEE is sufficient

| TABLE 1. Anthropometric values and accelerometry-determined energy expenditure. |
|-----------------------------|------------------|------------------|
| SED                         | ACT              | SP               |
| Age (yr)                    | 63.1 ± 1.3       | 60.7 ± 1.1       | 61.0 ± 1.0       |
| BMI (kg m⁻²)                | 26.5 ± 1.2       | 24.7 ± 0.7       | 25.4 ± 0.7       |
| Est RMR (kcal·m⁻³·h⁻¹)      | 1613.7 ± 75.0    | 1527.0 ± 48.2    | 1579.1 ± 62.4    |
| PAEE (kcal·m⁻³·h⁻¹)         | 373.0 ± 14.4     | 583.3 ± 27.8*    | 605.7 ± 21.0*    |
| EE (kcal·m⁻³·h⁻¹)           | 1986.7 ± 72.2    | 2110.2 ± 69.7*   | 2184.8 ± 72.2*   |

Values are means ± SEM for age, body mass index (BMI), estimated resting metabolic rate (Est RMR), daily physical activity energy expenditure (PAEE), and daily total energy expenditure (EE) for sedentary (SED, N = 13), active (ACT, N = 15), and sportive (SP, N = 15) subjects.

* $P < 0.001$, significant difference vs SED.

| TABLE 2. Physical activity profiles evaluated by accelerometry. |
|-----------------------------|------------------|------------------|
| Intensity of Physical Activity | SED | ACT | SP |
| Very light activities (≤2.5 METs) | 57.4 ± 4.4 | 70.3 ± 1.4* | 58.9 ± 1.4† |
| Light activities (2.6–4.4 METs) | 2.2 ± 0.3 | 3.3 ± 0.4* | 3.9 ± 0.4† |
| Moderate activities (4.5–5.9 METs) | 0.6 ± 0.2 | 0.5 ± 0.1 | 1.4 ± 0.2† |
| High-intensity activities (≥6 METs) | 0.1 ± 0.1 | 0.1 ± 0.1 | 0.6 ± 0.1† |
| Very high-intensity activities (≥8.5 METs) | 0.0 ± 0.0 | 0.0 ± 0.0 | 0.1 ± 0.1 |

Values are means ± SEM for weekly time (h wk⁻¹) spent at specific intensities of physical activity for sedentary (SED), active (ACT), and sportive (SP) subjects.

* $P < 0.05$, significant difference vs SED. † $P < 0.05$, significant difference vs ACT.
for observing higher absolute vagal-related HRV indexes and better overall health status, whatever the physical activity intensities considered; and 2) At equivalent moderate PAEE, vagal-related HRV indexes tend to be higher and parasympathetic dominance is significantly increased when activities of at least moderate intensity are undertaken, but without any further change in perceived health estimation.

**Effect of moderate PAEE at different intensities on HRV.** It is known that aging is associated with a decline in global HRV and a predominant loss of parasympathetic activity (4,16). Whereas regular physical activity is recognized as a safe antiarrhythmic therapy to increase HRV and parasympathetic tone (2), few data on the influence of moderate physical activity at different intensities on HRV are available for older subjects. Increased global HRV and vagal-related indexes have been reported with an increased physical activity level (17) in very old subjects with a sportive lifestyle compared with elderly having an active but nonsportive way of life (8). A linearly increasing trend of HRV level has been observed in elderly with increasingly nonsportive way of life (8). A linearly increasing trend of sportive lifestyle compared with elderly having an active but physical activity level (17) in very old subjects with a vagal-related indexes have been reported with an increased moderate physical activity at different intensities on HRV parasympathetic tone (2), few data on the influence of normalized as a safe antiarrhythmic therapy to increase HRV and in global HRV and a predominant loss of parasympathetic

**Limitations of the study.** The interpretation of the present results must be qualified by certain potential limitations. First, even if 7 d of accelerometer recording were shown to give reliable physical activity measurements (3), it could be that the one particular week was not always representative of usual lifestyle. In addition, one can hypothesize that whereas moderate to very high activity in the middle-aged individuals can be associated with enhanced cardiac vagal tone, only older persons with genetically high vagal-related HRV indexes still actively embrace such intense physical activities. Thus, care has to be taken in deciding whether a high level of physical activity is the cause or the consequence of high vagal-related HRV indexes. Although we have no data concerning cardiorespiratory fitness to confirm this (24), it is worth noting that the middle-aged subjects selected for this study were a healthy group of older adults. These findings may then be representative of only a small proportion of the population in this age range, and this possibility should be considered when comparing individuals in certain disease states (e.g., hypertension, heart failure). Finally, because in our study increased PAEE was due mainly to activities of very light intensity in ACT and moderate to very high intensity in SP, the specific...
effect on HRV of the intermediate-intensity exercise range still remains to be determined. Longitudinal studies should be more appropriate for learning the effect on HRV of exercise in the different intensity ranges.

CONCLUSION

Our results suggest that moderate PAEE is sufficient to be associated with higher vagal indexes of the heart and self-estimated health status in the middle-aged. However, moderate PAEE, when associated with moderate- to very high-intensity activities, is linked with a higher parasympathetic predominance compared with an equivalent PAEE obtained through lighter activities. These results lend support to guidelines that recommend a moderate EE for cardiac vagal control improvement and suggest that a greater cardioprotective effect may be realized when the moderate PAEE is obtained through higher intensity physical activities.

The authors thank Daniel Joly for technical assistance and data treatment and the volunteers for their participation.

REFERENCES