# THE EFFECT OF AGE ON SHORT–TERM HEART RATE VARIABILITY

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The aim of the study is to establish age dependence of the indices of short-term spectral analysis of HRV in the supine and standing position. We tested 132 healthy subjects (76 man and 56 woman) divided into two age groups: 12–24 years (n=62) and 43–70 years (n=70). Total spectral power was divided into three components: high frequency (HF) (150–500 mHz), low frequency (LF) (50–150 mHz) and very low frequency (VLF) (20–50 mHz). There were significantly lower values for total spectral power, indices calculated from the LF and HF components and mean frequencies of the VLF and HF components in the older group than in the younger group in the supine position. On the other hand, the values for indices %VLF, VLF/LF, VLF/HF and LF/HF were significantly higher in the older group. The differences between supine and standing values were either significantly less in the older group than in the younger group or did not exhibit a remarkable variation; the sole exception being the change in total spectral power which was significantly greater in the older group.

*Keywords: autonomic nervous system, power spectral analysis, aging, HRV, active orthostatic load.*

## INTRODUCTION

It is known, that advancing age in healthy humans and animals is accompanied by a deterioration in communication between the nervous system and the heart and vasculature (Xiao & Lakatta, 1991) and that a “dysautonomia of aging” occurs (Jarish et al., 1987).

Variations in the heart rate over time have a close relationship with changes in nervous system activities influencing the heart. A large number of scientific studies within the last 20 years have confirmed that spectral analysis of heart rate variability (SA HRV) is a valid noninvasive methodology aiding in the examination of the autonomic nervous system (ANS). By using an SA HRV, that transforms the time sequence of the R–R intervals into a frequency domain, it is possible to quite accurately specify the position of individual components on the frequency axis of the spectrum.

An increase in HRV occurs during early human life (Finley et al., 1987; Massin & Von Bernuth, 1997; Piha, 1991); in some studies it has been documented that from the age of six years HRV begins to decrease (Finley et al., 1987; Piha, 1991), in others, the authors have found the maximum for the total spectral power, or of its partial components, at between 15 to 30 years of age (Korkusho et al., 1991). It is, however, generally accepted that HRV gradually decreases and that such a dependence on age specifically affects total spectral power and its individual components (Byrne et al., 1996; Ingall et al., 1990; Korkusho et al., 1991; Lipsitz et al., 1990; Pagani et al., 1986; Piccirillo et al., 1995; Schwartz et al., 1991).

Postural change from a supine to an upright position is accompanied by a shift of the sympatho-vagal balance towards sympathetic activity (Malliani et al., Pomeranz et al., 1985; Saul, 1993). Although the results of examining the effects of increasing age on the HRV spectrum using postural changes are ambiguous, they seem less pronounced with older subjects both in the parasympathetic and sympathetic branches (Ingall et al., 1990; Lipsitz et al., 1990; Piccirillo et al., 1995, Ziegler et al., 1992).

In spite of relatively large number of studies, there are still some doubts about the results of monitoring the effects of aging on individual components of SA HRV. The results are very often controversial and their interpretation is, therefore, very difficult. Such contradictions and inconsistencies occur due to insufficiently standardized nomenclature and methods

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of measurement and to inaccurately defined physiological and pathophysiological correlates (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996).

The aim of our study is to establish the age dependence of commonly and less commonly used parameters of SA HRV with healthy humans both in the supine and upright positions. It is obvious, that apart from indices strongly affected by age there are some that are less affected and some that are not affected by age at all. In cardiac patients, neurological diseases (namely with patients suffering from diabetic autonomic neuropathy) and some renal diseases, the spectral power of HRV is altered as well (Van Ravenswaaij et al., 1993); e. g., with patients that have had a myocardial infarction, the reduction of the spectral power, especially that of its high-frequency components, is connected to an increased risk of sudden cardiac death. Because chronic cardiac disease development and sudden cardiac death are, along with aging, related to a decline in vagal activity, it is necessary to define the overlapping area of the reduced HRV between healthy older subjects and patients and thus set limit points for separating these groups. In order to accomplish this, it is necessary to determine the distinction between physiological changes accompanying aging and pathological changes of HRV (Kupari et al., 1993; Odemuyiwa, 1995; Piha, 1991; Suleiman et al., 1992; Van Hogenhuyze et al., 1986). Overall assessment of selected spectral indices with the highest validity in a supine position and their integral reactions to postural changes could aid in determining such a distinction.

## METHODS

### Subjects

132 healthy subjects (76 men and 56 women) took part in the study. They were divided into two groups of variying age: the first group (group A) consisted of subjects aged 12 to 24 (18.16 ± 3.60 yrs), the second group (group B) consisted of subjects aged 43 to 70 (50.20 ± 7.12 yrs). There were 62 subjects in group A (35 men and 27 women) and 70 subjects in group B (41 men and 29 women), (TABLE 1); the average age of the men and women within each group did not bayrdiffer significantly.

None of the subjects had taken any medications for at least 3 months prior to the examination. Criteria for exclusion from the study included pathological baseline ECG or during stress, diastolic blood pressure higher than 90 mmHg, systolic blood pressure higher than 155 mmHg, smoking of more than 5 cigarettes per day, cholesterolemia higher than 5.2 mmol/l, history or demonstrable evidence of diabetes mellitus and cardiovascular, respiratory, renal, hepatic, gastrointestinal, or systemic diseases. Informed consent was obtained from all volunteers.

### Measurement

The subjects were studied in the caffeine-free, nonabsorptive state. Prior to the HRV examination every subject underwent a basic physical, anthropometrical and ECG examinations. After completing the HRV measurement, the subjects' venous blood was taken for biochemical analysis, after which they underwent a stress test with the use of a CHR-test (Stejskal et al., 1993).

The HRV examination complied with the following protocol: The examination began between 8 and 9 a. m. After blood pressure measurement, the subjects lay in a quiet room with the temperature of 21 °C to 24 °C; for the purpose of isolating their sensual perception they lay with their eyes closed and with headphones playing music with a calming effect. An ECG record of 300 consecutive heartbeats was performed after five minutes of lying in the rest position. The subject then stood up and, after 1 minute of standing, an ECG record of 300 consecutive heartbeats was performed again. Immediately after that, the subject's blood pressure was measured. The subject then lay down again and, after reaching his/her steady state, an ECG record of 300 consecutive heartbeats was duly performed. Moving from a supine to a upright position took approximately 10 seconds. Two subjects, who showed a considerable decrease in systolic blood pressure, (>25 mmHg) in the upright position, were excluded from the test. Data were acquired during spontaneous respiration.

The first position, supine at rest, served only for the purpose of standardizing the examination and its results were not taken into consideration.

### Spectral analysis of heart rate variability

To calculate the SA HRV parameters in the study, we used a microcomputer system VariaPulse TF 3 (Sigma Media Olomouc Ltd., Czech Republic) (Salinger et al., 1995), which controls the process of the examination and monitors the ECG signal from which it collects R–R intervals with an accuracy of 1 ms. R–R intervals are telemetrically transmitted to the receiver which is connected to an IBM PC microcomputer through the COM port. The algorithm of the system software is a short-term spectral analysis of the HRV.

The parameters of the SA HRV are computed by means of a fast Fourier transformation with a partially adapted Coarse-Graining Spectral Analysis (CGSA) (Yamamoto & Hughoson, 1991) algorithm, which ensures optimal reduction of non – harmonic and noise elements of the analyzed HRV signal, especially in the range of low frequencies. Automatic and manual artifact filtration are a part of the software procedures.

A basic SA HRV parameter, which serves for derivation of a number of others, is Power Spectral Density (PSD) ($ms^2/Hz$). It is defined for individual frequency ranges: high-frequency (HF) (150–500 mHz), low-frequency (LF) (50–150 mHz) and very low-frequency (VLF) (20–50 mHz).

The following indices were calculated for all of the above mentioned components: integral level of the power spectrum (p) ($ms^2$), maximum density, i. e. PSD amplitude, the relative part of individual components in total power (%), the variation coefficient of individual components and of total spectral power (CCV) (Hayano et al., 1995) and the position of the average value of the maximum amplitude on the frequency axis (frequency = f) (mHz). VLF/HF, LF/HF, VLF/LF ratios were calculated from the values of the individual components.

The overall value of HRV was evaluated by the total spectral power (Tp) ($ms^2$) (sum of the VLF, LF and HF spectral powers) and by only one time domain index (MSSD – Mean Squared Successive Differences) ($ms^2$).

From the graphical point of view, we provide a "3D" chart of PSD (Fig. 1), which allows us to keep track of the frequency spectrum dynamics with respect to the change in standard or non-standard activity situations during the examination.

All indices were calculated both for the upright position and for the second supine following the upright position. This study states the values recorded in the supine position, and values of the differences between both positions (supine minus upright position).

**Statistical analysis**

Basic statistical quantities were calculated for each variable of the above mentioned SA HRV indices and the normal distribution was verified by the Kolmogorov – Smirnov test. In the case of a normal, or lognormal pattern, Student's non-paired t-test was used for comparison of age groups. Mann-Whitney's non-parametric test was used when the data did not show the normal pattern. A p-value < 0,05 was considered to indicate a statistical significance. The calculated values and sampling distribution are clearly shown in the tables.

**RESULTS**

In the supine position, the values of the total HRV indices (MSSD, Tp) in group A were significantly higher than in group B (TABLE 2). In the following terms the same differences were found in power, maximum density, and in the variation coefficient of the LF and HF components, while corresponding indices for VLF components did not significantly differ between the groups.

The relative representation of individual components on total spectral power gives us a different picture: significant differences between younger and older subjects were evidenced for %HF (group A showed higher values) and for %VLF (group A showed lower values). Significant differences between the groups were not evidenced for %LF (TABLE 2).

The ratios between components was significantly lower in the A group then in the B group (TABLE 2).

A statistical significance of the differences between the groups was evidenced for fVLF and fHF – which were higher with the younger subjects; fLF did not differ between the groups.

Both groups evidenced a considerable increase of the R–R interval, MSSD, all indices calculated from the HF component (pHF, PSDHF, CCVHF, %HF) and fLF after transition from upright to supine. On the contrary, the values derived from the VLF component (pVLF, PSDVLF, CCVVLF, %VLF), CCVLF, VLF/HF, LF/HF and CCVTp decreased significantly (TABLE 2).

While in the A group a considerable decrease in %LF and VLF/LF and a considerable increase in fHF was observed after transition from upright to supine, corresponding indices in the B group were not as statistically dynamic (TABLE 3). On the other hand, the older group showed a considerable decrease in total spectral power after position change; there was no significant change in the younger group.

The effect of postural changes on pLF, PSDLF, and fVLF indices were not significant in either group (TABLE 3).

A significant difference was found in the reaction to postural changes between the groups for R–R, MSSD indices and for all indices derived from the HF component: postural dynamics of the given indices were much lower with the older group than with the younger group (TABLE 3). Similarly, the differences between %VLF, %LF, CCVLF indices were significantly smaller within the older group in comparison to the younger group.

Contrarily, no significant differences between the groups were found for the values of pVLF, PSDVLF, CCVVLF, pLF and PSDLF indices influenced by postural change; similarly, the postural changes values of LF/HF and VLF/LF did not differ between the groups (TABLE 3).

An increase of fHF after position change was significantly greater in the younger group compared to the older group. Contrarily, an increase of fLF was equally significant in both groups and did not significantly differ between the groups (TABLE 3). The fVLF remained unchanged in both groups.

After the change from the upright position to supine, the total spectral power decreased with the older group; whereas, it did not significantly change with the younger group (TABLE 3) (this was the only index in the older group that showed accentuated dynamics over the younger group).

During the general evaluation of the effect of age, it is obvious that 22 indices — from 44 indices used — were significantly higher in the A group (50% of the indices used) and 6 indices (14%) were significantly higher in the B group. Generally, a significant difference between the groups was not proven for 16 indices (36% of the total number).

The greatest differences between groups in the supine position were calculated for MSSD, Tp and CCVTp, for all indices derived from the HF component, for %VLF and for VLF/HF ratio (TABLE 2). The highest level of significance for the differences in postural change between the groups was evidenced in the HF component indices, MSSD and R-R interval (TABLE 3).

**DISCUSSION**

Since spontaneous respiratory rate inhibition already occurs at middle age (Anderson et al., 1995), we chose, with respect to the pronounced age difference between the groups, an examination with spontaneous breathing to avoid the uneven effect on HF component power (Hirsch & Bishop, 1981). We chose an active change of position, because it is more suitable for the study of orthostatic regulation of circulation than a passive change of position (head-up-tilt) (Piha, 1991).

The results of our comparison of the two groups, whose difference in age was over 30 years on average, proved that more than 70% of the SA HRV indices we used were age-dependent in the supine position. This concerns, first of all, MSSD, total spectral power and high-frequency component indices, which show the greatest differences between the younger and older groups. There were considerably lower values of the above in the older group than in the younger one. Since it is generally accepted that all the indices mentioned are effected by vagal tone, such a finding is usually interpreted as reduced parasympathetic activity that occurs in older subjects (Lipsitz et al., 1990). Determination of the age-related HF component reduction is consistent with the age-related reduction of the vagal control of respiratory sinus arrhythmia and of bradycardiacal response to Valsalv's maneuver. The cause is usually attributed to a decrease in acetylcholine synthesis, a decrease in the number cholinergic receptors and in their affinity towards the agonists, a decrease in cholinergic plexus density and an involutional ANS plexus degeneration (Baker et al., 1985; Korkushko et al., 1991; Shvalev et al., 1989). Therefore, it is necessary that the indices are always related to the age of the patient.

Both groups differed on the same level of significance in relative VLF component power (%VLF) and VLF/HF ratio. Contrary to the indices of vagal activity, these above values increase with advancing age. These findings could prove that they can be considered as predominant sympathetic activity indices. This prevalence in older people is the result of an enormous reduction of the vagal component that has a significant effect on total spectral power.

A slightly less significant difference between both groups occurs with the indices derived from the LF component whose values decrease with advancing age (%LF does not show a significant difference at all); in spite of the ambivalence of the saturation of the component (Akselrod et al., 1981; Akselrod et al., 1985), the effect of the sympathetic activity on LF power, which reflects baroreceptor activity, is presumably greater. Because the levels of the indices were significantly reduced in older subjects in supine, the findings suggest that sympathetic activity decreases with aging. Many scientists interpret the findings in accordance with the above mentioned facts and explain it by decreases in the efficacy of beta-adrenergic modulation of cardiovascular functions (Lakatta, 1980; Shimada et al., 1986); the age-associated deficit in the effectiveness of beta-adrenergic control is largely postsynaptic in nature (Lakatta, 1993). Reduced sympathetic activity in older subjects can be explained by involutional degeneration of adrenergic elements of ANS and the decreased number of baroreceptors (Ferrari et al., 1986; Korkushko et al., 1991). Adenosine levels, that are enhanced in the aged myocardium may be responsible, in part, for the diminished contractile responsiveness of the older adult heart to beta-adrenergic stimulation (Dobson et al., 1990). Such a reduction in response to beta-adrenergic stimulation persists even after intensive exercise training (Stratton et al., 1992).

In this context we should accept the fact that by using the HRV methodology an isolated sympathetic activity cannot be identified (Ahmed et al., 1994; Kolai et al., 1994) and that the LF component does not specifically reflect cardiac sympathetic modulation in human (Hopf et al., 1995). In addition to this, the level of vagal activity affects the observed changes in heart rate variability that are associated with sympathetic stimulation (Kim et al., 1997). Therefore, it seems more correct to evaluate the dynamics of the changes in the balance between both ANS branches and to evaluate the effect of age more in the sense of a relative increase of sympathetic activity (as a result of a greater decrease in vagal tone).

The results of the comparison of both groups showed that the age related reduction in the supine position decreased from left to right. In other words, HF power decreased most with age, LF power decreased somewhat less and VLF power did not differ significantly between the groups. Therefore, the %LF age-associated reduction was non–significant and, to the contrary, that is why we observed a significant difference between the values of younger and older subjects not only for the VLF/HF ratio but for the LF/HF and VLF/LF ratios as well. The ratio between the power of individual components indicate best a sympatho-vagal balance. Since these values were higher with older people, we can draw the conclusion that sympathetic activity is prevalent in this age-group.

Similar conclusions were arrived at by Lipsitz et al. (1990), who calculated regression lines relating the log amplitude to the log frequency in the supine and upright positions. Regression lines for older subjects were lower and steeper; this implies that it was significantly more declivitous. Bigger et al. (1995) and

Yeragani et al. (1997), who performed long-term HRV examinations, found different age-associated reductions in different spectrum ranges for a group of healthy humans between 40–69 years of age; while the VLF, LF, and HF components decreased with age, the ultra-low frequency component did not change and the LF/HF increased. From the results of other authors (Korkushko et al., 1991; Ziegler et al., 1992), we-high-frequency band over changes in the low-frequency band of the HRV spectrum.

Generalizing this hypothesis, as an index of relative sympathetic activity, we can consider the ratio between the powers of two components, where the lower frequency component is in the numerator and the higher frequency is in the denominator. It seems logical that the greater the distance between the components is the better their ratio expresses the participation of the sympathetic activity on the total ANS activity.

Not all of the authors have reached the same conclusions. For example, Pagani et al (1986) found that the LF/HF ratio did not change with age and that aging was associated with a new ANS balance. Piccirillo et al. (1995) found that the older group had significantly lower LF and greater HF spectral power (analyzed in absolute and normalized units). It is difficult to explain such differing results; it could be because their younger group was formed by subjects at the age of our older group (44–64 years) and that a number of people from their older group (64–85 years) were outside of our target age range. It cannot be excluded that another considerable decrease in sympathetic activity takes place in the 6$^{th}$ decade of human life (Piccirillo et al., 1995); contrarily, it seems that the decrease in vagal activity is slower for ages over 70 or that it does not continue at all (Reardon & Malik, 1996).

From the results mentioned above it is obvious that, when comparing different studies evaluating individual components of the HRV spectral power, absolute values of age and the age range of compared subjects must always be taken into consideration. It seems that an age–associated decrease of component power at a lower band of frequencies (i. e. VLF and LF) is not only smaller, but takes place later (Korkushko et al., 1991).

At present, it is generally accepted that though sympathetic activity decreases with increasing age in adults, its decrease is smaller than the decrease in vagal activity (Korkushko et al., 1991; Lipsitz et al., 1990; Singer & Ori, 1995; Ziegler et al., 1992) and that adulthood is characterized by a shift of the vegetative balance towards sympathetic dominance.

Similarly, the values of VLF and HF maximum density frequency, in the supine position, show a considerable difference between the groups: the average values for younger subjects were significantly higher. In other words, the frequency of both border components shifts to the left (i. e., towards lower values) with increasing age. Such an oscillatory deceleration is probably due to a decrease of vagal activity which shifts the ANS balance towards the sympathetic activity, i. e., to the left.

By changing the position from supine to upright, a considerable decrease in all vagal activity indices occurs while the majority of relative sympathetic activity indices increases significantly (Malliani et al., 1991; Barger et al., 1985; Saul, 1993). No postural dynamic was, however, evidenced for pLF and PSDLF which, regardless of age, did not change considerably after postural changes. LF power is a result of the activity of both ANS branches and therefore sympathetic activity can be masked by antagonistic vagal activity (Akselrod, 1995). Spectral power, in the 50–150 mHz band, corresponds both to slow sympathetic and to faster vagal baroreceptor responses to arterial blood pressure changes (Sleight & Casadei, 1995).

If, by calculating the difference of CCVLF between supine and upright, we can, in part, eliminate the fact that with an increase in the carrier frequency its variability decreases, then the LF postural dynamic becomes significant – it increases when standing in both groups. Significant pLF postural dynamics can be observed as well, if they are related to pHF dynamics (LF/HF).

The upright position resulted in a considerable decrease of fLF in both groups while fVLF did not show any significant difference. Such a finding suggests that the effect of sympathetic activity is less in the higher frequency part of the LF spectral band than in its lower frequency part and that the rhythm activity, associated with vasomotion, is slowed while standing. Significantly greater VLF dynamics, in comparison to LF dynamics (Tab. 3), evidently affect the maximum density frequency of the adjacent LF component. Since the increase in pVLF in both groups is equal when standing, the fLF shift to the left is equally significant.

Standing caused a significantly smaller decrease of pHF in the older group than in the group of younger subjects; such a finding corresponds to results of other studies (Ingall et al., 1990; Piccirillo et al., 1995; Ziegler et al., 1992). Reduced pHF postural dynamics in older subjects resulted in an insignificant change of fHF; on the other hand, in younger subjects while standing fHF significantly decreases – as a result of the greater reduction of the HF component. By comparing the changes of power and the frequency of individual components after postural change we can better infer the dynamics and mutual relationship between both ANS branches.

It seems that the reason for age-related differences in postural maneuvering is the fact that a significant reduction of pHF in older subjects in supine does not allow further significant decrease of pHF in the upright position. Similarly, reduced LF postural dynamics were evidenced in older subjects (Ingall et al., 1990; Lipsitz et al., 1990; Piccirillo et al., 1995). Different results of postural changes of individual vagal or sympathetic indices for some authors can be explained by different examination conditions. For example, Lipsitz et al.

(1990) worked with different bandwidths and the postural change consisted of a passive 60° tilt. Furthermore, passive change of position resulted in a vasovagal syncope in 6 out of the 12 tested young subjects; these subjects were then characterized by a significant increase in total spectral power and LF power, while the rest of the tested subjects did not show any significant difference after postural change. Contrarily, Kochiadakis et al. (1997) found a decrease in the LF and HF bands in older subjects with vasovagal syncope and positive tilt testing when standing, and the LF/HF ratio did not significantly change. In healthy subjects or subjects with negative tilt test results, the LF band did not change or increased, the HF band decreased, and the LF/HF ratio increased. It seems that for patients with a tendency towards vasovagal syncope it will be necessary to consider the age factor when evaluating the ANS functional state.

At first sight, a significant increase of total spectral power due to the postural maneuver in older subjects is surprising, while in a younger group, the same index did not significantly change. The explanation can be simple: a physiological increase of sympathetic tone in older subjects results mainly in an increase of VLF power (Tp increases significantly), while in younger subjects, the same effect is achieved by a significant decrease of the HF component (Tp tends to decrease) (TABLE 3).

The result of these age-associated ANS changes is a considerably reduced dynamic of heart rate in older subjects after postural change. This same conclusion was arrived at by Byrne et al. (1996) as well. They did not find a significant relationship between the mean R-R interval and age in the supine, but they demonstrated a significant lengthening of the R–R interval with age in the seated and standing positions. The above mentioned considerations imply that such an age-associated reduction of heart rate postural dynamics is probably caused primarily by decreased baroreflex and myocardial sensitivity to beta-adrenergic stimulation.

## CONCLUSION

The results of a comparison of HRV spectral power and of its individual components in two significantly different age groups, confirmed an age-dependent HRV reduction, mainly in the high-frequency component; therefore, a relative prevalence of sympathetic activity occurs in older people. The analysis indicated the usability of indices derived from the power spectrum of the selected components.

With respect to the fact that orthostatic stimulation of the ANS expands the possibilities of its evaluation, consideration of the physiological changes associated with aging is absolutely necessary. Ascertainment of a disorder in age-associated dynamics extends the range of easily attainable information for a number of diseases.

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**TABLE 1**

Mean values ( $\overline{x}$ ) and standard deviations (SD) of the individual charakteristics for the groups of younger (A) and older (B) subjects.

| | Group A | | Group B | | |
|---|---|---|---|---|---|
| | $\overline{x}$ | SD | $\overline{x}$ | SD | D2 |
| Men | | | | | |
| Weight (kg) | 66,91 | 10,18 | 78,85 | 14,56 | $p < 0{,}001$ |
| BMI (kg. $M^{-2}$) | 21,37 | 2,4 | 25,18 | 3,57 | $p < 0{,}001$ |
| Body fat (%) | 8,52 | 4,79 | 16,06 | 6,27 | $p < 0{,}001$ |
| Age | 18,65 | 3,84 | 49,09 | 6,8 | |
| Women | | | | | |
| Weight (kg) | 63,89 | 16,8 | 69,99 | 12,95 | $p > 0{,}05$ |
| BMI (kg. $M^{-2}$) | 22,9 | 7,31 | 25,96 | 4,73 | $p > 0{,}05$ |
| Body fat (%) | 16,55 | 8,64 | 22,31 | 7,31 | $p < 0{,}05$ |
| Age | 17,52 | 3,28 | 52,12 | 7,41 | |
| Men and women | | | | | |
| Weight (kg) | 65,47 | 13,26 | 75,31 | 14,51 | $p < 0{,}001$ |
| BMI (kg. $M^{-2}$) | 21,96 | 5,1 | 25,5 | 4,06 | $p < 0{,}001$ |
| Body fat (%) | 11,76 | 7,7 | 18,69 | 7,36 | $p < 0{,}001$ |
| Age | 18,16 | 3,6 | 50,2 | 7,12 | |

**TABLE 2**

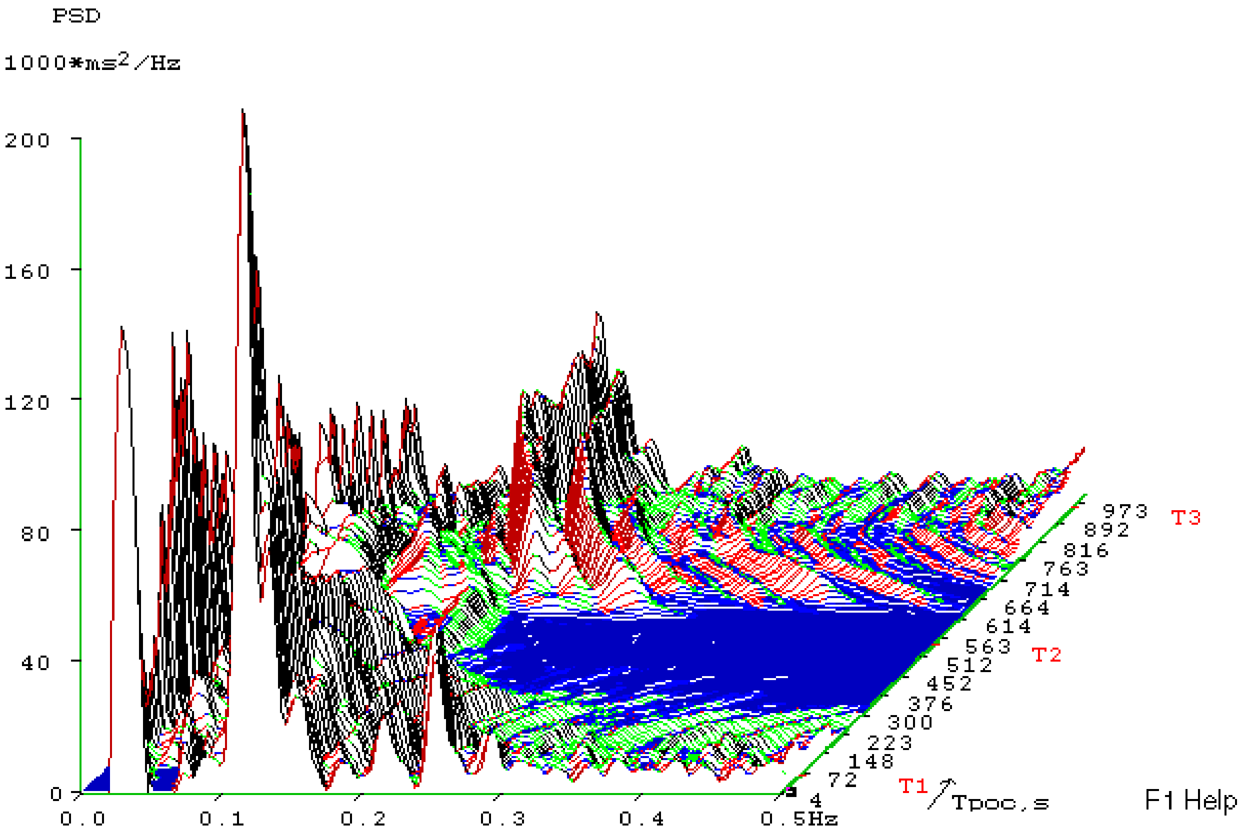
Mean values ( $\overline{x}$ ) and standard deviations (SD) of the individual indices in supine for the groups of younger (A) and older (B) subjects.
p = absolute power, Tp = total power, % = relative part of individual component in total power, PSD = power spectral density, f = average value of frequencies of maximal density powers, MSSD = mean squared successive differences, CCV = coefficient of component variations.
Ind. – compared indices. Dtr. – sampling distribution: 1 – normal distribution, 2 – log normal distribution, 3 – non normal distribution. D1 – statistical differences between the groups.
p > 0, 05 – no significant difference (NS)
p < 0, 05 – *
p < 0, 01 – **
p < 0, 001 – ***

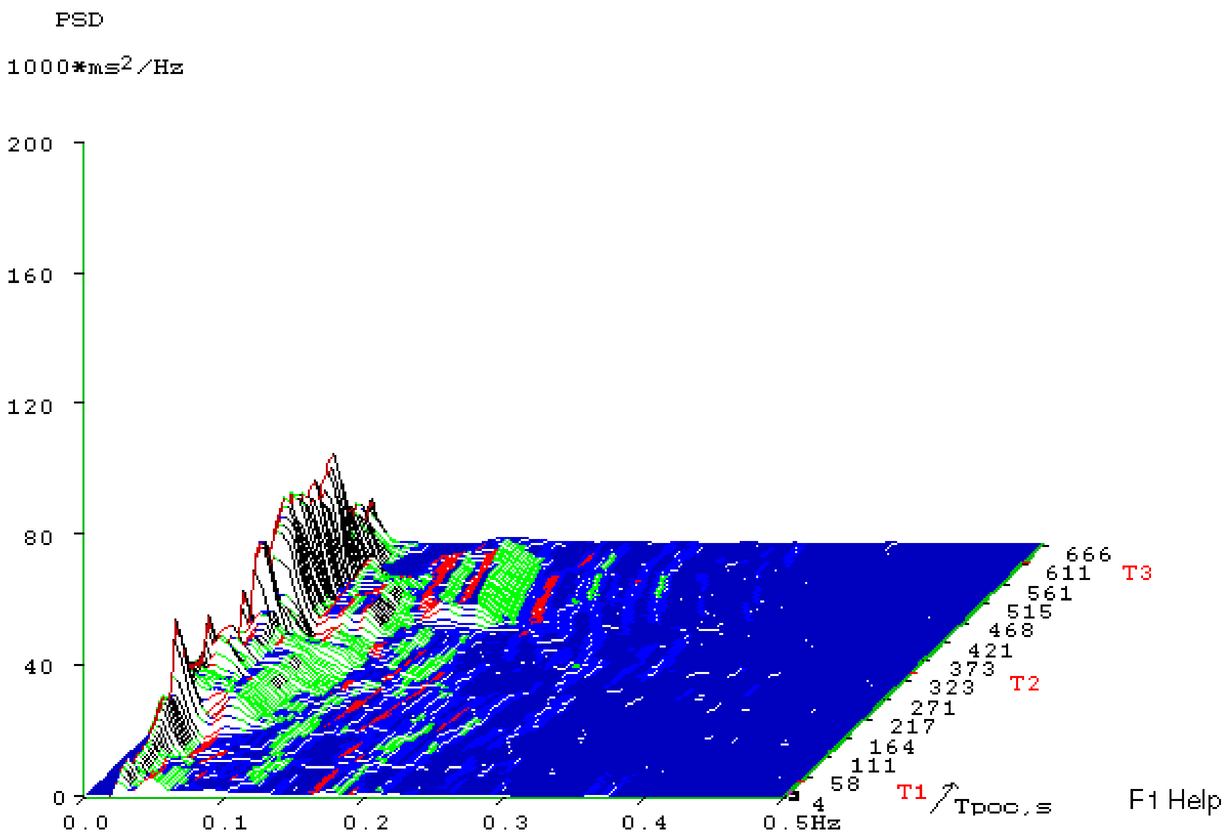
| | | group A | | group B | | |
|---|---|---|---|---|---|---|
| Ind. | Dtr. | $\overline{x}$ | SD | $\overline{x}$ | SD | D1 |
| PVLF | 2 | 6.33 | 0.84 | 6.51 | 0.83 | NS |
| PLF | 2 | 6.55 | 1.09 | 5.77 | 1.10 | *** |
| PHF | 2 | 7.65 | 0.85 | 5.66 | 0.92 | *** |
| Tp | 2 | 8.31 | 0.60 | 7.30 | 0.72 | *** |
| % VLF | 1 | 18.20 | 13.51 | 50.08 | 20.96 | *** |
| % LF | 1 | 24.33 | 18.50 | 26.76 | 14.80 | NS |
| % HF | 1 | 57.48 | 22.85 | 23.16 | 12.47 | *** |
| PSDVLF | 2 | 10.75 | 0.90 | 10.82 | 1.01 | NS |
| PSDLF | 2 | 9.99 | 1.05 | 9.00 | 1.00 | *** |
| PSDHF | 2 | 10.30 | 0.96 | 8.36 | 1.01 | *** |
| FVLF | 3 | 23.09 | 8.88 | 20.26 | 8.21 | *** |
| FLF | 1 | 98.76 | 29.08 | 90.97 | 26.44 | NS |
| FHF | 1 | 257.07 | 82.00 | 227.00 | 61.02 | * |
| VLF/HF | 2 | –1.32 | 1.20 | 0.85 | 1.08 | *** |
| LF/HF | 2 | –1.10 | 1.38 | 0.11 | 0.89 | *** |
| VLF/LF | 2 | –0.21 | 1.09 | 0.76 | 1.18 | *** |
| R–R | 1 | 1.02 | 0.17 | 0.99 | 0.12 | NS |
| MSSD | 2 | 8.76 | 0.76 | 6.82 | 0.84 | *** |
| CCVVLF | 2 | 0.86 | 0.44 | 0.97 | 0.42 | NS |
| CCVLF | 2 | 0.97 | 0.55 | 0.60 | 0.55 | *** |
| CCVHF | 2 | 1.52 | 0.41 | 0.55 | 0.43 | *** |
| CCVTp | 1 | 66.48 | 20.06 | 41.82 | 14.43 | *** |

**TABLE 3**
Mean values ( $\overline{x}$ ) and standard deviations (SD) of the differences of the individual indices (supine minus upright position) for groups of younger (A) and older (B) subjects.
D2 – statistical differences between (supine minus upright position) values.

| Ind. | Dtr. | group A $\overline{x}$ | group A SD | group A D2 | group B $\overline{x}$ | group B SD | group B D2 | D1 |
|---|---|---|---|---|---|---|---|---|
| PVLF | 3 | –1493 | 3976 | ** | –1303 | 3618 | ** | NS |
| PLF | 3 | –199.96 | 1167 | NS | –48.69 | 764.10 | NS | NS |
| PHF | 3 | 2510 | 2490 | *** | 258.84 | 483.38 | *** | *** |
| Tp | 3 | 818.39 | 4382 | NS | –1093 | 3767 | * | *** |
| % VLF | 1 | –24.29 | 28.83 | *** | –9.97 | 24.98 | ** | ** |
| % LF | 1 | –17.80 | 24.14 | *** | –3.96 | 20.56 | NS | *** |
| % HF | 1 | 42.09 | 26.51 | *** | 13.93 | 12.48 | *** | *** |
| PSDVLF | 3 | –205222 | 579553 | ** | –239686 | 617835 | ** | NS |
| PSDLF | 3 | 1209 | 44917 | NS | –3815 | 28215 | NS | NS |
| PSDHF | 3 | 39356 | 51164 | *** | 4133 | 7024 | *** | *** |
| FVLF | 3 | 2.11 | 13.93 | NS | 4.33 | 9.93 | NS | NS |
| FLF | 1 | 13.82 | 31.54 | ** | 10.63 | 29.59 | ** | NS |
| FHF | 1 | 70.08 | 76.60 | *** | 18.80 | 79.40 | NS | *** |
| VLF/HF | 3 | –21.65 | 61.24 | ** | –39.97 | 104.07 | ** | * |
| LF/HF | 3 | –4.41 | 4.84 | *** | –5.55 | 6.94 | *** | NS |
| VLF/LF | 3 | –5.37 | 19.18 | * | –2.07 | 16.43 | NS | NS |
| R–R | 1 | 0.28 | 0.11 | *** | 0.17 | 0.07 | *** | *** |
| MSSD | 3 | 7200 | 7054 | *** | 693.70 | 1280 | *** | *** |
| CCVVLF | 3 | –2.94 | 4.82 | *** | –1.96 | 3.78 | *** | NS |
| CCVLF | 1 | –1.46 | 1.91 | *** | –0.55 | 1.30 | *** | ** |
| CCVHF | 1 | 2.48 | 2.10 | *** | 0.63 | 0.80 | *** | *** |
| CCVTp | 3 | –15.99 | 40.19 | ** | –17.94 | 36.39 | *** | NS |

**Fig. 1**
"3D" plot. Spectral analysis of heart rate variability in one young (top) and one older (bottom) healthy subject in supine (T1, T3) and upright (T2) positions. The younger subject shows a greater total power, primarily in the HF component in supine



## DER EINFLUSS DES ALTERS AUF DIE VARIABILITÄT DER HERZFREQUENZ BEI DER KURZEN AUFNAHME

(Zusammenfassung des englischen Textes)

Das Ziel der Arbeit ist, die Abhangigkeit der Parametern der kurzen Aufnahme der Spectral Analyze die variabilität der Herzfrequenz von dem Alter beim Stand und Liegen festzustellen. 132 gesunde Personen wurden getestet (76 Männer und 56 Frauen). Sie waren in zwei Gruppen nach dem Alter geteilt: 12–24 Jahre (n=62) und 43–70 Jahre (n=70). Die Gesamtspektralleistung war in drei Komponenten geteilt: die hohe Frequenz (150–500mHz), die mittlere Frequenz (50–150mHz) und die niedrige Frequenz (20–50mHz). Die Werte der Gesamtspektralleistung, der Parametern gerechneten von den Komponenten LF und HF und der durchschnitlichen Frequenz von den LF und HF Komponenten im Liegen wurden signifikant niedriger bei der Gruppe der älteren Probanden als bei der jüngeren Gruppe. Im egenstand, die Werte der Parametern % VLF, VLF/HF, VLF/LF und LF/HF wurden signifikant höher bei der älteren Gruppe. Die Unterchiede zwischen den Werten, die im Liegen und und im Stand festgestelt wurden, waren entweder signifikant niedriger bei der alteren Gruppe oder sie haben sich nicht signifikant unterschieden; nur die Änderung der gesamt Spektralleistung war signifikant höher bei der älteren Gruppe.

*Schlüsselwörter: der autonome Nervensystem, der Alter, HRV, das aktive Orthostatischemanöver.*

## VLIV VĚKU NA KRÁTKODOBÝ ZÁZNAM VARIABILITY SRDEČNÍ FREKVENCE

(Souhrn anglického textu)

Cílem práce bylo stanovit závislost parametrů, získaných z krátkodobého záznamu spektrální analýzy variability srdeční frekvence v lehu a ve stoji, na věku. Vyšetřili jsme 132 zdravých jedinců (76 mužů a 56 žen) ve věku: 12 až 24 let (1. Skupina, n = 62) a 43 až 70 let (2. Skupina, n = 70). Celkový spektrální výkon byl rozdělen do tří komponent: s vysokou frekvencí (HF) (150–500 mHz), s nízkou frekvencí (LF) (50–150 mHz) a s velmi nízkou frekvencí (VLF) (20–50 mHz). Ve skupině starších osob jsme zjistili signifikantně nižší hodnoty celkového spektrálního výkonu, parametrů vypočítaných z komponenty LF a HF a průměrné frekvence komponent VLF a HF ve srovnání se skupinou mladších osob v poloze v lehu. Naopak, hodnoty parametrů %VLF, VLF/LF, VLF/HF a LF/HF byly ve skupině starších osob signifikantně vyšší. Rozdíl mezi hodnotami v leže a ve stoje byl ve skupině starších osob ve srovnání se skupinou mladších nižší, nebo se významně nelišil; pouze změna v celkovém spektrálním výkonu byla signifikantně větší ve skupině starších osob.

*Klíčová slova: autonomní nervový systém, spektrální analýza, stárnutí, variabilita srdeční frekvence, aktivní ortostáza.*