# MEASUREMENT OF BREATHING FREQUENCY FROM ECG IN THE EXAMINATION OF AUTONOMOUS NERVOUS SYSTEM ACTIVITIES: SUGGESTED METHODS AND THEIR VERIFICATION

**Jiří Salinger, Petr Štěpaník, Petr Kolisko, Pavel Stejskal, Šárka Theuerová, Milan Elfmark, Simona Gwozdziewiczová*, Jakub Krejčí**

*Faculty of Physical Culture, Palacký University, Olomouc, Czech Republic*
**Faculty of Medicine, Palacký University, Olomouc, Czech Republic*

Submitted in May, 2005

From a wide range of methods pertaining to breathing frequency measurement we opted for the less frequent method of breathing frequency diagnosis originating from the assessment of changes in ECG signal parameters pursuant to changes in thoracic volume during expiration and inspiration. The principal reason for selecting this method was in the fact that in the assessment of autonomous nervous system (ANS) activity the ECG signal is monitored and this can also be used for diagnosing breathing frequency. Changes in ECG signal parameters were analysed by the method of spectral analysis of heart rate frequency (BFrr), the method of spectral analysis of variability amplitudes of QRS complexes (BFqrs) and time analysis of periodicity in amplitudes changes of QRS complexes (BFv) in order to suggest the optimal method of measuring breathing frequency. Monitoring of the ECG signal and calculation of ECG parameters, including the mentioned analysis, were processed by the VarCor PF6 system with modified programme equipment. Statistical verification of the selected method and recommendation of the optimal method for breathing frequency measurement was carried out with the help of reference values of breathing frequency at 9 and 12 cycles/min that were via acoustic signals transmitted to the tested subjects.

Characteristics of the sample set: 55 men and women aged 22.7 ± 2.4 years, measurement was done in the positions supine 1 – standing – supine 2, the total number of statistically processed sets was n = 118.

Based on the statistical results where the significance of differences between average values regarding reference values were tested by t-test and furthermore, based on the calculation of values based on absolute differences between breathing frequencies, the BFqrs method was recommended since it allows for diagnosing breathing frequency in the range of 6–25 cycles/min. The designed method will be applied to the existing algorithm of the diagnostic system VarCor PF6, thereby helping to specify the interpretation of the results of ANS examination.

*Keywords: ECG signal, QRS complex, breathing frequency, heart rate variability, spectral analysis, autonomous nervous system.*

## INTRODUCTION

The autonomous nervous system (ANS) function is distinctively influenced by respiration (Kolisko et. al, 2003), manifesting itself (from the frequency point of view) mainly in the vagal (HF) frequency spectrum between 0.15–0.4 Hz that corresponds with a breathing frequency of 9–24 cycles/min. Dividing ANS into two subsystems – parasympathetic (n. vagus) and sympathetic (truncus sympathicus) coheres with optimal control of the body either under resting conditions or with a different physical as well as psychological (stressful) load. This is why diagnostics of neuro-vegetative reactivity in the body, defined as the actual condition of both subsystems of ANS, is steadily increasing and the focus here is on determining, as precisely as possible, the factors that may negatively influence the results of examination and in some cases may cause misinterpretation of the conducted ANS examination. One of the effects significantly influencing heart rate (HR) values is the breathing pattern, respectively the relation between breathing volume and breathing frequency (BF). The principle of ANS examination, originating from frequency (spectral) analysis of heart rate variability (SAHRV) lies in calculating the parameters of power spectral density (PSD) in a total frequency zone of 0.02–0.4 Hz divided into zones VLF (0.02–0.05 Hz), LF (0.05–0.15 Hz) and HF (0.15–0.4 Hz) and further, among others, also in calculating the average values of frequencies $f\_PSD_{VLF}$, $f\_PSD_{LF}$ and $f\_PSD_{HF}$ corresponding with maximal values of PSD in particular frequency zones. With regard to the fact that respiratory frequency characterises respiratory bound activity of the parasympathetic system, resp. vagus, Kolisko et. al.

(2004) and with regard to the fact that the inter-relation between breathing, vagus activity and the occurrence of respiratory sinus arrhythmia is known (Grossman, Kollai, & Mitzey, 1990; Grossman, Karemaker, & Wieling, 1991; Grossman, 1992a; Grossman, 1992b; Saul et al., 1989), we find that in people with spontaneous breathing frequency higher than 9 cycles/min the respiratory bound activity of vagus lies in the frequency zone HF. It is possible to verify this fact by observing the values of the frequency of maximal values PSD in the HF zone, or eventually, the LF zone, during different values of rhythmised breathing. The problem during assessment of SA-HRV results is the decline of breathing frequency below 9 cycles/min, transitioning from HF frequency zone to the LF zone (Kolisko et al., 1997, 2001, 2004). This fact causes distortion of examination results of vagus activity using the SAHRV method, leading to misinterpretation of the actual functional state of ANS. This situation appears in people with spontaneous bradypnoea of 9 or less cycles/min when the breathing frequency is not observed by the examiner during examination. The second reason why it is necessary to diagnose breathing frequency during ANS examination is the documented positive enhancement of the spectral power of respiratory bound vagus activity together with a decrease in breathing frequency (Kolisko et al., 1997; Kolisko et al., 2004) and even in the range of the HF frequency zone (Vlčková et al., 2005).

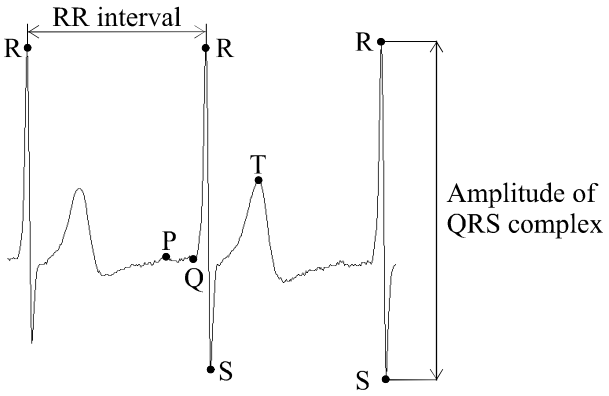
These facts purposefully proclaim the introduction of an innovated diagnostic system that allows, in addition to the existing ANS examination, monitoring of actual BF value at the same time. For reasons of minimal influence on ANS examination results it was necessary to propose and verify the methods of BF measurement originating from changes in ECG signal parameters pursuant to changes in thoracic volume during inspiration and expiration.

## METHODS

For precise interpretation of SAHRV results permitting accurate assessment of ANS activity it is necessary to determine the breathing frequency as well. From the entire range of BF measurement methods we concentrated on the less used method originating from evaluation of changes in ECG parameters secondary to changes in thoracic volume during inspiration and expiration. The principal reason for selecting this method lay in the fact that for the purposes of diagnosing ANS activity, the ECG signal is monitored, which can also be used for BF diagnosis. For this objective, when monitoring the ECG signal, calculation of SAHRV parameter and calculation of BF values from the ECG pattern were adopted in the existing diagnostic system VarCor PF6 (Salinger et al., 2003) with modified programme equipment.

Among the changing ECG parameters as a consequence of BF belong the heart rate (HR), characterised by the size of RR intervals that increase during breathing in and decrease with breathing out. Another significant changing parameter dependent on BF is the sum of amplitudes of R and S waves (amplitude of QRS complex) – Fig. 1, which increases during inhaling and during exhaling it attains minimal values. These changes in amplitudes of QRS complexes of ECG during breathing are caused by change of position in the electrical cardiac vector with respect to tightly placed electrodes on the ventral side of the chest that during breathing out exhibit changes in volume (Kapandji, 1974; Véle, 1997).

**Fig. 1**
ECG parameters dependent on breathing frequency




A complete summary of the methods assessing breathing frequency (BF) on the basis of ECG changes is presented in the block scheme in Fig. 2. The periodicity of these changing parameters dependent on breathing frequency allows BF calculation by standard mathematical means suitable for data processing in time and frequency (spectral) spheres. In the block scheme in Fig. 2 the broken line depicts the method using assessment of the changes in the time parameters of RR intervals, which is not suitable for BF measurement since, in changes to RR intervals also participate, apart from BF, the activity of ANS subsystems – sympathetic and parasympathetic causing equivocation or impossibility of detection maximums and minimums.

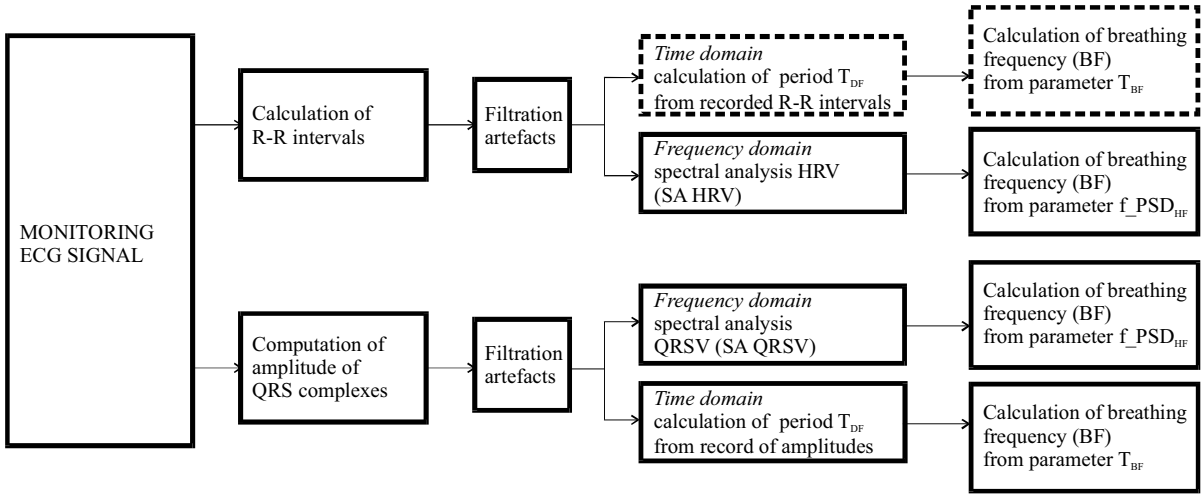
### *Principles of experimental methods*

The remainder of methods stated in the block scheme in Fig. 2 were verified with respect to BF measurement accuracy and their utility during ANS examination. The following are methods of BF measurement:

- *Method BFrr*

The principle applied here is spectral analysis of heart rate variability (Salinger et al., 2003) where the

**Fig. 2**
Summary of methods allowing assessment of breathing frequency from ECG signal

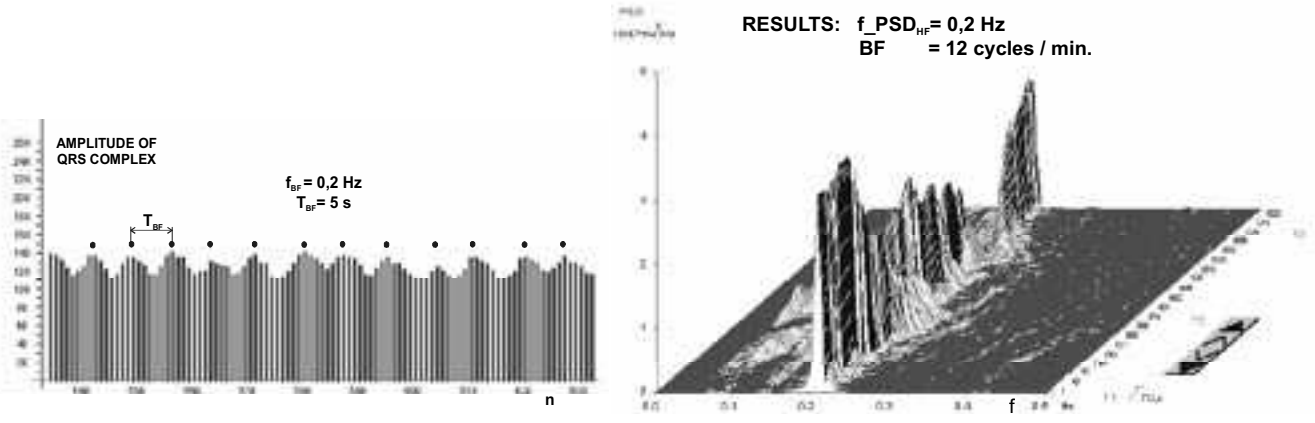



input is a time series formed by 300 RR intervals, measured with 1 ms accuracy. The output parameter for calculating BFrr is the average value of frequency $f\_PSD_{HF}$, corresponding to the maximum of power spectral density (PSD) in the HF zone.

- *Method BFqrs*

The algorithm of this method is consistent with the previous method of SAHRV where the input is in the form of time series formed by 300 amplitudes of QRS complexes. The results are parameters of the spectral analysis of amplitudes variability in QRS complexes (SAQRSV) from which the parameter $f\_PSD_{HF}$ corresponding to maximum PSD in frequency sphere LF and HF is used for calculating BFqrs value, as graphically illustrated in Fig. 3. Measurement was carried out in the positions supine 1 – standing – supine 2. From Fig. 3 the differences in maximal PSD values in particular positions is evident and these are caused by the differing extent of changes in thoracic volume in the supine 1 (2) and standing positions. These changes, however, do not influence either $f\_PSD_{HF}$ or BFqrs values.

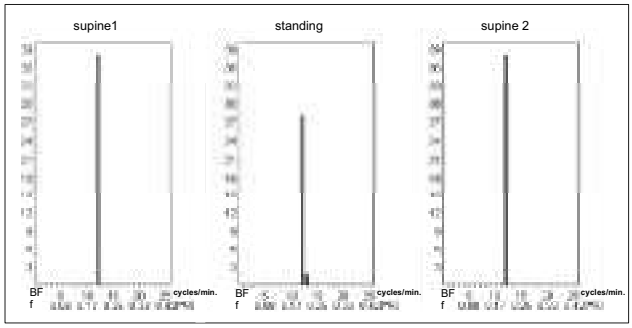
**Fig. 3**
A – Record of amplitudes of QRS complexes; B – Graphic output of spectral analysis of variability amplitudes of QRS complexes for controlled breathing BF12, measured by VarCor PF6 system




A B

*Legend*
PSD – power spectral density; f – frequency of spectrum of zones VLF, LF and HF; T1, T2 and T3 – moments of starting position supine 1– standing – supine 2

**Fig. 4**
Histogram BF in positions supine 1, standing, and supine 2 for value of controlled breathing at 12 cycles/min




*Legend*
n – number of breathing cycles in measured intervals of 300 amplitudes QRS complex; f – values of BF [cycles/min]

- *Method BFv*

It implies a time series resulting from the measurement of maximum/minimum periods ($T_{BF}$) formed by amplitudes of QRS complexes – see Fig. 3 A. The results are the values of BFv mentioned in Fig. 4 in the form of histograms for specific measured positions (intervals).

***Course of experiment and collection of data***

Verification of accuracy of each method and their mutual comparison was performed with the help of reference values of BF9 breathing frequencies corresponding to the constant of 9 cycles/min and BF12 corresponding to 12 cycles/min. Reference values of breathing frequency were transferred to the tested subjects through acoustic order.

Data sets were divided according to the realised experimental methods – BFrr, BFqrs and BFv. Measurement encompassed monitoring of ECG signals by means of electrodes placed on the ventral side of the chest and by calculating RR intervals and amplitudes of QRS complexes further in BF calculation according to the algorithms of the already mentioned methods. A total of 55 men and women aged 27 ± 2.4 years participated in the measurement where each passed the measurement for particular reference breathing frequency BF9 and BF12. Each measurement was carried out in the positions supine 1 – standing – supine 2. Due to artefacts in ECG records and severe faults in experimental methods caused by application of the automated measurement of amplitudes of QRS complexes, still unverified in practise, a total of n = 118 records for each of the verifying experimental methods remained to be statistically processed. The VarCor PF6 diagnostic system, together with the source of acoustic signal, type Smarton SM 88, was used for obtaining data.

***Statistical processing of experiments***

Measured and calculated values of particular breathing frequency in the selected experimental methods were statistically processed through the STATISTICA programme, version 6.0. Besides calculating fundamental statistical parameters, the results of particular experimental methods encompassing BFrr9, BFqrs9 and BFv9 were indicated by reference value BF9, and BFrr12, BFqrs12 and BFv12 by reference value BF12, tested from the aspect of normal distribution with the help of the Kolmogorov–Smirnov test and from the point of view of the significance of differences with the help of t-tests of averages regarding reference values of controlled breathing BF9 and BF12, characterised by a zero value of standard deviation. With the exception of statistical assessment of results of the experimental method, individual methods were judged also from the aspect of absolute differences calculated from average values of single experimental methods and reference values of BF.

## RESULTS

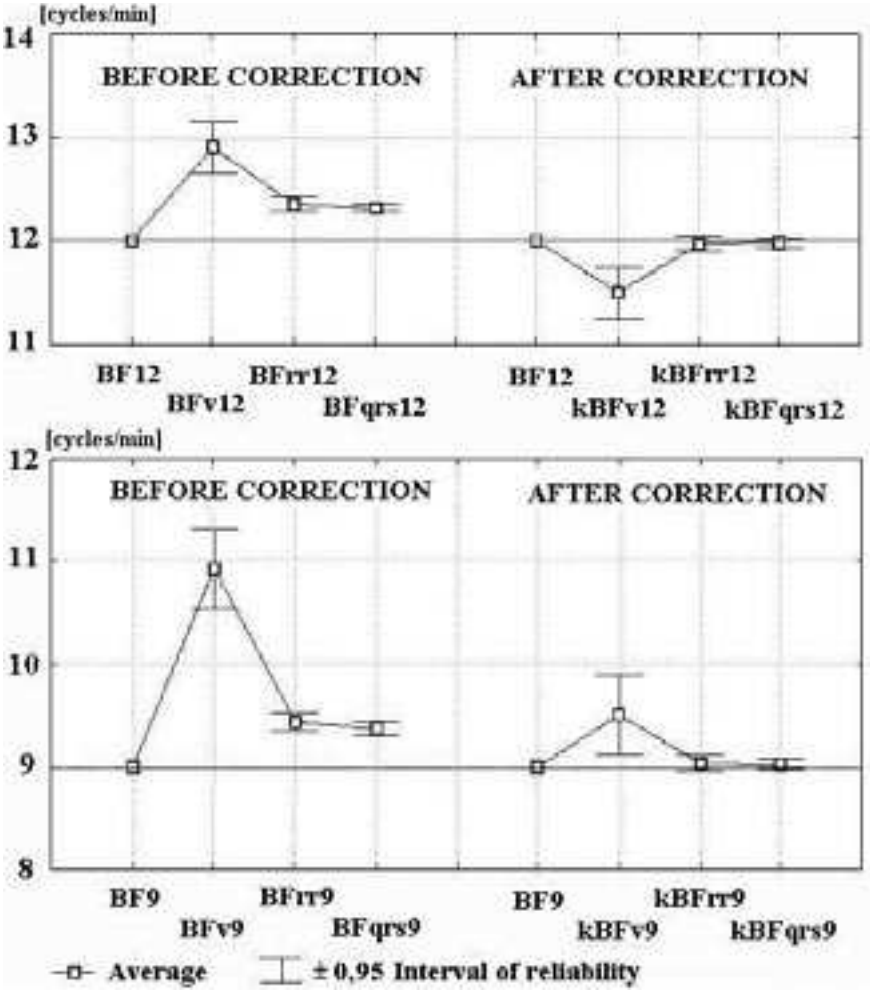
The average values and interval of reliability of particular experimental methods for reference value BF9 for BFrr9, BFqrs9 and BFv9 and for BFrr12, BFqrs12 and BFv12 by reference BF12 are graphically displayed in Fig. 5. With regard to the fact that differences in average values of breathing frequency in using the applied method mutually differ, for BF9 and BF12 values we calculated correction coefficients common to the given experimental methods and to the selected frequency range of BF. The stated correction coeficients were determined with the help of average values of differences between reference values BF9 and BF12 and the particular methods of BFv, BFrr and BFqrs – TABLE 1. In doing so, the existing values of breathing frequencies BFv, BFrr and BFqrs, with the help of correction coefficients, were transformed to kBFv, kBFrr and kBFqrs values.

**TABLE 1**
Calculation of correction coefficients for BFv, BFrr and BFqrs methods

| | BFv | BFrr | BFqrs |
|---|---|---|---|
| BF12 | 0.9045 | 0.3521 | 0.3181 |
| BF9 | 1.9158 | 0.4304 | 0.3690 |
| **Average (correction coefficient)** | **1.4101** | **0.3912** | **0.3435** |

Calculation of transformation values of breathing frequencies for particular experimental methods and for selected values of controlled breathing BF9 and BF12 was implemented according to the formulas described in TABLE 2. The average values of breathing frequen-

**Fig. 5**
Average values of breathing frequency and their reliability interval before and after performed correction for values of controlled breathing at 9 and 12 cycles/min




cies including their interval of reliability at ± 0.95 before and after correction are presented in graphical form in Fig. 5.

**TABLE 2**
Transformation formula

| | |
|---|---|
| **kBFv12** = DFv12 – 1.4102 | **kBFv9** = DFv9 – 1.4102 |
| **kBFrr12** = DFrr12 – 0.3912 | **kBFrr9** = DFrr9 – 0.3912 |
| **kBFqrs12** = DFqrs12 – 0.3435 | **kBFqrs9** = DFqrs9 – 0.3435 |

From the results presented in Fig. 5, it means that before and after correction there is evidently a low value of the interval of reliability in the BFrr and BFqrs methods, and additionally, in the corrected values there are small systematic errors, thereby inferring a difference in their averages from the defined values of controlled breathing (BF9 and BF12).

All measured as well as corrected values of breathing frequencies were judged from the perspective of the statistical significance of differences in the results of particular methods. For this judgement we used the t-test of averages against a reference constant, for our purposes the values of BF9 and BF12. The results for reference value BF12 and for n = 118 are presented in TABLE 3. From the results of this test there is an evident statistically insignificant difference between the average values of kBFqrs12 and kBFrr12 with regard to reference value BF12, that means corrected values of the methods BFqrs and BFrr. In the method of BFv measurement, a significant statistical difference in averages against the reference value of BF12 in corrected values on a significant level of $p < 0.05$ (bold line) was proved.

The results of the t-test for statistical significance of differences among results of experimental methods toward the reference constant BF9 for n = 118 are presented in TABLE 4. An insignificant statistical difference

**TABLE 3**
Test of averages of experimental methods against reference constant BF12

| | t-test of averages against reference constant (value) | | | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Average | St. dev. | n | St. error | RC | t | p |
| BF12 | 12.00000 | 0 | 118 | | 12.00 | | |
| ***kBFv12*** | ***11.49434*** | ***1.349597*** | ***118*** | ***0.124240*** | ***12.00*** | ***- 4.06998*** | ***0.000086*** |
| kBFrr12 | 11.96097 | 0.407754 | 118 | 0.037537 | 12.00 | -1.03966 | 0.300642 |
| kBFqrs12 | 11.97460 | 0.224060 | 118 | 0.020626 | 12.00 | -1.23135 | 0.220662 |

**TABLE 4**
Test of averages of experimental methods against reference constant BF9

| | t-test of averages against reference constant (value) | | | | | | |
|---|---|---|---|---|---|---|---|
| Variable | Average | St. dev. | n | St. error | RC | t | p |
| BF9 | 9.00000 | 0 | 118 | | 9.00 | | |
| ***kBFv9*** | ***9.50565*** | ***2.096417*** | ***118*** | ***0.192991*** | ***9.00*** | ***2.62009*** | ***0.009956*** |
| kBFrr9 | 9.03920 | 0.450679 | 118 | 0.041488 | 9.00 | 0.94492 | 0.346645 |
| kBFqrs9 | 9.02550 | 0.307266 | 118 | 0.028286 | 9.00 | 0.90150 | 0.369173 |

*Legend*
St. dev. = standard deviation, n = number of those which are valid, St. error = standard error, RC = reference constant, t = value of tested criterion, p = level of statistical significance

in averages was also found in the values kBFqrs9 and kBFrr9, that means in corrected values of the method BFqrs and BFrr. In experimental method of measurement BFv, a statistically significant difference of averages against reference value BF9 in corrected values on the significance level of $p < 0.05$ (bold line) was proved.

Besides assessment of statistically significant differences among particular methods the results of BF were also used for determining absolute differences in the applied methods. For this assessment we used average values and values of standard deviations of individual experimental methods for controlled breathing at 9 and 12 cycles/min and the values of variation coefficient (V) expressing the ratio of average value and standard deviation. The lowest values of variation coefficients were reached in using the method BFqrs (TABLE 5) where for kDFqrs12 the value of variation coefficient is V = = 1.9% and for kDFqrs9 it is V = 3.4% . These values are in bold characters in the TABLE 5.

For integrity we present in TABLE 6 the average values and standard deviation of absolute differences in BF results for particular experimental methods and reference values BF9 and BF12. The lowest difference in averages and standard deviation were reached in the BFqrs method for both values of controlled breathing when (BF12 – kBFqrs12) = 0.138678 ± 0.159407 cycles/min and (BF9 – kBFqrs9) = 0.179110 ± 0.250426 cycles/min. These values are in bold characters in TABLE 6.

**TABLE 5**
Calculation of variation coefficients

| Variable | Average [cycles/min] | St. dev. [cycles/min] | V [ % ] |
|---|---|---|---|
| kBFv12 | 11.49434 | 1.349597 | 11.7414 |
| kBFrr12 | 11.96097 | 0.407754 | 3.409038 |
| ***kBFqrs12*** | ***11.97460*** | ***0.224060*** | ***1.871127*** |
| kBFv9 | 9.50565 | 2.096417 | 22.05443 |
| kBBFrr9 | 9.03920 | 0.450679 | 4.985828 |
| ***kBFqrs9*** | ***9.02550*** | ***0.307266*** | ***3.404421*** |

*Legend*
St. dev. = standard deviation, V = variation coefficient

**TABLE 6**
Calculation of absolute differences of methods used regarding reference values DF12 and DF9

| Variables | Average [cycle/min] | St. dev. [cycle/min] |
|---|---|---|
| BF12 – kBFv12 | 1.171525 | 0.834837 |
| BF12 – kBFrr12 | 0.208288 | 0.350758 |
| ***BF12 – kBFqrs12*** | ***0.138678*** | ***0.159407*** |
| BF9 – kBFv9 | 1.587765 | 1.452684 |
| BF9 – kBFrr9 | 0.192783 | 0.408875 |
| ***BF9 – kBFqrs9*** | ***0.179110*** | ***0.250426*** |

*Legend*
St. dev. = standard deviation

## DISCUSSION

From the attained results it can be clearly inferred that for measuring breathing frequency from ECG, from the point of accuracy, the least suitable method is kBFv. The reason for this is probably in the inadequate amount of sampling levels of the 8 bit analog-digital converter used, because during analysis of maximal amplitudes of QRS we repeatedly observed two identical values of amplitudes. From the time aspect, this means inaccuracy in determining maxima of QRS signal amplitudes within the time range 2 s, that can correspond with the discovered inaccuracy of this method. Hence it would perhaps be suitable to verify, for kBFv method analog-digital converters with the number of sampling levels corresponding to 9 or 10 bits. The advantage with the kBFv method is monitoring of immediate breathing frequency unlike kBFrr and kBFqrs methods that, from the accuracy perspective, are suitable but allow assessing only of the average value of BF in the measured interval.

## CONCLUSIONS

From statistical processing of the results characterising particular experimental methods of diagnosis of breathing frequency regarding reference values of 9 and 12 cycles/min, it is evident that insignificant statistical differences were observed in BFrr and BFqrs methods. These methods analyse, as far as the spectral aspect is concerned, sets created by heart rate and amplitudes of QRS complexes of the ECG. With respect to the fact that ANS immediately, by its own subsystems – sympathetic and vagus effects the size and changes of heart rate, the set given by heart rate values is used for reflexive assessment of their activities.

For this purpose a method spectral analysis of heart rate variability is used that in frequency zones VLF, LF and HF quantifies, through parameter spectral power, the effect of sympathetic and vagus. With respect to the fact that frequency zone HF is mainly characterised by breathing bound activity of the vagus which corresponds to breathing frequency in the range of 9 to 24 cycles/min, in case of bradypnoea, it means BF less than 9 cycles/min representing a shift of breathing bound activity of vagus from the HF zone to frequency zone LF characterising baro-receptor activity. This ambiguity in interpretation during bradypnoea causes ambiguity in interpreting ANS activity assessment. From this it ensues that the BFrr experimental method using SA-HRV is usable only for measuring breathing frequency in the range of 9 to 24 cycles/min.

The BFqrs method derived from SAQRSV is minimally influenced by ANS activity and that's why it is possible to cut the lower border of the HF zone down to 0.1 Hz, which corresponds with the extent of monitored breathing frequency in the range 6 to 24 cycles/min. As demonstrated by the statistical assessment as well as by evaluation of absolute differences, this method is demonstrably more accurate and from the point of view of the extent of measured breathing frequency it is more suitable than the other observed methods of measuring breathing frequency from ECG.

On the basis of the results of single analysis and on the basis of the mentioned negatives and positives of the experimental methods, we regard the BFqrs method as most suitable for ascertaining breathing frequency from ECG. To this end we recommend equipping the existing diagnostic system VarCor PF6 with the proposed algorithm.

## REFERENCES

Grossman, P. (1992a). Breathing rhythms of the heart in a world of no steady state: A comment on Weber, Molenaar, and van der Molen. *Psychophysiology, 29,* 66–72.

Grosman, P. (1992b). Respiratory and cardiac rhythms as window to central and autonomic behavioral regulation: Selection frames, keeping the panes clean and viewing neural topography. *Biological Psychology, 34,* 131–161.

Grossman, P., Karemaker, J., & Wieling, W. (1991). Prediction of tonic parasympathetic cardiac control using respiratory sinus arrhythmia: The need for respiratory control. *Psychophysiology, 28*, 201–216.

Grossman, P., & Kollai, M. (1993). Respiratory sinus arrhythmia, cardiac vagal tone and respiration: Within and between subject relations. *Psychophysiology, 30,* 486–495.

Grossman, P., van Beek, J., & Wietjes, C. (1990). A comparison of three quantification methods for estimation of respiratory sinus arrhythmia. *Psychophysiology, 27,* 702–714.

Kapandji, J. A. (1974). *The physiology of the joints* (Volume 3). London: Churchill Livingstone.

Kollai, M., & Mizsei, G. (1990). Respiratory sinus arrhythmia is a limited measure of cardiac parasympathetic control in man. *Journal of Physiology, 424*, 329–342.

Kolisko, P., Salinger, J. et al. (1997). *Jógová cvičení a diagnostika funkčních změn autonomního nervového systému pomocí diagnostického systému TF 3, 4.* Olomouc: Fakulta tělesné kultury.

Kolisko, P., Salinger, J., Opavský, J., Stejskal, P., Jandová, D., Slováček, K., & Ježek, M. (2001). Vliv řízeného a spontánního dýchání na změny funkčního stavu autonomního nervového systému. In H. Válková &

Z. Hanelová (Eds.), *Sborník referátů mezinárodní konference „Pohyb a zdraví"* (pp. 269–275). Olomouc: Univerzita Palackého.

Kolisko, P., Jandová, D., Salinger, J., Opavský, J., Ježek, M., & Slováček, K. (2004). Application of method of spectral analysis of heart rate variability during assessment of selected breathing techniques on functional changes in the autonomous nervous system. *Acta Universitatis Palackianae Olomucensis. Gymnica, 34(2)*, 43–60.

Salinger, J., Stejskal, P., Opavský, J, Gwozdziewicz, M., Gwozdziewiczová, S., Novotný, J., Elfmark, M., & Bula, J. (2003). System type VarCor PF for non-invasive diagnostics of the heart rate variability and of the respiratory rate. In J. Salinger (Ed.), *Variabilita srdeční frekvence a její hodnocení v biomedicínských oborech - od teorie ke klinické praxi* (pp. 96–104). Olomouc: Univerzita Palackého.

Saul, J. P., Berger, H. D., Chen, M. H., & Cohen, R. J. (1989). Transfer function analysis of autonomic regulation: II. Respiratory sinus arrhythmia. *American Journal of Physiology, 256,* 153–161.

Véle, F. (1997). *Kineziologie pro klinickou praxi.* Praha: Grada publishing.

Vlčková, E., Stejskal, P., Jakubec, A., Řehová, I., Pavlík, F., & Botek, M. (2005). Controlled breathing and heart rate variability. *Medicina Sportiva, 9(1)*, 28–32.

This research was supported from the resource of grant of the Ministry of Education, Youth and Sport, Czech Republic VZ 6198959221.

## MĚŘENÍ DECHOVÉ FREKVENCE Z EKG SIGNÁLU S OHLEDEM NA VYŠETŘENÍ AKTIVIT AUTONOMNÍHO NERVOVÉHO SYSTÉMU: NÁVRH METOD A JEJICH OVĚŘENÍ

(Souhrn anglického textu)

Z celé řady metod měření dechové frekvence se autoři zaměřili na méně používanou metodu diagnostiky dechové frekvence, vycházející z hodnocení změn parametrů EKG signálu, které jsou způsobeny změnami objemu hrudníku v průběhu expiria a inspiria. Hlavním důvodem volby této metody byla skutečnost, že pro diagnostiku aktivity autonomního nervového systému (ANS) je monitorován EKG signál, který je tak k dispozici i pro diagnostiku dechové frekvence. Pro návrh optimální metody měření dechové frekvence byly změny parametrů EKG signálu analyzovány metodou spektrální analýzy variability srdeční frekvence (BFrr), metodou spektrální analýzy variability amplitud QRS komplexů (BFqrs) a časovou analýzou periodicity změn amplitud QRS komplexů (BFv). Monitorování EKG signálu a výpočet parametrů EKG signálu, včetně uvedených analýz, bylo provedeno systémem VarCor PF6 s modifikovaným programovým vybavením. Statistické ověření zvolených metod a doporučení optimální metody měření dechové frekvence bylo provedeno pomocí referenčních hodnot dechových frekvencí 9 a 12 dechů/min, které prostřednictvím akustických signálů byly předávány probandům. Charakteristika souboru: 55 mužů a žen ve věku 22,7 ± 2,4 roků, měření bylo provedeno v polohách leh 1 – stoj – leh 2, celková velikost statisticky zpracovávaného souboru byla n = 118. Ze statistických výsledků, kde byla testována pomocí t-testu významnost rozdílů průměrných hodnot vzhledem k referenčním hodnotám a dále z výpočtu hodnot absolutních rozdílů dechové frekvence byla doporučena metoda BFqrs umožňující diagnostiku dechové frekvence v rozsahu 6 až 25 dechů/min. Navržená metoda bude aplikována do stávajícího algoritmu diagnostického systému VarCor PF6, čímž se významně zpřesní interpretace výsledků vyšetření ANS.

*Klíčová slova: EKG signál, QRS komplex, dechová frekvence, variabilita srdeční frekvence, spektrální analýza, autonomní nervový systém.*

**Doc. Ing. Jiří Salinger, CSc.**

Palacký University
Faculty of Physical Culture
tř. Míru 115
771 11 Olomouc
Czech Republic

***Education and previous work experience***

1961–1966 VUT Brno, Electrotechnical Faculty, branch technical cybernetics,
1988 finished with external postgraduate study (CSc.),
1993 finished habilitation (doc.) – branch applied physics.
Since 1973 scientific assistant at Palacký University in Olomouc,
since 1990 research assistant, Department of Biomechanics and Engineering Cybernetics, Faculty of Physical Culture, Palacký University, Olomouc.

***Scientific orientation***

Microprocessing and microcomputing oriented measuring system designed for application in the sphere of diagnosis of human motorics and movement preconditions.

***First-line publication***

Salinger, J., Pumprla, J., Vychodil, R., Stejskal, P., Opavský, J., Novotný, J., & Bula, J. (1999). Microcomputer system for telemetric assessment of short term heart rate variability in the time and frequency domains, Type VariaCardio TF4. In A. Murray & S. Swiryn (Eds.), *Computers in Cardiology 1999* (pp. 599–602). Los Alamitos: The Institute of Electrical and Electronics Engineer (IEEE), Computer Society Press.

Salinger, J., Stejskal, P., Opavský, J., Gwozdziewicz, M., Gwozdziewiczová, S., Novotný, J., Elfmark, M., & Bula, J. (2004). System type VarCor PF for non-invasive diagnostics of heart rate variability and of the respiratory rate. In J. Salinger (Ed.), *Heart rate variability and assessment in biomedical fields - from theory to clinical practice* (pp. 96–104). Olomouc: Palacký University.