AUTONOMIC NERVOUS SYSTEM ACTIVITY ASSESSMENT IN RECREATIONAL HALF MARATHON RUNNERS

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BACKGROUND: Spectral analysis (SA) of heart rate variability (HRV) is considered to be a non invasive method for the quantification of autonomic cardiac activity in relationship to the sinoatrial node. It is well known that autonomic regulation is affected by various stress factors such as anxiety and/or physical activity.

OBJECTIVE: The aim of the present study was to evaluate the effect of pre-competitive anxiety on the autonomic nervous system (ANS) activity and, further, to monitor the time course of ANS recovery as well as perceived fatigue during 24 hours of a post-half marathon period in amateur runners.

METHODS: The SA HRV method was used for the evaluation of autonomic cardiac regulation. ANS activity was assessed one week before a competition and on the day of the competition. During the post-competition period ANS activity was measured at the 1st, the 12th, and the 24th hour. ANS activity was represented by the standard spectral parameters and complex indexes of SA HRV. Precompetition anxiety was evaluated by means of a modified Likert 10 point scale. The competitors' subjective feelings of fatigue were scored on a 6 point scale.

RESULTS: Perception of anxiety was significantly higher on the day of the competition than one week before the competition. The significant decrease in the complex index of sympathovagal balance on day of the competition implies l for and testifies to an increase in sympathetic activity. No significant differences between any selected HRV variables at the 12th hour as well as at the 24th hour of recovery compared to both pre-competition levels were found. Perceived fatigue remained significantly elevated up to the 24th hour of recovery.

CONCLUSION: Our study shows that elevated pre-competitive anxiety induced sympathetic predominance in autonomic regulation particularly during the period of orthostatic stimulation. ANS activity returned to its pre-competition level during the 12th hour after the finish of the competition. It is evident that the causes of soreness or fatigue do not markedly affect ANS activity during a later phase of recovery.

Keywords: Heart rate variability, recovery, pre-competitive anxiety, exercise, fatigue, performance.

INTRODUCTION

Half marathon runs are ranked among competitions with high participation by amateur athletes of different age and performance levels. It is known that during the pre-competition state, an increase in heart rate (HR), blood pressure and/or oxygen uptake occurs as a reflection of changes in autonomic nervous system (ANS) activity (Åstrand et al., 2003). ANS activity also affects the recovery process throughout the interaction between the sympathetic and parasympathetic (n. vagus) system which integrate homeostatic adjustment after exercise (Aubert et al., 2003). Spectral analysis (SA) of heart rate variability (HRV) is commonly considered to be a non invasive method for the quantification of autonomic cardiac activity in relationship to the sinoatrial node (Akselrod et al., 1981). High power frequency (P_{HF}) (0.15–0.5 Hz) is entirely modulated by vagal activity (Warren et al., 1997). The spectral power of low frequency (P_{LF}) (0.05–0.15 Hz) is commonly associated with baroreflex activity and the bilateral effect of sympathetic and vagal activity, and the very low frequency component (P_{VLF}) (0.02–0.05 Hz) is possibly related to, e.g., the renin-angiotensin system, and thermoregulatory peripheral blood flow adjustment (Task Force, 1996). Earlier studies show that the time course of ANS recovery depends mainly on exercise intensity (Arai et al., 1989; Stejskal et al., 2001), or cardiovascular performance (Hautala et al., 2001). So far, studies have been focused rather on assessing ANS activity during the recovery period after a marathon (Botek et al., 2008; Daniłowicz-Szymanowicz et al., 2005), the 46 kilometer wilderness trail run (Bernardi et al., 1997), or after a 75 km cross country skiing run (Hautala et al., 2001). Therefore, the aim of the present study was to evaluate the effect of pre-competitive anxiety on autonomic regulation, and further to monitor the time course of ANS recovery during a 24 hour post-half marathon period where there was concurrently assessed perceived fatigue.

METHOD

Participants

Eleven healthy and physically fit amateur male runners volunteered to participate in the present study. They were non smokers and none of the participants were taking any medication. All tested subjects had never run a half marathon before. The training preparation was carried out in an individual way without any supervision. Characteristics of the athletes are presented in TABLE 1. The study's design was approved by the Ethical Committee of the Faculty of Physical Culture at Palacký University.

Experimental procedure

Before the study started, all participants were closely informed about the study design. The subjects submitted their written informed consent. One week before the competition day, the tested subjects underwent, between 8 to 10 a. m., preliminary measurements in order to preclude any medical or health limitations to performing the maximal exertion test. The participants were required to avoid eating and drinking any substance affecting ANS activity for minimally 2 hours before the ANS measurement. Intensive exercise and alcohol were strictly forbidden for two days before entrance testing.

ANS activity was assessed using the non invasive method of the spectral analysis of heart rate variability (SA HRV). The ANS activity assessment was scheduled always in the morning one week before a race, and on the day of competition, respectively. During the post-competition period, ANS activity was measured at the 1st, the 12th, and the 24th hour of recovery. Electrocardiographic data were continually sampled in a quiet room during a standardized ortho-clinostatic maneuver of lying–standing–lying in accordance with the VarCor PF 7 system (Salinger & Gwozdziewicz, 2008), which records, for HRV analysis, both 300 R–R intervals and 300 s for each position. Frequency domain analyses were performed according to the methods described by Salinger et al. (1998). The amplitude density of the collected signal was estimated using the fast Fourier transformation method with a partly modified Coarse-Graining Spectral Analysis Algorithm (Yamamoto & Hughson, 1991). The power of mean spectral components were calculated by integrating the area under the power spectral density curve in the frequency ranges according to Salinger et al. (1998): power very low frequency (P_{VLF}) 0.02–0.05 Hz; power low frequency (P_{LF}) 0.05–0.15 Hz, power high frequency (P_{HF}) 0.15–0.5 Hz, and total power (P_T) 0.02–0.5 Hz, respectively. The resting heart rate (HRrest) was computed as a mean for 5 min in the second lying position. Autonomic cardiac activity was also expressed by complex indexes of SA HRV (Stejskal et al., 2002): the complex index of the vagal activity (VA), the complex index of the sympathovagal balance (SVB) and the complex index of the total score (TS). The reference values of SA HRV indexes range from –5.0 to +5.0 points. The physiological values have been established for both VA and SVB in range from –2.0 to +2.0 points; for TS from –1.5 to +1.5 points (Stejskal, Přikryl, & Jakubec, 2004).

Preliminary testing also includes the measurement of the basic anthropometrical characteristics of height (cm) and weight (kg). The percentage of body fat was investigated throughout the period of the use of the bio-

TABLE 1
Basic characteristics of the tested group

Athletes	Age [years]	Height [cm]	Weight [kg]	BMI [kg m^2]	Body fat [%]	HRrest [BPM]	HRmax [BPM]	VO_2peak [ml kg^{-1} min^{-1}]
M	30.41	181.47	83.97	25.30	15.03	54.24	189.60	52.74
SD	5.85	7.23	9.25	1.22	3.35	5.71	8.40	5.66

Legend:
BMI – body mass index, HRrest – resting heart rate, HRmax – maximal heart rate, VO_2peak – peak oxygen uptake, BPM – beat per minute, M – mean, SD – standard deviation

TABLE 2
Basic characteristics of exercise intensity and achieved performance

Athletes	HR_C [BPM]	Exercise intensity [% HHR]	Finish time [minutes]	Final ranking
M	170.72	86.55	111.30	507.36
SD	8.42	1.78	7.24	150.01

Legend:
HR_C – heart rate during competition, % HRR – percent of maximal heart rate reserve, BPM – beats per minute

impedance method by means of using a device called In Body 720 (from South Korea).

The maximal exertion test was performed on a treadmill (Lode Valliant, Netherlands) in order to establish the peak oxygen uptake (VO_2peak) and maximal heart rate (HRmax). The protocol consisted of an 8 min warm up period (4 min at 8 km h^{-1} and 4 min at 10 km h^{-1}, respectively) followed by an increase in elevation to 5.0%. Thereafter the speed increased by 1 km h^{-1} every min until the subject was in a state of exhaustion. Ventilation and gas exchange were continually analyzed (ZAN 600 Ergo USB, Germany) during the exercise and were reported as a mean for 30 s. HR responses were monitored (S810 Polar, Finland) continuously during all maximal exercise tests.

A half marathon race taking place in Olomouc started at 7:00 p. m. During a competition, the HR responses were continuously sampled by the HR monitor Polar S810 (Finland). The level of fatigue ranged from 0 to 5 point(s), and was taken by means of questioning, usually before the ANS activity measurement. This scale was developed only for this study, and therefore was not validated.

Pre-competition anxiety was evaluated by using a modified Linkert 9 point scale (0 – none; 9 – maximal anxiety level) (Martens, 1990). Amateur runners assessed their actual psychological state every day during the last week before the half marathon.

Statistical methods

Data were processed using software SPSS 17. The normal Gaussian distribution of the analyzed data was verified by means of the Kolmogorov-Smirnov test. The course of perceived fatigue was tested during the study by using one way repeated measures with the help of ANOVA with the Fischer LSD post hoc test. The Kruskal-Wallis H-test was followed by the Wilcoxon test (post hoc analysis), which was conducted in order to examine the effect of both precompetition anxiety, and exercise on selected SA HRV variables. Database, tables, and figures were prepared using MS Excel 2003.

RESULTS

TABLE 2 shows that the mean finish time among the athletes was 111.3 ± 7.24 minutes. The mean HR during the competition was 170.7 ± 8.4 beats min^{-1}, which is equal to 86.5 ± 1.8% of maximal heart rate reserve. The coefficient of variation was 2.01% for HR compared to 6.50% for the finishing time.

Pre-competitive anxiety analyses revealed a significantly higher perceived anxiety on the day of competition day than one week before the competition (Fig. 1).

The mean of the complex index of SVB was significantly lower in the 2nd compared to the 1st pre-competition assessment. A significant decrease in P_{LF}, P_T, and RR interval and a parallel increase in the ratio between P_{VLF}/P_{HF} and breath frequency (BF) compared to both pre-competition levels was identified during the 1st hour after the race (TABLE 3). Likewise, the mean value of CS, and VA was significantly lower in the 1st post-competition period than in both pre-competition measurements (Fig. 2). No significant differences between any selected HRV variables at the 12th hour as well as at the 24th hour of recovery compared to both pre-competition levels were found. Fig. 3 clearly shows that perceived fatigue remained significantly elevated up to the 24th hour of recovery.

DISCUSSION

The main aim of this study was to assess the changes in autonomic cardiac regulation induced by pre-competitive anxiety, and further to compare the time course of ANS recovery with the time course of perceived fatigue during 24 hours of the post-competition period in amateur endurance runners.

The psychological test used revealed a significant increase in pre-competitive anxiety perception in amateur runners approximately 10 hours before the start of a competition. In addition, a significant reduction in the complex index of SVB coupled with a constant level of vagal activity indicates indirectly an increase in sympathetic activity on the day of competition. In this context, Blásquez, Font, and Ortís (2009) found in elite swimmers, due to pre-competitive stress, a shift towards sympathetic predominance as a result of parasympathetic withdrawal. We suppose that discrepancies in these results are associated with different methods used for HRV analysis. ANS activity has been, in the last cited study, assessed according to spectral parameters that were collected only in a supine position. In our study, runners were additionally examined in the standing position, the ortho-clinostatic maneuver stimulated both branches of the ANS and the complex indexes of SA HRV were used to evaluate the results of measurements (Stejskal et al., 2002). These indexes were created from age dependent standard spectral parameters. In this context, Stejskal (2008) supposes that complex indexes of SA HRV are more sensitive for the evaluation of discrete changes in ANS activity than standardly used parameters obtained in the supine position.

Results of some previous studies show that the return of ANS activity to the base line depends on exercise intensity (Arai et al., 1989; Perini et al., 1990). In our study we found that amateur runners overcame a 21 km

TABLE 3
Statistical analysis of spectral variables in second lying position

Parameter [unit]	**PreC$_1$**	**PreC$_2$**	**R$_1$**	**R$_{12}$**	**R$_{24}$**
P$_{VLF}$ [ms^2]	282.31 ± 180.28	334.30 ± 223.02 NS	202.54 ± 183.94 NS	335.74 ± 519.68 NS	227.27 ± 178.27 NS
P$_{LF}$ [ms^2]	921.09 ± 938.56	826.91 ± 643.68 NS	260.19 ± 204.41 § †	1043.78 ± 987.74 NS	688.13 ± 674.30 NS
P$_{HF}$ [ms^2]	1333.71 ± 979.90	1371.95 ± 1093.27 NS	784.52 ± 836.41 § †	1493.52 ± 2172.22 NS	1194.94 ± 1029.00 NS
P$_T$ [ms^2]	2537.12 ± 1475.88	2533.16 ± 1551.50 NS	1247.26 ± 1445.38 § †	2873.04 ± 3163.75 NS	2110.33 ± 1315.85 NS
P$_{VLF}$/P$_{HF}$	0.33 ± 0.29	0.39 ± 0.32 NS	0.92 ± 0.91 § †	0.33 ± 0.42 NS	0.54 ± 0.71 NS
P$_{LF}$/P$_{HF}$	1.03 ± 1.22	0.92 ± 0.77 NS	1.47 ± 1.12 NS	1.23 ± 1.01 NS	0.98 ± 0.85 NS
RR [ms]	1.10 ± 0.13	1.08 ± 0.12 NS	0.85 ± 0.15 § †	1.06 ± 0.14 NS	1.11 ± 0.12 NS
BF [breath min^{-1}]	11.41 ± 0.95	12.25 ± 1.34 NS	14.29 ± 2.50 § †	11.99 ± 2.04 NS	11.86 ± 2.28 NS

Legend: P$_{VLF}$ – power very low frequency; P$_{LF}$ – power low frequency; P$_{HF}$ – power high frequency; P$_T$ – total power; RR – beat to beat interval; BF – breath frequency; PreC – precompetition measurement; R$_{1, 12, 24}$ – measurement at the 1st; 12th; and the 24th hour post-run; § ($P \leq 0.05$) vs PreC$_1$; † ($P \leq 0.05$) vs PreC$_2$ (Kruskal-Wallis H-test followed by Wilcoxon test post hoc analysis), NS – nonsignificant; values are expressed as Mean (±SD)

Fig. 1
Perceived anxiety during precompetition period

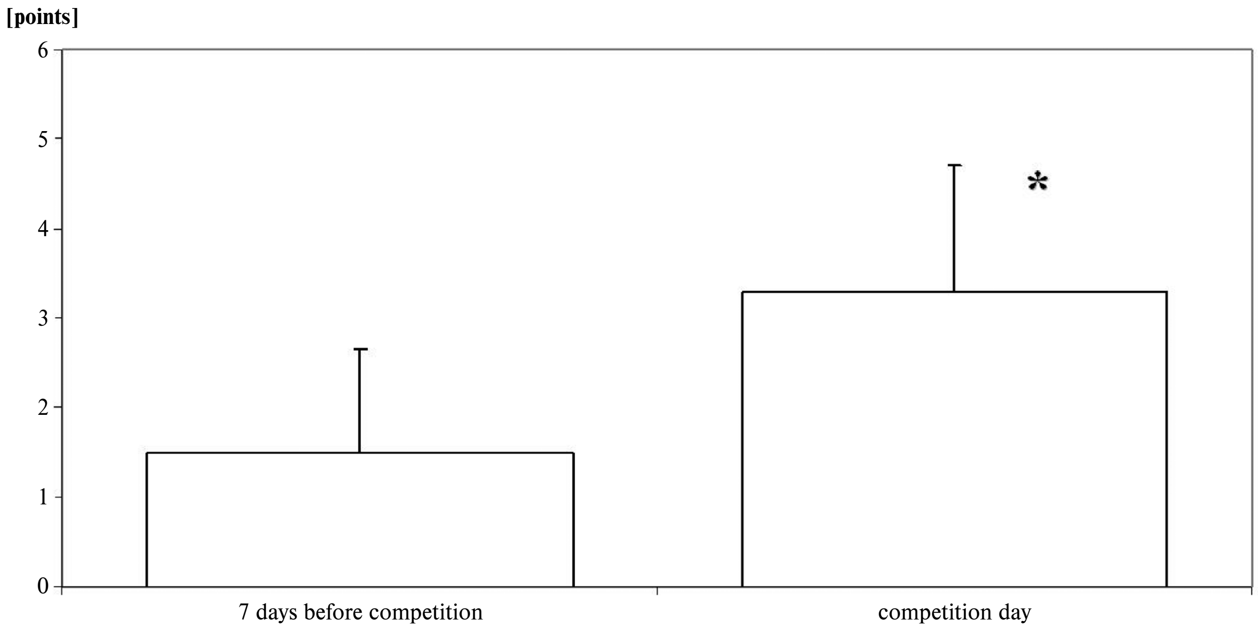
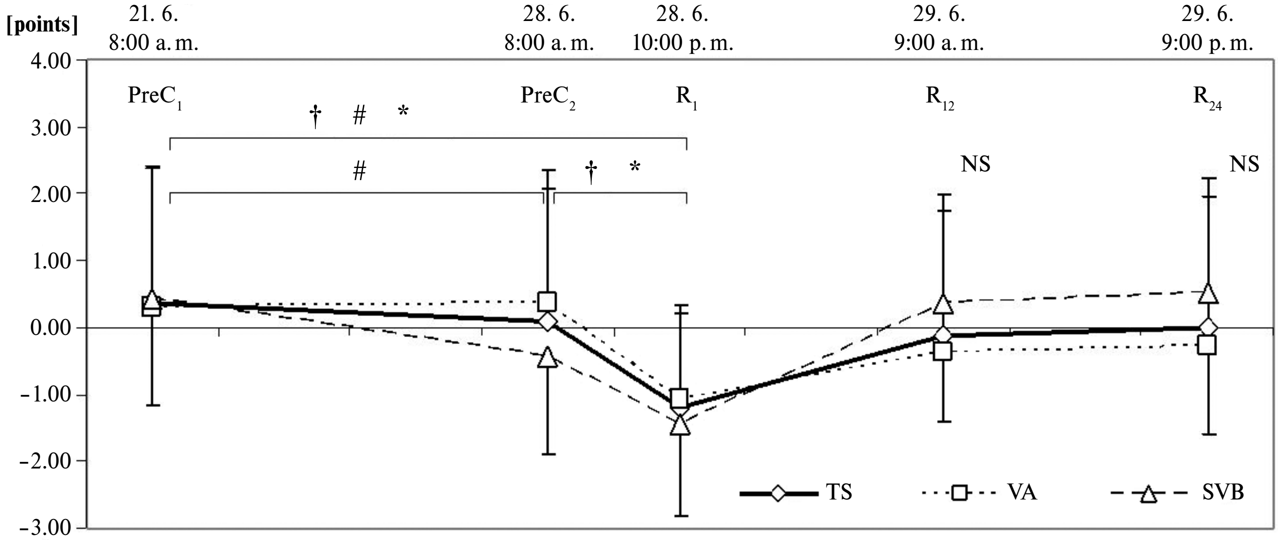
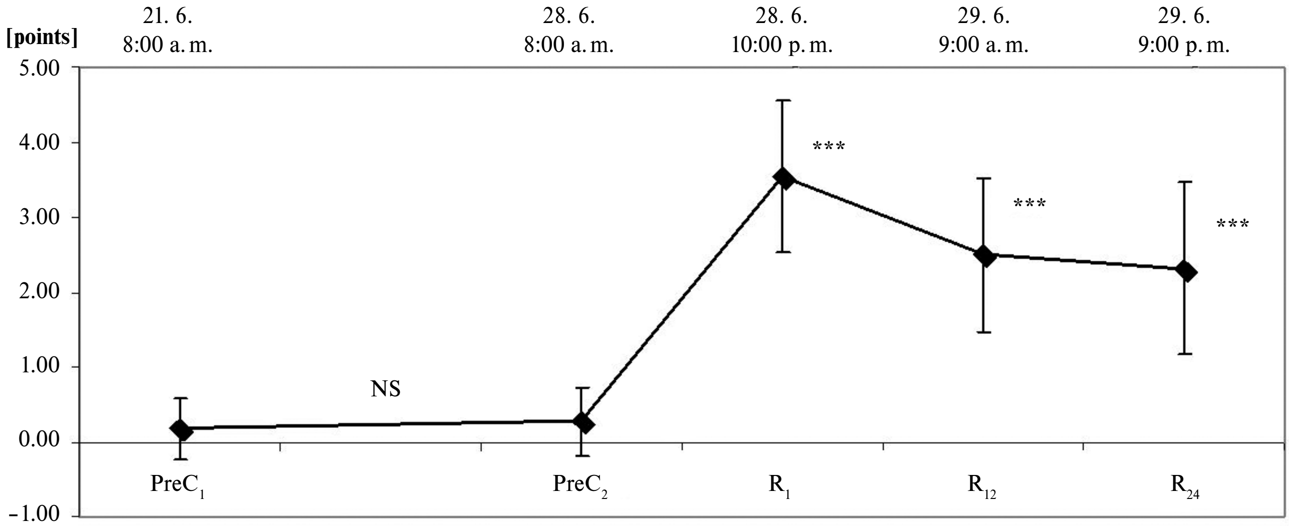


Fig. 2
A time course of recovery in complex indexes of SA HRV



Legend: PreC – precompetition measurement; $R_{1, 12, 24}$ – measurement at the 1st; 12th; and the 24th hour post-run; TS – complex index of total score; VA – complex index of vagal activity; SVB – complex index of sympatovagal balance; * ($P \le 0.05$) for TS; # ($P \le 0.05$) for SVB, † ($P \le 0.05$) for VA (Kruskal-Wallis H-test followed by Wilcoxon test post hoc analysis); NS – nonsignificant

Fig. 3
Statistical analysis of differences in perceived fatigue in athletes



Legend: PreC – precompetition measurement; $R_{1, 12, 24}$ – measurement at the 1st; the 12th; and the 24th hour post-run; *** $P \le 0.001$ (ANOVA followed by Fischer LSD post hoc test) for $R_{1, 12, 24}$ vs $PreC_1$, and $PreC_2$, respectively; NS – nonsignificant distance in a finishing time which varied more among athletes than their exercise intensity during the run. This highly similar vigorous exercise intensity induced a significant decrease in the standard spectral parameters of P_{LF}, P_{HF}, and P_T as well as in the indexes of CS and VA as a sign of attenuated vagal activity in the 1st hour of recovery. In addition, significant increased HR and BF, an elevated ratio of P_{VLF}/P_{HF}, and an nonsignificant reduction in the SVB index demonstrated a persisting sympathetic predominance in autonomic regulation up to one hour after exercise.

After 12 hours of recovery, the return of both HR, and BF was observed at the baseline. Further, an insignificant increase in certain spectral parameters (P_{LF}, P_{HF}, and P_T) obtained in the supine postion could be considered to be the supercompensatory state of vagal activity in some athletes. Interestingly, the means of VA and CS were still insignificantly reduced in the 12th hour of recovery, whereas the SVB index returned to a level identified several days before the competition. It was above this level on the day of competition. The above mentioned results indicate that ANS activity seems to be recovered and/or even supercompensated for during clinostatic stimulation, but orthostatic stimulation revealed a persisting reduction in vagal activity. The assessment of ANS activity in the 24th hour of recovery brought results similar to a previous measurement.

A high variability in the dynamics of both standard spectral variables and the complex index of SA HRV provides evidence that the time course of ANS recovery after vigorous exercise depends on several factors such as aerobic capacity, exercise intensity, basal ANS activity level, and/or the subjective perception of local muscle fatigue. For instance Hautala et al. (2001) have presented to us that the recovery time of the reduced vagal outflow depends on individual cardiorespiratory performance ($r = -.712$; $P < 0.016$). In this context, Seiler et al. (2007) concluded that the time course for ANS recovery is linked to the level of training status. Authors found that the return of ANS activity after exercise for < or =120 min at the level of the second ventilatory threshold (~85% VO_2max) occurred within 90 minutes in trained athletes ($VO_2max = 60 \pm 5$ ml min^{-1} kg^{-1}). In highly trained athletes ($VO_2max = 72 \pm 5$ ml min^{-1} kg^{-1}), ANS activity returned to the pre-exercise level within 5–10 minutes. In our study, the values of VO_2peak were within a range from 42.5 to 58.9 ml min^{-1} kg^{-1}. Therefore, there is no surprise that a similar exercise intensity and duration induced a delay of ANS recovery in the amateur athletes compared to elite endurance trained athletes. Nevertheless, an insufficient recovery of ANS after exercise shows itself during orthostatic rather than during clinostatic stimulation.

Our results further show that perceived fatigue was significantly raised up to 24 hours after the finish of the run. There is no relationship between the time course of ANS recovery and perceived fatigue. We suppose that the prolongation of the fatigue or of pain perception could be associated rather with local muscle fatigue, the shortening of hard worked muscle groups of the lower extremities, edemas, and/or post-exercise joint soreness than with changes in ANS regulation. Similarly, Iellamo et al. (1999) concluded that vagal reactivation and its stronger effect on the sinoatrial node leads to afall in HR in the earlier phases of recovery, in spite of the persistent local muscle ischemia.

CONCLUSION

In conclusion, we can state that elevated pre-competitive anxiety induced the sympathetic predominance in autonomic regulation, particularly during orthostatic stimulation. Over the recovery period, vagal activity remained still reduced during orthostasis, while the mean values of standard spectral variables obtained in a lying position achieved a baseline within the 12th hour of the recovery period. The rate of ANS recovery markedly contrasts with fatigue perception which was significantly elevated in the 12th hour as well as in the 24th hour after the finishing of a competition. It stands to reason that the causes of soreness or fatigue do not markedly affect ANS activity during the later phase of recovery.

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HODNOCENÍ AKTIVITY AUTONOMNÍHO NERVOVÉHO SYSTÉMU U REKREAČNÍCH ÚČASTNÍKŮ PŮLMARATONSKÉHO BĚHU

(Souhrn anglického textu)

VÝCHODISKA: Spektrální analýza (SA) variability srdeční frekvence (VSF) je považována za neinvazivní metodu kvantifikace autonomní kardiální regulace sinoatriálního uzlu. Je známo, že autonomní regulace je ovlivňována různými stresory jako například nervozitou nebo tělesnou prací.

CÍL: Cílem předložené studie bylo zhodnotit vliv předstartovního stavu na aktivitu autonomního nervového systému (ANS) a dále pak monitorovat časový průběh zotavení ANS paralelně se subjektivně vnímanou únavou v průběhu 24 hodin od ukončení půlmaratonu u amatérských běžců.

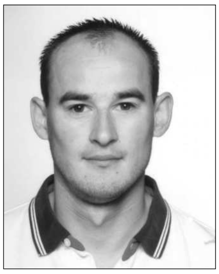
METODY: Autonomní kardiální regulace byla posuzována pomocí metody SA VSF. Aktivita ANS byla hodnocena jeden týden před závodem a v den závodu. Po ukončení závodu proběhla měření aktivity ANS v 1., 12. a 24. hodině. Aktivita ANS byla reprezentována standardními spektrálními parametry a také komplexními indexy SA HRV. K hodnocení velikosti předstartovní nervozity byla využita modifikovaná Likertova 10bodová škála. Subjektivně vnímaná únava byla hodnocena na 6bodové škále.

VÝSLEDKY: Vnímání nervozity bylo signifikantně vyšší v den závodu než týden před závody. Signifikantní pokles komplexního indexu sympatovagové balance v den závodu nepřímo svědčil o vzestupu aktivity sympatiku. Ve 12. ani 24. hodině zotavení se již žádný ze sledovaných parametrů VSF signifikantně nelišil od obou vstupních vyšetření. Subjektivně vnímaná únava zůstala zvýšená ještě 24 hodin od ukončení závodu.

ZÁVĚRY: Naše práce ukázala, že zvýšená předzávodní nervozita vede k převaze sympatiku v autonomní regulaci zejména během orthostatické stimulace. Dále bylo zjištěno, že aktivita ANS se navrátila na předzátěžovou úroveň během 12. hodiny od ukončení závodu. Ukazuje se, že příčiny pocitů bolesti nebo únavy se v průběhu pomalé fáze zotavení do změn aktivity ANS již výrazněji nepromítají.

Klíčová slova: variabilita srdeční frekvence, vyléčení, úzkost pociťovaná před soutěží, cvičení, únava, výkonnost.

PhDr. Michal Botek, Ph.D.



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2003 – Master's degree – Mgr. (Physical Education and Geography), Faculty of Physical Culture, Palacký University, Olomouc.

Scientific orientation

Exercise physiology and its application into the sport events, main research objects: assessment of autonomic nervous system activity by spectral analysis of heart rate variability and its using in various areas for instance: simulated altitude; training dose optimalization; talent identification in sport; quantification of fatigue; jet lag syndrome problematic and/or vagal threshold determination.

First-line publications

Botek, M., Stejskal, P., Krejčí, J., Jakubec, A., & Gába, A. (2010). Vagal threshold determination. Effect of age and gender. *International Journal of Sports Medicine, 31*(11), 768–772.

Botek, M., Stejskal, P., & Klimešová I. (2010). Vliv normobarické hypoxie na aktivitu autonomního nervového systému: pilotní studie. *Medicina Sportiva Bohemica et Slovaca, 19*(4), 191–195.

Botek, M., Stejskal, P., & Svozil, Z. (2009). Autonomous nervous system activity during acclimatization after rapid air travel across time zones: A case study. *Acta Universitatis Palackianae Olomucensis. Gymnica, 39*(2), 13–21.

Botek, M., Stejskal, P., & Neuls, F. (2008). Monitoring of the autonomic nervous system activity during post-marathon recovery by spectral analysis of heart rate variability: A case study. *Medicina Sportiva, 12*(2), 31–35.