RETURN TO PLAY AFTER HEALTH COMPLICATIONS ASSOCIATED WITH INFECTIOUS MONONUCLEOSIS GUIDED ON AUTONOMIC NERVOUS SYSTEM ACTIVITY IN ELITE ATHLETE: A CASE STUDY

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Submitted in January, 2012

BACKGROUND: Infectious mononucleosis (IM) is an acute serious illness which requires among other things an interruption of training. The return to play for athletes after IM is complicated and a long-term process which could result in the relapse of health complications linked fundamentally with the illness.

OBJECTIVE: The aim of this study was to design a convalescence program which leads to an improvement in physical fitness and provides a safe return to play without relapse of health complications for an elite athlete who suffered from IM.

METHODS: The convalescence program lasted almost 3 months. Training load was optimized based on autonomic nervous system (ANS) activity which was assessed by spectral analysis (SA) of heart rate variability (HRV). There were evaluated an individual spectral variables – very low frequency power (P_{VLF}) (0.02–0.05 Hz); low frequency power (P_{LF}) (0.05–0.15 Hz), high frequency power (P_{HF}) (0.15–0.50 Hz), total power (P_T) (0.02–0.50 Hz), ratio P_{VLF}/P_{HF} and P_{LF}/P_{HF}; heart rate (HR), and age-dependent complex index of SA HRV – index of vagal activity, sympathovagal balance, and total score. Further, perceived exertion during exercise and morning fatigue was assessed. Repeated biochemical analysis was focused on the selected transaminase level.

RESULTS: Among recovery periods, an increase in mean of P_T was accompanied by elevation of P_{VLF}/P_{HF} and P_{LF}/P_{HF}. No significant differences in mean values of any complex index of SA HRV among periods were found. A decline in HR was identified during measurements in lying, but mostly in supine. A significant elevation of perceived exertion during exercise occurred between periods. The morning fatigue culminated during the last period. No relationship between subjective feeling of fatigue and complex index of SA HRV was found.

CONCLUSIONS: A convalescence strategy based on assessment of ANS activity brought an improvement in physical fitness, in spite of borderline or mild elevated transaminase level. We suggest that a combination of both non-invasive SA HRV and periodic assessment of biochemical indicators of liver state seems to be a promising strategy for determination of safe application of training load during convalescence after IM.

Keywords: Heart rate variability, fatigue, hepatitis, Epstein-Barr virus, detraining, convalescence.

INTRODUCTION

Infectious mononucleosis (IM) is a disease caused the Epstein-Barr virus which afflicts many athletes each year (Putukian et al., 2008). A conservative way of treatment IM is commonly accompanied by the advice of the restriction of contact sport (Papesch & Watkins, 2001) and/or intestive physical activity and e.g. the diet (Candy, Chalder, Cleare, Wessely, & Hotopf, 2005). However, athletes often rush the return to training and competition participation, and thus risk a relapse of health complications linked with fundamental disease. In literature, there is still a lack of information or ambiguous recommendations how to manage convalescence after IM in term of the suitable start or optimal intensity of exercise. Some authors recommended beginning with low physical activity after two week (Welch & Wheeler, 1986), but also after 8 weeks (Moolenar, Peters, & Bolk, 1988). The consensus from more current literature is that light noncontact activities may commence 3 weeks from symptom onset, but the returning to contact activities is more complicated (Putukian et al., 2008). Moreover, from review of Waninger and Harcke (2005) results that no strong evidence-based information supports use of a single parameter to predict the safe return to sport participation.

Spectral analysis of heart rate variability (SA HRV) is a non-invasive method which enables quantification of autonomic nervous system (ANS) activity which is accepted as sensitive marker of homeostatic disturbances (Aubert, Seps, & Beckert, 2003). It well documented that IM is associated with the prolonged fatigue (Katz, Shiraishi, Mears, Binns, & Tailor, 2009; Rea, Russo, Katon, Ashley, & Buchwald, 2001) that causes an impairment in ANS activity in terms of the reduction in vagal activity and the shift of sympathovagal balance towards sympathetic predominance (Wyller, Barbieri, Thaulow, & Saul, 2008). Impairment in autonomic regulation may induce a decrease in adaptation capacity of athlete that delays a convalescence process. On the other hand, higher ANS activity is linked with better homeostasis regulation which could positively affect physical performance (Pichot et al., 2002).

The main purpose of this study was to design a convalescence program for elite athlete after IM which was based on the maintaining ANS activity in balance via optimization of training intensity using SA HRV.

METHODS

Participants

One elite Czech basketball player after IM volunteered to participate in the present study. He was a non-smoker and during the study he did not use any medication which may affect ANS. Characteristics of the athlete is presented in TABLE 1.

Time frame of health complication and subsequent treatment

An acute cytomegalovirus accompanied with elevation of transaminase level was identified in our subject in January 2010. Athlete underwent a standard treatment (a strictly diet with rest on bed) lasting two months which resulted in an improvement in health status. Thus, he decided for the return to play. Unfortunately, deterioration in health complication associated with the fundamental disease occurred after one month from the return to competition again. The relapse caused another interruption of sport participation including physical activities for next two months when he was still highly fatigued, and frequently suffered by infection of the upper respiratory tract.

Approximately in half of August 2010 began the convalescence program which lasted to the end of the September 2010. Athlete returned for the first time to competition in the 6th of September, and during next month he fully participated in the basketball training and competitions. Particular parts of developed program including both the exercise intensity, and training drills are clearly presented in TABLE 2. During convalescence period athlete repeatedly underwent analysis of alanine amino transferase (ALT) level; aspartat amino transferase (AST) level, and gama glutamyl transferase (GGT) level (TABLE 5).

Experimental design

Before the study started, the participant was closely informed about the study design, and then he submitted written informed consent. Further, athlete underwent preliminary measurements in order to preclude any medical or health limitations to performing the maximal exertion test. Before performing of maximal stress test, athlete underwent basic anthropological measurement

TABLE 1

Basic morphological a physiological characteristics

Parameter [unit]	Age [year]	BMI [kg.m^{-2}]	Body Fat [%]	HRrest [BPM]	HRmax [BPM]	VO_2peak [ml.kg^{-1}.min^{-1}]	MPO [W.kg^{-1}]	BP [torr]
Pre-test	28	21.73	9.1	65	180*	36.8 *	3.4*	128/72
Post-test	28	22.01	7.6	53	177	61.1	7.0	124/79

Legend: HRrest – resting heart rate, HRmax – maximal heart rate, BPM – beat per minute, BP – blood pressure, VO_2peak – peak oxygen uptake, BMI – Body Mass Index, MPO – maximal power output, percentage of body fat was computed from 10 skin fold caliper testing according to Pařízková (1962), * value was achieved during measurement on bicycle

TABLE 2

Characteristics of physical activities and mean exercise intensity during recovery period

Convalescence	1st phase	2nd phase	3rd phase
HR [BPM]	110–125	125–145	145–175
HRmax [%]	61–66	66–77	77–97
Duration [min.]	10–20	30–50	60–90 (120)
Physical activity	Walking (uphill-downhill), swimming, cycling on stationary bicycle, rowing on simulator, easy work out with own body.	Jogging, swimming, cycling, rowing on simulator, moderate work out with own body, athletics training.	Running, work out, swimming, basketball drills, athletics training, circle resistant training.

Legend: HR – heart rate, BPM – beat per minute, HRmax – maximal heart rate, % – percentage, min. – minute and monitoring of resting ANS activity. All measurements were performed between 8 to 10 a.m. Athlete was required to avoid eating and drinking any substance affecting ANS activity for minimally 2 hours before the ANS measurement.

Pre-convalescence maximal stress test was performed on a bicycle ergometer Ergoline 900 in order to establish the peak oxygen uptake (VO_2peak) and maximal heart rate (HRmax). Ventilation and gas exchange were continually analyzed (Oxycon 4, Mijnhardt Holland) during the exercise and were reported as mean for 30 s. Post convalescence maximal stress test was performed on a treadmill (Lode Valliant, Netherlands). Ventilation and gas exchange were continually analyzed (ZAN 600 Ergo USB, Germany) during the exercise and were reported as mean for 30 s. HR responses were monitored (S810 Polar, Finland) continuously during both maximal exercise tests.

ANS activity was measured by the athlete himself after properly training each day in the morning. Electrocardiographic data were continually sampled in a quiet room during a standardized ortho-clinostatic maneuver of lying–standing–lying by system VarCor PF 7 (Salinger & Gwozdziewicz, 2008) which requests for short-term spectral analysis of HRV both 300 R–R intervals and 300 seconds per position. Frequency domain analyses were performed according to the methods described by Salinger et al. (1998). Amplitude density of the collected signal was estimated using the fast Fourier transform method with a partly modified Coarse-Graining Spectral Analyze algorithm (Yamamoto & Hughson, 1991). Power of mean spectral components were calculated by integrating 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. Resting heart rate (HRrest) was computed as a mean for 5 min. in second lying position. The 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). Parameter function age (FA) represents the value of TS which was adjusted into the age. 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).

The aim of the optimizing process was to keep the ANS activity in balance and throughout avoiding long-term reduction in ANS activity due to excess training load. The process starts automatically when the subject finished at least the fifth measurements of ANS activity. Optimizing procedure is based on comparing a magnitude of differences between ANS activity in actual measurement with the mean of ANS activity at least five and maximally twenty previous measurements. In this case, autonomic activity is represented by FA. The tested subject received one of the four possible recommendations – an increase in intensity; preserved actual intensity; reduce intensity and/or temporally interrupt the training. The whole procedure is detailed described in study of Šlachta, Stejskal, and Elfmark (2003).

In all training sessions, HR was controlled by HR Polar 810 monitor (Finland). Immediately after training sessions was evaluated perceived exertion on the 16 points Borg scale. The athlete further assessed the feeling of fatigue each time before the ANS activity measurement. The level of subjective feeling of fatigue ranged from 0 (no fatigue) to 5 (extremely high) point(s). This scale was established only for this project, therefore it was not validated.

Statistical analysis

Data were analysed using software STATISTICA 9.0. The normal Gaussian distribution of the analysed data was verified by the Kolmogorov-Smirnov test. Values of HR, fatigue, and perceived exertion were tested using one-way repeated-measures of ANOVA with Fischer LSD post hoc test. Kruskal-Wallis *H*-test followed by Wilcoxon test (post hoc analysis) was conducted to examine the effect of exercise on complex index of SA HRV. Relationship between selected variables was analyzed by Pearson correlation. In all analysis, $p \leq .05$ was considered to be statistically significant.

RESULTS

TABLE 3 shows that a significant increase in mean P_{VLF}, P_{LF}, P_{HF}, P_T and ratio P_{VLF}/P_{HF} was found in the 2nd and the 3rd period compared to the 1st period in standing position. The mean P_{LF} and P_T significantly increased in the 3rd compared to 2nd period in standing. Mean HR in standing position decreased significantly among periods. In lying position, only P_{VLF} and ratio P_{VLF}/P_{HF} significantly increased in the 2nd compared to the 1st period. The mean P_{VLF}, P_{LF}, P_T and ratio P_{VLF}/P_{HF} and P_{LF}/P_{HF} significantly increased in the 3rd period compared to the 1st period. The ratio P_{LF}/P_{HF} significantly increased also in the 3rd period compared to 2nd period. A significant reduction in mean HR in lying position was investigated only in the last period compared to both previous periods.

TABLE 4 shows that statistical analysis did not find any significant differences in mean values of complex index of SA HRV among periods. A significant increase in mean value of perceived exertion occurred between subsequent periods. The mean value of perceived fatigue was significantly higher only in the 3rd period compared to the 1st period (TABLE 4).

TABLE 3
Statistical analysis of individual variables of SA HRV during convalescence periods

Parameter [unit]	1st period N = 29	2nd period N = 29	3rd period N = 29
S_P_{VLF} [ms²]	60.57 ± 64.06	186.98 ± 102.85*	256.28 ± 152.53 †
S_P_{LF} [ms²]	233.99 ± 150.72	353.34 ± 159.15*	531.50 ± 221.62 † §
S_P_{HF} [ms²]	19.09 ± 12.65	31.97 ± 17.14*	49.21 ± 31.96 †
S_P_{VLF}/P_{HF}	3.62 ± 3.56	7.91 ± 7.36*	6.24 ± 4.62 †
S_P_{LF}/P_{HF}	13.38 ± 5.01	13.49 ± 7.79 NS	13.46 ± 6.85 NS
S_P_{T} [ms²]	313.66 ± 206.97	572.28 ± 220.31*	836.99 ± 329.98 † §
S_HR [BPM]	97.59 ± 7.16	84.11 ± 2.82*	79.19 ± 5.99 † §
L_P_{VLF} [ms²]	310.02 ± 226.19	439.67 ± 275.00*	618.33 ± 428.00 †
L_P_{LF} [ms²]	392.17 ± 242.73	480.77 ± 268.89 NS	939.86 ± 572.20 † §
L_P_{HF} [ms²]	4,125.09 ± 1,371.29	4,389.80 ± 1,272.23 NS	3,966.05 ± 1,252.93 NS
L_P_{VLF}/P_{HF}	0.08 ± 0.07	0.11 ± 0.06*	0.16 ± 0.10 †
L_P_{LF}/P_{HF}	0.11 ± 0.08	0.12 ± 0.08 NS	0.25 ± 0.16 † §
L_P_{T} [ms²]	12,920.14 ± 4,248.69	14,095.80 ± 3,865.08 NS	16,731.56 ± 5,620.09 †
L_HR [BPM]	51.18 ± 4.13	50.22 ± 2.52 NS	48.11 ± 4.06 † §

Legend: S –standing position, L – lying position, P_{VLF} – power very low frequency, P_{LF} – power low frequency, P_{HF} – power high frequency, P_T – total power, HR – heart rate, * – 1st period vs 2nd period, † – 1st period vs 3rd period, § – 2st period vs 3rd period (Kruskal-Wallis *H*-test followed by Wilcoxon test), $P \leq .05$, NS – non significant, values are given as mean ± SE

TABLE 4
Statistical analysis of investigated parameters during different convalescence period

Parameter [unit]	1st period N = 29	2nd period N = 29	3rd period N = 29
TS [points]	0.83 ± 0.54	0.98 ± 0.44 NS	0.86 ± 0.55 NS
VA [points]	0.52 ± 0.51	0.67 ± 0.38 NS	0.62 ± 0.53 NS
SVB [points]	1.40 ± 0.85	1.57 ± 0.84 NS	1.31 ± 0.97 NS
Borg scale [points]	11.12 ± 2.71	13.31 ± 2.29*	14.69 ± 2.16 † §
Fatigue [points]	1.38 ± 0.94	1.59 ± 0.98 NS	2.10 ± 1.01 †

Legend: TS – complex index of total score, VA – complex index of vagal activity, SVB – complex index of sympathovagal balance, $P \leq .05$ (Kruskal-Wallis *H*-test followed by Wilcoxon test), NS – non significant, * – 1st period vs 2nd period, † – 1st period vs 3rd period, § – 2st period vs 3rd period (ANOVA; Fischer LSD post hoc test), $P \leq .05$, NS – non significant, values are given as mean ± SE

TABLE 5
Results of transaminase levels analysis during convalescence and after 3 months

Marker [unit] (RV)	19. 7. 2011	10. 8.	17. 8.	1. 9.	3. 10.	4. 12.	28. 3. 2012
ALT [ukat L^{-1}] (0.15–0.73)	1.10	0.83	0.76	0.83	1.35	1.21	0.76
AST [ukat L^{-1}] (0.04–0.66)	0.59	0.55	0.44	0.50	0.64	0.76	0.50
GGT [ukat L^{-1}] (0.14–0.84)	0.79	0.68	0.64	0.75	0.76	0.72	0.64

Legend: RV – reference value, ALT – alanine amino transferase, AST – aspartat amino transferase, GGT – gama glutamyl transferase, RV – reference values

TABLE 6
Results of Pearson correlation analysis between selected variables (N = 87)

r_p	TS	VA	SVB
Perceived Fatigue	−0.054	0.060	−0.154

Legend: TS – complex index of total score, VA – complex index of vagal activity, SVB – complex index of sympatovagal balance, r_p – Pearson correlation

TABLE 5 shows that the values of ALT were classified as slightly elevated, AST as normal (except for one investigation). All values of GTT were indentified in normal range. An improvement in all parameters occurred after three moths of return to standard training exercise. No relationship between any complex index of SA HRV and morning fatigue was found.

DISCUSSION

The aim of this study was to design a convalescence program for elite athlete after IM which contributes to an improvement of his fitness level and with the safe return to play without relapse of the fundamental disease. Our strategy was based on the optimizing of training load according to the ANS activity by using SA HRV.

The analysis revealed an increase in mean of P_T during both tested position resulting from the increase in ANS activity. A dynamics of parameter P_{HF} which purely reflects vagal activity (Malik, 1995) shows that vagal activity increased in lying, but remained unchanged in supine position. Therefore an increase in P_T was mainly induced by rising of spectral power in slow fluctuations area (P_{VLF} and P_{LF}) which is under influence either of both branches of ANS (Task Force, 1996) or mostly by sympathetic activity (Malliani, Pagani, Lombardi, & Cerruti, 1991). Significant elevation of ratio P_{VLF}/P_{HF} and P_{LF}/P_{HF} during subsequent periods of convalescence could be sign of relative increase in sympathetic activity despite persisted prevailing vagal activity in autonomic cardiac regulation during supine. These changes in autonomic regulation results from the continuously rising training load among periods when the last period was classified as the most intensive. In addition, in this period was investigated significant growth in perceived fatigue. In this context Furlan et al. (1993) reported that trained athletes during peak intensity training showed a resting bradycardia together with high LF values, thus suggesting a more complex neural interaction modulating HR. We suppose that mentioned changes in ANS activity in well trained athlete could be classified positively, because a short recovery will follow by withdrawal of elevated sympathetic activity accompanied with the increase in vagal activity.

Our results further show non-significant changes in index of SA HRV between particular convalescence periods which means only small complex changes in ANS activity. Stejskal, Šlachta, Elfmark, Salinger, and Gaul-Aláčová (2002) supposed that complex index of SA HRV are more sensitive for assessment of discrete changes ANS activity than individual spectral variables, because these indexes includes all age-dependent individual spectral parameters which were sampled in both standing, and supine position. A well-balanced state of ANS was reached via optimization of training load when each negative change in index of SA HRV was followed by the reduction in training load or temporally interruption of training process. On the contrary, positive course of these indexes facilitated a more intensive training, and thereby an enhancement in physical fitness.

Noffsinger (1996) recommended that athletes for first few days of convalescence after IM should listen his or her body, and increase physical activities according to toleration. However, from the performed correlation analysis between ANS activity and morning fatigue in our study, it is evident that an athlete based on his subjective feelings is not able to assess his actual adaptation capacity. Nevertheless, the level of actual adaptation capacities plays an important role in adequate training load determination. Therefore, we inclined to opinion that self-perception of fatigue could be use as a tool for training load determination only in the few first days of convalescence after long lasting disease. However, long-term determination of the training load based on feeling of fatigue could be in this sense a misguided.

An investigation of functional state or size of liver and spleen could be helpful in determination of time frame of the return to play (Putukian et al., 2008; Waninger & Harcke, 2005). In our study, we investigated a border line or mild elevated values of ALT (AST only in one measurement) while liver and spleen had, according to a medical report normal size. From review of Waninger and Harcke (2005) results that there has been no definitive correlation identified between an increase in of the spleen and blood liver/enzyme parameters, and further, no data support the use of serial hematological studies as an indicator of safety return to play. Therefore, we suppose that in given case the dynamics of liver enzymes did not indicate an excessive increase in training load during convalescence periods.

In our study we further found successive decline in HR in supine and mostly in orthostatic stimulation. It is evident that this HR dynamics could be considered as a sign of new adaptation development. Because, two months of training interruption caused detraining which is associated with the partial or complete loss of training-induced anatomical, physiological and performance adaptations (Mujika & Padila, 2001). From dynamics of HR is evident that a time course of cardiovascular adaptation could be controlled both in supine, and during orthostatic stimulation.

Limitations

An absence of control patient group together with only case study report could be considered the main limitation of this study. More research in this field is needed.

CONCLUSIONS

Our study shows that convalescence strategy based on assessment of ANS activity contributed an improvement in physical fitness, in spite of borderline or mild elevated transaminase level. Probably training guided by subjective feeling of fatigue within convalescence after IM could be inaccurate. In conclusion, we suggest that combination of both non-invasive SA HRV method and periodical assessment of biochemical indicators of liver state seems to be a promising strategy for determination of safe application of the training load during convalescence after IM. Finally, SA HRV can be accepted as an auxiliary method in infectious hepatitis patients with borderline biochemical parameters.

ACKNOWLEDGEMENTS

The study has been supported by the research grant from the Ministry of Education, Youth and Sports of the Czech Republic (No. MSM 6198959221) "Physical Activity and Inactivity of the Inhabitants of the Czech Republic in the Context of Behavioral Changes".

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REKONVALESCENCE PO INFEKČNÍ MONONUKLEÓZE ŘÍZENÁ NA ZÁKLADĚ AKTIVITY AUTONOMNÍHO NERVOVÉHO SYSTÉMU U VRCHOLOVÉHO SPORTOVCE: KAZUISTIKA

(Souhrn anglického textu)

VÝCHODISKA: Infekční mononukleóza (InM) je závažné onemocnění vyvolané Epstein-Barr virem, které vyžaduje okamžité přerušení tréninku.

CÍLE: Hlavním cílem naší práce bylo vytvořit optimální rekondiční program pro vrcholového sportovce po recidivě InM, který povede k jeho bezpečnému návratu do vrcholového sportu.

METODIKA: Řízená rekonvalescence trvala téměř tři měsíce. Dávkování zatížení bylo podřízeno aktuální úrovni aktivity autonomního nervového systému (ANS), která byla opakovaně diagnostikována metodou spektrální analýzy variability srdeční frekvence (SA VSF). Hodnoceny byly individuální parametry – spektrální výkon v oblasti velmi nízké frekvence (P_{VLF}) (0,02–0,05 Hz); výkon v oblasti nízké frekvence (P_{LF}) (0,05–0,15 Hz); výkon v oblasti vysoké frekvence (P_{HF}) (0,15–0,50 Hz); celkový spektrální výkon (P_T) (0,02–0,50 Hz); poměry P_{VLF}/P_{HF} a P_{LF}/P_{HF} a srdeční frekvence (SF). Dále byla aktivita ANS posuzována pomocí komplexních indexů SA HRV – indexu vagové aktivity, sympatovagové balance a celkového skóre. V práci bylo hodnoceno i subjektivní vnímání zatížení společně s ranní únavou. Prováděny byly také biochemické analýzy aktivity vybraných jaterních enzymů.

VÝSLEDKY: Během rekonvalescence došlo ke zvýšení průměrné hodnoty P_T, které doprovázelo zvýšení poměru P_{VLF}/P_{HF} a P_{LF}/P_{HF}. Mezi jednotlivými etapami rekonvalescence nedošlo k signifikantním změnám u žádného z komplexních indexů SA HRV. V lehu a především ve stoji byl zaznamenán signifikantní pokles SF. Dále byl během rekonvalescence pozorován signifikantní vzestup subjektivně vnímaného zatížení a v poslední etapě došlo ke kulminaci ranní únavy. Mezi komplexními indexy SA HRV a pocitem ranní únavy nebyl prokázán žádný vztah.

ZÁVĚRY: Rekonvalescence řízená na základě monitoringu aktivity ANS přispěla ke zlepšení kondice, přestože aktivita jaterních enzymů zůstávala hraniční až mírně zvýšená. Dávkování zatížení založené na subjektivním hodnocení únavy v rámci rekonvalescence po InM bude pravděpodobně nepřesné. Proto se domníváme, že neinvazivní metoda SA VSF společně s pravidelnou biochemickou analýzou jaterních enzymů se zdá být slibnou strategií pro stanovení bezpečného zatížení během rekonvalescence po InM, která povede k návratu sportovce do plného zatížení.

Klíčová slova: variabilita srdeční frekvence, únava, hepatitida, Epstein-Barr virus, detrénink, rekonvalescence.

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Education and previous work experience

Since 2007 – Institute of Active Lifestyle (Center of Kinanthropology Research), Faculty of Physical Culture, Palacký University, Olomouc.
2008 – Doctoral degree – PhDr. (Philosophy), Faculty of Physical Culture, Palacký University, Olomouc.
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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

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