AUTONOMIC NERVOUS SYSTEM OBSERVATION THROUGH TO USE OF SPECTRAL ANALYSIS OF HEART RATE VARIABILITY IN ICE HOCKEY PLAYERS

Lukáš Cipryan, Pavel Stejskal, Olga Bartáková, Michal Botek, Hana Cipryanová, Aleš Jakubec, Milan Petr, Iva Řehová

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

Submitted in August, 2007

The aim of our study was to investigate the influence of regular sport training on the activity of the autonomic nervous system (ANS) and to disclose patterns of interrelations between them. The activity of the ANS was evaluated by means of the spectral analysis of heart rate variability (SA HRV). We used complex indices (total score – TS, vagal activity – VA, sympathovagal balance – SVB) and age standardized values of total spectral power (P_T) for SA HRV results evaluation (Stejskal et al., 2002). The study group consisted of four ice hockey players, of whom all were 17 years old. The SA HRV was monitored by using VarCor PF7 hardware and VarCorMulti computer software, which enables four individuals to be measured at the same time. The examination of heart rate variability took place once a week in the morning. Information about the previous day's training load, the duration and quality of sleep, and their self-reported health status (SRH) was also obtained by completing a questionnaire before the SA HRV examination. Overall sports performance was evaluated by the team's coach on a scale of 1 (very poor) to 10 (excellent). The results demonstrated that the player with the highest average TS (0.8) and the highest average P_T (3.22) also showed the most consistent results (SD of TS = 0.74; SD of P_T = 1.02) and objectively the best performance in sport. On the other hand, the player with the lowest average TS (–2.15; SD = 1.42) and the lowest average P_T (–2.52; SD = 1.4) also obtained the lowest average mark in the coach's evaluation of his sports performance. The tendency to progression of the ANS activity was different for each subject. The SRH, which was given before measurements were taken, did not correspond with the results of the SA HRV measurement. We came to the following conclusion: training quality influences the ANS activity and according to changes in the ANS activity we can deduce the athlete's changes in adaptability.

Keywords: Spectral analysis of heart rate variability, sport, ice hockey, training.

INTRODUCTION

Sports performance is determined, among other factors, by the autonomic nervous system's (ANS) activity. A high and balanced level of activity of the sympathetic nervous system (SNS) and the parasympathetic nervous system (PNS) results in better training adaptability and thus also in better sports performance. If both branches of the ANS are out of balance or their activity is reduced for a long time, then the ability to train becomes worse and the sports performance decreases (Aubert et al., 2003; Carter et al., 2003; Stejskal, 2004).

Some studies have concluded that heart rate variability (HRV) can be positively influenced by sports training. Endurance training in particular has a positive effect on an increase in HRV and PNS activity, as well as the accompanying bradycardia (Aubert et al., 2003; Carter et al., 2003). Regular sports training modulates the balance between SNS and PNS (Task Force, 1996). Trained athletes have a higher level of HRV than non trained subjects. The HRV can also play an important role in predicting and detecting overtraining, which can be characterized by an impaired autonomic balance (Achten & Jeukendrup, 2003; Aubert et al., 2003).

Thus, the ANS activity is an important factor influencing sports performance. This is particularly valid in individual sports events in which the result could directly depend on the ANS activity and the balance between both branches. In team sports games, an interpretation of interrelationships between sports performance and the ANS activity is far more complicated. The sports result is not usually based only upon the performance of the individual athlete but also on the very important role played by the interference of many factors (e.g. skill level, teamwork in teammates and opponents, decisions of referees, etc.). However, individual sports training in team games is increasingly emphasized. In addition, the ANS activity evaluation could be used not only in sports training but also in the selection of promising players and the choice of which positions they will play.

The HRV can be evaluated by means of many methods (Task Force, 1996). Spectral analysis of heart rate variability (SA HRV), which can be classified as frequency domain analysis, enables researchers to quantify the activity of the ANS quickly and easily (Stejskal & Salinger, 1996). Three main spectral components are distinguished in a spectrum calculated from short term recordings: very low frequency (VLF), low frequency (LF), and high frequency (HF). All these components are influenced by particular physiological mechanisms, which enable researchers to determine directly or indirectly the activity and balance of the SNS and PNS (Stejskal & Salinger, 1996; Task Force, 1996). The results of the SA HRV can be interpreted more sensitively by means of complex indices (Stejskal et al., 2002). In sports practice, the changes in complex indices allow researchers to appropriately adjust a training load to the athlete's actual readiness for practice and also restrict the risk of overtraining. The result should be the maximal development of abilities and the improvement of sport performance. This way of optimizing the training load is based on repeated SA HRV measurements through which the optimal range of the total score (TS) is determined. All following SA HRV examinations are related to this range and the training load is recommended. The changes in sympathetic and parasympathetic activity are evaluated in the crosswise graph, where the complex indices VA (vagal activity) and SVB (sympathovagal balance) are projected (Stejskal et al., 2002; Stejskal, 2004).

This study is the first step towards using longitudinal measurements of the HRV in ice hockey. The aim of the study is to assess development of the ANS activity during the sports season and its possible relationship to sports performance.

METHODS

The study group comprised four ice hockey players, all were 17 years old. We obtained the values of the complex indices (total score – TS, vagal activity – VA, sympathovagal balance – SVB) and age standardized values of total spectral power (P_T) (Stejskal et al., 2002) by examining the SA HRV. For the measurement of the SA HRV and the data evaluation of the SA HRV we used the VarCor PF7 (Salinger et al., 2006) and VarCorMulti computer software (unpublished), which enables four subjects to be measured at the same time. We used orthoclinostatic stimulation (supine – standing – supine), which was described in a previous study (Šlachta et al., 2002). Each measurement took place in the morning, undisturbed in a quiet room. The condition of the ANS was monitored mostly once a week. Three players were measured for a period of five months, one player for three months. For each examination of the SA HRV, the subjects completed a questionnaire about their previous day's training load (RPE scale; Borg, 1970; Borg & Kaijser, 2006), the duration and quality of sleep, and their self-reported health status (SRH) (on a scale 1 = very poor, 10 = excellent). This state was characterized by complete physical and mental well being. The team coach evaluated game performance every week in which the team played a match, and the SA HRV was also measured. We used a simple scale from 1 to 10 (1 = very bad, 10 = excellent).

The data was statistically evaluated by Microsoft® Office Excel 2003 computer software.

RESULTS

A total of 72 measurements of the SA HRV were obtained: 21 from player A, 19 from player B, 20 from player C, and 11 from player D. Average values of the TS and the P_T are shown on TABLE 1. Players A, B, and C were measured in the period from 09/26/2006 to 02/27/2007 and player D in the period from 11/21/2006 to 02/27/2007. The head coach also evaluated actual game performance (scale 1 = very bad, 10 = excellent). The average values are also shown on TABLE 1.

TABLE 1
Total score (TS), total spectral power (P_T), and average mark of game performance

	Number of measuring	TS		P_T		GP
		$\bar{x}$	SD	$\bar{x}$	SD	
Player A	21	−1.41	1.42	−0.81	2.56	7.0
Player B	19	0.80	0.74	3.22	1.02	6.1
Player C	20	−2.15	1.42	−2.52	1.40	5.9
Player D	11	−0.75	0.95	1.69	1.38	6.3

Legend
$\bar{x}$ – average
SD – standard deviation
GP – average mark of game performance by coach

The ANS activity developed differently for each player during the study. TS and P_T increased significantly from the 11th SA HRV measurement for player A. His game performance, as evaluated by the coach, decreased slightly and reached an average score of 7.0. Player B achieved the highest values of TS and P_T in the long term. These values were also the most consistent. The coach evaluated this player with an average score of 6.1, which was the 3rd highest. For the player C, the progression of the TS and P_T formed a wave pattern. From around the 14th or 15th SA HRV measurement, the values of the TS and P_T increased gradually, and this was accompanied by increased evaluation scores for game performance. The progression of P_T for player D had a tendency to increase constantly, but the value of TS was stable at the beginning. The evaluation of game performance was between a score of 6 and 8. Between the 8th and 9th SA HRV measurement, the value of P_T decreased significantly but temporarily. At the same time, the score for game performance became distinctively worse. After that, the value of P_T increased again, but the value of TS and game performance decreased. All the TS and P_T values are shown on TABLE 2.

TABLE 2
Total score (TS) and total spectral power (P_T) for each player

Player A		Player B		Player C		Player D	
TS	P_T	TS	P_T	TS	P_T	TS	P_T
−2.15	−3.46	1.34	3.84	−1.70	−3.90	−1.50	−1.34
−4.41	−4.41	0.47	2.03	−4.47	−4.47	−1.45	−0.66
−1.46	0.02	−0.49	3.84	−2.95	−3.08	−0.82	1.61
−0.65	0.66	0.38	3.40	−0.76	−0.60	−1.19	1.89
−2.21	−0.30	0.51	3.39	−1.41	−3.08	−0.62	0.21
−3.27	−3.14	1.64	3.62	−1.42	−1.68	−1.56	2.34
−1.58	−1.34	−0.38	4.74	−0.41	−0.01	−1.18	3.00
−4.07	−4.07	0.93	3.98	−2.31	−2.79	−1.17	3.95
−1.63	−3.52	1.26	2.82	−4.62	−4.62	1.59	1.26
−3.47	−2.40	1.32	3.14	0.01	−1.86	0.61	2.77
−2.21	−3.92	−0.19	0.31	−2.73	−3.09	−0.96	3.56
−0.01	1.15	2.35	2.57	−1.26	−0.03		
0.13	−0.18	1.58	2.91	−4.41	−4.41		
−0.30	3.24	0.60	3.47	−3.66	−2.61		
−0.92	1.82	1.02	3.26	−1.66	−3.25		
0.21	1.77	1.06	4.59	−3.33	−2.99		
−0.13	3.87	1.39	2.81	−0.37	−2.91		
−0.72	2.21	0.41	2.10	−2.92	−2.56		
−0.30	−3.19	0.05	4.34	−1.58	−2.52		
−0.14	−2.97			−1.05	−0.01		
−0.29	1.26						

Part of the questionnaire completed by the players before every SA HRV measurement, was the SRH. The correlation of this evaluation and the results of the SA HRV showed that the subjective evaluation and the ANS activity did not relate to one another.

TABLE 3
Dependence of the total score for the SRH before SA HRV measurement

Correlation coefficient ($p < 0.05$)	
Player A	−0.063
Player B	0.049
Player C	0.015
Player D	−0.005

Legend
p – significant level

DISCUSSION

The results of our study confirm that the ANS activity is an important factor which influences sports performance. Player B, who achieved the highest values of TS and P_T, was in a line up for nine games with the Czech ice hockey team U18 during the period in which the SA HRV measurements were taken. Although his average mark for game performance was only 6.1, we can say that this player achieved the best sports success. Repeatedly, his SA HRV results were above average and also relatively stable. This means that his ANS is able to respond to training loads very effectively. Thus, this player has the potential to succeed in professional sports.

Player D achieved the second best SA HRV results. He was also in the line up for two games with the Czech ice hockey team U18 during the period of the SA HRV measurements. The progression of TS and P_T values was similar to the progression of game performance. TS did not noticeably change at the beginning and P_T increased gradually. TS and P_T changed notably from the 8th SA HRV measurement onwards. These differences were followed by changes in game performance. Objective information about the current condition of the ANS obtained by SA HRV measurement was supported by the coach's opinion about the player's game performance.

Player A achieved the best average score for game performance. His SA HRV results were below average until the 11th SA HRV measurement and were mostly in the lower left quadrant of the crosswise graph (Stejskal, 2004). This indicates a relevant decrease in the ANS activity and an imbalance between both subsystems. A position in the lower left quadrant can be a marker of overreaching due to high training intensity and insufficient recovery. TS and P_T values increased significantly from the 11th SA HRV measurement. Since then the appraisals for game performance had started to become relatively high. P_T decreased meaningfully at the 19th and 20th SA HRV measurements, and this fact was noticed by the coach as a decline in game performance. This variation in P_T value and game performance was only temporary.

From the long term aspect, the lowest ANS activity has been shown in player C. Occasional positive changes in TS and P_T values were rather short term and came only after several days without training or reduction in a training load. Thus, we presume that the recovery of player C is considerably slower and his ability to cope with the training load is lower than in players A, B, and D. He also obtained the lowest average mark of game performance by the coach, and he was not always in the line up for league games. The P_T values increased slightly from the 14th SA HRV measurement and the TS also had a tendency to increase. We claim that these changes were accompanied by an improvement in game performance.

SA HRV measurement is used to optimize the training load in individual athletes. In team games, where athletes practice in large groups, the use of the SA HRV measurement is limited. Sports performance in games depends on a great number of abilities, which fade into one another and compensate for each other. We can find significant differences in abilities among players at the same performance level, because these abilities influence the sports performance of each player differently. From this point of view, the measurement of the ANS activity can not lead to the sports performance prediction or training program modification, because the ANS activity is a result of effects of many factors. Because the SA HRV indicates the immediate ANS activity and also its progression during long term measurement, we can use the SA HRV for the assessment of the athlete's adaptability on the dominating influences. Since the permanent decline of the ANS activity practically negates a good sports performance (it is expression of reduced athlete's adaptability), it is possible to include the SA HRV measurement in training control even in ice hockey or other games.

Results of SA HRV measurement, namely the TS, did not relate to the SRH before examination. Subjective feelings about readiness for training load may not correspond with the current ANS activity. Therefore, objective information about the ANS activity can be a very effective instrument in the optimizing of a training program.

CONCLUSION

Training quality influences the ANS activity and according to these changes we can judge changes to an athlete's adaptability, which can significantly influence sports performance. Thus, the optimizing of the adaptation process via control of training load based on the SA HRV measurement may bring some new aspects to sports training.

REFERENCES

Achten, J., & Jeukendrup, A. E. (2003). Heart rate monitoring: Applications and limitations. *Sports Medicine, 33(7),* 517–538.

Aubert, A. E., Seps, B., & Beckers, F. (2003). Heart rate variability in athletes. *Sports Medicine, 33(12),* 889–919.

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation and Medicine, 2,* 92–98.

Borg, E., & Kaijser, L. (2006). A comparison between three rating scales for perceived exertion and two different work tests. *Scandinavian Journal of Medicine and Science in Sports, 16(1),* 57–69.

Carter, J. B., Banister, E. W., & Blaber, A. P. (2003). Effect of endurance exercise on autonomic control of heart rate. *Sports Medicine, 33(1),* 33–46.

Salinger, J., Štěpaník, P., Krejčí, J., & Stejskal, P. (2006). Non invasive investigation of the function of the autonomic nervous system with the use of the VarCor PF7 system. In Z. Borysiuk (Ed.), *5th International conference Movement and Health: Proceedings* (pp. 486–493). Opole: Opole University of Technology.

Stejskal, P. (2004). Využití nové metodiky hodnocení SA HRV pomocí komplexních indexů v klinické a sportovní praxi. In J. Salinger (Ed.), *Variabilita srdeční frekvence a její hodnocení v biomedicínských oborech – od teorie ke klinické praxi* (pp. 105–116). Olomouc: Univerzita Palackého.

Stejskal, P., & Salinger, J. (1996). Spektrální analýza variability srdeční frekvence: základy metodiky a literární přehled o jejím klinickém využití. *Medicina Sportiva Bohemica & Slovaca, 2,* 33–42.

Stejskal, P., Šlachta, R., Elfmark, M., Salinger, J., & Gaul-Aláčová, P. (2002). Spectral analysis of heart rate variability: New evaluation method. *Acta Universitatis Palackianae Olomucensis. Gymnica, 32(2),* 13–18.

Šlachta, R., Stejskal, P., & Elfmark, M. (2002). Age and heart rate variability. *Acta Universitatis Palackianae Olomucensis. Gymnica, 32(1),* 59–67.

Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology (1996). Heart rate variability: Standards of measurement, physiological interpretation, and clinical use. *Circulation, 93(5),* 1043–1065.

POZOROVÁNÍ AKTIVITY AUTONOMNÍHO NERVOVÉHO SYSTÉMU PROSTŘEDNICTVÍM SPEKTRÁLNÍ ANALÝZY VARIABILITY SRDEČNÍ FREKVENCE U HRÁČŮ LEDNÍHO HOKEJE

(Souhrn anglického textu)

Cílem studie bylo poodhalit vliv pravidelného sportovního tréninku na aktivitu autonomního nervového systému (ANS), která byla hodnocena pomocí spektrální analýzy variability srdeční frekvence (SA HRV). K vyhodnocení výsledků SA HRV byly použity komplexní indexy (celkové skóre – TS, aktivita vagu – VA, sympatovagová balance – SVB) a věkově standardizovaná hodnota celkového spektrálního výkonu (P_T) (Stejskal et al., 2002). Výzkumný soubor tvořili čtyři hráči ledního hokeje.

Na základě získaných výsledků jsme došli k závěru, že kvalita sportovního tréninku ovlivňuje aktivitu ANS. Změny aktivity ANS, a tím velikosti adaptability sportovce, mohou významně ovlivnit sportovní výkon. Optimalizace adaptačních procesů prostřednictvím kontroly tréninkového zatížení na základě měření SA HRV může přinést nové aspekty řízení sportovního tréninku.

Klíčová slova: spektrální analýza variability srdeční frekvence, sport, lední hokej, trénink.

Contact
Mgr. Lukáš Cipryan
lukas.cipryan@seznam.cz