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INDIVIDUAL TRAINING IN TEAM SPORTS BASED ON AUTONOMIC NERVOUS SYSTEM ACTIVITY ASSESSMENTS

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Abstract

The aim of this study was to present inter-individual differences in the reaction of autonomic nervous system (ANS) activity to the same training program, and to thereby support the importance of individual training in team sports during the conditioning period.

Methods: 18 ice hockey players, separated into two groups, were tested. The first group (S1) was composed of 8 players (age 18.0 ± 0.7 years) of a junior ice hockey team. The second group (S2) consisted of 10 players (age 26.7 ± 3.8 years) who were members of an adult ice hockey team. The spectral analysis of heart rate variability (SA HRV) in the orthoclinostatic stimulation was used for the ANS activity assessment. The results of the SA HRV examinations were interpreted by the complex index of the total score (TS), the complex index of vagal activity (VA), the complex index of sympathovagal balance (SVB) and the age-standardized values of the total spectral power (P_T) [1]. The SA HRV examination took place regularly twice a week over two months of conditioning.

Results: The SA HRV monitoring mostly revealed significant differences in the level of the ANS activity among the players. A number of junior and adult players (P6, P9, P15, and P16) were characterized by almost permanently high ANS activity whereas other players (P4 and P12) occurred below the ANS activity level of healthy individuals.

Conclusion: Based on the evidence of relevant differences in ANS activity, the training efficiency (overreaching and injury reduction) can be positively influenced by creating training groups of players with similar ANS activity. In this sense the coach can make a training program easier if the team consists of players with high ANS activity. Consequently, constructing a sports team based on ANS activity monitoring could play a significant role.

Key words: *heart rate variability, conditioning, overtraining, performance*

Introduction

There are a number of factors which can influence performance in team sports. Particular mention should be made of skills and abilities along with the psychological and psychosocial factors of the individual members of a team. Since team cooperation is one of the most important, it is logical that the team must train together. There are some disadvantages, however, to this manner of organizing the training process. The training load should fit the needs of the majority of players and therefore a number of mistakes can arise when creating the training program.

There are several principles that can be applied to all forms of sports training. One of them is the principle of individuality. Each athlete has a different ability to respond to an acute exercise bout and the capacity to adapt to exercise training. Genetic background plays a major role, with there being individual variations in cellular growth rates, metabolism, cardiovascular and respiratory changes, and neural and endocrine regulation. This is the explanation why certain athletes show major improvement after participating in a given program whereas others experience little or even abient changes after following the same program. What works for one athlete might not work for another.

Another principle of a well-designed training program emphasizes the progressive overload. Since the body adapts to the current training stimulus, the training load must be progressively increased. When this concept is carried too far, the body is pushed beyond its ability to adapt and one can not expect any conditioning or performance improvement. It can even lead to performance decrements. Conversely, if the training stimulus is too low, an optimal performance will not be achieved [2].

Heart rate variability (HRV) is the conventionally accepted term for describing oscillation in consecutive RR intervals of cardiac cycles [3, 4]. The cardiovascular system is mostly controlled by autonomic regulation through the activity of sympathetic and parasympathetic pathways of the autonomic nervous system (ANS). Spectral analysis of HRV (SA HRV) permits insight in this control mechanism and its parameters represent the autonomic reaction to the visceral afferent signal [5]. SA HRV is considered a valuable non-invasive tool for the evaluation of parasympathetic activity and sympatho-parasympathetic balance changes [6] and for the investigation of reflex mechanisms of cardiovascular regulation after sports training for detraining and overreaching [7]. Aerobic training enhances the cardiovascular autonomic control without change in the sympatho-vagal balance. Autonomic adaptations induced by the sports training decrease as early as the second week training cessation, to stabilize afterwards [8].

Autonomic nervous system (ANS) activity is an important factor which influences sports performance. High and balanced activity between the sympathetic and parasympathetic nerve system describes the high adaptation capacity of the human body. In this case an athlete is able to deal with all external stress factors including the training load more effectively and faster. If the balance between both ANS subsystems is disturbed, or the ANS activity declines for a longer period (the negative change in autonomic reflex mechanism of cardiovascular regulation, respectively), the adaptation capacity decreases along with long-term performance [1, 9, 10]. SA HRV monitoring makes an understanding of the interrelations between the systemic regulation of homoeostasis and the training load possible.

The aim of this work was to supply information on the pertinence and importance of individual sports training based on measurements of ANS activity over two months of conditioning of ice hockey players. There is also a presentation of possible means for employment of SA HRV in team sports.

Materials and methods

The study group consisted of 18 ice hockey players, which were divided into two groups. The first group (S1) consisted of junior ice hockey players (n = 8; age 18.0 ± 0.7 years), the second group (S2) was composed of adult players (n = 10; age 26.7 ± 3.8 years). The reason for the separation of the study group was the different age and belonging to different ice hockey team (junior and adult). These two subgroups practised separately and underwent a different training program. They were without any acute health disorders at the time of the measurements.

The VarCor PF7 and VarCorMulti (unpublished) or VarCorSport PC computer software were used for the SA HRV measurement and the data evaluation [11, 12]. This device and computer software was developed in the Department of Biomechanics and Engineering Cybernetics at the Faculty of Physical Culture of Palacky University in Olomouc.

All the monitored athletes participated in the repeated SA HRV monitoring twice a week (Monday, Friday) for the entire two-month conditioning phase. The SA HRV measurements were always performed in the morning. All disturbances were eliminated during the SA HRV measurement. The short-term recording of RR intervals for the HRV evaluation was obtained under orthoclinostatic stimulation, which consisted of three parts: supine – standing – supine. The position change was active. Each part lasted at least 300 seconds and 300 heart beats. The players also received instructions to avoid any intensive physical activity, caffeine drinks and eating before the SA HRV measurement.

Table 1. *The complex index of total score (point) in group S1*

	P1	P2	P3	P4	P5	P6	P7	P8
$\overline{x}$	-0.61	0.12	-0.57	-3.02	1.03	1.52	-1.01	-0.54
SD	1.37	0.59	0.87	1.63	1.33	0.73	1.97	0.58
>NR (%)	0.0	0.0	0.0	0.0	36.4	40.0	0.0	0.0
NR (%)	73.3	100	86.7	40.0	63.6	60.0	66.7	100
<NR (%)	26.7	0.0	13.3	60.0	0.0	0.0	31.3	0.0

Table 2. *The complex index of total score (point) in group S2*

	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
$\overline{x}$	3.02	0.75	-0.04	-4.00	0.68	1.31	1.85	2.14	0.39	1.06
SD	0.87	0.63	1.38	1.72	1.18	0.70	0.69	0.65	0.72	0.86
>NR (%)	85.7	13.3	6.7	0.0	28.6	46.1	80.0	78.6	0.0	33.3
NR (%)	14.3	86.7	86.6	13.3	71.4	53.9	20.0	21.4	100	66.7
<NR (%)	0.0	0.0	6.7	86.7	0.0	0.0	0.0	0.0	0.0	0.0

Legend for Tables 1 and 2: P1-18 – player, $\overline{x}$– arithmetic mean, SD – standard deviation, >NR (%) – the relative number of values above the normal range (> +1,5 point); NR (%) – the relative number of values in the normal range (-1.5 to +1.5 point); <NR (%) – the relative number of values below the normal range (< -1.5 point).

Table 3. *The complex index of vagal activity (point) in group S1*

	P1	P2	P3	P4	P5	P6	P7	P8
$\overline{x}$	-0.62	-0.82	-0.44	-2.46	1.67	2.01	-0.70	-0.80
SD	0.75	0.58	0.83	0.82	1.24	0.57	1.36	0.63
>NR (%)	0.0	0.0	0.0	0.0	45.5	53.3	0.0	0.0
NR (%)	100	100	100	26.7	54.5	46.7	75.0	100
<NR (%)	0.0	0.0	0.0	73.3	0.0	0.0	25.0	0.0

Table 4. *The complex index of vagal activity (point) in group S2*

	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
$\overline{x}$	2.82	0.76	-1.21	-2.79	0.52	0.84	1.70	1.85	0.71	0.82
SD	0.71	0.70	0.93	0.79	1.01	0.80	0.63	0.54	0.83	0.91
>NR (%)	92.9	13.3	0.0	0.0	7.1	15.4	26.7	35.7	0.0	11.1
NR (%)	7.1	86.7	93.3	6.7	92.9	84.6	73.3	64.3	100	88.9
<NR (%)	0.0	0.0	6.7	93.3	0.0	0.0	0.0	0.0	0.0	0.0

Table 5. *The complex index of sympathovagal balance (point) in group S1*

	P1	P2	P3	P4	P5	P6	P7	P8
$\overline{x}$	0.09	1.90	-0.82	-0.77	-0.19	0.60	-0.39	-0.05
SD	1.60	1.07	1.09	1.24	1.59	1.31	1.35	1.24
>NR (%)	20.0	56.2	0.0	0.0	9.1	20.0	6.2	0.0
NR (%)	66.7	43.8	86.7	73.3	81.8	80.0	81.3	93.3
<NR (%)	13.3	0.0	13.3	26.7	9.1	0.0	12.5	6.7

Table 6. *The complex index of sympathovagal balance (point) in group S2*

	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
$\overline{x}$	3.40	0.72	2.80	-0.47	0.98	2.19	2.13	2.70	-0.21	1.52
SD	1.51	1.02	0.68	1.52	1.60	0.92	1.29	1.01	1.07	0.98
>NR (%)	85.7	13.3	80.0	6.7	21.4	61.5	60.0	71.4	0.0	22.2
NR (%)	14.3	86.7	20.0	80.0	71.4	38.5	40.0	28.6	92.9	77.8
<NR (%)	0.0	0.0	0.0	13.3	7.2	0.0	0.0	0.0	7.1	0.0

Legend for Tables 3-6: P1-18 – player, $\overline{x}$ – arithmetic mean, SD – standard deviation, >NR (%) – the relative number of values above the normal range (> +2.0 points); NR (%) – the relative number of values in the normal range (-2.0 to +2.0 points); <NR (%) – the relative number of values below the normal range (< -2.0 points).

Table 7. *The age-standardized values of the total spectral power (point) in group S1*

	P1	P2	P3	P4	P5	P6	P7	P8
$\overline{x}$	-2.11	0.65	1.26	-3.56	1.07	4.44	-0.12	0.23
SD	1.39	1.14	1.37	1.26	1.68	0.53	3.03	1.19
>NR (%)	0.0	6.2	13.3	0.0	18.2	100	25.0	6.7
NR (%)	53.3	93.8	86.7	13.3	81.8	0.0	50.0	93.3
<NR (%)	46.7	0.0	0.0	86.7	0.0	0.0	25.0	0.0

Table 8. *The age-standardized values of the total spectral power (point) in group S2*

	P9	P10	P11	P12	P13	P14	P15	P16	P17	P18
$\overline{x}$	4.11	2.89	-1.95	-4.09	2.01	1.94	3.95	4.59	3.11	2.74
SD	0.40	1.05	1.42	1.82	1.62	1.63	0.84	0.36	1.01	1.91
>NR (%)	100	46.7	0.0	0.0	50.0	38.5	93.3	100	78.6	77.8
NR (%)	0.0	53.3	66.7	13.3	50.0	61.5	6.7	0.0	21.4	22.2
<NR (%)	0.0	0.0	33.3	86.7	0.0	0.0	0.0	0.0	0.0	0.0

Legend for Tables 7 and 8: P1-18 – player, $\bar{x}$ – arithmetic mean, SD – standard deviation, >NR (%) – the relative number of values above the normal range (> +2.5 points); NR (%) – the relative number of values in the normal range (-2.5 to +2.5 points); <NR (%) – the relative number of values below the normal range (< -2.5 points).

The complex indices (total score - TS, complex index of vagal activity - VA, complex index of sympathovagal balance - SVB) and age-standardized values of the total spectral power (P_T) [13] were obtained from the SA HRV measurement. These indices were employed for the ANS activity evaluation. The authors based their method on the hypothesis that a disorder or aging effect the ANS activity negatively and the SA HRV parameters, which decrease with disorder, aging or exercise intensity, can be assessed as "positive" parameters. The opposite trend characterises the "negative" SA HRV parameters. The complex indices VA and SVB were established on the basis of the integration of SA HRV parameters with the same trend. The third complex index is TS, which associates all the age-dependent SA HRV parameters. The normal range of TS is between -1.5 and +1.5 points. The complex index VA consists of all parameters, the values of which decrease along with increasing age and exercise intensity. The complex index SVB is the indicator of sympathovagal balance and consists of all parameters, the values of which increase along with increasing age and exercise intensity. The normal range of VA and SVB is from -2.0 to + 2.0 points and the normal range of P_T is from -2.5 to +2.5 points [1]. The TS increment in repeated SA HRV measuring is evaluated as the ANS activity increases, the VA increment as vagal activity increase and the SVB increment as a progress of ANS activity toward vagal activity [14]. The ANS activity was assessed by means of changes in the TS over the monitored period. The other indices (VA, SVB, and P_T) supplemented the acquired information in term of the vagal activity and sympathovagal balance. The SD values describe the stability of the indices (Tables 3-8).

The changes in autonomic cardiac regulation were identified during the monitored period according to the complex indeces and P_T examination.

Statistics

The data was statistically analyzed by Microsoft® Office Excel 2003 and STATISTICA 6.0 computer software. The arithmetic mean ($\bar{x}$) and standard deviation (SD) for each complex index and P_T obtained from repeated SA HRV measurements were used for statistical analysis. The NR (%) parameter shows the relative number of values of the complex indices and P_T in the normal range (see above), >NR (%) and <NR (%) parameters present the relative number of these values above or below the normal range.

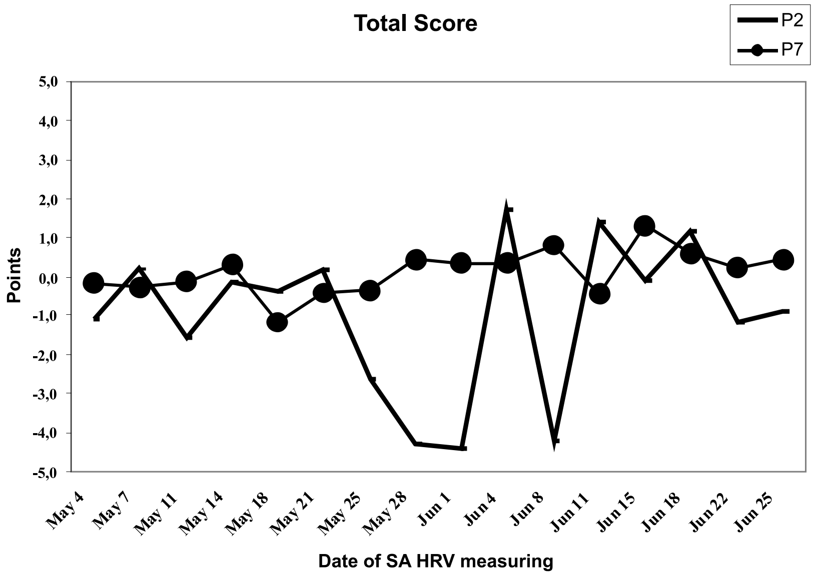

Figure 1. *Two players (P2 and P7) with different Total Score stability*

Results

The total number of SA HRV measurements in each individual was different (average 14.18; SD 1.72). The least number of SA HRV measurements (nine) was accomplished in player 18 (P18), who became injured during the conditioning phase. The highest number of SA HRV measurements was 16. The average values and standard deviation values (SD) of the complex indices and P_T are shown in Tables 1-8. These tables also indicate the relative number (%) of SA HRV measurements inside or outside the normal range.

The Figure 1 shows the example of two players from the same group (S1) with significantly different stability of TS. These two players underwent the same training program.

Discussion

The training intensity in individual sports can be controlled in a feedback manner in order to maintain optimal ANS activity, which responds to an athlete's capability [14]. At present, it is not possible in team sports because the athletes spend most of the time performing the same training activity. The training intensity can be too low for some of them and too high for others. Consequently, a number of athletes are trained inadequately and their performance does not respond to their abilities and talent.

This situation can also be observed in the monitored group of ice hockey players. There is a different level of ANS activity in each individual even if the training load was the same for each group. These inter- and intra-individual differences in the indices of SA HRV should be considered during the training process (also see Fig 1). Numerous factors can influence these differences. The most important include heredity [15, 16], type and severity of exercise [17], adequate recovery [18, 19], psychosocial stress [20, 21], and lifestyle.

The SA HRV results with junior players (S1) show above-average adaptation capacity in players P5 and P6 (mean TS 1.03 and 1.52 points). These players were able to endure a much more intensive training load during the monitored period from the ANS activity point of view. Conversely, player P4 (mean TS -3.02 points) needed an entirely different training program, because the SA HRV results obviously showed, in 60 % of the measurements, the low ANS activity with a risk of overreaching.

A similar situation occurred in the group of adult players (S2). Three players (P9, P15 and P16, mean TS 3.02, 1.85 and 2.14 points) recovered adequately in approximately 80 % of the SA HRV measurements and were ready to endure a more intensive training load. Due to the fact that the training program did not change at all, it can be said that their relatively higher adaptation capacity was not utilized and consequently the training was not optimal. An advisable training modification could lead to performance improvement in these players. The SA HRV results at the opposite side of the evaluating scale were repeatedly measured in player P12 (mean TS -4.00 points). The ANS activity could not increase because the training program did not conform to the SA HRV results. The low level of ANS activity was manifested in the worse results of the laboratory exercise testing (not presented) at the end of the monitored period. There was also a higher risk of more frequent health complications.

It is obvious, that the training of these four players was not optimal with the possibility that their sport performance was negatively influenced. The SA HRV results of other players from this group, however, (P10, P11, P13, P14, P17, and P18) were mostly in the normal range. This means that the training program was adequate for most players (60 %) on the team.

The object of this study was not the feedback use of SA HRV into the control of training process even if we mentioned this hypothetic possibility. However, according to the SA HRV and maximal exercise test results, a coach could increase the effect of the training program by forming groups of players with a similar adaptation capacity. Two subgroups, for example, could be made in group S2 based on the repeated SA HRV measurement. The first subgroup of six players with the 'normal' SA HRV results could train in a similar manner as during the monitored period. The second subgroup of players with high TS values could train more intensively or the training program could be supplemented by additional individual training. The player with persistent low ANS activity should leave the team temporarily and try to optimize the adaptation capacity by training intensity reduction and improved recovery. This training modification would respond to the abilities of individuals and could lead to performance improvement in group S2.

The high ANS activity of most players on the team is the desired state for the coach. Under these conditions the training intensity would be high and its optimizing easier. Therefore SA HRV can be applied in talent seeking and also in building the right team structure.

On the basis of evidence that individuals with a high level of ANS activity are more resistant to certain external stress (including the training load) [14], one can detect suitable players for elite sports at his / her adolescent age. At present the demands are very high in terms of physical and mental resistance for elite sports. Talented players sometimes have to discontinue their participation in sport because of repeated illness or injuries. This fact is confirmed indirectly by the difference in ANS activity between groups S1 (mean TS -0.39, SD 1.29) and S2 (mean TS 0.72, SD 1.79). The higher average ANS activity in the adult team can be partly explained by the other selection level and also by the more demanding competition typical for professional sport. Therefore the more resistant players with higher ANS activity gradually assert more. This hypothesis could be confirmed or rejected through comparison of ANS activity and training quality between a professional sports team and an amateur sports team with a significantly lower performance.

Coaches can evaluate the effect of a training program according to periodic SA HRV examinations. For example, if the ANS activity decreases along with the adaptation capacity, performance deterioration can be expected. Coaches should consider changes to the training program, especially training intensity decreases and improving the recovery process. If the ANS activity increases, however, in most players, it is possible to use a more demanding training load. The training adaptability and performance could become better.

It is a particularly difficult situation when a team suddenly loses several games in a row. A coach must choose a correct intervention which will serve to bring the team back to a higher level of sports performance. As a first step the coach should analyze the possible reasons with SA HRV being a particularly useful tool which can confirm or negate the overreaching (quite rarely overtraining) of players. In the first case a decrease in the training load until the pronounced increase in the ANS activity of the majority of the players can be recommended.

Finally, SA HRV measurements could be used in individual and team sports for well-timed returns to a training load after an illness or injury.

Conclusion

In this work, making use of an ice hockey example, there is a discussion about the possibilities for employing SA HRV results in team sports. In regards to the relevant ANS activity differences in each individual, it is obvious, that the training efficiency can be positively influenced by separating the players into training groups based upon ANS activity. From this point of view it is easier to lead the training process in the team where the majority of players have high ANS activity. Consequently, the SA HRV can be used in talent seeking and building a team. SA HRV can also be used for overreaching prevention and optimizing rehabilitation after injuries.

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