VOLLEYBALL PLAYERS TRAINING INTENSITY MONITORING THROUGH THE USE OF SPECTRAL ANALYSIS OF HEART RATE VARIABILITY DURING A TRAINING MICROCYCLE

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BACKGROUND: Volleyball players in different specializations are required to meet specific demands in terms of movement behaviour and skills performance. These specific demands need to be individualized according to the training ability level (adaptability to sports training) of particular players, which is mainly dependent on the activity of the autonomic nervous system (ANS). Spectral analysis of heart rate variability (SA HRV) gives us information on cardiac activity regulation, where the activity of ANS participates in a significant way. Longitudinal assessment of SA HRV within a certain part of a training period can help us to observe the dynamics of the ANS activity and adaptability (training ability) changes of an observed player to training.

OBJECTIVE: The goal of the work was to verify the possibility of volleyball players' training load optimalization during a one week training microcycle based on the longitudinal observation of dynamics of SA HRV complex indices.

METHODS: The SA HRV method was used for the evaluation of autonomic cardiac regulation. The study group consisted of eight volleyball players who took part in 28 training sessions focused on conditioning and volleyball skills development. During the microcycle, there were 7 HRV examinations.

RESULTS: The results demonstrated that notable and considerably varied changes in the activity of ANS in players were assessed owing to both training and extra-training stimuli. The results in two players show a high activity of ANS which enables them to increase their training intensity. Four players achieved average values of their ANS activity, which reflects a corresponding training load. In the last two players we found a very low level of their ANS activity and it refers to their reduced adaptability to the training load, which was too high for them.

CONCLUSION: The presented results support the necessity of the individualization of, at least a part of, team training. Such an optimalization and increase of training process efficiency should lead to a sports performance improvement, also in team sports games.

Keywords: Volleyball players, individualization, training ability level.

INTRODUCTION

Sports performance in volleyball is influenced by a number of qualities, skills, and the functional states of players, which come out in a match, including jump height, the power and precision of a hit, and the speed or timing of a move. Volleyball players in different specializations are required to meet specific demands in terms of movement behaviour and skills performance. It is clear that knowledge of particular players' reactions to training or a match load enables them to optimize their training programmes. Therefore one of the key conditions for achieving good sports performance is the consistent individualization of their training load (Alberda, 1995; Polglaze & Dawson, 1992).

Spectral analysis of heart rate variability (SA HRV), based on methods of frequency analysis of R-R intervals from ECG records, gives us information on the autonomic regulation of cardiac activity. This autonomic nervous system (ANS) regulation significantly affects the adaptation of an athlete's organism to training and thereby also his/her sports performance. The high and balanced activity level of both ANS branches is an indicator of a good adaptability level and optimal readiness for sports performance. On the other hand, a long time low activity level of ANS (mainly parasympathetic) and a significant prevalence of sympathetic activity results in a decrease of training adaptability and of sports performance mostly as well (Bosquet, Papelier, Léger, & Legros, 2003; Jakubec, 2005; Stejskal, 2002; Stejskal, 2008).

If the intensity and volume of the previous training exceed the actual adaptation capacity of an athlete, his ANS is reduced and shifted towards sympathetic activity. The actual activity of ANS can consequently be a cause of the fact that the same training can induce different reactions in the same athlete. The result then can be exceeding of the actual training capacity or its insufficient utilization (Stejskal, 2004).

The aim of this work was to verify the possibility of volleyball players' training load optimalization during a one week training microcycle based on the longitudinal observation of the dynamics of SA HRV complex indices.

METHODS

The study was conducted on eight players of the SKUP Olomouc men's volleyball team (age 21.9 ± 4.9 years, height M = 188.5 ± 7.7 cm, weight M = 82.9 ± 11.5 kg) who volunteered to participate in the study. The specializations of the observed players were following: 3 hitters (diagonal players) – H1, H2, H3, 2 blockers – B1, B2, 2 passers – P1, P2 and 1 libero – L. The players were divided into two groups for technical reasons.

The observation took place during a week long training microcycle in August 2009 in the FTK UP training camp Pastviny. Within the period the players were measured 7 times (6 morning measurements and 1 control afternoon measurement). The measurements took place under standard conditions (morning measurements after an overnight fast immediately after waking). The players trained according to a preplanned programme in its full range, neither the coach nor the players were informed about the running results of the measurements.

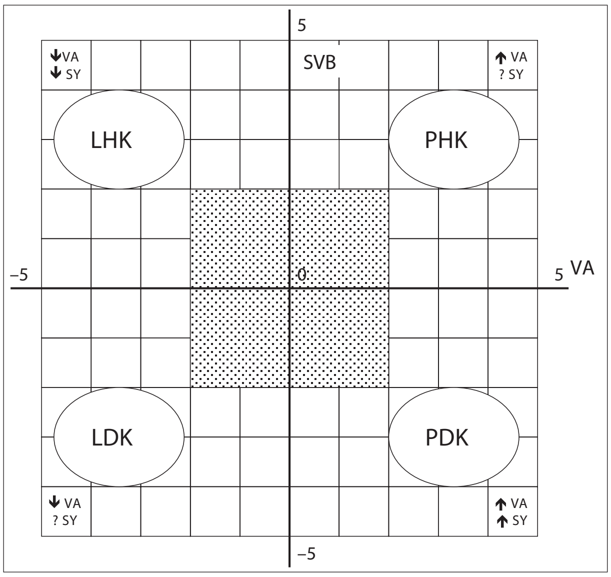
Spectral analysis of heart rate variability

Short term ECG recordings (300 heart beats and 5 minutes) and the SA HRV were performed by means of VarCor PF7 (Salinger et al., 2006) and VarCorMulti computer software, which enables four subjects to be measured at the same time. Frequency domain analysis was performed by calculating the power density spectrum using the fast Fourier algorithm. We computed high frequency: (0.15–0.50 Hz), low frequency (0.05–0.15 Hz) and very low frequency (0.02–0.05 Hz) components for every 5 min. interval. The results of the SA HRV were interpreted by means of complex indices (Stejskal, Šlachta, Elfmark, Salinger, & Gaul-Aláčová, 2002). The complex index of vagal activity (VA) combines values of factors and indicators decreasing with age and load intensity. The SVB complex index is an indicator of sympathovagal balance and it represents parameters increasing with age and rising load intensity. The normal interval of the values of these indicators varies from –2.0 to +2.0 points. All the age dependent factors of SA HRV are associated with the complex indicator of an SA HRV denominated Total score (TS) with the normal interval being between –1.5 and +1.5 points. A high level of the activity of ANS is also projected in the age standardized values of total spectral power (PT) with a normal interval between –2.5 and +2.5 points. In long term monitoring, an increase in TS was interpreted as rising of the ANS total activity, whereas an increase in VA was interpreted as a rising of the vagal activity and an increase in the SVB level indicates a shift in ANS activity towards the vagus (Stejskal, 2008).

The athletes were investigated under the conditions of sense isolation from disturbing stimuli – they had their eyes closed and listened to relaxation music during the whole test. After at least 5 min (or 300 heart beats) had gone by in the initial lying position, the players slowly stood up and, after a 30 sec interval, another record in the standing position was collected. Then they moved again into the last horizontal position. The first lying position was used only for examination standardization and its results were not evaluated (Salinger et al., 1998).

For an easy interpretation of the activity changes of particular ANS branches, we chose the cross graph of VA and SVB complex indices (the value of VA is applied to the horizontal axis, the SVB value to the vertical one) on a scale from –5.0 to +5.0 points (Fig. 1). Normal values of the intersections are limited to –2.0 and +2.0 points on both axes. The whole area of the graph is divided into four quadrants:

Fig. 1
Cross graph of VA and SVB Intersections (Stejskal, 2008)



Description of training load

During the course of 7 training days, the players took part in 25–31 training sessions with a total load volume of 1745 ± 135 min., of which 11–13 training sessions of the total number were volleyball oriented (914 ± 76 min.) and 14–16 of them were focused on conditioning (790 ± 89 min.).

Volleyball oriented training sessions consisted of 3 parts. One part was represented by a 6v6 preparatory game without any rules modifications for a total of

329 ± 82 min. In this game, the middle blockers (B1, B2) played in the front row all the time (i.e. without playing in the back row or being relieved by the libero). The second part of the volleyball oriented training sessions was a 2v2 preparatory game played on half of the field for 170 ± 38 min. and the third part consisted of preparatory and game like drills for 395 min. (B1 335 min.). The preparatory and game like drills were focused on correct techniques of volleyball skills and the players were divided into two separated groups according to their game specializations (middle blockers + setters, power hitters + libero) during this part. The applied drills represented a middle intensity load (60–79% HRmax) (Háp & Lehnert, 1999).

Conditioning parts of the training sessions were focused:

- on strengthening – the isometric strengthening of trunk muscles – a total of 170 min. (B1 135 min.); (there were 2 programmes regularly taking turns, 12–14 exercises, the interval of the load was 30 s and the interval of rest was 30 s long.), the strengthening of abdominal muscles lasted for 60 min. (B1 40 min.), (always 3 exercises, 2–3 sets, the number of repetitions was 8), and canoeing was done for 155 min.
- on the development of general aerobic endurance – running (147 ± 13 min. – intensity % HRmax), cycling in hilly terrain (50 ± 26 km, intensity at 60–90 % HRmax) and speed endurance (running uphill with the interval of the load being 8 s, number of repetitions 6, number of sets 3, maximal intensity).

RESULTS

During the one week training microcycle in players' distinct and considerably different changes in ANS activity (TABLE 1) occurred, owing to training and off training stimuli. All the time, the highest ANS activity was recorded in player S2, whose high vagal activity steadily conditioned the biggest spectral power (the highest average value and the lowest standard deviation of P_T). On the other hand, player B2 had the worst average values of all complex indicators and he recorded their lowest stability.

DISCUSSION

Out of the total number of eight players, the values of the complex indices of two players (L1 and S2) document the relatively high ANS activity for all the time of the monitoring (the average value is above the upper limit of normal values). From such an ANS state, we can understand that the training load was lower than the training capacity of the players enabled them to perform (Botek, Stejskal, & Svozil, 2009). We suppose that increasing the training quality (an individual increase of the intensity during team training and individual training extension) could also positively influence their sports performance.

In four players (B1, S1, S3 a N2), ANS activity was lower (the average values of TS were positive, but below the upper limit of normal values) and it shows evidence of a certain level of fatigue and a lower level of adaptation to sports training; therefore the training intensity during the camp corresponded to their training capacity.

In two players (B2, N1) the average values of TS were negative and their training adaptability was reduced. In these players an individual decrease in training intensity and better regeneration would increase the quality of the training.

In light of sports training it is important to monitor not only the absolute values of complex indices,

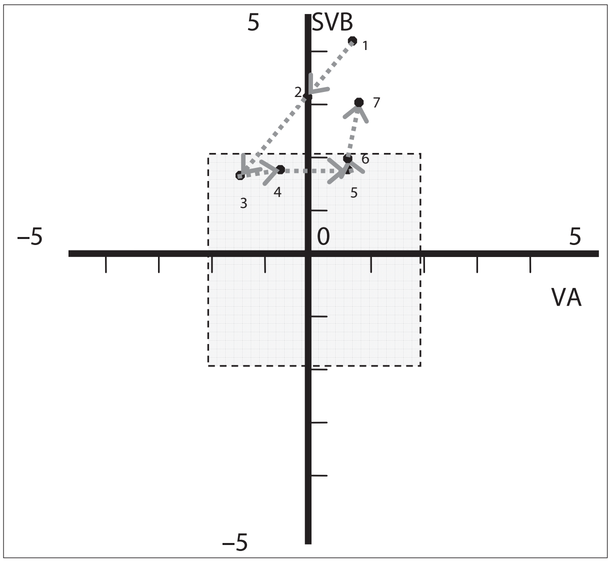
TABLE 1
Average values of complex indices in observed players

Player	TS		VA		SVB		P_T	
	M	SD	M	SD	M	SD	M	SD
S1	0.26	2.03	0.95	1.42	0.44	0.81	2.92	3.08
S2	2.14	0.88	1.99	0.88	2.43	1.25	4.63	0.41
S3	1.06	0.19	0.52	0.31	2.09	0.69	1.77	1.03
Se1	−1.60	0.82	−0.82	0.98	−3.08	0.89	−0.63	2.01
Se2	0.91	0.81	1.25	0.70	0.26	1.19	1.43	0.64
B1	0.97	0.70	0.12	0.79	2.57	0.83	2.22	1.92
B2	−3.28	2.48	−1.67	1.95	−2.42	1.83	−3.53	2.12
L1	1.59	0.88	1.20	1.29	2.32	0.71	1.62	1.68

Legend: TS – total score, VA – vagal activity, SVB – sympathovagal balance, P_T – total spectral power, M – average, SD – standard deviation, S1 – spiker 1, S2 – spiker 2, S3 – spiker 3, Se1 – setter 1, Se2 – setter 2, B1 – middle blocker 1, B2 – middle blocker 2, L – libero but also their total dynamics. In our players we have registered three different courses of complex indicator changes that we can demonstrate based on the examples of three players.

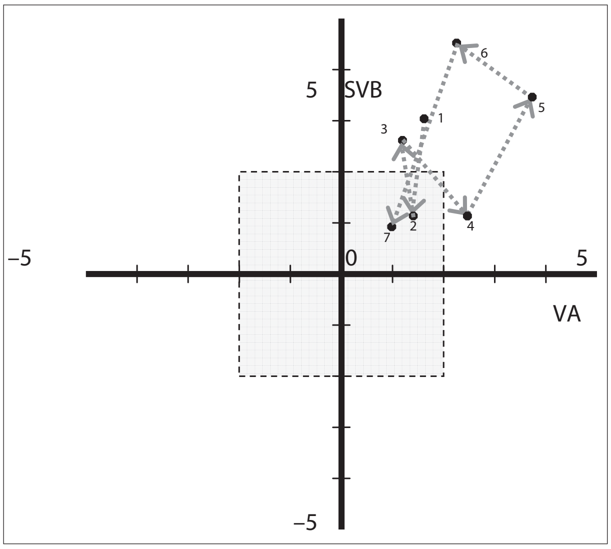
The dynamics of the VA and SVB complex indices in player B1 are recorded in the cross graph (Fig. 2). The shift of the VA and SVB intersection from the right upper quadrant (PHK) diagonally down to the left upper quadrant (LHK) during the first three days of the camp is evidence of decreasing vagal activity and the increasing predominance of sympathicus. In agreement with Cyprian et al. (2007), we can state that it is probable that this change of regulation mechanism was evoked by fatigue from training. During the following days, the VA and SVB intersection gradually shifted back to PHK and the vagal activity of the last three days of the camp got to the same level as where it had been on the first day. Slightly reduced SVB values shifted the intersection a little lower giving evidence of increased sympathetic activity and a smaller vagal predominance at the end of the camp. The mentioned changes document the optimal dynamics of ANS activity, which corresponded to adequate adaptation to the one-week training period and the full utilization of the player's training capacity.

Fig. 2
Activity changes of both ANS branches are demonstrated in the cross graph, in particular measurements made during the training microcycle (player B1)



On the other hand, the development of ANS activity in player B2 is evidence of the fact that the player was not able to adapt to the training undergone (Fig. 3). The first measurement shows very good values of complex indices, but, already after the first training day, a rapid decrease in ANS activity occurred and the player was not able to respond adequately to the given load. From the graph results we can see that, from the first till the fifth day his vagal activity decreased sharply and the VA and SVB intersection shifted down and to the left into the LDK. It is probable that the player was getting into overreaching connected with cumulated fatigue and limited adaptation capacity. In the case of this player then, multiphase training seems to have been incorrect. The results of the longitudinal monitoring of the ANS activity of the player unambiguously support the necessity of systematic training individualization, also in team sports.

Fig. 3
Activity changes of both ANS branches demonstrated, in the cross graph in particular, measurements made during the training microcycle (player B2)

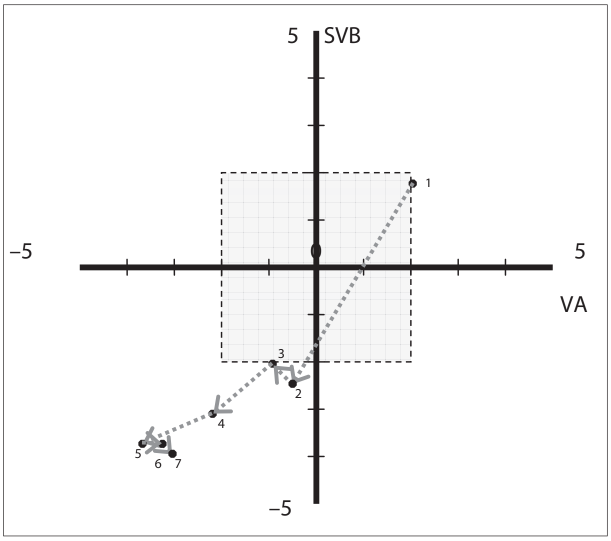


A reason for the individualization of a training load can also be the opposite situation, when the relatively high training capacity of a player is not utilized sufficiently and high ANS activity does not change nor even increase during the training camp. This is the case of the player S2 (Fig. 4) who achieved the highest values of the complex indices and the VA and SVB intersection was in PHK all the time. In his case, it would be possible to increase his training intensity or to supplement team training with some individual training. Hereunder we can expect also an increase in his sports performance.

Limits of the study can be found in a lack of comparable studies. Foreign studies dealing with heart rate variability and sports are mainly connected with descriptions of changes in HRV after the long or short term application of a training load to endurance athletes (Borresen & Lambert, 2008; Bosquet et al., 2003) or after resistance training (Berkoff, Cairns, Sanchez, &

Moorman, 2007), not with the interpretation of the responses of the players to a planned training programme (the response of a number of individuals to the same training programme) or the following of recommendations resulting from the description.

Fig. 4
Activity changes of both ANS branches demonstrated in the cross graph in particular measurements during the training microcycle (player S2)



CONCLUSIONS

The load control of volleyball players through the use of the spectral analysis of heart rate variability has demonstrated its usefulness in sports games, although it also revealed some difficulties connected with the different training needs of particular players within one team and the time demands of the method during the normal training process. During a one week training microcycle in some players, distinct and considerably different changes in ANS activity occurred, owing to training and off training stimuli. Attention must be directed towards the identification of markers reflecting an individual's responsiveness or adaptability to training. In players whose ANS activity was high most of the time irrespective of the training load, it is possible to increase training intensity and volume or to add individual training to their team training. On the other hand, a decrease in ANS activity or a constantly low level of complex indices indicates a limited training capacity requiring the reduction of intensity and training volume and regeneration improvement. It is obvious that an overly large distinction between the values of the SA HRV complex indices does not make possible the high quality team preparation of volleyball players. Therefore mainly longitudinal ANS activity monitoring could contribute to the quality improvement of the drafting of talented athletes and it could go for not only individual sports, but for team sports as well.

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KONTROLA ZATÍŽENÍ HRÁČŮ VOLEJBALU METODOU SPEKTRÁLNÍ ANALÝZY VARIABILITY SRDEČNÍ FREKVENCE BĚHEM TÝDENNÍHO TRÉNINKOVÉHO MIKROCYKLU

(Souhrn anglického textu)

VÝCHODISKA: Pro volejbal platí, že z hlediska pohybového režimu i způsobu provedení herních činností jsou na hráče v jednotlivých hráčských specializacích kladeny specifické nároky. Tyto specifické nároky je nutné individualizovat podle úrovně trénovatelnosti (adaptability na trénink) jednotlivých hráčů, která je závislá zejména na aktivitě autonomního nervového systému (ANS). Spektrální analýza variability srdeční frekvence (SA HRV) nám podává informace o regulaci srdeční aktivity, na níž se významně podílí aktivita ANS. Longitudinálním měřením SA HRV v průběhu určité části tréninkového období tedy můžeme sledovat dynamiku aktivity ANS a tím i změny adaptability (trénovatelnosti) sledovaného hráče na tréninkové zatížení.

CÍLE: Cílem práce bylo ověřit možnost optimalizace tréninkového zatížení hráčů volejbalu během týdenního tréninkového mikrocyklu na základě sledování dynamiky komplexních ukazatelů SA HRV.

METODIKA: Metoda SA HRV byla použita pro hodnocení regulace srdeční aktivity. Testovaný soubor hráčů volejbalu (n = 8) absolvoval během sedmi dní 28 tréninkových jednotek zaměřených na rozvoj kondice a volejbalových dovedností. V tomto období podstoupili hráči sedm měření SA HRV.

VÝSLEDKY: Výsledky ukazují, že u hráčů došlo vlivem tréninkových i mimotréninkových podnětů k výrazným a značně odlišným změnám v aktivitě ANS. Výsledky vyšetření dvou hráčů dokumentují vysokou aktivitu ANS, která umožňuje zvýšit intenzitu tréninku. U čtyř hráčů byla aktivita ANS na průměrné úrovni a svědčí o odpovídajícím tréninkovém zatížení. U zbývajících dvou hráčů byla aktivita ANS velmi nízká a dokumentovala jejich redukovanou adaptabilitu na tréninkové zatížení, které bylo pro ně příliš vysoké.

ZÁVĚRY: Uvedené výsledky podporují nezbytnost individualizace minimálně části společného tréninku. Taková optimalizace a zvýšení efektivity tréninkového procesu by měly vést ke zvýšení sportovní výkonnosti i v týmových sportech.

Klíčová slova: hráči volejbalu, individualizace, úroveň trénovatelnosti.

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