HEART RATE RECOVERY CHANGES DURING COMPETITION PERIOD IN HIGH-LEVEL BASKETBALL PLAYERS

Audrius Gocentas[1], Anatoli Landõr[2], Aleksandras Kriščiūnas[3]
State Research Institute Centre for Innovative Medicine[1], Vilnius, Lithuania
Department of Sports Medicine & Rehabilitation, University of Tartu[2], Tartu, Estonia
Lithuanian University of Health Sciences[3], Kaunas, Lithuania

ABSTRACT

Research background and hypothesis. Replete schedule of competitions and intense training are features of contemporary team sports. Athletes, especially the most involved ones, may not have enough time to recover. As a consequence, aggregated fatigue can manifest in some undesirable form and affect athlete's performance and health.

Research aim. The aim of this study was to evaluate the changes in heart rate recovery (HRR) and investigate possible relations with sport-specific measures of efficacy in professional basketball players during competition season.

Research methods. Eight male high-level basketball players (mean ± SD, body mass, 97.3 ± 11.33 kg; height 2.02 ± 0.067 m, and age 23 ± 3.12 years) were investigated. The same basketball specific exercise was replicated several times from September till April during the practice sessions in order to assess the personal trends of HRR. Heart rate monitoring was performed using POLAR TEAM SYSTEM. Investigated athletes were ranked retrospectively according to the total amount of minutes played and the coefficients of efficacy.

Research results. There were significant differences in the trends of HRR between the investigated players. The most effective players showed decreasing trends of HRR in all cases of ranking.

Discussion and conclusions. Research findings have shown that the quality of heart rate recovery differs between basketball players of the same team and could be associated with sport-specific efficacy and competition playing time.

Keywords: adaptation, autonomic control, monitoring training.

INTRODUCTION

Heart rate (HR) is one of the most usable physiological variables in applied conditioning (Achten, Jeukendrup, 2003). HR monitoring was ranked as a moderate and objective method for the assessment of physical activity (Westerterp, 2009). HR can be measured frequently, inexpensively and noninvasively. The monitoring of HR allows the evaluation of HR recovery (HRR). After physical load HRR reflects the changes in the sympathovagal balance and has prognostic implications under a broad range of exercise conditions (Lahiri et al., 2008). Indices of HRR have been proposed in attempt to monitor and control the changes in the training status (Baumert et al., 2006; Buchheit, Gindre, 2006; Perini et al., 2006; Borressen, Lambert, 2008, Lamberts et al., 2009; Ng et al., 2009). The number of heart beats recovered during 1 min after cessation of exercise is the simplest and frequently used HRR index associated with reactivation of parasympathetic activity (Cole et al., 1999; Shetler et al., 2001; Lahiri et al., 2008).

The depiction and monitoring of the training status as well as laboratory simulation of some specific activities for intermittent team game representatives was always a challenge in the field of applied physiology. The amount of scientific data on physiological responses in high-level team sport athletes is still limited because of limited accessibility to high-level athletes, the necessity to implement the monitoring without any influences on the training process and the specific features of team sport games. High variability of training content is associated with limited possibility to find some comparable activities during training sessions, when monitoring of some physiological variables is planned in basketball. The longitudinal effects of training on HRR were studied in several studies (Yamamoto et al., 2001; Perini et al., 2006; Lamberts et al., 2009) but seldom in team game and never in basketball athletes. Despite the individualization of training in accordance with the playing position, the playing time could be the most influencing factor when exertion or total physical bout are compared between athletes in the same team. We tested our hypothesis that possible modifications of the cardiovascular autonomic control occurring in basketball players over the competitive season are associated with the playing time and sport-specific efficacy.

The aim of this study was to investigate the changes in HRR during basketball season and reveal relations between them and sport-specific measures for attainment of efficacy in high level athletes.

RESEARCH METHODS

Subjects. Eight well-trained male basketball players participated in the study. All subjects followed the same structured training programme that included training sessions, competition games and days of rest. The research participants were involved in two competition frames, National championship and European Cup for clubs. The study design and the procedures were used in accordance with the ethical standards and the Declaration of Helsinki.

Design. The basketball-specific exercise applied in this study was described in our previous research (Gocentas, Landõr, 2006). This activity continued for 3.5 minutes until it was stopped by the audio signal. The exercise described was always executed in the last part of the practice session. We selected four consecutive practices sessions that included basketball-specific 3.5-minute shooting exercise. All the analysed practice sessions were held in the morning. The intervals between the selected practice sessions were from seven to eleven weeks. In the current research, we analysed HRR immediately after the cessation of the described exercise. HR was monitored using downloadable, frequency-coded heart rate monitors (Polar TEAM SYSTEM) with 5-second registration intervals. We extracted values of the HR on the peak of sport-specific exercise (HR_{peakE}), and the values of the HR 60 s after the cessation of the exercise ($HR_{post60s}$). HRR was calculated as subtraction of abovementioned values ($HRR = HR_{peakE} - HR_{post60s}$). Individual trends of HRR were constructed for each athlete using HR data from the files of practices performed in the preseason, beginning, middle and the end of basketball season.

The data regarding playing time and individual efficacy are available on the official internet sites of the Lithuanian Basketball League and the Union of European Leagues of Basketball. The coefficient of efficacy is a cumulative value of all beneficial and harmful actions (missed and made shots, rebounds, fouls, blocks, assissts etc.) executed by a player during his playing time. Each beneficial action adds one point but each harmful action subtracts one point. The investigated athletes were ranked retrospectively according to the total amount of the minutes played and the coefficients of efficacy in both tournaments.

Statistics. The data are presented as means and standard deviations (SD). All statistics were calculated with the SPSS 11.0 (SPSS Inc, Chicago, USA) software package.

RESEARCH RESULTS

The descriptive data of the athletes are presented in Table 1. The trends of HRR after the sport specific exercise repeated several times during real practices are presented in Figure 1. Individual ranges of fluctuation in HR_{peakE} and $HR_{post60s}$ are shown in Table 2. The individual HR responses during the analysed sport-specific exercise showed a satisfactory repeatability. The fluctuations in HR_{peakE} were less expressed compared to $HR_{post60s}$.

Table 1. **Descriptive characteristics of the investigated athletes**

Variable \ Values	Minimum	Maximum	Mean	Standard error	Standard deviation
Age, years	20	30	23	1.1	3.12
Stature, m	1.92	2.10	2.02	2.38	6.74
Body mass, kg	80	110	97.31	4.01	11.33
BMI, kg / m^2	21.68	25.18	23.75	0.44	1.25
VO_{2peak}, mL · kg^{-1} · min^{-1a}	39	57.90	47.35	2.24	6.32
VE, L · min^{-1a}	109.8	168.90	133.8	7.78	22.01

Note. [a] – VO_{2peak} and VE were measured during graduated exercise test using VMAX (Sensormedics Inc., Yorba Linda, USA) gas analyser in laboratory enviroment. BMI = body mass index, VO_{2peak} = peak oxygen consumption, VE = minute ventilation.

Table 2. **Individual fluctuations in heart rate on the peak of sport-specific exercise and 60 s later**

HR \ Athletes	ATHL_1	ATHL_2	ATHL_3	ATHL_4	ATHL_5	ATHL_6	ATHL_7	ATHL_8
ΔHR_{peakE}	16	14	6	17	6	8	9	4
$\Delta HR_{post60s}$	15	18	28	16	39	29	12	45

Note. ΔHR_{peakE} = the highest variation in HR_{peakE}; $\Delta HR_{post60s}$ = the highest variation in $HR_{post60s}$.

Table 3. **Ranks of investigated athletes based on playing time and sport-specific efficacy**

Athletes \ Ranks	t_{EC}, min	$Rank_{tEC}$	t_{NC}, min	$Rank_{tNC}$	eff_{EC}	$Rank_{effEC}$	eff_{NC}	$Rank_{effNC}$
ATHL_1	426	1	915	2	13.8	2	11.29	3
ATHL_2	133	5	741	7	5.3	5	10.86	4
ATHL_3	22	8	440	8	2.3	7	3.45	8
ATHL_4	378	2	924	1	16.7	1	13.22	1
ATHL_5	111	6	904	3	3.2	6	11.44	2
ATHL_6	76	7	818	5	2.1	8	5.68	7
ATHL_7	270	3	812	6	6.1	4	7.57	6
ATHL_8	263	4	860	4	6.8	3	9.15	5

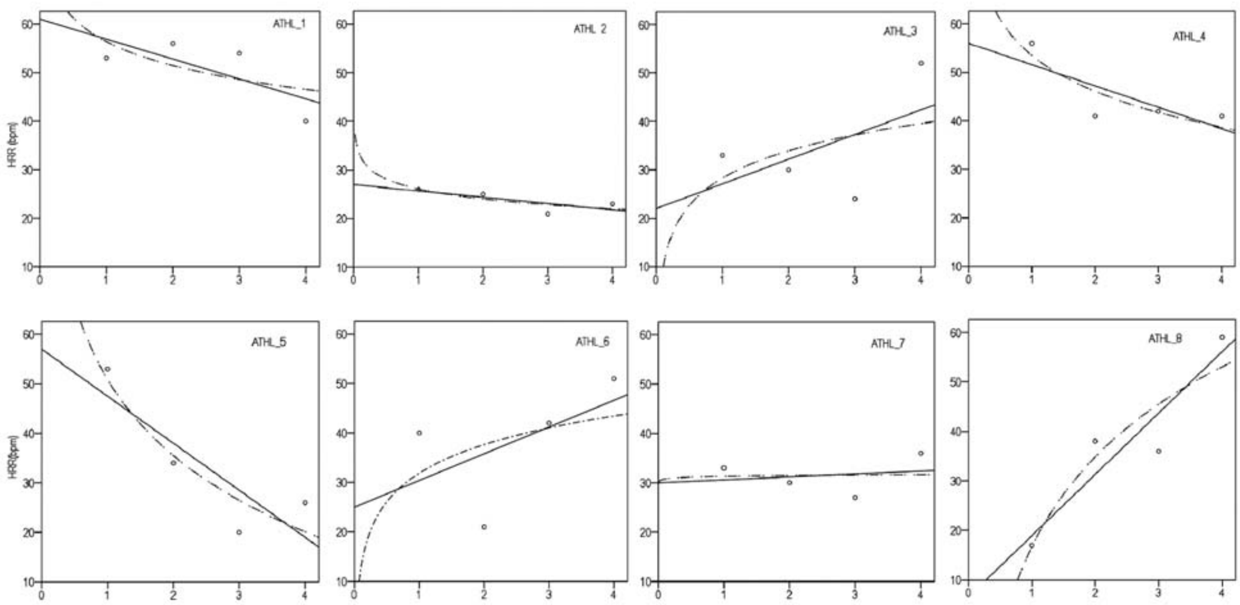
Note. t_{EC} = total playing time in European Cup matches; t_{NC} = total playing time in National Championship matches, eff_{EC} = coefficient of efficacy in European Cup matches; eff_{NC} = coefficient of efficacy in matches of the National Championship. ATHL_1… ATHL_8 = investigated athletes.

Each player in each frame of the competition ranked according to the time played and to the coefficient of efficacy. The differences in the playing time and efficacy between the players are reported in Table 3. Despite the category of the evaluation, the individual ranks of investigated players were stable enough. We can also observe that in all cases of ranking the athletes ranked as the first and the second demonstrate descending trend of HRR. The athlete ranked as the last has ascending HRR trend in all cases of ranking. The ranks of efficacy in the domestic league fully coincide with the HRR trends: four most effective players show descending trends but four less effective players have demonstrated ascending trends of HRR.

DISCUSSION

This is the first study investigating changes in sympathovagal balance during the whole season in basketball. The results have shown that trends in HRR differ in the investigated subjects. Large interindividual variability of responses was observed for both direction of trend and grade of inclination. Different changes in HRR during the period of observation suggest that the quality of recovery differs in high-level basketball players. The presented findings can be interpreted as indicators of insufficient recovery in some athletes. In contrast, the ascensional character of other trends toward pre-season levels could be considered as an indicator of the adequate recovery.

Figure. **Individual trends in HRR of the investigated athletes**



Note. ATHL_1… ATHL_8 = investigated athletes; HRR (bpm) = heart rate recovery measured in beats per minute. Points represent actual values, solid line and dashed line represent linear and logarithmic trend respectively. 1,2,3,4 = Results of measures in September, November, January, and April, respectively.

The described differences could be explained by individual threshold above which further training impulses do not improve the cardiorespiratory fitness of athletes (Kiviniemi et al., 2007). Altered autonomic cardiovascular control can be a sign of overtraining (Achten, Jeukendrup, 2003, Baumert et al., 2006), but we could not confirm the presence of overtraining in part of our athletes referring to just one separate index. The content of practice sessions in basketball varies day-by-day regarding the vision of the coaching staff and is associated with the current aims of the team. Despite it and the individualised training process, the main cause of the distinction in the executed exertion is a disparity in the playing time. The playing time alone cannot precisely describe the executed exertion during physical activity, especially when the nature of activity is not cyclical. The ranks of efficacy did not reflect physical efforts or the executed exertion directly. The values of the efficacy are tools to assess the quality of sport-specific technical variables but sufficient playing time is necessary to collect positive points for a high coefficient of efficacy. Playing five is decided by the team coach in basketball. The coach selects the players depending on the situation and many other factors. The principles of such a selection are not the point of interest in the current study, but our results clearly confirm that cardiac autonomic control of the most effective players falls down during the course of the season because players ranked as the first and second have shown descending trends of HRR after a sport-specific exercise in all the cases of ranking. Simultaneously, the player ranked as last had ascending trend of HRR after a sport-specific exercise in all the cases of ranking.

T. Otsuki et al. (2007) showed that both strength- and endurance-trained athletes have improved their heart rate recovery after 8 min of steady-state exercise at 40% of maximal oxygen uptake compared to untrained controls. The training process in basketball is a composite and complicated matter. Besides the efforts to develop strength, power and endurance, the tactical and technical individual and team activities take much time during practice sessions. Furthermore, athletes take part in1-3 games each week. So, different HRR dynamics in individual athletes were evoked by unequal responses after the executed loads. Individualised loads during the practice sessions promote the process of recovery. Immoderate or oversized loads rise an overstrain of regulatory mechanisms (Baumert et al., 2006; Kiviniemi et al., 2007). The deceleration of recovery could be expression of such unbeneficial status. Thus, the dynamic assessment of the quality of recovery allows detecting individual capacity to tolerate the proposed and executed physical loads. Training impulse and playing time are important but not the sole factors influencing recovery. The practical questions are when a particular subject reaches this limit, how to recognize it, and what options we have to manage such situations. M. Buchheit et al. (2010) suggested the existence of a common genetic denominator responsible for the function of the autonomic nervous system and aerobic performance. So, in our previous study (Gocentas, Landõr, 2006) the relations between HRR and aerobic capacity were shown in high- level basketball. Despite this, we used individual values of VO_{2peak} only for the description of involved subjects in the current study, because the measurement of this variable was performed on a one-off basis, at the beginning of the observation.

The findings in the current report are based on longitudinal short-term episodes. Our choice to analyse this short-term exercise was conditioned by the specificity of practice sessions in basketball. Its main challenge when monitoring some physiological variables in basketball is planned to find some comparable activities in particular training sessions. In the previous study we described and analysed a basketball-specific 3.5-minute shooting exercise (Gocenta, Landõr, 2006). This choice was based on the appropriate features of the above-mentioned exercise. Namely, the exercise had even duration and was always performed as the last exercise of the morning practice session, the athletes were always motivated by their coaches. The validity of analysing short-term recordings was confirmed earlier (McCraty et al., 1995; Ng et al., 2009). Moderate intraindividual ranges of HR_{peakE}, as shown in Table 2, indirectly support the tolerable repeatability of the analysed exercise. The number of investigated athletes is the main limitation of this study but high-level athletes form just a small part of the community, and often studies of competitive athletes come across a similar problem. So, scarce statistical methods are also associated with the same reason. Despite that, single subject research is recommended in the field of applied conditioning research (Kinugasa et al., 2004).

CONCLUSSIONS AND PERSPECTIVES

In conclusion, our findings provide longitudinal data about changes in sympathovagal balance in the presence of the high-level stress. Our results show that the use of the Polar monitor during practice sessions in high-level basketball can provide a HRR analysis in a useful, non-invasive and inexpensive way for evaluating the functional status of athletes.

The sport-specific analysis is proposed as a technique for complementing the evaluation of the functional state of athletes for enabling strategies that can be directed towards the optimization of the impact of the training process on performance. However, the underlying mechanisms still need to be more exactly revealed in the future research.

REFERENCES

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

Baumert, M., Brechtel, L., Lock, J. et al. (2006). Heart rate variability, blood pressure variability, and baroreflex sensitivity in overtrained athletes. *Clinical Journal of Sport Medicine*, 16 (5), 412–417.

Borressen, J., Lambert, M. I. (2008). Autonomic control of heart rate during and after exercise: Measurements and implications for monitoring training status. *Sports Medicine*, 38 (8), 633–646.

Buchheit, M., Chivot, A., Parouty, J. et al. (2010). Monitoring endurance running performance using cardiac parasympathetic function. *European Journal of Applied Physiology*, 108 (6), 1153–1167.

Buchheit, M., Gindre, C. (2006). Cardiac parasympathetic regulation: Respective associations with cardiorespiratory fitness and training load. *American Journal of Physiology. Heart and Circulatory Physiology*, 291, H 451–458.

Cole, C. R., Blackstone, E. H., Pashkow, F. J. et al. (1999). Heart-rate recovery immediately after exercise as a predictor of mortality. *New England Journal of Medicine*, 341, 1351–1357.

Gocentas, A., Landõr, A. (2006). Dynamic sport-specific testing and aerobic capacity in top-level basketball players. *Papers on Anthropology*, 15, 55–63.

Kinugasa, T., Cerin, E., Hooper, S. (2004). Single-subject research designs and data analyses for assessing elite athletes' conditioning. *Sports Medicine*, 34 (15), 1035–1050.

Kiviniemi, A. M., Hautala, A. J., Kinnunen, H. et al. (2007). Endurance training guided individually by daily heart rate variability measurements. *European Journal of Applied Physiology*, 101 (6), 743–751.

Lahiri, M. K., Kannankeril, P. J., Goldberger, J. J. (2008). Assessment of autonomic function in cardiovascular disease: Physiological basis and prognostic implications. *Journal of the American College of Cardiology*, 51, 1725–1733.

Lamberts, R. P., Swart, J., Noakes, T. D. et al. (2009). Changes in heart rate recovery after high-intensity training in well-trained cyclists. *European Journal of Applied Physiology*, 105 (5), 705–713.

McCraty, R., Atkinson, M., Tiller, W. A. et al. (1995).The effects of emotions on short-term power spectrum analysis of heart rate variability. *American Journal of Cardiology*, 76, 1089–1093.

Ng, J., Sundaram, S., Kadish, A. H. et al. (2009). Autonomic effects on the spectral analysis of heart rate variability after exercise. *American Journal of Physiology. Heart and Circulatory Physiology*, 297 (4), H 1421–1428.

Otsuki, T., Maeda, S., Iemitsu, M. et al. (2007). Postexercise heart rate recovery accelerates in strength-trained athletes. *Medicine and Science in Sports and Exercise*, 39, 365–370.

Perini, R., Tironi, A., Cautero, M. et al. (2006). Seasonal training and heart rate and blood pressure variabilities in young swimmers. *European Journal of Applied Physiology*, 97 (4), 395–403.

Shetler, K., Marcus, R., Froelicher, V. F. et al. (2001). Heart rate recovery: Validation and methodologic issues. *Journal of the American College of Cardiology*, 38 (7), 1980–1987.

Westerterp, K. R. (2009). Assessment of physical activity: A critical appraisal. *European Journal of Applied Physiology,* 105 (6), 823–828.

Yamamoto, K., Miyachi, M., Saitoh, T. et al. (2001). Effects of endurance training on resting and post-exercise cardiac autonomic control. *Medicine and Science in Sports and Exercise*, 33 (9), 1496–1502.

DIDELIO MEISTRIŠKUMO KREPŠININKŲ ŠIRDIES ATSIGAVIMO KAITA VARŽYBŲ LAIKOTARPIU

Audrius Gocentas[1], Anatoli Landõr[2], Aleksandras Kriščiūnas[3]
Valstybinio mokslinių tyrimų instituto Inovatyvios medicinos centras[1], Vilnius, Lietuva
Tartu universitetas[2], Tartu, Estija
Lietuvos sveikatos mokslų universitetas[3], Kaunas, Lithuania

SANTRAUKA

Tyrimo pagrindimas ir hipotezė. Šiuolaikiniam sportui būdinga varžybų gausa ir intensyvios pratybos. Toks intensyvus tvarkaraštis gali turėti įtakos sportininkų atsigavimui, sudaryti sąlygas nuovargiui atsirasti. Darome prielaidą, kad krepšininkų krūvio skirtumas per metinį rengimo ciklą susidaro dėl labai skirtingos žaidimo trukmės, tenkančios atskiriems atletams. Toks nevienodumas galėtų lemti atsigavimo kokybę, ir tai parodytų širdies autonominės reguliacijos rodiklių kaita.

Tikslas: įvertinti širdies atsigavimo kaitą ir ištirti galimą ryšį su sporto šakos specifiškumu.

Metodai. Buvo tiriami aštuoni didelio meistriškumo krepšininkai. Jie dalyvavo Lietuvos pirmenybių ir Europos taurės turnyruose. Širdies susitraukimų dažnis buvo registruojamas realių pratybų metu „Polar Team System“ pulsomačiu ir programine įranga. Analizei atlikti parinktas specifinis sporto šakos pratimas, kurio pulsogramomis buvo naudotasi retrospektyviai analizuojant atsigavimą.

Rezultatai. Individualūs žaidėjų ŠSD atsigavimo kryptingumo grafikai parodė nevienodą krepšininkų atsigavimo kokybę per metinį rengimo ciklą. Žaidėjus surangavus pagal vidutinį abiejų turnyrų žaistų minučių kiekį ir veiksmingumo koeficientus, žemėjantis ŠSD atsigavimo kryptingumas pastebėtas tarp daugiausia laiko žaidžiančių ir didžiausius veiksmingumo koeficientus turėjusių krepšininkų. Visais rangavimo atvejais krepšininkas, esantis rangų lentelės apačioje, turėjo kylantį ŠSD atsigavimo kryptingumo grafiką.

Aptarimas ir išvados. Širdies autonominės reguliacijos rodiklių kaita parodė, kad daugiausia ir naudingiausia žaidusių krepšininkų atsigavimo kokybė per metinį rengimo ciklą blogėja. Į tai turėtų būti atsižvelgta planuojant treniruotės vyksmą. Rezultatai patvirtina autonominės širdies reguliacijos rodiklių tinkamumą sportininkų funkcinei būklei stebėti.

Raktažodžiai: adaptacija, autonominė kontrolė, treniruotės vyksmo stebėsena.

Gauta 2010 m. liepos 9 d.
Received on July 9, 2010

Priimta 2011 m. kovo 17 d.
Accepted on March 17, 2011

Corresponding author **Audrius Gocentas**
State Research Institute Centre for Innovative Medicine
Žygimantų str. 9, LT-011002 Vilnius
Lithuania
Tel +370 52619161
E-mail audrius.gocentas@ekmi.vu.lt