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**CARDIOVASCULAR HEALTH AND PHYSICAL CAPACITY IN
STUDENT AND ELITE BASKETBALL PLAYERS**

Anna Zakharova (a)*, Kamilia Mekhdieva (a), Vitaly Smirnov (a)

* Corresponding author

(a) Ural Federal University, Mira, 19, Ekaterinburg, Russia, sport_tsp@mail.ru

Abstract

Taking into account the features of contemporary approach to trainings in team sports, and basketball in particular, issues of cardiovascular health are under consideration. The purpose of the study was to evaluate health issues and physical capacity of amateur high school and professional basketball players in order to prescribe exercise programs to increase their athletic performance without medical risks. The study involved two groups of basketball players of different levels – student team of UrFU (n = 11, age $19,55 \pm 1,57$ years) and the professional club team of Sverdlovsk region (n = 12, age $24,17 \pm 4,76$ years). Methods: multifrequency bio-impedance analysis of body composition, 12-lead ECG, the hemodynamic monitoring during the orthostatic and clinostatic tests), and cycle exercise testing (ET) with heart rate monitoring and gas-exchange measurement, statistical analysis. Findings: despite the observed normal physical status of subjects, disorders of cardiovascular adaptation were found. The research revealed the insufficient hemodynamic indices (SI & EDI) in students, that lead to higher HR at rest and during ET regardless of the level of intensity. Professional basketball players demonstrated higher ET results (AT = 83.5 ± 6.77 %, $P_{\max} = 381.5 \pm 41.44$ W, $VE = 141.4 \pm 38.14$) in comparison to students (73.7 ± 8.93 %, = 317.09 ± 49.18 W and 115.8 ± 31.9 accordingly). So the development of the cardiovascular system must be the first priority for healthsaving even in basketball, which is basically not considered as endurance sport.

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Keywords: Basketball players; athletes' health; cardiovascular system; hemodynamics; physical capacity.

1. Introduction

Basketball is a very challenging sport. The success of the game depends on a number of physical and psychological abilities: strength, coordination, general and special endurance, technical competence,

psychological stability, etc. Whereas physical inactivity leads to cardiovascular diseases and health issues (Chandra et al. 2013; Corrado et al. 2005; Mekhdieva et al. 2015), can we esteem an athlete trying to improve their performance in sports as a healthy person? Intense training and the strain of competition may affect the athletes' health, especially, when athletes are physically underdeveloped (Mann, 2013).

Thus the aim of the research was to evaluate health issues and physical capacity of amateur high school and professional basketball players in order to suggest exercise programs to increase their athletic performance without medical risks.

2. Research methods

Twenty-three young healthy sportsmen were recruited for the study. The first group was distributed by elite basketball players (n = 12) of professional team "Uralmash" (Yekaterinburg, Russia), the second – by high performance student team of Ural Federal University (Yekaterinburg, Russia), members of International Student Basketball League and the main leaders of Student Basketball Association. All participants were informed of the purpose of the research, methods and any possible risks, before their written consent was obtained. The study design had been previously approved by The Ural Federal University Ethics Committee. Testing was carried out in the laboratory "Technologies of recovery and selection in sport" at Ural federal university, Russia. The schedule of investigations matched the training period of athletes and was conducted after 24 hours of recovery from the previous training. Athletes' examination in both groups started from personal and family history data collection of cardiovascular diseases. Physical examination was based on anthropometric measurements (Table.1) by means of bioelectrical impedance detailed analysis of body composition with the use of Professional Body Composition Monitor Tanita MC-980MA (TANITA, Japan).

The cardiovascular examination included 12-lead resting ECG registration with professional electrocardiograph Schiller AG AT-104 (SCHILLER AG, Switzerland), followed by interpretation of the results in line with international standards (ACC / AHA 2002 Guidelines) and hemodynamic monitoring during active orthostatic test.

The hemodynamic monitor of anesthesiologists and reanimatologists MARG 10-01 "Microlux" (Cheliabinsk, Russia) operation is based on such noninvasive methods of hemodynamic monitoring as impedance cardiography and spectrophotometry, electrocardiogram monitoring (ECG), pulse oximetry monitoring, reography and central hemodynamics monitoring, blood pressure and temperature. Thus monitor provides the researcher with the a whole range of important sport-relevant parameters such as the heart and breathing rate, the stroke and end-diastolic volume, ejection fraction, the vascular tone and etc.

To evaluate the aerobic capacity of athletes, the stress-system Schiller AG Cardiovit AT-104 (Schiller AG, Switzerland) was used. Each subject performed cycle exercise testing (ET). The maximal ramp ET protocol was developed according to ACC/AHA 2002 guideline update for exercise testing (2006) to estimate peculiarities of cardiovascular adaptation to increasing exercise loads. Maximum oxygen uptake (VO_{2max}) as a measure of aerobic capacity was determined by indirect calorimetry with the use of portable desktop metabolic system FitmatePro (COSMED, Italy). After a 1 min warm-up, subjects started at zero load, continuously increasing by 40 W per minute and were maintaining the pedaling frequency of 80 cycles per minute until volitional exhaustion in order to determine HR_{max} , VO_{2max} , maximum attained

load (P_{max}), minute ventilation (VE_{max} , l/min), anaerobic threshold (AT). Heart rate monitoring was carried out simultaneously with Garmin Forerunner 305 (Garmin, USA) during the test and the following 3 minutes of post-exercise recovery period.

The statistic software package “SPSS Statistics 17.0” (IBM) was used for statistical analysis. Mean value (M) and standard deviation (SD) for the used parameters were calculated, t-test was applied for comparative analysis. The level of significance was set at $P < 0.05$.

3. Findings

Results of physical examination of athletes are distributed in Table 1.

Table 1. Athletes’ physical characteristics (M ± SD)

Variable	Student players (n = 11)	Professional athletes (n = 12)
Age, years	19.6 ± 1.6	24.2 ± 4.8
Height, cm	189.95 ± 7.9	196.2 ± 8.1
Weight, kg	86.4 ± 13.9	89.5 ± 1.5
BMI, kg/m ²	23.8 ± 2.1	23.2 ± 2.2
% fat	13.2 ± 4.9	8.8 ± 5.2
FFM, kg	24.4 ± 2.9	25.6 ± 2.4
LLM, kg	74.5 ± 8.4	81.3 ± 8.6

BMI – body mass index; FFM – fat free mass; LLM – leg lean mass.

One can see that generally, anthropometric parameters corresponded to the athletic physiologic norm. Although, major indices varied within a certain range in both groups, there no significant differences between values of BMI, fat free mass, leg lean mass and percentage of fat in groups of professionals and student-athletes. Thus, body composition of studied athletes irrespective of their professional level was comparable.

According to investigation of personal and family history of athletes, no positive data of previous cardiovascular events or chronic disease in both groups were obtained. Analysis of 12-lead resting ECG observations showed no pathologic changes in all studied subjects. Major ECG changes were considered as training related normal variants in reference to refined criteria (Sheikh, 2014). These findings were as follows in all studied athletes: sinus bradycardia (17 % of all studied subjects; n = 4), incomplete RBBB (30 %; n = 7), early repolarization (65%; n = 15). Moreover, no training unrelated ECG changes (P-wave, QRS or QT-interval changes, the rhythm or conduction abnormalities etc.) were defined.

Thus, in most cases the decrease of HR was observed (less than 60 beats per minute), which indicated the physiological adaptation of the heart to physical stress and corresponded to the adequate reaction of the cardiovascular system. In all cases mentioned above, at the time of the survey, there were no clinically significant arrhythmias and conduction abnormalities, which confirms the normal functional condition of the heart based on the ECG data. All registered ECG changes (ST-segment changes, the T-wave (amplitude increase) in the chest leads) were considered as the consequence of the normal heart reaction to intense long-term physical activity (over 5 years).

Hemodynamic monitoring during orthoclinostatic test (supine position1 – standing – supine position2) allowed to evaluate the cardiovascular health of the subjects (Shishkina, 2014). The most informative indicators of athletes hemodynamics were selected for observation (table 2): athlete heart rate during

orthostatic test ($HR_{at\ supine}$ and $HR_{standing}$), stroke volume (SV, ml) and stroke index (SI, ml/cm²), end-diastolic index (EDI, ml/cm²). The stroke index is the ratio of the stroke volume to the body surface area; whereas the end-diastolic index is the ratio of the end-diastolic volume (the maximum amount of blood received in the left ventricle at the end of diastole) to the body surface area in square centimeters.

Table 2. Hemodynamic parameters and indices in basketball players (M±SD)

Hemodynamic parameters and indices	Student team	Professional team	Athletes norm
$HR_{at\ supine}$, beats/min	62,00±8,02	49,08±6,56**	55
$HR_{standing}$, beats/min	84,73±9,14	72,58±7,72**	65
$\Delta HR_{standing} - HR_{at\ supine}$, beats/min	21,82±8,58	23,50±6,57	<18
$SV_{at\ supine}$, ml	124,91±19,21	137,00±19,93*	>120
$SV_{standing}$, ml	88,64±12	103,42±17,35*	>100
$SI_{at\ supine}$, ml/cm ²	60,27±5,80	68,17±7,23**	>70
$SI_{standing}$, ml/cm ²	41,64±3,53	49,58±6,05**	-
$(SI_{at\ supine} - SI_{standing}) / SI_{at\ supine\ position}$, %	30,48±7,27	26,64±10,36	
$EDI_{at\ supine\ position}$, ml/cm ²	98,72±8,04	108,42±7,39**	>100
$EDI_{standing}$, ml/cm ²	79,55±6,01	89,25±7,79**	-

*- statistically significant at $P < 0.05$,

** - statistically significant at $P < 0.01$

The heart rate at rest (RHR) in professional basketball players corresponded to that of high performance endurance sport representatives whereas RHR in students were normal for healthy people in supine. During active orthostatic test, an HR increase after transition from supine to the vertical body position must be less than 18 in ordinary people and 10 in advanced athlete as it is demonstrated by the elite athlete model in fig. 1. Quality of athlete adaptation to vertical position especially for tall basketball players can be estimated by the action of physiological systems regulation. The deviation of HR while standing from the initial value is the main indicator of quality of regulation (Stickland, 2006). The less $\Delta (HR_{standing} - HR_{at\ supine})$, the better functioning of an athlete vascular system. It is worth mentioning that most athletes compete in a vertical body position, hence it is necessary to take into account not only $RHR_{at\ supine}$ as the majority of medical protocols prescribe, but also HR standing and $\Delta HR_{standing} - HR_{at\ supine}$. Comparison of organism reactions while active orthoclinostatic tests revealed that there was no significant difference between two observed groups, but the average HR increase in ortostasis is higher than in ordinary people and, moreover, basketball players demonstrated the strong reaction of the heart rate after transient into a standing position (table 2): it was 2 times greater than that in advanced athletes (fig.1).

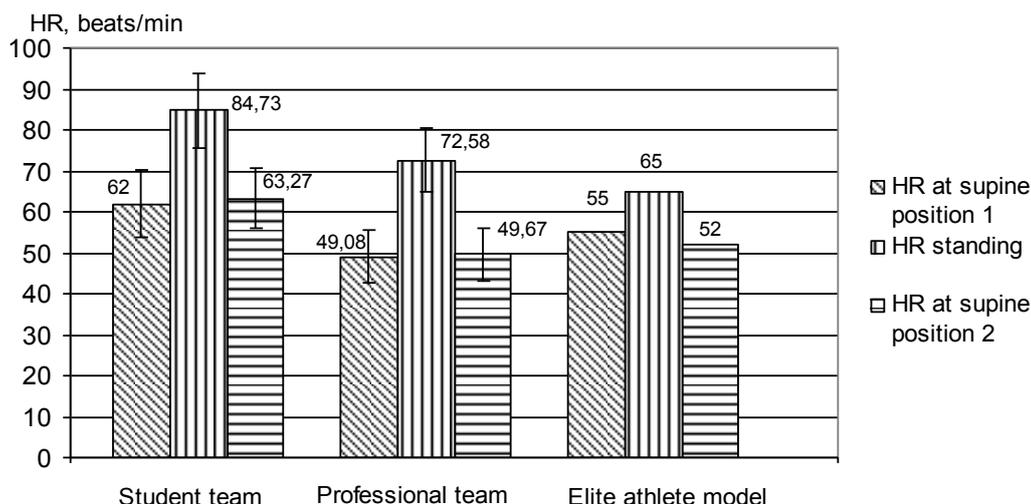
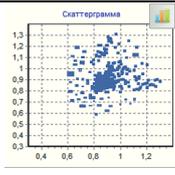


Fig. 1. HR during orthoclinostatic test in student and professional basketball players

The correlation rhythmogram is a set of points which have coordinates defined by two adjacent cardiointervals values RR_i and RR_{i+1} (fig.2). This method is highly sensitive to a sudden duration changing of RR-intervals. With the help of the correlation rhythmogram, we evaluated the "sinus arrhythmia", normally formed as a picture of a "cloud" and pathologic arrhythmia as well as "loss" QRS-complexes and beats that are clearly visible on the correlation rhythmogram. In case of a large scatter of heart rate data or the presence of emissions, an athlete needs to be consulted by a cardiologist. The correlation rhythmogram analysis (table 3) of two basketball team members are presented in fig. 2.

Table 3. Classification and interpretation of athletes correlation rhythmogram

Type	Name	Rank	Description
	Point	1	Normal heartbeats. Consistent rate. There was correct training program accompanied with athlete's day regiment keeping.
	Blurred point	2	Athlete's normal correlation rhythmogram
	Cloud	3	Normal "sinus arrhythmia" intrinsic to athlete under adequate physical load especially in endurance sport
	Blurred cloud	4	There are arrhythmias or abnormal heartbeats. The possible reasons are fatigue, incomplete recovery, imbalances in the blood or athlete's day regiment disturbance.

	Unformed cloud	5	Serious cardiorhythm disorders. May be caused by crucial physical and overall fatigue, incomplete recovery after recent high intensive physical load. Beyond that, such correlation rhythmogram may be early predictors of emerging infections or other diseases which yet had no external manifestations.
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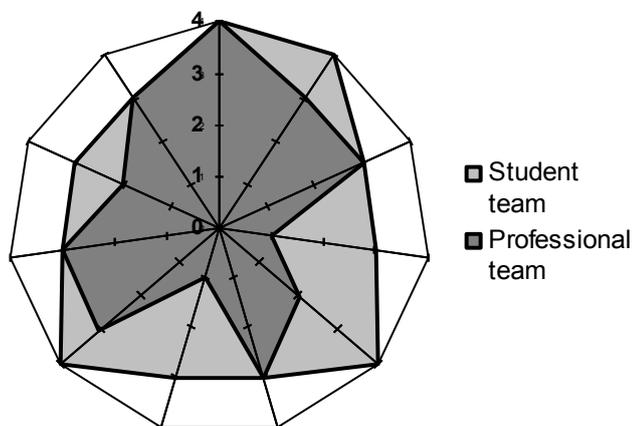


Fig. 2. Radar chart of correlation rhythmogram distribution in basketball student team and professional club team

Radar chart of correlation rhythmogram distribution among the basketball student team and professional club players is displayed with athletes represented on axis (spokes). The data length of a spoke is proportional to the rhythmogram rank (table 3) of each subject. So the smaller the square of the inner colored zone, the better cardio rhythm characteristics in group of athletes.

Heart rate monitoring during ET (fig. 3) revealed:

1. The higher values of HR in students than that in professional basketball players at the similar pedaling power regardless the physical load intensity. Insufficient development of athletes' cardiovascular system and low hemodynamic indices of students basketball players (table 2) causes the higher HR during any physical activity than in endurance athletes.
2. The greater average values of attained load (P_{max} , W) in professional team $P_{max} = 381.5 \pm 41.44$ W in comparison with students' $P_{max} = 317.09 \pm 49.18$ W.
3. The longer trajectory of professional basketball players than that of students. It is due to better strength abilities and overall endurance of professional players than that in student team.
4. Athletes of both teams refused to continue ET or were stopped by the researcher because of their inability to maintain the necessary pedaling rate at moderate HR (below 180 bpm). In maximal stress-test, HR_{max} lower than 180 bpm, which serves an indicator of the priority in the cardiovascular fitness over muscles.

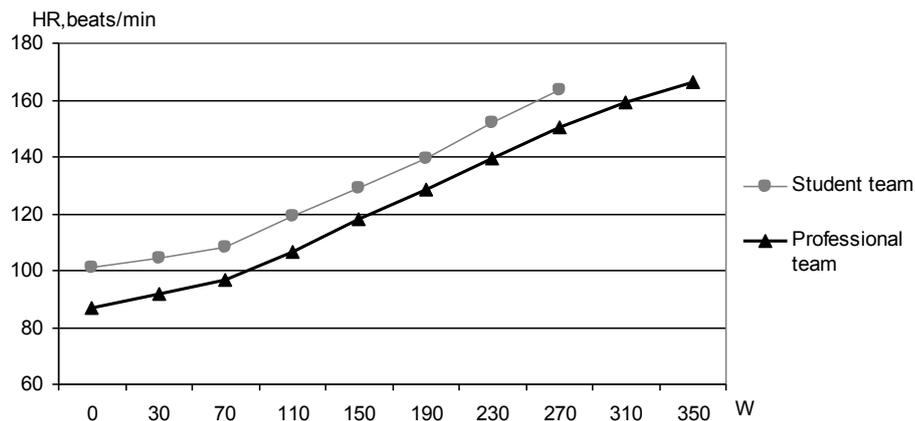


Fig. 3. HR (mean values) dynamics during ET in studied groups

Gas-exchange measurements during ET allowed us to compare major indicators of aerobic performance between athletes depending on qualification. Fig. 4 demonstrates comparison of maximum oxygen uptake, minute ventilation and anaerobic threshold (% VO_{2max}) as the most sensitive indicator of exercise performance (Vilikus, 2012).

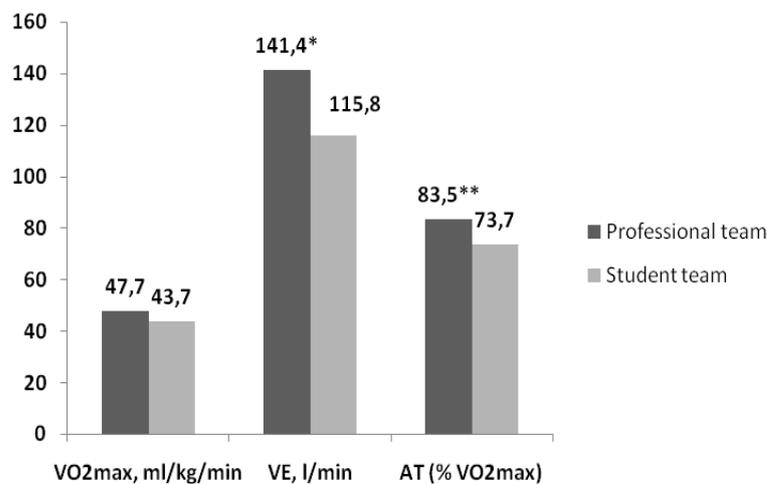


Fig. 4. Comparison of exercise testing parameters in both studied groups of basketball-players

VO_{2max} – maximum oxygen uptake; VE – minute ventilation; AT – anaerobic threshold; * statistical significance at $P < 0.05$ and ** $P < 0.01$.

Maximum oxygen uptake (VO_{2max}) is an indicator of maximal aerobic capacity (Bassett, 1997), pointing at the athletes' ability to transport oxygen to working muscles as well as to utilize it with this skeletal muscles at maximum load. Thus, VO_{2max} affected by overall endurance factors (cardiovascular and respiratory systems) and P_{max} affected by strength factors are the main characteristics of an athlete's integral readiness. The following recommendation for student basketball team was developed: at first it was necessary to provide sufficient SV and end-diastolic volume in athletes, then enhance their strength. As the professional team players had sufficient heart volume parameters and thereby low RHR,

appropriate HR dynamics during ET and the HR_{max} below 180 bpm, the evident way for them to improve performance is strength training.

Thus, analysing the obtained data on the VO_{2max} value with full details about cardiovascular health allowed us to determine the limiting factors of athlete's performance and to explain the top-priority importance of cardiovascular development in training of basketball players of any professional level.

4. Conclusions

The research of cardiovascular health in basketball-players allowed us to identify the absence of abnormalities in the cardiovascular system of athletes. Along with normal anthropometric and ECG parameters, the insufficient hemodynamic indices (SI and EDI) were revealed in students, especially in a vertical body position. These hemodynamic peculiarities caused the high HR during athletes' training and competitive activity. So the development of cardiovascular system must be the first priority for health-saving even in basketball, which is basically not considered as endurance sport.

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