Physical and Psychophysiological Profiles of Sub-elite Basketball Players
Novel Approach to Complex Testing

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Abstract: Basketball is a very demanding sport. Game effectiveness depends on a large number of physical and psychological abilities, technical competence, etc. Thus appropriate comprehensive complex approach to laboratory testing and its data interpretation play a considerable role in suggestion the proper training prescription and schedule. The aim of the proposed study was to choose appropriate and accessible laboratory testing methods and present their results. Fourteen professional male basketball players aged 24.8±5.4 years underwent bioimpedance analysis of body composition, maximal cycling test, hemodynamics monitoring, Wingate-test, jump performance analysis and psychophysiologic tests. These allowed to define the physical and psychophysiologic profiles of athletes. It was revealed, that (i) athletes had low percentage of fat (10.3±4.7 %) and high level of muscle mass (85.4±4.5 %); (ii) excellent volume heart parameters (SV – 137.00±19.93 ml) and low RHR – 49.08±6.56 bpm; iii) lowered VO_{2max} 47.52±6.14 ml/kg/min, P-VO_{2max} – 4.13±0.58 W/kg; (iiii) lower than expected strength abilities – peak power of arms – 6,47 ±0,87 W/kg and relative maximal power of legs – 42,17±4,22 W/kg, respectively. The obtained data provided with valuable information for further improvement of training process.

1 INTRODUCTION

Professional basketball is a challenging kind of sports. It is critically important to consider a wide range of aspects for its demands evaluation (Ransone, 2016):

- Anthropometric features and body composition;
- Strength, power and agility, as they are valuable predictors of success in team sports and basketball in particular.
- Anaerobic abilities, as basketball is an intermittent sport with specific significant anaerobic metabolism.
- Aerobic abilities, as a player may run about three miles during the game.

Success in basketball requires adequate and appropriate complex control of physical, physiologic, psychological and specific skills changes in athletes. Based on mentioned above, the main objectives of athletes' complex control in professional basketball are as follows:

- To understand the profile of successful basketball players (Ostojic et al., 2006) and reveal the individual strong and weak points in order to improve the quality of trainings.
- To obtain the detailed information on physical and psychophysiological characteristics of athletes from the tests for considering during planning athletes' daily practice, week schedule or even long-term programme to improve the quality of training (Ziv and Lidor, 2009).
- To provide appropriate control in order to promote prevention of overreaching and overtraining, as minimizing risk factors significantly impact on higher sports achievements in basketball.

According to revised data numerous studies of various research groups worldwide had been performed to reveal physiological, physical, psychological etc. features and profiles of professional basketball players (Ziv and Lidor, 2009; Thomas and Nelson, 2005; Krustrup et al., 2006;

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Bed Abdelkrim et al., 2007). Meanwhile, according to existing data, a number of limitations of currently used control in basketball have been highlighted.

The proposed study was focused on development of accessible comprehensive control of athletes, covering most of important aspects in basketball. In particular, we evaluated anthropometric and body composition parameters, aerobic and anaerobic abilities, cardiovascular functional state, strength and power abilities and psychophysiological indicators. The obtained complete information ultimately is extremely important and accessible for coaches, athletic trainers and sports practitioners in basketball.

Professional basketball club "Uralmash" (Yekaterinburg, Russia) recruited for the study was renovated in 2016 to take part in Super League of Russian Basketball. "Uralmash" was a well-known professional basketball club with more than 50 years old history with 20 resounding victories in Soviet and Russian basketball championships. So the challenging task was set for coaches and players – to win the Super League 2 Cup 2016/2017 in order to join Super League 1 and compete for entering United League VTB (the highest Russian National Basketball League).

2 ORGANIZATION AND METHODS

Subjects. Fourteen healthy male professional basketball players (mean age 24.8±5.4 years, height 198.4±7.9 cm, weight 94.3±13.3 kg) of the team "Uralmash" were recruited for the study. The participants of the study had more than 10 years of sport experience in basketball. Eight athletes previously played for teams from Super League 1 and VTB United league. During the season participants of the study practice on a daily basis, once or twice a day, have 40 games and approximately 5 to 10 friendly matches, 3 to 5 National Cup games. All tested subjects were free of cardiovascular or any other chronic disease. The investigation conforms to the principles of the Declaration of Helsinki of the World Medical Association. Athletes involved in the study had been provided with comprehensive information on the procedures, methods, benefits and possible risks before their written consent was obtained. The study was approved by the Ural Federal University Ethics Committee.

All laboratory tests were conducted in the research laboratory "Sports and health technologies" of the Institute of Physical education, sports and youth policy, Ural Federal University.

2.1 Anthropometric Measurements

Anthropometric features, body composition, height and lean muscle mass in particular are commonly considered in most type of sports, contributing into success prediction in different sports. Notably changes in body composition can be achieved through both adequate training and proper nutrition strategy (Ransone, 2016).

Weight and segment body composition were measured with the use of the MC-980MA Plus Multi Frequency Segmental Body Composition Monitor (TANITA, Japan) based on the advanced Bioelectric Impedance Analysis (BIA) technology. The following parameters were registered: body mass (kg), body mass index (BMI), muscle mass – absolute and relative (kg; %), absolute and relative fat mass (kg; %), fat free mass (kg), bone mass (kg), separately lean mass of the trunk, upper and lower extremities (kg).

2.2 Hemodynamics Measurements

The hemodynamic monitor MARG 10-01 "MicroLux" (Chelyabinsk, Russia) functioning is based on such noninvasive methods of hemo-dynamic monitoring as impedance cardiography and spectrophotometry, electro-cardiogram monitoring, reography and central hemodynamics monitoring.

Before data recording all subjects were at rest in supine position during 10 minutes. The active orthostatic test (in the Shellong modification) and active klinostatic test (Danielopolu test) were carried out. So the combined orthoklinostatic test included 5 stages:the rest stage (at supine – 2 min); transition to the vertical position;standing position – 2.5 min; transition from the vertical position to the supine position and supine position (2.5 minutes).

All measured indicators of the central hemodynamics were automatically registered with beat-to-beat record. To investigate the functional state of basketball players we chose the most informative for sport practice hemodynamic parameters and their indices (Shishkina, 2013): heart rate (HR, bpm), stroke volume (SV, ml), end-diastolic volume (EDV, ml), stroke index (SI, ml/m^2) and end-diastolic index (EDI, ml/m^2) which are the ratio of stroke volume and end-diastolic volume to the body surface area in square meters and ejection fraction (EF, %).

2.3 Maximal RAMP Cycling Test

Aerobic performance testing was performed with the use of a bicycle ergometer ERG 911S (Schiller AG, Switzerland) and a desktop metabolic monitor Fitmate PRO (COSMED, Italy). Maximal ramp protocol was applied according to ACC/AHA 2002 guideline update for exercise testing (2006). The test started from the load of 0 W during warm-up stage (1 min) with further load increase (40 W per minute). It was recommended to keep the cadence about 80 rpm. The test was considered to have been performed at a maximal level of effort in case of: (1) the inability of the subject to maintain the expected cadence (80 rpm) despite verbal inciting; (2) refusal to continue the test due to subjective exhaustion of the muscles; (3) the appearance of absolute medical indicators.

The used portable device allowed to record the following parameters starting with the first 1 min warm-up stage and continuously during exercise testing: oxygen uptake (VO_2, ml/kg/min), heart rate (HR, bpm), stated exercise load (P, W), volume of ventilation (Ve, l/min), and respiration rate (Rf, 1/min).

Measurements of indices of gas-exchange during stress test gave an important information on athletes' aerobic capacity (Vilikus, 2012) and accurate values of metabolic changes under stress conditions: VO_{2max}, anaerobic threshold (AT) and its relation to VO_{2max} (%).

A combination of the obtained physiologic characteristics during stress test provided with comprehensive information about integral response of respiratory apparatus, muscles and cardiovascular systems to exercise load. In other words, it allowed estimating not only oxygen uptake, transport and utilization, but also efficiency of respiration at a maximal level of effort (Ve_{max}, l/min – maximal volume of ventilation per minute; Rf_{max}, 1/min – maximal respiration rate; V_{max} – maximal volume of one inspiration) and muscle strength of athletes (P-VO_{2max} – the power reached at VO_{2max}). These indicators are considered as maximal individual for this certain type of test.

2.4 Arm Cycling Wingate Test

Cycling Wingate test was conducted with the use of the ergometer TOP EXCITE 700 MD (TechnoGym, Italy). Anaerobic power measures were obtained using arm cycling Wingate anaerobic test, and included peak power (PP, W), relative PP (W/kg), average power (AP_{30}) and its relative value (AP_{30}, W/kg).

2.5 Performance Analyses for Vertical Jumps

Performance analysis for vertical jumps is widely used tests in power and sprint sports (Ntai, 2017, Van Hooren, 2017). There were many ways to obtain data about the aspects of jumps parameters (Lara, 2006, Ntai, 2017, Van Hooren, 2017) but nowadays due to high speed jumping dynamics force plates are the demandable instruments to describe fast sport movement quantitatively. Kistler (Switzerland) - the leader in the field of sport performance analysis – uses piezoelectric sensors to measure forces and moments for sports and performance analysis. The more sensitive the force plate is, the more precise and reliable data are obtained.

The purposes of this part of study were (1) to obtain descriptive data about maximal anaerobic power output of the lower extremities with a force platform from countermovement jump (CMJ) and squat jump (SJ) performed by basketball players and (2) to define issues in muscle realization of jumping that is the important component of basketball.

Professional basketball players made three CMJs jumps and three SJs and the highest jumps of each player were analyzed. They were instructed to perform the jumps with maximum effort. All data were collected using two Kistler Jump force plates (type 9269AA3) with 64-channel block for data processing 5695B. MARS Software was used. We were interested in the jump height (cm), relative maximal power (W/kg), push off time (s) and impulse (Ns) in CMJ and SJ.

2.6 Psychophysiological Tests

The choice of diagnostic methods for the study of psychophysiological features of the nervous system was determined by the specifics of sports activities of basketball players. The capabilities of the computer complex "NS-PsycheTest" ("NeuroSoft", Russia) were used to identify a simple visual-motor reaction, reaction to a Moving Object and abilities for high intensive work.

2.6.1 A Simple Visual-motor Reaction

During testing of a simple visual-motor reaction (Zimkina, 1978) seventy red light signals were shown consistently to athletes. The signals appear at a different time interval, so that the reflex was not formed. The first 5-7 signals were "trial" and intended for adaptation of the subject. When a signal appears, the examinee must press the button as soon as possible, trying to avoid mistakes such as a prematurely pressing of the button or a skip of the signal.

The following indicators were determined:

1. Time of visual-motor reaction and subject's quality of the reaction to the stimulus (M, ms);
2. Equilibrium of nerve processes and stability of sensorimotor reactions (SD, ms);
3. Level of functional capabilities (LFC). The criterion reflects the ability of athletes to form an adequate functional system and to maintain it (Mantrova, 2007).

2.6.2 Reaction to a Moving Object

Reaction to a Moving Object is a complex sensor motor reaction that includes a response to a specific signal – visual alignment of two moving objects.

On their monitors, the subjects were shown a circle on which there were two marks at different intervals, changing the position from presentation to presentation. The circle was filled in a clockwise rotation. The athlete had to press the button of the analyzer at the moment when the fill reached the second mark.

Processing of the results was made by comparing of the number of advanced and delayed reactions. Level of the excitation and inhibition processes of the nervous system was estimated on the basis of the diagnostic results.

2.6.3 Express-method "Tapping Test"

Express-method "Tapping test" (Ilyin, 2005) is reflecting overall performance and strength of the nervous processes. The test was carried out using two special instruments: «pencil» and "a rubber platform". The athlete was instructed to tap the platform with the maximum possible frequency for 30 seconds.

Processing of the results was made by counting the number of movements performed in each of the five-second intervals of the test. Based on the obtained results a graph was built which characterized the overall performance of the subject and the strength of the nervous processes (Figure 1):

1. Strong nervous system is characterized by increasing in the rate of movement in the first 15 seconds by more than 10%; then the rate decreases to the original (± 10%).
2. Nervous system of medium strength: movement rate is kept at the same level with fluctuations of ± 10% throughout the test.
3. Weakness of the nervous system is indicated by the descending type of the line. The maximum number of movements is established during the first five-second interval, then the rate of movement decreases by more than 10%.
4. If the athlete has a medium-weak nervous system, the maximum number of movements is established during the first two to three five-second intervals, then the rate of movement falls.
5. Medium-strong nervous system tends to show a decrease at the beginning of testing, then a short-term increase in the rate to the initial level (± 10%).

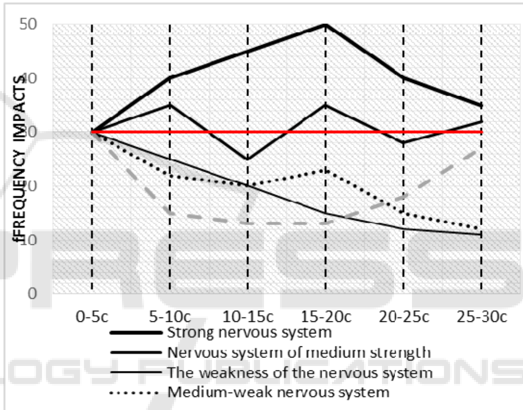

Figure 1: Graphic representation of the individual-typological features of the nervous system.

2.7 Statistical Analysis

Statistical analysis was performed with the use of statistic software package "SPSS Statistics 17.0" (IBM). We used descriptive analysis of the obtained data in order to estimate basic functional status of athletes. Normality of distribution was assessed by the Shapiro-Wilk test. Mean value (M), standard deviation (SD), minimum and maximal values of the measured parameters were calculated. This enabled us to describe the physical, physiologic and psychological profiles of studied athletes.

3 RESULTS AND DISCUSSIONS

The detailed descriptive data on body composition and anthropometric measurements of sub-elite basketball players (Table 1) show that generally studied athletes are tall have low percentage of fat and high index of lean mass. High value of lean mass in studied athletes is undoubtedly an advantage and may serve as a proof of appropriate sports selection as well as proper training and nutrition.

Table 1: Anthropometric and body composition analysis of sub-elite basketball players.

Parameters	M±SD	(min-max)
Height, cm	198.4±7.9	185-210
Body mass, kg	93.3±13.3	74.2-123
Body mass index	24±2.1	21.6-28.3
MM, kg	80.3±11.1	57.1-102.4
MM, %	85.4±4.5	75.4-91.3
Fat mass, kg	9.8±5.0	3.1-22.6
Fat mass, %	10.3±4.7	4-20.7
Bone mass, kg	4.1±0.5	3.0-5.2
MM trunk, kg	42.9±5.4	31-51.1
MM right hand, kg	5.3±1	2.8-7
MM left hand, kg	5.2±1	2.8-7.2
MM right leg, kg	13.4±1.95	10.4-18.4
MM left leg, kg	13.5±2	10.1-18.7

MM – muscle mass.

Notably, all studied athletes had good body balance (comparison of left and right composition parameters of upper and lower extremities), as well as high indices of muscle mass.

Results of hemodynamic monitoring (Table 2) showed that average heart rate at rest at supine in professional basketball players is lower than athletes' norm for sport games. What was more surprising is the HR corresponding to that of high performance endurance sport representatives in 5 of 14 examined basketball players. Excellent heart volume parameters and indices of basketball players are the guarantors of good tolerance to high intensity load in training and competitive activities.

Active orthostatic test revealed higher deviation of HR while standing up from the initial value at supine (23.50±6.57 bmp) than it is should be in athletes (less than 18). HR increase after transition from supine to the vertical body position estimates the quality of athlete adaptation to vertical position and the action of physiological systems regulation. The less Δ ($HR_{standing} - HR_{at\ supine}$), the better functioning of an athlete vascular system is. 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 heart volume parameters and indices in athletes vertical position (Table 2). We were satisfied with all hemodynamic parameters except Δ ($HR_{standing} - HR_{at\ supine}$). There are several reasons of excessive heart rate in basketball players while standing: (1) high body height, (2) poor vascular adaptation to vertical position, (3) insufficient recovery or fatigue.

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

Hemodynamic parameters and indices	Basketball players	Athletic norm
$HR_{at\ supine}$, beats/min	49.08±6.56	55
$HR_{standing}$, beats/min	72.58±7.72	65
$\Delta HR_{standing} - HR_{at\ supine}$, beats/min	23.50±6.57	<18
$SV_{at\ supine}$, ml	137.00±19.93	>120
$SV_{standing}$, ml	103.42±17.35	>100
$SI_{at\ supine\ 1}$, ml/cm^2	68.7±7.23	>70
$SI_{standing}$ ml/cm^2	49.58±6.05	–
$EDI_{at\ supine\ position}$, ml/cm^2	108.42±7.39	>100
$EDI_{standing}$, ml/cm^2	89.25±7.79	–

HR – heart rate; SV – stroke volume; SI – stroke index; EDI – end-diastolic index.

We also found that average HR before the cycling test measured sitting on cycle ergometer was higher than the sports norm (Table 3).

Table 3: Stress-test parameters of sub-elite basketball players.

Parameters	M±SD (min-max)	Athlete norm
VO_{2max}, ml/kg/min	47.52±6.14 (38.4-63.5)	55
HR before the test, bpm	78±7.48 (64-92)	70
HR_{max}, bpm	163±13.8 (143-188)	180-195
P-VO_{2max}, W	383.7±53.1 (310-500)	>450
P-$VO_{2max/kg}$, W/kg	4.13±0.58 (3.3-5.1)	>5
Ve_{max}, l/min	145.3±36.4 (91-210)	160-180
AT, %VO_{2max}	77.8±7.1 (66-88)	
METS	13±1.16 (11-15)	>17.5

HR – heart rate; P-VO2max - power reached at VO2max; P-VO2max/kg – relative maximum power at P-VO2max; VO2 – oxygen consumption; Vemax – maximal volume of ventilation per minute; AT – anaerobic threshold.

Obtained from the cycling test data demonstrate that most of the measured parameters varied within a wide range in the studied group. Although mean values of VO_{2max} corresponded to physiologic norm in reference to age and gender for healthy subjects, it was lower than the one for elite basketball players (Ziv and Lidor, 2009) reported in most studies as VO_{2max} = 50-60 ml/kg/min (Tavino et al., 1995; Gosentas et al., 2004).

Strength abilities of basketball player legs were lower than we expected. Power index (P-$VO_{2max/kg}$, W/kg) was good but not excellent. HR_{max} was lower than athletic norm that means predominant heart development over the muscle system of sub-elite basketball players.

Meanwhile, some studies (Hoffman, 2003) revealed that increase in aerobic capacities may not increase game performance in basketball. However, it is assumed that anaerobic threshold is the most sensitive and reliable indicator for basketball players. According to data from numerous researches, the average oxygen uptake during the game is about 64.7% for male basketball players (Narazaki, 2008). Thus, increase of AT to realistic 70% may benefit in using more aerobic pathways and eventually result in minimizing fatigue during games. (Ziv and Lidor, 2009).

The obtained data from stress-test in our study showed that mean value of AT of basketball players corresponded to high level of aerobic metabolism. This fact is critically important in evaluation of physical profile of sub-players, as it serves as a proof of appropriate aerobic state, as in professional basketball impact of AT is significantly higher, than absolute values of VO_{2max}.

As power and acceleration abilities are of great importance in sport games and both arms and legs are involved in specific movement realization we consider to analyze power abilities in arms and legs in basketball players. The results of arm cycling Wingate test (Table 4) reveal the wide range of peak power in sub-elite basketball players, low relative PP and high level of fatigue.

Table 4: Arm Wingate-test parameters of sub-elite basketball players.

Parameters	M±SD (min-max)
PP, W	570.5 ± 141.6 (440-780)
PP, w/kg	6.47 ±0.87 (5.5-7.8)
AP_{30}, W	417.16 ± 93.29 (299-528)
AP_{30}, W/kg	4.76 ± 0.64 (3.52-5.28)
Fatigue, %	52.5 ± 15.82 (30-72)
t_{pp}, s	6.67 ± 2.54 (4-10)

PP – peak power; AP – average power; t_{pp}, - time of PP attainment.

Performance analysis for vertical jumps (Table 5) revealed lesser CMJ performance than physical education students (34.6±4.3cm, Lara, 2006) and elite and sub-elite fencers (30.1 ± 7.4 cm, Ntai, 2017). CNJ performance is almost always better than SJ performance (Van Hooren, 2017) and in examined basketball players SJ height is better than one of CMJ but no significant difference was found in CMJ and SJ parameters except push off time. The last peculiarity of vertical jumps performance in basketball players may root from specific technique of basketball jumps as well as insufficient power and strength determined through maximal cycling testing and arm Wingate-test.

Table 5: Maximal anaerobic power of the lower extremities of basketball players (M±SD (min-max).

Parameters	CMJ	SJ
Height jump, cm	28.55 ±4.49 (16.2-33.1)	30.08±5.66 (17.6-40.4)
Relative max power, W/kg	42.17±4.22 (33.91-49.13)	42.96±4.89 (33.22-49.7)
Push off time, s	0.326 ±0.037 (0.246-0.367)	0.475 ±0.047** (0.394-0.554)
Impulse, Ns	225.91±32.75 (175.8-295.2)	229.45±34.60 (181.1-308.5)

**Significant differences between CMJ and SJ parameters $P < 0.01$.

The results of simple visual-motor reaction (SVMR) of basketball players (Table 6) were in the upper norm of individuals not engaged in professional sports.

As we can see from the obtained results, steadiness of attention concentration differ significantly from the mean statistical values of not engaged in professional sports healthy people. The reaction rate and the functional level capabilities also indicate the predominance in motor reactions in professional athletes.

Table 6: SVMR characteristics of sub-elite basketball players.

Parameters	M±SD (min-max)	Norm
Reaction time, ms	195.88±8.48 (174.18-284.17)	193-233
Stability of response, ms	35.91±1.97 (16.72-49.8)	23-97
Steadiness of attention concentration, c.u.	0.07±0.02 (0.00-0.21)	0.08-0.15
Functional level, c.u.	4.04±0.17 (4.99 – 2.97)	4.2-3.0

The SVMR results analysis (Figure 2) reflects the high reacting speed in 67 % of team members, 25% of the players showed average level of response reaction and one athlete demonstrated low reaction.

The indicator of functional level of basketball players is in the mid range and it is optimal for implementation of sports activity (Zimkina, 1978). Only 8% of basketball players demonstrate inertia in gaming and have a low functionality level (2.97 c.u.) that might lead to an increase in the number of erroneous actions.

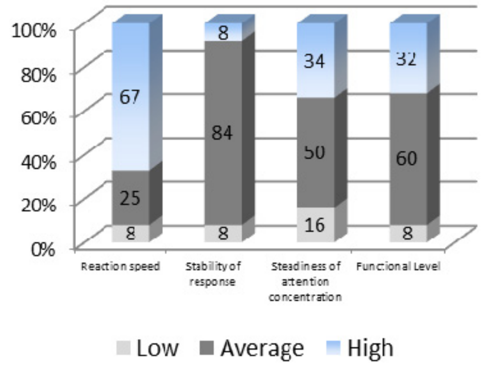

Figure 2: SVMR results of basketball team athletes, %.

The study of response strategies (Park et al., 2011) pointed out a significance of processes management in gaming activity.

A balanced version of the inhibitory and excitatory process is revealed in 50% of basketball players (Figure 3) 33.3% of the subjects demonstrate the predominance of excitatory process in their nervous systems, at the same time 16.7% of the subjects demonstrate the inhibitory process. The results indicate the success of the activities in difficult conditions that require rapid response. So, athletes engaged in high-intensity game sports have predominant process of excitation of nervous systems because intensive, high-speed gaming activity presupposes actions for anticipation.

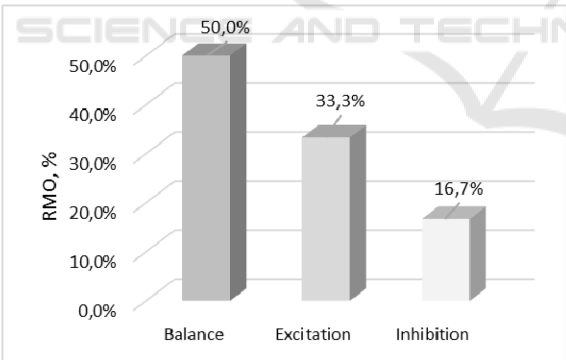

Figure 3: The results of reactions to a moving object (RMO) in basketball players, %.

Success rate of basketball players is higher in subjects with stable and strong nervous system types. The results of Tapping test method (Ilyin, 2005) made it possible to determine nervous system type of the subjects (Figure 4). The team was practically homogeneous. 70% have a medium-weak type of nervous system, which indicates good tolerance to intensive physical activity. Only 7% of the subjects are characterized by a weak type of nervous system.

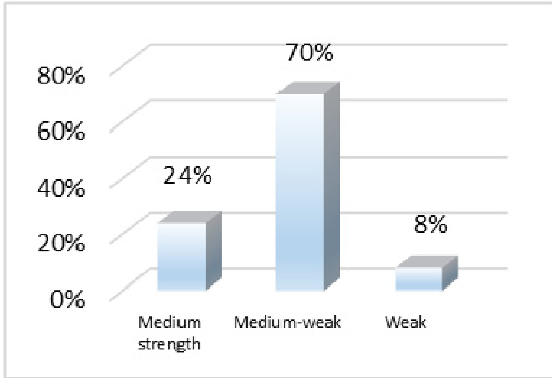

Figure 4: Types of nervous systems in basketball players, %.

Such athletes are emotional susceptible and prone to stress. 23% of the subjects possess the ability to fulfill the stated tasks under stress successfully.

4 CONCLUSIONS

1. Complex testing of sub-elite basketball players includes high-tech, though accessible methods: bioimpedance analysis for anthropometric and body composition evaluation, maximal stress cycling testing with gas-exchange measurements for estimation of aerobic capacities, hemodynamics monitoring for evaluation of cardiovascular functional state, arm Wingate test and performance analysis for vertical jumps to define strength output of upper and lower extremities, psychophysiological computer tests for estimation of abilities to perform fast and situational challenging physical actions in team sport.

2. We found that: (i) generally athletes had low percentage of fat (10.3±4.7 %) and high index of muscle mass (85.4±4.5 %); (ii) the following parameters of aerobic capacity in studied basket-ball players were obtained: mean value of VO_{2max} 47.52±6.14 ml/kg/min, Ve – 145.3±36.4 l/min, P-VO_{2max} – 4.13±0.58 W/kg, AT equal to 77.8±7.1 %VO2max; (iii) lower than expected strength abilities of athletes – peak power of arms – 6.47 ±0.87 W/kg and relative maximal power of legs in countermovement jumps – 42.17±4.22 W/kg, respectively.

3. Monitoring of psychophysiological features of athletes showed that sub-elite basketball players are characterized by good reaction time (195.88±8.48 ms), predominance of balance and excitation in their nervous systems and following nervous system

types: a medium-weak type (70%), medium-strong type (23%) and weak type (7%).

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