Comprehensive Fitness Control in Young Soccer Players
Comparison of Laboratory and Field Testing Indicators

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Abstract: Young athletes require a specialized approach to training process, taking into consideration a broad range of physiological and training aspects. The study is focused on the evaluation of fitness level of young soccer players and the search for interrelations between parameters of laboratory and field tests with the physiologic measurements during match play. The proposed paper provides coaches, sports scientists and physicians with important information on effective training control based on accessible and reliable tests. Twenty six healthy male soccer players born in 2004 currently aged 12-13 were recruited for the study. Data obtained from laboratory testing (cycling stress-test with gas-exchange measurements, Wingate cycling test, and blood lactate measurements), maximal interval running field test and soccer game analysis with heart rate monitoring were analysed. Firstly, Wingate cycle test parameters in young soccer players aged 12-13 were described in details. Furthermore, significant interrelations between indicators of physical state, obtained from the various types of tests were revealed. The most important finding was close correlations between measured indicators during the game with results of laboratory and field tests. Based on mentioned above, laboratory and field tests can be widely used in training control of young soccer players.

1 INTRODUCTION

Successful training of an athlete is determined by the timeliness and quality of the periodic control. The fitness level control in sport means monitoring and evaluation of physical capacities and in any kind of sport measurements are to:

- correspond to the competitive activity, i.e. be specific;
- match the athletes age and their sport achievements;
- provide with informative and reliable data that appraise the athlete current state, their strengths and weaknesses.

At present the regular control of the functional state of young soccer players gradually gets a greater meaning because of the early age beginning of sport training in soccer, increase of training load at the initial stage of training, and moreover due to the high intensity in competition and its athletic character in the adult soccer. The other problem we faced in the XXI century is poor children's cardiovascular system development (Zakharova, 2015) because of easy social, transport and living conditions in comparison with those of latter half of the twentieth century.

Thus in boyhood days it is necessary to lay the foundation for specific physical fitness level and monitor it to meet the requirements to the robust athlete in future soccer career.

It is commonly assumed that data obtained during the competition are the most reliable indicators of athletes' fitness level. Much information can be received from numerous portative sport devices but heart rate belts and monitors are not permitted during official soccer matches (Laws of the Game. FIFA, 2016, Impellizzeri, 2004).

Stated above enabled us to formulate the aim of the study − to assess the fitness level of young soccer players by means of laboratory and field tests and find connections between functional testing parameters and physiological measurements during match play.

Modern functional diagnostics provides us with the opportunities to study thoroughly various athletes' indicators that are important in sports activities. The only stumbling block is the set of

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methods to be used. They must be limited in number but provide overall information about physical competence. For research in a sport team it is important to choose the quickest testing procedure possible.

2 ORGANIZATION AND METHODS

Subjects. Twenty six healthy male soccer players born in 2004 currently aged 12-13 (height – 161.5±7.32 cm, body mass – 49.5±6.71 kg) were recruited for the study. The participants of the study had about 5 years of sport experience in soccer. All 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 parents' written consent was obtained and their permission was given. The study was approved by the Ural Federal University Ethics Committee.

2.1 Anthropometric Measurements

Weight and 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 (kg; %), fat mass (kg; %), fat free mass (kg), bone mass (kg), intracellular and extracellular water (%), metabolic rate (kcal) and body mass balance.

2.2 Laboratory Exercise Testing

All laboratory tests were conducted in the research laboratory "Sports and health technologies" of the Institute of Physical education, sports and youth policy, UrFU. Laboratory exercise testing included maximal ramp cycling test with gas-exchange evaluation, cycling Wingate test and blood lactate measurements.

2.2.1 Maximal Ramp Cycling Test

Exercise 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 in accordance with 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). Athletes were 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. Maximal cycling test is widely used by sports physicians and practitioners in assessment of physical fitness and aerobic capacity. This type of protocol is quite informative, relatively safe and easily reproducible.

The following parameters were recorded starting with the first warm-up stage (1 min) and continuously during exercise testing: oxygen consumption (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). The current values of all measured parameters were demonstrated on the metabolic analyzer screen and saved in the device memory for ongoing analysis.

Systolic blood pressure (SBP, mm Hg) and diastolic blood pressure (DBP, mmHg) were registered with the use of integrated tonometer blood pressure monitor (Shiller AG, Switzerland) after each second minute of the test. Immediate post-exercise measurements of HR, SBP and DBP during 5 minutes of recovery period were recorded. SBP and DBP values were manually fixed into metabolograph memory.

Gas-exchange measurements during stress test enabled us to obtain important information on athletes' aerobic capacity (Vilikus, 2012) and accurate values of metabolic changes under stress conditions. VO_{2max} – the maximal value of oxygen consumption during the test, anaerobic threshold (AT) and its relation to VO_{2max} (%) were determined through the stress-test. These indices characterize athletes' aerobic abilities and efficiency of oxygen utilization by working muscles.

A combination of the obtained physiologic characteristics during stress test with their further analysis 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 particular type of test.

We also consider P_{170}, W – cycling power at a heart rate 170 beats per min, as a physical working capacity indicator similar to PWC 170 – Cycle test, the primary purpose of the which (Cambell et al., 2001) is to predict the power output at a projected heart rate of 170 beats per minute (bpm). For example, one athlete has 180 W at the HR =170 bpm while the other has only 150 W. The former is more physically fit than the latter.

2.2.2 Cycling Wingate Test

Cycling Wingate test was conducted with the use of the ergometer BIKE MED (TechnoGym, Italy) and Cardio Memory software V 1.0 SP3. Anaerobic power measures were obtained using leg cycling Wingate anaerobic test, and included peak power (PP, W), relative PP (W/kg), power at 15 (P_{15}, W) and 30 sec (P_{30}, W), average power (AP_{30}) and their relative values (P_{15}, W/kg, P_{30}, W/kg, AP_{30}, W/kg).

2.2.3 Lactate Measurements

Blood lactate concentration (La, mmol/l) during performance testing of athletes was measured with the use of the portable device Vario Photometer DP 300 (Diaglobal, Germany) on microsamples of capillary blood from the fingertip. Post-exercise measurements of lactate were performed immediately after interval field testing and twice during the match (after the first and the second halves). It is well-known that lactate is the end product of the metabolic process of glucose utilization (anaerobic glycolysis) (Goodwinn, 2007). Thus, both in terms of the soccer game, as well as the interval running field testing, the rate of lactate elevation was considered as a measure of anaerobic abilities and a response to physical exertion.

2.3 Field Soccer Tests

The maximal running interval testing was carried out on a pitch in a circle (lap) marked by 4 cones (20m x 20 m). Athletes performed High Intensity Interval Training (HIITraining) of 8 sets of 20-second interval (Tabata Protocol) with an “all-out” effort separated by 10 seconds of passive recovery (Tabata, 1996). GPS Garmin Forunner 310XT was used to measure the distance length covered in each of 8 intensive bout and monitor heart rate (HR) during the HIIT-test and HR recovery after it. For quick and easy data access and HR and distance information acquisition and processing the GPS navigator configurations were installed on the interval training (12 intervals × 20 sec + 10 sec for rest). The additional 4 intervals were used for processing an athlete recovery data. According to the classification of training and competitive physical activities the highest result shown in the first cycle of the test corresponds to the zone of anaerobic alactic power (D_{max}, m; V_{max}, km/h) and it is the indicator of speed abilities (Tarbeeva, 2011) or athlete’s running speed (Zakharova, 2015). The sum of the first three results ($D_{1\text{-}3}$), which depends mainly upon the degree of the covered distances decrease, serves the marker of ability to maintain high speed. The result obtained within all 8 cycles corresponds to the work in anaerobic glycolic zone and the sum of 8 distances ($D_{1\text{-}8}$) characterizes special stamina and anaerobic glicolytic potential of athlete’s working muscle groups (Tarbeeva, 2011, Zakharova, 2015).

All players were informed of the rating of the perceived exertion rating (RPE) scale (CR-10) and familiarized with it a month before the start of the study. The CR-10 scale proposed by Foster (1995, 2001), was presented to each player 12 min after Maximal running interval testing. This was done to exclude the influence of emotional factor after the test.

2.4 Soccer Game Analysis with Heart Rate Monitoring

To estimate age features of competitive activity of young soccer players the heart rate monitoring with GPS Garmin Forerunner 310XT (Garmin, USA) was used. HR was recorded every 5 sec during each training session using HR monitor with individually coded HR transmitters to avoid interference. To measure the distance length covered during the game GPS navigation was used. Software Garmin Express and Garmin Connect helped us to determine the maximal velocity of young soccer-players, maximal and average HR, amount of time in different heart rate zones and others recovery speed.

The match (11 vs 11) was played on a regular size (105 × 68 m), synthetic-grass soccer pitch in two halves of 35 minutes (the official duration of the game for a given age of players), with 10-minute rest interval. During the game a ball of size 5 was used. To ensure that the game would restart immediately if the ball left the field of play, spare balls were kept all around the perimeter of the pitch. Six players were observed during the match.

The perceived exertion rating (RPE) scale (CR-10) was presented to each player 7 minutes after each half of the game.

2.5 Statistical Analysis

Statistical analysis was performed with the use of statistic software package "SPSS Statistics 17.0" (IBM). The descriptive analysis of the obtained data was applied to determine basic functional status of athletes. Normality of distribution was assessed by the Shapiro-Wilk test. Mean value (M) and standard deviation (SD) of the used parameters were calculated. Pearson correlations between the measured parameters were calculated to estimate the relations between results of laboratory, field and real-game measurements. The level of significance was set at $P < 0.05$.

3 RESULTS AND DISCUSSIONS

The obtained data of anthropometric measurements of young soccer players (Table 1) show that generally athletes had age and gender appropriate body mass, height and most part of other indices. High values of fat free mass (muscle mass) point at good physical status and beneficial training effect of soccer.

Table 1: Anthropometric and body composition analysis of young soccer players (12-13 years).

Parameters	M±SD	(min-max)
Height, cm	161,07 ± 7,64	149-176
Weight, kg	49,37 ± 6,41	36,8-61,7
CC, cm	73,65 ± 3,57	66-79
NC, cm	34,04 ± 2,13	30-39
MM, kg	38,85 ± 5,14	29,4-48,4
MM, %	78,59 ± 3	70,96-83,81
Fat, kg	8,48 ± 1,97	4,9-12,9
Fat, %	17,13 ± 3,15	11,7-25,1
BMI, kg/m^2	18,95 ± 1,54	16-21,5

CC – chest circumference; NC - neck circumference; MM- muscle mass.

Table 2 shows the results of laboratory cycling stress-test. On average, VO_{2max} in the studied group corresponded to high level in reference to age and gender norm in soccer for 12-13 years (Cunha, 2011) and slightly lower one for age of 14.2±0.5 years reported VO_{2max}= 56.5 ± 0.9 (Buchheit, 2008).

Average HR before the test, measured at rest sitting on cycle ergometer, was higher than sport norm. This result indicates the poor cardiovascular development that leads to low aerobic abilities. At the same time HR_{max} was within athletic norm (Table 2), that means the balanced heart-muscle development of young soccer players. But this balance was reached thanks to good but not excellent power index ($P\text{-}VO_{2max/kg}$, W).

Meanwhile, most of the stress-test parameters varied within a certain range. This indicated considerable difference of level of aerobic performance and physical state of players of the same age.

Table 2: Stress-test parameters of soccer players.

Parameters	M±SD (min-max)	Athlete norm
VO_{2max}, ml/kg/min	54.34 ± 6.08 (45.8-66.6)	55
HR before the test, bpm	90.28 ± 10.59 (70-109)	70
HR_{max}, bpm	182.89 ± 5.63 (172-192)	180-195
P_{170},W	183.78 ± 35.14 (136-258)	-
$P\text{-}VO_{2max}$, W	222.67 ± 35,18 (152-294)	>250
$P\text{-}VO_{2max}$/kg, W/kg	4.74 ± 0.46 (4.04-5.48)	>5
Ve_{max}, l/min	82.37 ± 16.97 (55.2-123.2)	80-100
Rf_{max}, 1/min	54.57 ± 12.98 (35.4-81.6)	-
V_{max} (Ve/Rf), l	1.55 ± 0.45 (0.96-2.86)	>2
METS	15.56 ± 1.79 (13-19)	>15.5

HR – heart rate; $P\text{-}VO_{2max}$ - power reached at VO_{2max}; $P\text{-}VO_{2max}$/kg – relative maximum power at $P\text{-}VO_{2max}$; VO_2 – oxygen consumption; Ve_{max} – maximal volume of ventilation; Rf_{max} – maximal respiration rate; V_{max} – maximal volume of one inspiration.

As running speed and acceleration abilities are of great importance in soccer we reported opportunity to measure peak power in cycling Wingate test for testing of 11-12 years old (Zakharova, 2016). No information about Wingate-test parameters in the age of 12 was found.

In the present study (Table 3) relative PP and AP were as high as the same indicators of 15-16 years old soccer players (Jastrzębski, 2011, Junior, 2010) and higher than that of forwards (Joo, 2016) whereas all absolute values were lower. In comparison with 17 years old players with identical experience in soccer, the tested players showed lower values of PP, but the same values of AP

(Chtourou, H., 2012). This undoubtedly demonstrates the high level of leg muscles fitness for anaerobic work specific for soccer.

Table 3: Wingate-test parameters of soccer players.

Parameters	M±SD (min-max)
PP, W	517.21 ± 102.9 (371-698)
PP, w/kg	10.83 ± 1.24 (8.67-12.92)
P_{15}, W	421.71 ± 96.87 (292-628)
P_{15}, W/kg,	8.53 ± 1.12 (6.99-10.33)
P_{30}, W	337.71 ± 95.6 (226-497)
P_{30}, W/kg	6.78 ± 1.11 (5.06-9.15)
AP_{30}, W	415.29 ± 87.01 (314-607)
AP_{30}, W/kg	8,69 ± 0.96 (7.22-10.6)
Fatigue, %	41.29 ± 10.17 (25-62)
t_{pp}, s	5.64 ± 4.63 (2-17)

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

The results of interval running test are showed in Table 4 and Figures 1 and 2.

Table 4: Results of interval running test of soccer players.

Parameters	M±SD	Max
D_{max} per interval, m	114.45 ± 7.03	132
ΣD, m	746.82 ± 57.64	831
ΔD, m	31.82 ± 9.36	45
HR_{max}, bpm	189.36 ± 7.51	202
HR_{mean}, bpm	161.91 ± 6.22	171
V_{max}, km/h	20.6 ± 1.27	23.76
V_{mean}, km/h	16.8 ± 1.3	18.7
V_{min}, km/h	14.87 ± 1.69	17.1
ΔV, km/h	5.73 ± 1.19	8.1
La, mmol/l	7.89 ± 3.1	15.6
RPE	7 ± 1.41	9

D_{max} – distance covered in the best interval; ΣD – total distance for the test; ΔD – individual RPE – rate of the perceived exertion; La – capillary lactate concentration; V – velocity; ΔV – drop of the velocity during the test (between individual V_{max} and V_{min})

ΔD (m) was calculated as the difference between the best interval and the interval with the minimum distance in the HIIT-test. This indicator ΔD (m) was adopted as a criterion of the ability to perform high-intensity running with minimal loss of productivity. The optimum value was assumed at ΔD ≤ 30 m.

The desirable excellent conditioning bar chat of young football players is shown in Figure 1.

Figure 1: The desirable excellent conditioning bar chat of young soccer players.

The results of running interval test detect the physical fitness of every subject. The comparison and ranking of the first (best) distance results of all athletes reveal the winner in speed, while champion in 8 distances amount shows the desirable level of specific endurance (Figure 2).

Many researchers have repeatedly performed the subsequent detailed analysis of external and internal load indicators, as well as technical and tactical preparedness of athletes during the played soccer matches (Mohr M., 2003; Castagna, C., 2003; Krustrup, P., 2005; Castagna, C., 2009; Aquino, R.L., 2016). The value of data obtained during the game cannot be overestimated. A variety of match analysis methods and tools allows not only to characterize one or several sides of a player's preparedness, but also to compare the obtained data with the results of the other tests. It is provided by short, but not less informative tests that do not require sophisticated equipment and huge energy costs for players (as during the game).

During the whole game players (n = 12) covered 8500 ± 460 m (7930-8910 m), of which 4000 ± 550 m (3190-4560 m) were performed in the first half of the game and 4500 ± 500 (3910-5210 m) in the second half. The studied group of players showed a high level of the total distance covered per game in comparison with the data of other researchers in accordance with the age and gender norms in soccer (Barbero-Álvarez, 2013: age – 14.3 ± 1.3 years, total distance – 7145 ± 685 m; Buchheit, 2010: age – U13, total distance – 6549 ± 597 m, age – U14, total distance – 7383 ± 640 m; Buchheit, 2008: age – 14.2 ± 0.5, total distance – 5372 ± 125 m).

The average and peak HR during the match were 160.5 ± 6.06 bpm (154-170 bpm) and 194.83 ± 6.94 bpm (range 188-206). The values of HR_{max} and HR_{mean} during the game were authentically lower

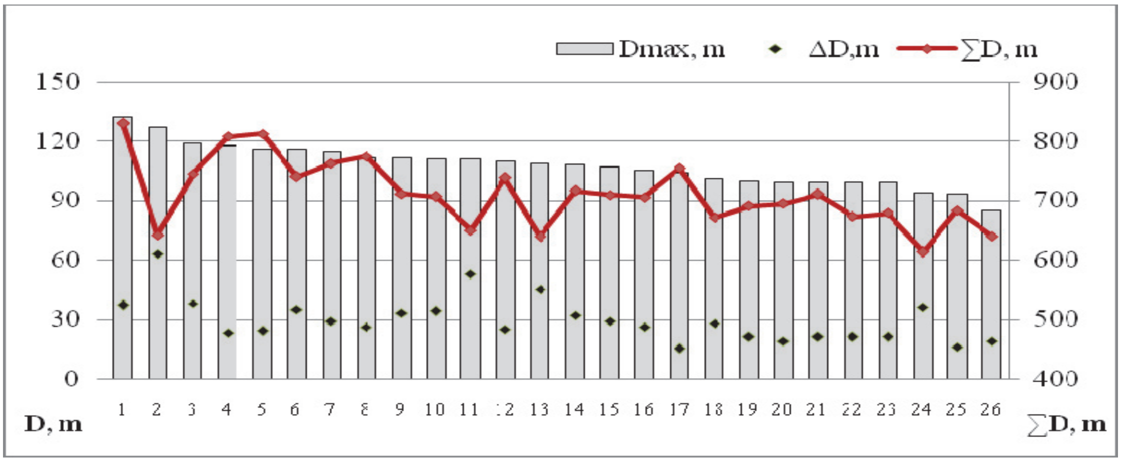

Figure 2: Young soccer players (n=26) individual results of interval running test.

than in Barbero-Álvarez study (2013) (HR_{max} – 205.7 ± 5.4 bpm, HR_{mean} – 179.7 ± 6.8 bpm).

Lactate values after the first and second half of the game were 5.48 ± 2.28 ml/l (2.87-9.25 ml/l) and 3.71 ± 1.81 ml/l (2.44-6.91 ml/l) respectively. RPE response of players showed values of 4.17 ± 0.41 (4-5) and 5.5 ± 0.55 (5-6) after the first and second half of the game respectively.

During the match the players showed an average speed of 10.4 ± 1.61 km/h (7.6-11.54 km/h). The peak game speed was 20.4 km/h and it was lower than average values reported by Buchheit, 2010 about the players of the same age (age – U13, peak game speed – 22.3 ± 1.4; age – U14, peak game speed – 24.4 ± 1.8).

Taking into account the results of laboratory tests and field tests discussed above it can be assumed that low values of maximum speed during the game are associated with the game tactics but not with low fitness level of young players.

Data obtained from correlative analysis showed that there were strong interrelations between the parameters of physical fitness of young soccer players obtained from different tests.

In particular, we found significant correlations between PP and P-VO_{2max} ($r = .805$, $P < 0.01$), PP and P_{170} ($r = .630$, $P < 0.05$), AP and P-VO_{2max} ($r = .822$, $P < 0.01$), AP and P_{170} ($r = .626$, $P < 0.05$), AP and VO_{2max} ($r = .566$, $P < 0.05$).

Above-mentioned proves the interrelation between athletes' maximal power and strength manifestation in VO_{2max} protocol, or strange as it may seem between anaerobic power (PP, AP) and aerobic capacities in athletes. In other words, muscle strength abilities provide athletes with advantage in endurance, as shown in better physical characteristics during aerobic laboratory and field tests, as well as lower exertion during the game.

Furthermore, we found strong correlations between the results of laboratory and field tests and measurements obtained during the soccer game. Our results showed that RPE during the game correlated with VO_{2max} ($r = -.622$, $P < 0.05$), La concentration after the 1st half well correlated with the following indices: PP ($r = .923$, $P < 0.01$), relative PP ($r = .934$, $P < 0.01$), AP ($r = .884$, $P < 0.05$), relative AP ($r = .841$, $P < 0.05$), D_{max} ($r = .859$, $P < 0.01$).

Concentration of La after the 2nd half correlated with P-VO_{2max} ($r = -.946$, $P < 0.01$) and P_{170} ($r = -.898$, $P < 0.01$).

HR at 150 W during stress test correlated with the following indices of Wingate test: PP ($r = -.518$, $P < 0.05$), AP ($r = .-628$, $P < 0.01$), AP/kg ($r = -.640$, $P < 0.01$), HR_{max} at interval running field test ($r = .564$, $P < 0.05$) and La concentration after the 2nd half ($r = -.967$, $P < 0.01$); HR_{max} during interval running field test correlated well with HR_{mean} during the game ($r = .816$, $P < 0.05$).

Moreover, we found the following relationship of external load indicators between HIIT-test and measurements obtained during the soccer game: distance covered in the first half of the game correlated with the total distance in HIIT-test (ΣD) ($r = .628$, $P < 0.05$) and D_{max} ($r = .629$, $P < 0.05$); distance covered in the second half of the game correlated with ΣD ($r = -.889$, $P < 0.05$), D_{max} ($r = -.746$, $P < 0.05$), D_{min} (minimum distance covered per interval) ($r = -.929$, $P < 0.05$).

The internal load indicators of the same tests also showed a good correlation. RPE after the 2nd half correlated with RPE of HIIT-test ($r = .71$, $P < 0.05$); HR_{max} during HIIT-test correlated well with HR_{mean}

during the game ($r = .82$, $P < 0.05$) and HR_{max} during the game ($r = .63$, $P < 0.05$).

Figure 3 demonstrates the relation between the rate of the perceived exertion during the game and maximum oxygen consumption. One can see that the higher VO_{2max} was the lower rate of exertion athletes had after the game. Thus better abilities of oxygen consumption, transport and utilization in young soccer players provide them with better physical load tolerance during the game.

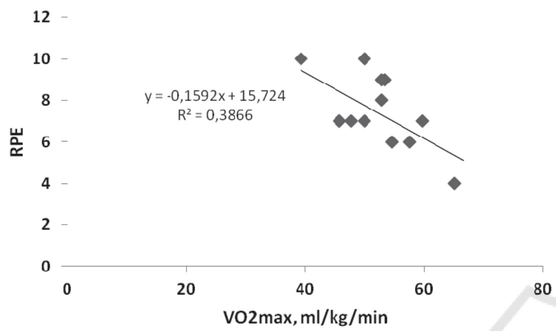

Figure 3: Graph, describing relations between the rate of the perceived exertion (RPE) after the game and maximum oxygen consumption (VO_{2max}).

4 CONCLUSIONS

1. Complex testing of soccer players aged 12-13 in laboratory and field condition revealed very good (better-than-average) physical preparedness of athletes. The fitness indicators of the young soccer players in tested group corresponded to the general patterns of athletes' development of age mates in soccer. Currently there is a negative trend of poor cardiovascular development in young players that causes low aerobic abilities. The roots of this problem go far beyond the training process. But the inability to allocate time for replenishment of this component in the training process provokes a chain reaction of fitness underdevelopment that will lead to pathological changes in the functional system and early withdrawal from sports in the near future.

High fitness level of young players is a good basis for the further harmonious development of athletes that will provide the best conditions for the development and manifestation of technical and tactical skills. Nevertheless, in future it is necessary to pay special attention to development of cardiovascular system, since it will be the limiting factor of exercise performance.

2. Wingate cycle test parameters in young soccer players aged 12-13 were described in detail for the first time. There are significant interrelations between indicators of physical state, obtained from the various types of laboratory and field tests. As major physiologic parameters during the game correlate with the indicators from laboratory and field tests, these easy reproducible and accessible tests can be widely used in training control of young soccer players.

3. A close interrelation of indicators of external and internal load in the field test and the soccer game allows asserting the optimality of the application of the HIIT-test for testing the preparedness of young players. A short test time in contrast to the duration of the game allows one to assess comprehensively the physical preparedness of a player without use of additional sophisticated technical equipment.

4. The complex testing used in this study is optimal and provides comprehensive information about the functional state and physical fitness of soccer players. Laboratory and field tests fully complement each other, have clear evaluation criteria and contribute to sport science and training and testing practice.

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