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KINESIOLOGY OF PHYSICALLY DEMANDING JOBS

KINESIOLOGY OF TOP-LEVEL SPORT

DEVELOPMENT ANALYSIS OF SOCCER PLAYERS FUNCTIONAL CHARACTERISTICS

Marko Erceg, Igor Jelaska and Boris Maleš

Faculty of Kinesiology, University of Split, Croatia

Abstract

The purpose of this paper was to identify functional abilities of soccer players, as well as to determine differences in spiroergometric parameters among soccer players in the U-15, U-17 and U-19 category. The research included the following variables: absolute maximal oxygen uptake, relative maximal oxygen uptake, maximum minute ventilation, maximum heart rate, and before mentioned variables at the anaerobic threshold, resting lactate concentration and lactate concentration at the end of the test, body height and weight, and body mass index. Analysis of variance show that soccer training has a major influence on the development of functional abilities, and the results are progressively better with age. Therefore, it is to be expected that soccer players in the U-15 and U-17 category will achieve similar values once they reach the age of U-19 players.

Key words: *soccer, functional abilities, anaerobic threshold*

Introduction

Interpreting functional abilities of soccer players is more difficult than in individual sports, where it is easier to predict the results more accurately on the basis of functional abilities. Nonetheless, by determining functional abilities of soccer players useful information may be obtained, both on the team and on individual players. Functional diagnosis ensures a detailed overview of the current state of an individual player and the entire team; the training process may be observed and controlled, and it is possible to make comparisons with other teams. The development of individual capacities requires in-depth knowledge of specific training operators and specific exertion and resting intervals, which are determined on the basis of data on the current state of functional parameters. For achieving optimum state of fitness it is necessary to observe and apply accomplishments of modern sports science, and specific diagnosis of athlete fitness. As the basis for functional characteristics analysis in sports disciplines in which success is determined in terms of oxygen transport system capacity, maximum progressive exercise tests (Wasserman et al. 1999) are mostly used. The most frequently used controlled exercise machines are cycle ergometer and treadmill, even though lately specific ergometers for individual sports (rowing, kayaking, cross-country skiing....). Those devices truly reproduce the dynamic movement stereotype specific for each sport and they are increasingly used in various scientific research. Continuous and progressive exercise tests on treadmills are mostly used today. Here the load is increased either by increasing the speed of the treadmill or by increasing the incline of the treadmill or by progressively increasing both the speed and the incline. The test is generally performed until the subject is exhausted, unless there are contraindications or limiting factors (Rowland, 1996). Therefore, the main objective of this research was to identify functional abilities of soccer players, and determine differences in variables for assessing spiroergometric parameters among soccer players in the U-15, U-17 and U-19 category.

Methods

The research was carried out on a sample of 66 soccer players competing in the First Croatian Soccer League. The subjects were divided into three age groups: U-15 (N=22), U-17 (N=22) and U-19 (N=22). The sample of variables used to asses functional abilities is made up of spiroergometric parameters obtained in a progressive exercise test on a spiroergometric system and Quark pft4 (COSMED, Italy) software package. The heart rate value was monitored on the Polar RS800CX monitor (Polar Electro, Finland), while the blood lactate concentration at the beginning and end of the progressive exercise test was measured with a Accutrend lactate analyser (Roche, Germany). The research included the following variables: absolute maximal oxygen uptake (VO_{2max}), relative maximal oxygen uptake (RVO_{2max}), maximum minute ventilation (VE_{max}), maximum heart rate (HR^{max}), absolute oxygen uptake at the anaerobic threshold (VO_{2max}/AT), relative oxygen uptake at the anaerobic threshold (RVO_{2max}/AT), minute ventilation at the anaerobic threshold (VE/AT), heart rate at the anaerobic threshold (HR/AT), resting lactate concentration (LAC_{res}) and lactate concentration at the end of the test (LAC_{max}). In addition to these parameters, body height and weight, as well as body mass index were measured. All the variables were subjected to test of normal distribution by using the Kolmogorov-Smirnov test and descriptive statistical parameters were calculated: arithmetic mean, standard deviation, minimum result, maximum result and K-S value. For comparative analysis among different groups of subjects Factorial ANOVA with Fisher LSD post-hoc test was used.

Results

Table 1 shows the basic statistical parameters of applied variables for the U-15 category of soccer players: arithmetic mean (AM), standard deviation (SD), minimum (Min) and maximum results (Max), distribution skewness (Skew) and kurtosis (Kurt), and the K-S (Kolmogorov-Smirnov) test of normal distribution. As can be gathered from table 1, neither value of the K-S test exceeds the limit value of the Kolmogorov-Smirnov procedure for the sample of subjects observed. Therefore, we can conclude that all variables have distribution for which it can be said it does not deviate significantly from the normal distribution.

Table 1. Basic descriptive parameters of applicable variables for U-15 soccer players (AM – arithmetic mean; SD - standard deviation; Min – minimum measured results; Max – maximum results; Skew - skewness; Kurt - kurtosis; maxD - Kolmogorov-Smirnov test)

	U-15 (N = 22)						
Morphological variables	**AM**	**Min**	**Max**	**SD**	**Skew**	**Kurt**	**maxD**
H (cm)	176.40	163.00	184.00	5.60	-0.83	0.11	0.18
W (kg)	63.52	41.00	74.00	7.41	-1.62	3.45	0.18
BMI (kg/m²)	20.35	15.43	22.18	1.63	-1.48	3.08	0.15
Functional variables							
L_{res} **(mmol/L)**	1.96	1.50	2.60	0.34	0.52	-0.95	0.27
L_{max} **(mmol/L)**	9.81	5.70	13.80	2.84	0.13	-1.41	0.16
HR_{max} **(1/min)**	189.70	176.00	202.00	9.47	-0.31	-1.08	0.17
VE_{max} **(L/min)**	142.28	104.50	171.40	21.99	-0.87	-0.59	0.28
VO_{2max} **(L/min)**	4.10	3.89	4.78	0.37	0.54	-0.10	0.18
RVO_{2max} **(mL/min/kg)**	58.76	52.00	65.00	3.52	-0.93	0.59	0.17
HR_{VP} **(1/min)**	158.00	151.00	178.00	7.95	1.83	2.66	0.29
VE_{VP} **(L/min)**	88.07	66.90	114.30	19.31	0.36	-1.62	0.17
VO_{2maxVP} **(L/min)**	3.02	2.71	3.73	0.41	-0.09	-1.08	0.20
RVO_{2maxVP} **(mL/min/kg)**	43.04	36.00	52.00	5.77	-1.05	-0.49	0.30

Limit value maxD for N=22 totals 0.30

By inspecting the basic statistical parameters of applied variables for the U-15 category of soccer players: arithmetic mean (AM), standard deviation (SD), minimum (Min) and maximum results (Max), distribution skewness (Skew) and kurtosis (Kurt), and the K-S (Kolmogorov-Smirnov) test of normal distribution (Table 2), it can be gathered that neither value of the K-S test exceeds the limit value of the Kolmogorov-Smirnov procedure for the sample of subjects observed. Therefore, we can conclude that all variables have distribution for which it can be said it does not deviate significantly from the normal Gauss distribution.

Table 2. Basic descriptive parameters of applicable variables for U-17 soccer players (AM – arithmetic mean; SD - standard deviation; Min – minimum measured results; Max – maximum results; Skew - skewness; Kurt - kurtosis; maxD - Kolmogorov-Smirnov test)

	U-17 (N = 22)						
Morphological variables	**AM**	**Min**	**Max**	**SD**	**Skew**	**Kurt**	**maxD**
H (cm)	178.04	170.00	187.00	4.98	0.30	-1.02	0.12
W (kg)	69.00	60.00	80.00	6.53	0.07	-1.29	0.12
BMI (kg/m²)	21.72	18.93	23.45	1.24	-0.49	-0.51	0.11
Functional variables							
L_{res} **(mmol/L)**	2.54	1.50	3.50	0.52	-0.10	0.08	0.13
L_{max} **(mmol/L)**	12.06	7.10	17.60	2.98	-0.21	-0.89	0.15
HR_{max} **(1/min)**	188.33	161.00	202.00	9.84	-0.80	1.53	0.10
VE_{max} **(L/min)**	141.83	106.60	164.10	16.72	-0.35	-0.80	0.11
VO_{2max} **(L/min)**	4.22	3.45	4.78	0.26	0.30	-0.67	0.19
RVO_{2max} **(mL/min/kg)**	60.40	52.00	65.00	3.80	-0.00	0.06	0.13
HR_{VP} **(1/min)**	162.71	147.00	181.00	10.94	0.13	-1.27	0.14
VE_{VP} **(L/min)**	83.95	54.70	106.00	12.01	-0.31	0.67	0.13
VO_{2maxVP} **(L/min)**	3.23	2.27	3.73	0.32	-0.24	-0.96	0.15
RVO_{2maxVP} **(mL/min/kg)**	46.30	35.00	53.00	5.48	0.21	-1.24	0.13

Limit value maxD for N=22 totals 0.30

Table 3 shows basic statistical parameters of the variables applied to the U-19 category of soccer players: arithmetic mean (AM), standard deviation (SD), minimum (Min) and maximum (Max) results, distribution skewness (Skew) and kurtosis (Kurt), and the K-S (Kolmogorov-Smirnov) test of normal distribution. As can be gathered from Table 3, neither value of the K-S test exceeds the limit value of the Kolmogorov-Smirnov procedure for the sample of subjects observed. Therefore, we can conclude that all variables have distribution for which it can be said it does not deviate significantly from the normal distribution.

Table 3. Basic descriptive parameters of applicable variables for U-19 soccer players (AM - arithmetic mean; SD - standard deviation; Min – minimum measured results; Max – maximum results; Skew - skewness; Kurt - kurtosis; maxD - Kolmogorov-Smirnov test)

	U-19 (N = 22)						
Morphological variables	**AM**	**Min**	**Max**	**SD**	**Skew**	**Kurt**	**maxD**
H (cm)	181.88	175.00	192.00	4.72	0.56	-0.05	0.10
W (kg)	75.05	63.00	89.00	6.07	0.26	0.89	0.17
BMI (kg/m²)	22.67	19.46	25.94	1.49	-0.02	0.76	0.15
Functional variables							
L_{res} (mmol/L)	3.12	1.90	4.70	0.78	0.38	0.03	0.12
L_{max} (mmol/L)	11.79	6.70	17.80	2.46	0.27	0.94	0.13
HR_{max} (1/min)	183.53	171.00	197.00	7.01	0.23	-0.71	0.14
VE_{max} (L/min)	149.29	106.10	186.10	21.70	-0.39	0.26	0.15
VO_{2max} (L/min)	4.61	3.62	5.66	0.56	-0.25	-0.54	0.13
RVO_{2max} (mL/min/kg)	62.30	52.00	71.00	5.06	0.10	-0.29	0.14
HR_{VP} (1/min)	162.25	147.00	173.00	6.96	-0.53	0.07	0.15
VE_{VP} (L/min)	102.66	77.80	136.50	16.53	0.57	-0.16	0.12
VO_{2maxVP} (L/min)	3.77	2.67	5.06	0.55	0.16	0.32	0.08
RVO_{2maxVP} (mL/min/kg)	50.65	41.00	58.00	5.35	-0.51	-0.95	0.16

Limit value maxD for N=22 totals 0.30

Table 4 shows that there is a rising trend of morphological variables toward the older age group of the soccer players. The U-17 soccer players are slightly taller than the U-15 players, but these differences are not statistically significant. The U-19 soccer players are statistically significantly taller than the U-15 and U-17 players. With regard to the weight and BMI it is apparent that there are statistically significant differences between all studied groups of soccer players.

Observing the differences of functional variables between the U-15 and U-17 players, it is noticeable that the U-17 players achieved on average higher values in almost all parameters. These differences are statistically significant only in the L_{res}, and L_{max} variables. Analysing the differences between the U-17 and U-19 players it can also be said that the U-19 players have on average achieved higher values in the majority of parameters. These differences are statistically significant in the majority of the anaerobic threshold variables, as well as in the VO_{2max} and L_{res} values. There are statistically significant differences in nearly all functional variables when comparing the U-15 and U-19 players.

Table 4. Comparative analysis of the variables applied to the soccer players of various age groups

	U-15 (N = 22)	U-17 (N = 22)	U-19 (N = 22)
Morphological variables	**AM (SD)**	**AM (SD)**	**AM (SD)**
H (cm)	176.40 (5.60)	**178.04 (4.98)†**	**181.88 (4.72)^{2}**
W (kg)	**63.52 (7.41)***	**69.00 (6.53)††**	**75.05 (6.07)^{3}**
BMI (kg/m²)	**20.35 (1.63)****	**21.72 (1.24)†**	**22.67 (1.49)^{3}**
Functional variables			
L_{res} (mmol/L)	**1.96 (0.34)****	**2.54 (0.52)††**	**3.12 (0.78)^{3}**
L_{max} (mmol/L)	**9.81 (2.84)***	12.06 (2.98)	**11.79 (2.46)^{1}**
HR_{max} (1/min)	189.70 (9.47)	188.33 (9.84)	**183.53 (7.01)^{1}**
VE_{max} (L/min)	142.28 (21.99)	141.83 (16.72)	149.29 (21.70)
VO_{2max} (L/min)	4.10 (0.37)	**4.22 (0.26)††**	**4.61 (0.56)^{2}**
RVO_{2max} (mL/min/kg)	58.76 (3.52)	60.40 (3.80)	**62.30 (5.06)^{2}**
HR_{VP} (1/min)	158.00 (7.95)	162.71 (10.94)	162.25 (6.96)
VE_{VP} (L/min)	88.07 (19.31)	**83.95 (12.01)†††**	**102.66 (16.53)^{2}**
VO_{2maxVP} (L/min)	3.02 (0.41)	**3.23 (0.32)†††**	**3.77 (0.55)^{3}**
RVO_{2maxVP} (mL/min/kg)	43.04 (5.77)	**46.30 (5.77)††**	**50.65 (5.35)^{3}**

Key: analysis of variance - Factorial ANOVA with Fisher LSD post-hoc test; (AM – arithmetic mean; SD - standard deviation);

*p<0.05; **p<0.01; ***p<0.001 – significance of differences between the U-15 and U-17 group of soccer players

†p<0.05; ††p<0.01; †††p<0.001 – significance of differences between the U-17 and U-19 group of soccer players

^{1}p<0.05; ^{2}p<0.01; ^{3}p<0.001 – significance of differences between the U-15 and U-19 group of soccer players

Discussion and conclusion

Table 4 shows a visible rising trend of the morphological variables toward the older age group of soccer players. The U-17 players are taller than the U-15 players, and the U-19 players are statistically significantly taller than both the U-15 and the U-17 players. The analysis of the weight and BMI shows that there are statistically significant differences between all studied groups of soccer players. The average height and weight values of the U-15 soccer players are considerably higher in relation to the reference values, and they are located above the 75 % in comparison with the results of previous studies. The reason for this should be sought in the fact that among the studied U-15 soccer players there is a number of players who experienced accelerated growth, i.e. who matured earlier. The changes in the size and composition of the body and functional capacities occur and increase with puberty and maturation. The variations among boys of different maturity (the same biological, but different chronological age) are most evident between 13 and 16 years of age (Malina et al., 2003). The growth and maturation of young soccer players may affect the selection process, which is probably the case with the U-15 players from this research. The soccer players are selected according to their growth and maturity. At the selection time they were probably the best players due to their size, strength and power, which is connected with earlier maturation of the U-15 soccer players. With all three age groups of soccer players, resting lactate levels are somewhat above the physiological limits. Such results are probably the consequence of differences in activities of soccer players of different categories before the sampling, which is consistent with the findings of previous studies (Bangsbo et al., 1991). The registered differences are statistically significant among all studied age groups of soccer players. The maximum registered lactate values are significantly higher in the U-17 group in relation to the U-15 group. The maximum lactate values in the U-17 and the U-19 group do not statistically significantly differ while there is statistical significance in the differences between the U-15 and the U-19 players. It is interesting to note that the U-19 players, although "more acidic" before testing, had lower lactate values in blood after exertion in relation to the U-17 players. It is obvious that the U-19 players have a capacity to better adapt their organism to exertion because they have been in soccer training longer, and it has a strong influence on the development of functional abilities. The assumption is that longer soccer engagement of the U-19 players in relation to the U-17 and U-15 players results in increased number of capillaries around the muscle fibres, as well as in increased number of mitochondria in muscle cells, and thus in the improvement of aerobic metabolism activities. A better technique of movement performance may change the ratio of inactive and active muscle fibres so that less muscle fibres are used for the same activity due to the better technique. In that case there are more inactive muscle fibres that "attract" lactic acid from the active fibres and oxidise it. Further analysis of data in Table 4 shows a trend of decreasing heart rate value at VO_{2max} toward the older age group, which is physiological and is consistent with previous statements (Wilmore and Costill, 1999). The heart rate values at the anaerobic threshold are similar in all studied age groups of soccer players and there are no statistically significant differences among them. Nevertheless, these values rise with age of the soccer players, which points to a higher level of fitness in the U-17 and U-19 group in relation to the U-15 group. The U-17 and U-19 players cross the anaerobic threshold later, i.e. they enter the anaerobic mode at higher heart rates so they can perform sports activities longer and more effectively than the U-15 players.

As aforementioned, the heart rate may be decreased as a result of endurance training, and since the U-17 and the U-19 players have on average been in soccer training longer in relation to the U-15 players, the differences in maximum heart rate are logical. Furthermore, the overview of Table 4 shows visible increase in the minute ventilation at VO_{2max} toward the older age group. The U-15 and U-17 players achieve similar values, while ventilation values of the U-19 players are somewhat higher. There are differences among the studied groups of soccer players, but they are not statistically significant. In addition, a similar increase trend can be noticed in the ventilation values at the anaerobic threshold. The U-19 players have statistically higher values from both the U-15 and the U-17 players. The lung function changes considerably with age. The minute ventilation increases with age up to the physical maturity, and then decreases with age. These changes are connected to the growth of the entire lung system. As the size of the body increases with growth and development, so does the size and function of lungs increases, which explains the obtained differences of minute ventilation in the soccer players studied. Table 4 also shows a rising trend of maximal oxygen uptake values toward the older age group. The rising trend is also visible in the VO_{2max} values at the anaerobic threshold. The U-15 and U-17 players achieve similar results, while the U-17 and U-19 players, as well as the U-15 and U-19 players statistically significantly differ in the achieved VO_{2max} values. The increase of the absolute and relative VO_{2max} in the older age group of the soccer players is to a great extent the consequence of increased height reflected on the muscle mass. The relative maximal oxygen uptake rises around 1 mL/min/kg per year. This means that the aerobic working capacity follows the body development or is even faster, which is consistent with the results obtained in this research. As aforementioned, the majority of researchers agree that VO_{2max} is the best indicator of cardiorespiratory endurance, i.e. capacity. The VO_{2max} considerably increases in response to the endurance training. Soccer training has a great influence on the development of functional abilities, and the results are progressively better with age, and it is therefore expected that the U-15 and U-17 players will achieve similar results in the U-19 age group.

The preadolescence is crucial for the development of physical, technical and tactical abilities of young soccer players. Furthermore, the development of intellectual and motor abilities leads to the improvement of technical, tactical and psychological abilities. Adequate development of body and motor abilities during this period is crucial for the progress of young soccer players because after that age the process of sport selection is very difficult. Success in soccer depends on various factors, including physical characteristics and physiological capacities of a player, on their level of skills and the degree of their motivation, as well as on technical and tactical preparations. Some factors are not easy to measure, but others can be tested using standardized methods and can provide useful information to the trainer and the team of experts. Differences in physiological indicators of various age groups are evident, and they should be integrated in the planning and programming of the training process. The results obtained point to high efficacy of the cardiopulmonary system of the subjects tested. This research definitely did not cover all the factors and dimensions on which success in soccer depends, but it can be a useful basis for the creation and implementation of new programmes in the field of planning, programming and implementation, and control of training for young soccer players.

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