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RELATIONS OF ANTHROPOMETRIC CHARACTERISTICS WITH VO_2 MAX AND HEART RATE UNDER LOAD IN FOOTBALL PLAYERS OF JUNIOR AGE

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Abstact

The research was conducted on a sample of 23 football players of FC "Čukarički Stankom" in Belgrade of who there was performed the measurement of anthropometric characteristics (Body height, Body weight and Mean thorax circumference) and functional abilities (Maximal oxygen consumption and Heart rate under load). The regression analysis revealed a statistically significant effect of the predictor system of anthropometric variables on both criteria: VO_2 max and Heart rate under load. Variables Body height and Mean thorax circumference have a statistically significant positive effect on the criterion VO_2 max by which the maximal oxygen consumptions assessed. In the second criterion, Heart rate under load, the variables Body height and Mean thorax circumference showed a statistically significant negative effect on the criterion variable.

Keywords: *VO_2 max, heart work under load, body height, body weight, thorax circumference*

Introduction

Measuring and monitoring (diagnostics) of the functional abilities as well as diagnostics of anthropometric characteristics are an integral part of the training process in most sports (Farraly, 1995a and Farraly, 1995b; Jones, 1997; Ramsbottom, Brewer & Williams, 1988). It is also frequently used as an aid or guidance to those involved in the recreation-kinesiology process, in order to maintain good health (Sprunt, 2000). The term "aerobic capacity" means the general scope of aerobic metabolic processes in the human body (athletes), and is the basis of the physical working capacity of an athlete. The values of maximum oxygen consumption (VO_2 max) are the best indicators of the differences in the aerobic capacity.

Aerobic capacity is an essential component in most sports. It is also necessary to football players who want to be actively, ie. professionally involved in football, toothier sport

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teachers who teach them the sport. It is also very important for all participants in the training process. All participants in sport (sport teachers, athletes, sports medicine doctors, professors of kinesiology) are equally interested in following progress in terms of several functional capabilities including aerobic abilities, which is essential for sports science (kinesiology) in general.

Football is characterized by a continuous stream of activities with a variable intensity of activities and a very low coefficient of performance (eg. a number of goals scored can be taken into account when talking about the coefficient of success in football) to the possession of the ball. A football player during a match runs out approximately 10 km (Reilly, Clarus & Stibbe 1993; Mayhew& Wenger, 1985). In that, easy cyclical locomotor movement (<11km/h, <80% of maximal oxygen consumption-VO_2max) is represented in the largest percentage of the total motion actions, after which are walking and intense cyclic locomotor movement (11-18 km/h, about 80 % VO_2 max) and then sprint (11-27 km/h, <85% VO_2 max). By the nature of such activity that corresponds to the aerobic needs of about 80% of maximal oxygen consumption (Reilly, Clarus& Stibbe, 1993; Helgerud, Engen& Wisloff, 2001).

Good aerobic capacity undoubtedly affects also the performance of explosive motion actions during this activity, both in terms of quantity (number of sprints per game), and quality (without slowing down). Research of Reilly, Clarus & Stibbe (1993) show that, especially in football, a good aerobic capacity of the body is one of the most important prerequisites for achieving the best results. Energy requirements of the body in footballvary and to a large extent depend on the league, team position, athletemodel, training cycle phase, age (Reilly, Bangsbo & Franks, 2000). Such requirements mean exceptional motoric and functional readiness of all the athletes on the field, of all ages, which could be the reason for minor differences in the aerobic capacity in relation to the position in the team. It is well known that the aerobic capacity depends on three important factors: VO_2 max, anaerobic threshold and work economy (Pate & Kriska, 1984), ie. running economy ("running economy"; RE).

Maximal oxygen consumption is the greatest amount of oxygen a person can take from the inhaled air during a dynamic motoric activity that engages large muscle groups (Wagner, 1996). Economy of running represents an oxygen debt in the submaximal exercise intensity and can vary by over 20% in athletes with an approximate value of VO_2 max.

Genetics represents a major role in a human maximal aerobic endurance, while anthropometric characteristics slightly affect these results (Bouchard, Dionne, Simoneau, Boulay, 1992). Heredity can be explained by 25-50% variation between individuals, especially when comparing athletes, the difference in maximum oxygen consumption and aerobic endurance is reduced to about 10% with age (Wilmore and Costill, 2005). Maximum oxygen consumption decreases with age, and the average measure of the decrease is usually accepted at about 1% per year or 10% per decade after 25 years.

The aim of this research was to determine the association between anthropometric characteristics, aerobic capacity (maximal oxygen consumption) and heart rate under loading athletes (football players) of junior ages.

Method

Testing and measurement (diagnostics) of the functional abilities and anthropometric characteristics was conducted on a sample of 23 subjects, football players of *FC "ČukaričkiStankom"* from Belgrade, aged 17-18 years.

Anthropometric characteristics which were measured (the predictor variables accounted for in the paper):

1) body height,
2) body weight,
3) mean thorax circumference.

The selected anthropometric characteristics were chosen because each of them can affect the aerobic capacity and the heart rate under load, especially mean thorax circumference and body weight. For the measurement of the anthropometric characteristics there were used theanthropometer by Martin, a decimal scale and a centimeter tape. The measurement of the anthropometric characteristics was performed immediately before testing the functional capacity-maximal oxygen consumption and heart rate under load.

The assessment of the maximal oxygen consumption (VO_2 max) and heart rate under load (which constituted the criterion variables in the paper), were measured using a direct method:

1. Bicycle-ergometer "all out" test for 6 minutes. The subjects were tested on a bicycle-ergometer with paddles for air brake where the heart rate under loadwas simultaneously monitored.

The description of the test:

The test on the **bicycle-ergometer**(protocols KF20)-duration of an individual load level is 1 minute, and the power increasewas 20W (KF20) every 30 seconds. A subject began pedaling with the power of 100 W (juniors). The number of rotations was defined at 50-75 rotations/minute and would be constant. The load on the bicycle-ergometer was determined based on the previous calibration with an engine of known power, and the number of the wheel rotations was precisely measured with an electronic counter. Respiratory parameters were registered with the gas analyzer OXICON-OX2, calibrated with a gas mixture of known concentration.

In processing the data there was used the descriptive statistics to calculate the basic descriptive statistics of the anthropometric and functional variables: arithmetic mean (AM), standard deviation (S), minimum and maximum values of the measurement results. In order to determine statistically significant relations between the anthropometric and the functional variables, the regression analysiswas has been used.

Results

Table 1. shows the values of the basic descriptive statistics of the anthropometric and functional variables for 23 football players of *FC "Cukaricki Stankom"* from Belgrade. From this table, it can be concluded that the athletes were homogeneous in the variables for assessment of the longitudinality of the body (Body height) and body volume (Mean thorax circumference) and the variablefor assessment of the heartwork under load(Heart rate under load). Based on these data it can be concluded that the athletes are of similar growth, body constitution, and that their heart rate under load is at a similar level. In the variablefor assessment of maximal oxygen consumption (VO_2 max), the homogeneity was not observed, due to large individual differences in oxygen consumption (large are the

differences between the minimum and maximum results registered in this sample of subjects).

Table 1. *Basic deskriptive statistics of the assessedvariables*

Variable	N	MIN	MAX	AM	S
Body height (mm)	23	1547	1821	1683.00	82.45
Body weight (kg)	23	40.00	76.90	58.80	12.24
Mean thorax circumference (cm)	23	70.00	99.10	85.97	9.84
VO_2 max (l O_2/min)	23	1.58	5.49	3.04	1.15
Heart rate under load (freq.)	23	182	201	191.48	5.25

Legend: N - number of subjects; AM - arithmetic mean; S - standard deviation; MIN minimum values of measurement results; MAX - maximum value of measurement results.

In Tables 2. and 3.are shown the regression analyses of each criterion variable in the system of predictor variables.

In the presented regression analysis of the criterion VO_2 max, it can be concluded that the value of the coefficient of multiple correlation(R = 0.84) indicates that the predictor system shows a statistically significant effect on the tested criterion (P = 0.00). The system of predictor (anthropometric) variables explains 70% of the common variability, while the remaining variability can be attributed to some other characteristics and capabilities that were not included in the applied system of predictors (motivation, the current level of training of the athletes and the muscles condition, the condition of other functional, motoric, cognitive and conative systems). The values of the standardized regression coefficient Beta indicate that the predictor variables Body height and Mean thorax circumference have a statistically significant positive effect on the criterion (functional variables). This means that taller athletes with higher values of the mean thorax circumference make higher (better) values of maximum oxygen consumption.

The values of the Pearson correlation coefficient indicate that all three predictor (anthropometric) variables are in a statistically significant positive correlation with the criterion. Such a correlation confirmsthattaller and more developed athletes (in the upper body part, with larger thorax circumference), achieve higher values of maximum oxygen consumption.

The data on linear correlations of the predictor variables with the criterion variables indicate that thiscorrelations is most pronounced in the variable Meanthorax circumference (r = 0.78), more than in other predictor variables. Looking at the values of the partial correlation for the variable Mean thorax circumference, it can be concluded that, after the partializationbyother predictor variables, *Body weight* and *Body height*, this correlation between the predictor and the criterion remains in positive statistically significant correlation, because the value of the coefficient of partial correlation (r_{part} = 0.68) and that it decreased in relation to the coefficient of linear correlation (r = 0.78) and remained statistically significant. It can be concluded that the body height and body weight contributed to the subjects with higher values of the mean thorax circumference to achieve better (faster) results of VO_2 max.

Also the data on linear correlations of the other predictor variable, *Body height* with the criterion (r = 0.63). Looking at the values of the partial correlation for the variable *Body height*, it can be concluded that, after the partializationby other predictor variables, this correlation (between the predictor and criterion) remains in positive statistically significant correlation, because the value of the partial correlation coefficient (r_{part} = 0.50) and that it decreased compared to the coefficient of linear correlation (r = 0.78) and remained statistically significant. It can be concluded that the higher values of mean thorax circumference and body weight contributed to the taller subjects to achieve better (faster) results of VO_2 max.

Table 2. *Results of regression analysisof the variablevo$_2$ max*

Variable		r	p	r_{part}	p_{part}	Beta	p_{beta}
Body height		0.63	0.00	0.50	0.02	0.47	0.02
Body weight		0.63	0.00	-0.39	0.08	-0.55	0.08
Mean thoraxcirc.		0.78	0.00	0.68	0.00	0.98	0.00

R = 0.84 R^2 = 0.70 P = 0.00

Legend: r - Pearson correlation coefficient; p - level of statistical significance for r; r_{part}–value of partial correlation coefficient; p_{prat} - the level of statistical significance for r_{part}; Beta - regression coefficient; p_{beta} - the level of significance of the regression coefficient; R - coefficient of multiple correlation; R^2- coefficient of determination; P - significance of the coefficient of multiple correlation

From the results of the regression analysis of the second criterion, it was found that there was a statistically significant effect of the system of predictor variables also in the criterion *Heart rate under load*, because the significance of the coefficient of multiple correlation (P = 0.02), that is, the value of the multiple correlation coefficient (R = 0.62), which explains 39 % of the common variance, while the remaining percentage can be attributed to some other characteristics and capabilities that were not included in the applied system of predictors in this research (condition of other functional systems, the level of training and other anthropological space). Looking at the variables individually, it can be seen that the variables *Body height* and *Mean thorax circumference* show a statistically significant mathematicallypositive, but logically negative effect on the criterion variable (p = 0.04). From this it can be concluded that taller athletes and the subjects with higher valuesof the thorax have a higher heart rate during the test performed on a bicycle-ergometer, which is actually a consequence of the higherrecorded values of the results of VO_2 max and lower aerobic capacity of these athletes. Between these two criterion variables there is a cause-effect relationship.

All three predictor anthropometric variables are inpositive statistically significant correlations with the criterion. The taller, heavier, and subjects with higher values of the mean thorax circumference (larger and heavier athletes) during the applied cardio test have increased heart rate values. It may refer to a smaller degree of their training, lower aerobic capacity of these subjectswho compete in a lower league, where the pace of activities is slower. The need for some exceptional changes of movements, in the form of cyclic locomotor movement is less obvious (or is it increasing fatigue and hard work during the testing, which was manifested by increased heart work under load).

From the data on linear correlations of the predictor variables with the criterion it can be seen that this correlation is most pronounced and statistically significant in the variables *Body height* (r = -0.48) and *Mean thorax circumference*(r = 0.47). Looking at the partial correlation values for the variable *Body height*, it can be concluded that with the partialization of the remaining predictor variables (*Body weight* and*Mean thorax circumference*) remains in positive statistically significant correlation with the criterion, because the value of the partial correlation coefficient (r_{part} = 0.44) decreased compared to the coefficient of linear correlation (r = 0.48) and remained statistically significant. Body weight and increased mean thorax circumference led to increased values of heart rate intaller athletes.

In the second predictor variable, *Mean thorax circumference*, the value of the partial coefficient (r_{part} = 0.46) also decreased compared to the linear coefficient (r = 0.47), and it can be assumed that the body height and body weight hindered the ability (led to increased values of heart rate) of the cardio-respiratory system of the subjects with higher values of the mean thorax circumference.

Table 3. *Results of regression analysis of the variableheart rateunder load*

Variable	r	p	r_{part}	p_{part}	Beta	p_{beta}
Body height	0.48	0.01	0.44	0.04	0.58	0.04
Body weight	0.34	0.06	-0.38	0.09	-0.76	0.09
Mean thorax circ.	0.47	0.01	0.46	0.04	0.79	0.04

R = 0.62R^2 = 0.39 P = 0.02

Legend: r - Pearson correlation coefficient; p - level of statistical significance for r; r_{part}–value of partial correlation coefficient; p_{prat} - the level of statistical significance for r_{part}; Beta - regression coefficient; p_{beta} - the level of significance of the regression coefficient; R - coefficient of multiple correlation; R^2- coefficient of determination; P - significance of the coefficient of multiple correlation.

Discussion

Functional tests provide useful information about athletes health, planning and monitoring the effects of the training process, can be used in the early selection of athletes, and are the major factor in the diagnostic of sport. The fact that most of our athletes have never been subjected to a similar testing (Spiroergometry) is really worrying. Education of sports medicine doctors and professors of kinesiology, the improvement in the dosage of an optimal, individual-specific training process, especially in working with younger categories with regular health checks and constant supervision of sports medicine doctors are an essential step towards achieving top sports results.

This research confirmed that the predictor system, which consisted of anthropometric variables, significantly influences the criteria *VO_2 max* and *Heart rate under load*. They depicted with the criteria 39% to 70% of common variability, while the remaining percentage can be attributed to some other characteristics and capabilities of the anthropological status such as motivation, the current emotional state, the state of the muscles, the level of trainingof athletes, subcutaneous adipose tissue and many others.

Variables *Body height* and *Mean thorax circumference*, affected positively the maximal oxygen consumption in this group of subjects. With the increasing volume of the thorax, which may indicate a greater development of the thorax muscles and increased respiration (functional) capability, there is a greater possibility of the body to transport oxygen to the muscles and organs and use it in the course of activities with a gradual progression of intensity, with which was also higher the aerobic capacity of such morphologically includedsubjects. The higher vital capacity and better development of the thoracic part of the body (better blood flow to the muscles of the caudalbody part) intaller athletes contributed to better transport of oxygen, which allowed for better functioning of the body with higher loads. It directly affected the increasing aerobic endurance and aerobic capacity. These results could also be affected by the economy of running, which is extremely important for maximal oxygen consumption, genetic predisposition, ie. aerobic capabilities of the organism during prolonged activities with increasing load intensity (Pate & Kriska, 1984). It can be concluded that taller athletes and athletes with more developed thoracic part of the body (thorax) are at an advantage, because they have a higher aerobic capacity - higher aerobic capacity compared to lowerathletes, smaller by the constitution. Perhaps this is due to the completion of development of the respiratory and cardiovascular system intaller athletes with higher mean thorax circumference, which can be the next potentialresearch.

For the second criterion, *Heart rate under load*, the variables *Body height* and *Meanthorax circumference*negatively affected the manifestation of the heart work under load. The taller the subjects were and the higher values of the mean thorax circumference they had, their heart rate was higher during the load. Taller subjects with higher mean circumference achieved higher maximum valuesof oxygen consumption (and it is known that between the heart rate under load and maximal oxygen consumption there is a cause-effect relationship - higher O_2 consumption demands faster heart rate, because that O_2 must be transported to the muscles and organs), and the body is tired more quickly. Higher heart rate also provides more blood flow to the tissues, muscles; it provides greater aerobic capacity of athletes in general. Despite the fact that they achieved better results compared to lower athletes, the tallersubjects needed more power for the heart muscle to "pump" the blood to distant parts of the body to the periphery which realize work (the muscles of the lower extremities).

Because eduring the development of a superior athlete the maximal value of the aerobic capacity is reached between the age of 17 to 22 years, after which it decreases linearly with age (Shephard, 1999), these athletes can count on a significant improvement in VO_2 max by only a few years, when it will give a more realistic picture of their aerobic capacities. New rules and a great competition dictate exceptional aerobic capacity of all in the field, and it should not be surprising that the tallersubjects with higher mean thorax circumference achieved higher values of maximum oxygen consumption. It often happens that some athletes do not change the position in smaller clubs (because someone wants him to be a striker at all costs). This may be the reason for the major difference in VO_2 max of our athletes who work at different positions. One of the possible reasons may be inadequate individual-specific dosing of the training process itself which would explain the huge difference in aerobic capacity (inhomogeneity of the subjects in the variable for assessment of maximal oxygen consumption).

In order to precisely determine the condition of maximum oxygen consumption, it is necessary in future researches, to divide athletes into several groups (goalkeepers, defenders, midfielders, forwards), and then there will be a more realistic picture of the status of training of the athletes, in this case, football players.

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