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The Relationship between Body Composition and Aerobic Fitness in Boys and Girls Distance Runners

Erkan Demirkan[1,*], Sema Can[1], Erşan Arslan[2]

[1]Hitit University / Physical Education and Sports School, Çorum, Turkey
[2]Siirt University / Department of School of Physical Education and Sports, Siirt, Turkey

Abstract The purpose of the study were (a) to assess the maximum oxygen uptake capacity (VO_{2max}) and body composition in boys and girls distance runners; and (b) to determine the relationship between these parameters. Thirteen boys (average age 16.5 ± 2.4) and twelve girls (average age 16.2 ± 2.1 years) totally twenty-five athletes voluntarily participated in the study. The subjects' body fat percentage (FP), free fat mass (FFM) and basal metabolic rate (BMR) were estimated by bioelectrical impedance. VO_{2max} was determined by both 12 minute walk-run and Multi stage running tests (MST). The difference in VO_{2max} and FP was significant between boys and girls athletes. The VO_{2max} and FP showed strong negative correlation (r = - 0.77 and -0.76 respectively for both of different tests) and FFM showed moderate correlation (r = 0.48 and 0.44 respectively for both of different tests). FP and FFM were inversely related to aerobic fitness. It also demonstrates that lower FP and higher FFM contribute to VO_{2max}.

Keywords Aerobic, Fat percentage, Fat free mass, Training, Distance running

1. Introduction

In sports achievements, aerobic endurance is an important factor of success. It is commonly considered the best determiner of cardio respiratory fitness [1]. VO_{2max} refers to the intensity of aerobic process and actually denotes the maximum capacity to transport and utilize oxygen during exercise done at increasing intensity [1]. Aerobic fitness is the main factors that enhance human to doing daily jobs and also improve the ability to long time duration exercise [2]. Regular exercise is the main cause to improve body composition and cardiovascular fitness [2]. The influence of body composition may be particularly important for sports disciplines in which athletes are required to have an appropriately high aerobic performance together with high muscle mass [3].

The primary purpose of the study was to assess the relationship between body composition and aerobic fitness in boys and girls distance runners. On the other hand, for a better understanding of gender differences in aerobic fitness, the study will be important to understand the interaction of body fat, fat free mass and basal metabolic rate in both boys and girls. It was hypothesized that a higher level of aerobic fitness would be positively associated with FFM and negatively associated with FP.

* Corresponding author:
erkandemirkan@hitit.edu.tr (Erkan Demirkan)
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2. Material and Methods

Participants

Twenty five young athletes, 13 male (average age 16.5 ± 2.4 year; height 169.7 ± 5.2 cm; weight 57.1 ± 5.9 kg; training experience 2.4 ± 1.7 years) and 12 female (average age 16.2 ± 2.1 year; height 162.5 ± 5.2 cm; weight 49.3 ± 8.0 kg; training experience 1.4 ± 1.1 years) distance runner, voluntarily participated in this study. The athletes were asked not to participate in a daily training program within 24 hours prior to testing. Testing was completed for all athletes in the same laboratory and field facilities. Written informed consent was obtained from all the participants and their parents. All athletes and parents were notified of the research procedures, requirements, benefits, and risks before giving informed consent. The study was approved by the local Ethics Committee, and was conducted in a manner consistent with the institutional ethical requirements for human experimentation in accordance with the Declaration of Helsinki.

Measures

Measurements of Height and Body Weight

Body height and weight measurements were made using a digital scale (Seca 664, Hamburg, Germany) in bare feet and wearing only shorts. The body mass index (BMI) of each female and male were calculated as weight in kg divided by weight in meters squared.

Assessment of Body Composition

In this study, a BC-418 8-contact electrode BIA system

(Tanita Corp., Tokyo, Japan) was used to determine body composition. Body fat percentage, fat free mass, basal metabolic rate were obtained by using this device.

Aerobic endurance tests (maximum oxygen uptake capacity (VO_{2max})

12 minute walk-run test protocol

Male and female athletes ran on a 400-m round track for a total duration of 12 min. They were highly motivated to run as many laps as possible. The total number of laps was counted and the finishing point was marked. Total distance (in meters) covered in 12 min was calculated by multiplying the number of complete laps with 400-m plus the distance covered in the final incomplete lap. The distance in meters was converted into kilometres and the following equation was used to predict the VO_{2max} [4]

VO_{2max} (ml.kg^{-1}.min^{-1}) = (22.351 x distance covered in kilometres) - 11.288

Multistage progressive shuttle run test (MST)

Maximum oxygen uptake capacity was determined by using shuttle run (20-m) test. The all athletes started running back and forth a 20-m course and touched the 20-m line. The initial speed was 8.0 km/h which got progressively faster (0.5 km/h. every minute), in accordance with a pace dictated by a sound signal on an audiotape. The subjects were instructed to keep pace with the signal for as long as possible. When the subjects could no longer follow the pace, the last stage recorded was used to predict VO_{2max}. A predicted VO_{2max} was calculated using the equation of Leger and Gadoury [5].

VO_{2max} (ml.kg^{-1}.min^{-1}) = –32.678 + 6.592 x Maximal Aerobic Speed (MAS) [5]

Procedures

The athletes participate in training programs of 1.5-hour exercise in a day, 6 days per week during the season. The season was divided into three training parts (basic preparatory, pre competition term, competition term). All the measurements were conducted in competition term. Standardized testing procedures were followed as defined in the American College of Sports Medicine Guidelines [6]. All measurements were performed by same researchers after an overnight fast. All measurements were performed at a similar time of the day between 8:00 and 12:00 a.m. in order to have similar chronobiological characteristics [7].

3. Analysis

Standard statistical methods were used for the calculation of the mean and standard deviations (±SD). Before analysis, normality and equality of variance of the variables were assessed using a Shapiro-wilk test. The differences between male and female athletes were determined using the Independent t test. The differences between 12 minute walk-run and MST were determined using the One simple t test. Additionally, Pearson correlation coefficients were calculated to examine the relationships between variables. The level of significance for all statistics was set at $p<0.05$. SPSS 19 software was used to calculate the data.

4. Results

Table 1 shows the mean and standard deviation of physical and physiological profiles by based on gender. Aerobic endurance values of male and female athletes are presented in Table 2. The correlation between VO_{2max} tests and some of parameters are presented in Table 3.

No significant difference were detected for age, BMI and TE variables among groups (male - female) ($p>0.05$) (Table 1). There were significant differences for another variables (Height, Weight, FP, FFM, BMR) among groups (male - female) ($p<0.05$) (Table 1).

There was significant difference in VO_{2max} values between MST and 12 minute walk-run test protocols ($p<0.05$) (Table 2). For both of test protocols, there was significant difference in VO_{2max} values between male and female athletes ($p<0.05$) (Table 2).

It was identified strong correlation between FP and both of VO_{2max} test values (MST and 12 minute walk-run) (Table 3). It was also identified strong correlation between MST and 12 minute walk-run test protocols (Table 3). It was identified moderate correlation between FFM and both of VO_{2max} test values (MST and 12 minute walk-run) (Table 3). There was strong correlation between FFM and BMR (Table 3).

Table 1. Some of physical and physiological profiles in athletes

	Boy (n=13) X±SD	Girl (n=12) X±SD	p
Age (year)	16.5 ± 2.4	16.2 ± 2.1	0.75
Height (cm)	169.7 ± 5.2	162.5 ± 5.2	0.00*
Weight (kg)	57.1 ± 5.9	49.3 ± 8.0	0.01*
BMI (kg/m^2)	19.8 ± 1.6	18.7 ± 2.6	0.20
FP (%)	11.3 ± 3.7	19.2 ± 4.5	0.00*
FFM (kg)	50.6 ± 5.8	39.5 ± 4.7	0.00*
BMR (kcal)	1649 ± 92	1325 ± 141	0.00*
TE (year)	2.4 ± 1.7	1.4 ± 1.1	0.85

$p<0.05$*, BMI: body mass index; FP: fat percentage; FFM: fat free mass; BMR: basal metabolic rate, TE: training experiences

Table 2. The statistics of VO_{2max} scores derived from various tests and genders

	Boy (n=13) X±SD	p^a	Girl (n=12) X±SD	p^a	p^b
MST (VO_{2max}) ml.kg-^{1} min-^{1}	53.6 ± 6.5^{ab}	0.00	42.4 ± 7.3^{ab}	0.00	0.00
Copper (VO_{2max}) ml.kg-^{1} min-^{1}	57.2 ± 13.6^{ab}		38.8 ± 11.6^{ab}		0.00

$^{ab}p<0.05$, MST: multistage progressive shuttle run test; 12 minute walk/run test; p^a compares to MST and 12 minute walk-run test; p^b compares to male and female athletes

Table 3. The correlation among some of parameters

r	FP	FFM	BMR	MST	Cooper	TE	BMI
FP	1	-0.52**	-0.33	-0.77**	-0.76**	-0.64**	0.13
FFM		1	0.88**	0.48*	0.44*	0.25	0.68**
BMR			1	0.34	0.31	0.06	0.64**
MST				1	0.94**	0.67**	0.05
Cooper					1	0.62**	-0.08
TE						1	0.01
BMI							1

FP: fat percentage; FFM: fat free mass; BMR: basal metabolic rate, MST: multistage progressive shuttle run test;
TE: training experiences, BMI: body mass index;
P<0.01**; 0.05*

5. Discussion

The determination of VO_{2max} using analyzers (gas and ventilation) demands expensive laboratory exercise ergometers, experienced personnel, and also requires medical attendance, so it may not be suitable for some applications [8, 9]. For these reasons, there are some predictive tests for athletes' maximal oxygen uptake and sports scientists focus on using and comparing these tests with each other.

The major finding of this study is that VO_{2max} values are higher in boy athletes than girl athletes (Table 2). We also found that boys had higher FFM, BMR and lower FP compared to the girls (Table 1). The higher FP in girls is consistent with the results of the studies in the literature that report higher such values in general [10, 11]. Marta et al., [11] reported also that the boys had higher aerobic capability (VO_{2max}) compared to the girls. The boys are higher to girls in aerobic fitness because, lower fat mass [11] and other factors mainly linked to the cardiac size and oxygen-carrying capacity (i.e., left ventricular inner diastolic diameter, maximal heart rate (HRmax), and maximal stroke volume) [10]. Dencker et al., [10] found that gender differences for VO_{2max} where boys (9.9±0.6 years-body fat %: 18.2 – Lean Body Mass (LBM): 26.1±3.4 kg - 41.4±7.2 $ml.kg^{-1}.min^{-1}$) had 8-18% higher VO_{2max} values than girls (9.7±0.6 years – body fat %: 23.4 – LBM: 24.1±3.5 kg - 35.8±6.4 $ml.kg^{-1}.min^{-1}$). They reported that most important contributing factors for absolute values of VO_{2max} were LBM, HRmax and gender. Woll et al., [12] reported that VO_{2max} continues to increase during puberty with a slower rate for girls than for boys, resulting in a gender-specific pattern. The body composition differences among genders may have affected the values of VO_{2max}.

Another finding of this study is that of a high negative correlation between FP and both of estimated VO_{2max} values for the subjects (Table 3). However, the study result showed positive correlation between FFM and VO_{2max} tests values. The study results are consistent with the findings of several studies in the literature. Minasian et al., [13] reported that FP augmentation leads to a decrease in aerobic fitness of children. This study results [13] revealed that a moderate-strong inverse relationship (r = –0.81 for boys vs. r = –0.77 for girls) between aerobic fitness and fat percentage of subjects. Maciejczyk et al., [3] found that significant positive correlation (r =0.38) between lean body mass and absolute values of VO_{2max}. However, they reported that there was a negative correlation between FP and VO_{2max}. Ekelund et al., [14] reported that for both genders (age: 14.8±03 years), FP was significantly and negatively related to VO_{2peak} (r = -0.48 and r = -0.43). Goran et al., [15] reported that FFM was the strongest determinant of VO_{2max} (r= 0.87), after separating children into lean and obese sub-groups. McInnis and Balady [16] compared VO_2 during submaximal effort between body builders (FP = 8%) and men with normal body fat percentage (FP =24%), having similar body weight. They concluded that body builders had a significantly higher VO_{2max} during motor tasks. This study was designed by Laxmi et al., [17] to evaluate the VO_{2max} and its relation with BMI in young healthy male subjects. The study [17] result showed that a significant negative correlation between BMI and VO_{2max} ($ml.kg^{-1}.min^{-1}$) (r= -0.48). Moreira et al., [18] suggest that the visceral fat area (VFA) and BMR significantly influence the VO_{2max} of postmenopausal women, regardless of age and the characteristics of menopause. They reported that presence of VO_{2max} levels > 30.94 $ml.kg^{-1}.min^{-1}$ is associated with less fat and VO_{2max} < 26.87 $ml.kg^{-1}.min^{-1}$ tend to show a greater VFA. The study and other studies results show that FP was associated negatively and FFM was also associated positively with aerobic endurance. We suggest that to reduce FP and increase FFM are important to obtain high VO_{2max}. The main limitation of the study is a small group of boys and girls participants. The previous study results [19-21] clearly demonstrated that FP and FFM not only aerobic endurance, but also have the greatest impact on anaerobic and muscle strength.

The mean (±SD) and correlation values from MST and 12 minute walk-run tests are given in Table 2 and Table 3. The study results indicate that strong correlation (r=0.94) between MST and 12 minute walk-run test protocols (Table 3). However, there was significant difference in VO_{2max} values between MST and 12 minute walk-run test protocols (Table 2). Grant et al., [22] found that significant difference among 12 minute walk-run, MST and treadmill $VO_{2\,max}$ tests scores and it was inappropriate to compare VO_{2max} scores obtained from different predictive tests. They suggested that the 12 minute walk/run test is the best predictor of $VO_{2\ max}$. The findings from this study [22] which is consistent with the study result. It is possible that the reason for the scores of the predicted VO_{2max} can be partly explained by the fact that having used different test procedures and equations.

6. Conclusions

The obtained results indicate that the athletic boys showed higher VO_{2max} responses in our study compared to the girl athletes. Higher body fat percentage may make them less efficient in terms of cardio respiratory response and performance on tests that require VO_{2max}. As regarding the correlation between VO_{2max} and body fat percentage; there was statistically significant a negative correlation. In boys and girls athletes, FP and FFM were inversely related to aerobic fitness. It also demonstrates that lower FP and higher FFM contribute to VO_{2max}. Coaches and athletes of aerobic disciplines should not only increase on FFM levels but also reduce on levels of FP. However, another important result about the comparing two different methods, not appropriate to compare VO_{2max} scores obtained from different predictive tests.

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