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The Relationship Between Body Fat Percentage and Aerobic Capacity Among Pre-Adolescent Individuals

Adölesan Dönem Öncesi Bireylerde Vücut Yağ Yüzdesi İle Aerobik Kapasite Arasındaki İlişki

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ABSTRACT

Aerobic capacity is considered to be an indicator of future health risks associated with chronic diseases arising from sedentary lifestyle. Due to difficulties in performing the tests for measuring aerobic capacity such as environmental, equipmental, or individual factors, other parameters that are easier to measure and can be used to predict aerobic capacity gain importance. This study aimed to assess the body fat percentage for estimating aerobic capacity among sedentary and recreational athlete groups of pre-adolescent male and female individuals. A total of 85 participants aged 8–13 years were divided into sedentary and recreational athlete groups according to the responses of verbal interviews. The anthropometric characteristics (height, weight, body mass index, and body fat percentage) of all participants were measured, and then the participants performed progressive aerobic cardiovascular endurance run test to determine aerobic capacity in accordance with Fitnessgram test battery instructions. Sedentary- and recreational group-adjusted body fat percentages were moderately correlated with aerobic capacity in the negative direction ($r = -,546$, $p < ,05$), while gender-adjusted body fat percentages were in negative strong correlation with the aerobic capacity ($r = -,803$, $p < ,05$). Similarly, the two parameters were strongly correlated in the negative direction in all of the participants ($r = -,800$, $p < ,01$). It can be concluded that there is a reciprocal and continuous cycle between body fat percentage and aerobic capacity among both sedentary and recreationally active individuals. The findings of this research support that body fat percentage indicates aerobic capacity, but researches with larger sample sizes administered in equal environmental and equipmental conditions should be planned for more accurate results.

Keywords: Aerobic capacity, body fat percentage, body mass index, Fitnessgram, VO2max

ÖZ

Aerobik kapasite, sedanter yaşam tarzından doğan kronik hastalıklara ilişkin gelecekteki risk göstergesi olarak kabul edilmektedir. Aerobik kapasite ölçümünde kullanılan testlerin gerçekleştirilmesinde karşılaşılan çevresel, donanımsal ve bireysel zorluklar nedeniyle; ölçümü daha kolay olan ve aerobik kapasite tahmininde kullanılabilecek parametreler önem kazanmaktadır. Bu çalışma, adölesan dönem öncesi erkek ve kız bireylerden oluşan sedanter ve rekreasyonel sporcu gruplarda vücut yağ yüzdesi ile aerobik kapasite arasındaki ilişkinin değerlendirilmesini amaçlamaktadır. 8–13 yaş arası toplam 85 katılımcı, sözel görüşme yanıtlarına göre sedanter ve rekreasyonel sporcu gruplarına ayrıldı. Tüm katılımcıların antropometrik ölçümleri (boy, kilo, vücut kitle indeksi, vücut yağ yüzdesi) yapıldı ve ardından aerobik kapasite ölçümü için Fitnessgram test bataryası talimatlarına göre tüm katılımcılara progresif aerobik kardiyovasküler endurans koşusu yaptırıldı. Sedanter ve rekreasyonel gruplara göre düzeltilmiş vücut yağ yüzdesi değerleri, aerobik kapasite ile orta derecede negatif korelasyon gösterirken ($r = -,546$, $p < ,05$); cinsiyete göre düzeltilmiş vücut yağ yüzdesi değerleri, aerobik kapasite ile güçlü derecede negatif yönde korele idi ($r = -,803$, $p < ,05$). Benzer şekilde, katılımcıların tamamı göz önüne alındığında iki parametre arasında güçlü derecede negatif korelasyon izlendi ($r = -,800$, $p < ,01$). Buna göre hem sedanter hem rekreasyonel olarak fiziksel aktif bireylerde, vücut yağ yüzdesi ile aerobik kapasite arasında karşılıklı ve sürekli bir döngünün varlığından bahsedilebilir. Bu sonuçlar, vücut yağ yüzdesinin aerobik kapasite için bir gösterge olabileceği görüşünü desteklemektedir, ancak daha ikna edici sonuçlar için eşit çevresel ve donanımsal şartlar sağlanarak, geniş örneklem gruplarının dahil edildiği çalışmalar planlanmalıdır.

Anahtar Kelimeler: Aerobik kapasite, Fitnessgram, VO2max, vücut kitle indeksi, vücut yağ yüzdesi

Introduction

Sedentary lifestyle is known to be a risk factor for chronic diseases such as obesity, hypertension, cardiovascular pathologies, and dyslipidemia, as well as affecting mental and psychological health negatively (Çakır, 2019; Güler et al., 2019; Lam et al., 2004). It interrupts the homeostatical balance of the body not only in adults but also in pediatric groups. Recent studies disclose a distinct association between sedentary lifestyle and components of cardiometabolic syndromes (Goldfield et al., 2013; Tremblay et al., 2011).

In order to avoid or minimalize the development of such chronic diseases, encouraging physical activity seems to be a promising solution (Kurak, 2020; Uçan et al., 2018). Regular physical activity habit which is adopted during childhood is likely to continue through adulthood in a high rate (Güler et al., 2019; Pate et al., 1999; Uçan et al., 2018). Thus, various evaluation and training programs have been developed for pre-adolescent and adolescent individuals to fight with sedentary lifestyles. Fitnessgram test battery is considered among the motivating and funny ones for children and ensures the measurement and follow-up of physical fitness parameters (Plowman & Meredith, 2013).

Aerobic capacity (VO_2max) is reflected as one of the important indicators of physical fitness level regardless of gender (Eler, 2018). It is the utmost consumed oxygen rate during exercise with maximal loading (Shete et al., 2014). The gold standard measurement technique of this parameter is a progressive exercise test in gradually increasing speed in the athletic health laboratory. During the test, the oxygen uptake rate is recorded using advanced devices and equipments. Although this direct measurement technique is regarded as the gold standard one, it is not cost and time effective and practical in field conditions (Plowman & Meredith, 2013). These limitations canalize researchers to use easier indicators. Body fat percentage (BFP) is a parameter that can be easily measured via different techniques in both laboratory and field conditions (Plowman & Meredith, 2013). Many researches have revealed the effects of athletic performance on BFP and VO_2max separately (Bayram et al., 2020; Çetin et al., 2018; Eler, 2018; Hazar & Akyol, 2019). This raises the question of whether there is a relationship between these two parameters.

The ages between 7 and 14 are quite important for performance ability, as significant progress is observed during this period (Kurak, 2020). The maximal performance rate is reported in the ages of 12–13 (Güler et al., 2019). So, this study has been designed to observe any correlation between BFP and VO_2max among pre-adolescent male and female individuals.

Methods

The study was carried out following local ethics committee approval (Gülhane Military Medical Academy Ethics Committee, 05-04/07/2012 and revised on 32-12/02/2014) and provincial national education directorate written permission (14588481/605.99/133532).

Participant Selection

The participants of this study were a total of 85 (8–13 years) volunteer female ($n = 54$) and male ($n = 31$) students whose parents gave written approval from four different schools. All of them had a health certificate valid for the last 1 year, which represented that they had no health-threatening pathology and could participate in sports activities. The physical examination and issuance of certificates were planned by the researchers.

The tests were not performed in the case of any existing musculoskeletal injury (e.g., muscular strain and ligamentous sprain), active urinary tract, gastrointestinal tract, upper or lower respiratory tract infection, and any pathology causing nausea and vomiting.

Collection of data was based on verbal interview with the parents and physical education and sports teachers and Fitnessgram test battery. The verbal interview interrogated the weekly physical activity level of the participants.

Grouping of the Participants

Depending on the responses of verbal interviews, 2 main groups were formed as sedentary individuals and recreational athletes. The sedentary group (SG) consisted of individuals who did not attend any sportive course or activity out of school and were spending leisure time on sedentary behaviors. The recreational athlete group (RAG) consisted of individuals who attended basketball course 3 days a week for 1.5 hours during the last 6 months or more.

Of the total 85 participants, 42 were included in the SG (18 male and 24 female), while 43 were in the RAG (13 male and 30 female).

Fitnessgram Test Battery

Fitnessgram is an evaluation and follow-up software system which has been designed for sport and exercise professionals to help tracking youth fitness individually. It determines the 3 basic health-related components of physical fitness: (1) body composition, (2) cardiovascular endurance (VO_2max), and (3) musculoskeletal fitness (muscular endurance, strength, and flexibility). Body composition evaluation is based on skinfold measurement or bioelectrical impedance analysis (BIA). Aerobic capacity is evaluated through progressive aerobic cardiovascular endurance run (PACER), 1-mile run test, or 1-mile walk test. Musculoskeletal fitness is determined by curl-up, trunk extension, 90° push-up, back saver sit and reach, and shoulder stretch tests. Any component can be tested at any particular time, and all items of a component are not obligatory (Plowman & Meredith, 2013).

Physical characteristics, body composition, and VO_2max parameters of the participants were measured using Fitnessgram test battery. For body composition, skinfold measurement was preferred since the estimated standard error of this item is similar with that of BIA. Also, it can be performed by a mobile and easily accessible caliper, whereas BIA is device dependent. For VO_2max, 1-mile walk test was eliminated since it can be performed on individuals aged 13 and over. Progressive aerobic cardiovascular endurance run was preferred among the remaining options because it imitates the gradually increasing nature of speed better and is influenced by motivation less than the 1-mile run test (Plowman & Meredith, 2013).

Initially, all tests were described in detail to the participants. Height, weight, BFP, and VO_2max were measured, respectively. The tests were not conducted on extremely hot, cold, or humid weather in order to minimalize the false results. All parameters were measured in indoor sport courts.

Body Composition

Evaluation was based on body mass index (BMI) and BFP parameters, depending on the measurements of height, weight, and skinfold. The measurements of each participant were performed in privacy.

Height and weight parameters were measured in meters and kilogram units, respectively, providing the calculation of BMI parameter in kg/m[2] unit. All participants wore only light sport shorts and t-shirt on barefoot during the measurements. Medisana 48455 branded mechanical weighbridge measuring between 0 and 150 kg with a sensitivity of 0.1 kg, a tape measure with a sensitivity of 0.1 m, and a Holtain Tanner/Whitehouse branded skinfold caliper were used for weight, height, and skinfold measurements, respectively. The participant was requested to stand upright, heels contacting, and knees extended while measuring height.

Right triceps and right gastrocnemius medial head regions were preferred for skinfold measurement.

For triceps skinfold, the midpoint of the distance between olecranon and scapular acromial process on the posterior approach of the right arm was marked. Triceps muscle was pinched separating dermal and subdermal tissues with the marked point in center, and then the measurement was performed using caliper three times consecutively. Each result was interpreted as the nearest 0.5 mm value, and the median value of three measurements was accepted as the final triceps skinfold result.

For gastrocnemius skinfold, the participant stepped onto a stair with his/her right foot flexing the knee 90°. The measurement was performed on the level where the calf diameter was the widest, and the medial head of gastrocnemius muscle was pinched separating dermal and subdermal tissues. Similar with the triceps skinfold measurement, three-times-protocol was performed.

The skinfold measurement results were the replacing values of the following equation (Slaughter et al., 1988) to calculate the BFP:

(Male individuals) BFP = [0.735 × (triceps result + gastrocnemius result)] + 1.0

(Female individuals) BFP = [0.610 × (triceps result + gastrocnemius result)] + 5.0

VO_2max

VO_2max measurement was based on 20 m PACER protocol. Two points at a distance of 20 m apart were determined, and the participant was requested to run forward and backward between these points in accordance with music warning by beep sound. All participants were given sufficient time to stretch before starting the test.

The test started with a speed of 8 km/h. The participant began to run from one point to the other by the first beep sound and had to reach the target point before the next beep; this was continued in a cyclic manner. Running speed increased by 0.5 km/h per minute. It was counted as a fault if the participant could not reach the target point before the beep sound, and the test was terminated with the second fault. The result was the score of completed laps including the first fault.

The result was converted to 1-mile-run duration (MRD), using a specific chart (Zhu et al., 2010). The final value was substituted in the following equation to calculate VO_2max in mL/kg/min unit (Cureton et al., 1995):

$$VO_2max = (0.21 \times age \times gender) - (0.84 \times BMI) - (8.41 \times MRD) + (0.34 \times MRD \times MRD) + 108.94,$$

where gender is 1 for male individuals and 0 for female individuals.

Statistical Analysis

All results are reported as mean ± standard deviation ($\bar{X}$ ± SD). The normality of distribution was tested by Kolmogorov–Smirnov test, disclosing that variables of this study were not skewed. Thus, parametric tests were preferred. Student's *t*-test, Pearson correlation test, and partial correlation coefficient test were used to analyze the statistically significant differences and relationship of variables between the groups, respectively. PASW (Predictive Analytics SoftWare) Statistics 18.0 for Windows ((IBM Corp., New York) was used for analysis.

Results

The descriptive characteristics of all participants are presented in Table 1. The SG had higher values of weight and BMI than RAG.

There were statistically significant differences for BFP and VO_2max between the designated groups ($p < .05$) (Table 2). The SG had higher values of BFP than RAG contrary to VO_2max. However, the differences for both variables between the gender-adjusted groups were statistically insignificant ($p < .05$) (Table 3).

The results of the correlation analysis are presented in Table 4. Values of BFP and VO_2max showed a negative strong correlation, which is considered to be statistically significant (Schober et al., 2018). When recreational exercising and gender difference was kept in view, negative moderate and strong correlations were observed between these variables with the adjustment of each of the two groups, respectively (Schober et al., 2018).

Table 1.
Descriptive Characteristics of the Participants ($\bar{X}$ ± SD)

	SG (n = 42)		RAG (n = 43)		Total (n = 85)	
	Girls	Boys	Girls	Boys	Sedentary	Recreational
	(n = 24)	(n = 18)	(n = 30)	(n = 13)	(n = 42)	(n = 43)
Age (years)	10.792 ± 1.668	9.667 ± 1.283	11.333 ± 1.322	10.385 ± 0.768	10.310 ± 1.600	11.046 ± 1.253
Height (m)	1.491 ± 0.091	1.469 ± 0.053	1.476 ± 0.068	1.462 ± 0.042	1.482 ± 0.080	1.469 ± 0.060
Weight (kg)	53.536 ± 6.127	46.694 ± 4.896	40.028 ± 4.868	32.976 ± 4.024	50.435 ± 5.585	38.675 ± 4.655
BMI (kg/m²)	22.890 ± 1.693	23.653 ± 2.715	17.983 ± 1.762	18.203 ± 2.601	23.217 ± 2.193	18.049 ± 2.022

Note: BMI = body mass index; RAG = recreational athlete group; SD = standard deviation; SG = sedentary group.

Table 2.
Mean Values of Compared Variables in the Sedentary–Recreational Groups ($\bar{X}$ ± SD) and the Results of the t-Test

Parameters	SG (n = 42)	RAG (n = 43)	Total (n = 85)	P-Value for t-Test	
BFP (%)	30.093 ± 4.199	20.024 ± 5.398	24.999 ± 6.987	9.583	.000
VO_2max (mL/kg/min)	38.548 ± 1.458	43.700 ± 2.605	41.154 ± 3.338	−11.284	.000

Note: BFP = body fat percentage; BMI = body mass index; RAG = recreational athlete group; SD = standard deviation; SG = sedentary group; VO_2max = aerobic capacity.

Table 3.
Mean Values of Compared Variables in the Female–Male Groups ($\bar{X}$ ± SD) and the Results of the t-Test

Parameters	Female (n = 54)	Male (n = 31)	Total (n = 85)	P-Value for t-Test	
BFP (%)	24.928 ± 6.024	25.123 ± 8.517	24.999 ± 6.987	−.123	.902
VO_2max (mL/kg/min)	40.960 ± 2.686	41.492 ± 4.275	41.154 ± 3.338	−.625	.535

Note: BFP = body fat percentage; SD = standard deviation; VO_2max = aerobic capacity.

Table 4.
Sedentary and Recreational Group-Adjusted Partial Correlation Coefficients Among BFP and VO_2max, Female and Male Group-Adjusted Partial Correlation Coefficients Among BFP and VO_2max, and Bivariate Correlation Coefficients of the Total Participants

	SG- and RAG-adjusted BFP	Gender-adjusted BFP	Total BFP
VO_2max (mL/kg/min)	−0.546*	−0.803*	−0.800**

Note: SG = sedentary group; RAG = recreational athlete group; BFP = body fat percentage; VO_2max = aerobic capacity.
*$p < .05$.
**$p < .01$.

The coefficient of determination (R^2) in Figure 1 suggests that about 63.9% of the VO_2max variability can be explained by the relationship with the BFP parameter.

Discussion, Conclusion and Recommendations

Our results support that a negative correlation exists between BFP and VO_2max both in sedentary and in physically active pre-adolescents, in an increasing ratio with increasing physical activity. Several studies have focused on the negative correlation between these two parameters among either sedentary or physically active individuals (Çetin et al., 2018; Eler, 2018; Garcia-Pastor et al., 2016; Shete et al., 2014) and also among heart transplant recipients (Nytrøen et al., 2014), the results of which verify our findings. This model considers a bipartite and dynamic relationship between body fat and VO_2max and also presents a view for the evaluation of BFP as a predictive factor of VO_2max.

VO_2max is one of the indicators of future health risks associated with sedentary lifestyle besides presenting the physical fitness level (Mondal & Mishra, 2017). Thus, other parameters which are considered to be predictive for VO_2max and measured easily in a more comfortable way are in the focus of several studies. Although both BMI and BFP have been reported to be predictive for VO_2max in various researches, BFP has been reflected as a better indicator of cardiorespiratory functional status than BMI (Mondal & Mishra, 2017). Adiposity increases triglyceride and low-density lipoprotein cholesterol levels along with decreasing high-density lipoprotein cholesterol. This leads to overloading of the heart, and associated deterioration of heart functions is thought to reduce VO_2max (So & Choi, 2010).

The decrease of body fat is associated with prolonged aerobic training especially (Güler et al., 2019; Meckel et al., 2018), bringing along with raised relative muscle mass (Mondal & Mishra, 2017). The consequent increase of fat oxidation in skeletal muscles (Azimkhani et al., 2019) may be another cause of accompanying VO_2max increase. It is known that less than 30% of VO_2max is affected by genetics, so this parameter is accepted as a reflector of habitual exercising level (Plowman & Meredith, 2013). But a decrease of body fat cannot be explained only by physical fitness parameters; also other factors such as genetics, sleep disorders, stress level, and family lifestyle are effective (Garcia-Pastor et al., 2016).

Another benefit of exercise is the reduction of serum inflammatory protein concentrations, besides the changes of VO_2max and BFP values (Garcia-Pastor et al., 2016). This approach suggests that the negative correlation between these parameters may be the result of a mechanism through immune response.

In order to keep BFP level in healthy ranges, increasing physical activity and regular dietary habits are encouraging solutions for especially pre-adolescent individuals (Çetin et al., 2018; Garcia-Pastor et al., 2016). Moreover, these interventions will not only increase VO_2max but struggle with various types of psychological disorders (Sever et al., 2017; Yıldırım, 2018). Therefore, it is very important to improve physical activity habit among pediatric population.

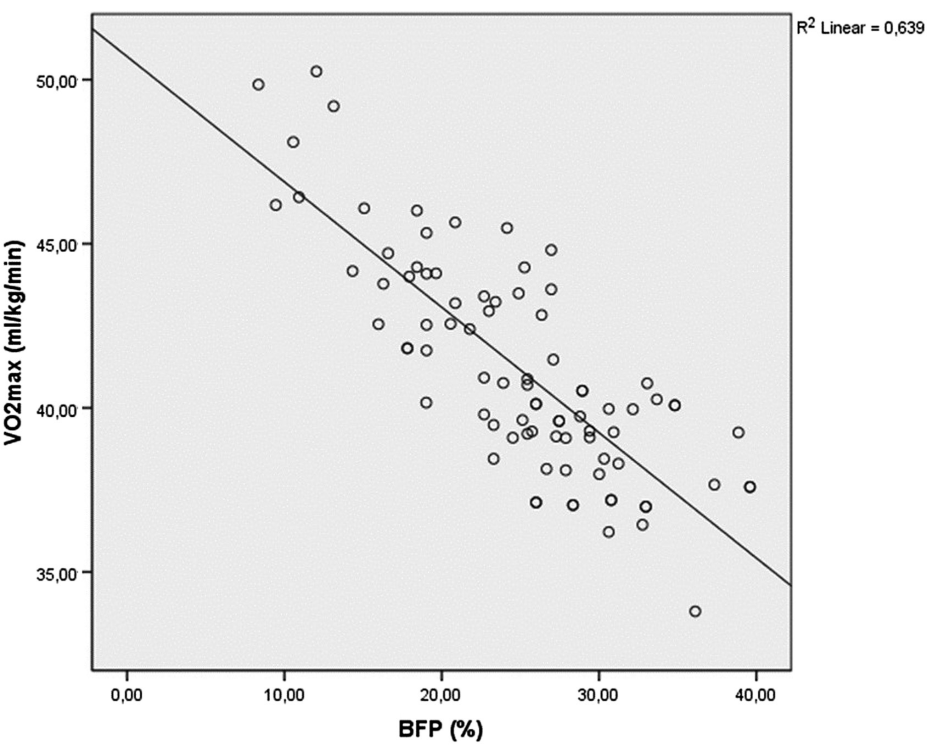

Figure 1.
Correlation Between BFP and VO_2max Parameters and Coefficient of Determination. BFP = body fat percentage; VO_2max = aerobic capacity.

There are some limitations regarding this research. The fallibility of responses and bias may have affected the verbal interviews and so grouping of the participants. We have not regarded sports background and history of the participants; thus, an existing heterogeneity of the groups may be concluded. The footwear of the participants also was not monotype (each wore her/his own one), so we cannot comment in which direction the surface friction was affected for each participant and whether the VO_2max results were altered. Due to the cross-sectional design of the study and participant selection from a single geographical area, it is difficult to interpret a certain causal relationship between the parameters. Further longitudinal researches should be planned to obtain more accurate results.

This study presents that BFP may be a predictive factor of VO_2max. Sports injuries and season breaks cause deconditioning. The main goal of athletes and physically active individuals is to reach at the pre-injury or better-than-before physical fitness level. Finding the easiest way of repeated VO_2max measurements is essential. This study is believed to be an important step in this respect and lead to new researches.

Ethics Committee Approval: First local ethics committee approval (05-04/07/2012) and the revised approval (32-12/02/2014) with provincial national education directorate written permission (14588481/605.99/133532) were obtained.

Informed Consent: The signed informed consent was obtained from the parents of the participants, as the participants were under the age of 18.

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