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ORIGINAL ARTICLE

Elevated Body Mass Index and Body Fat Percentage Are Associated with Decreased Physical Fitness in Soccer Players Aged 12-14 Years

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Abstract

Purpose: **Adolescents are in increased risk for the development of obesity, while sport has been suggested as an effective means against adolescent obesity. The objectives of this study were to examine (a) the prevalence of overweightness/obesity, (b) the relationship between body mass index (BMI) and body fat percent (BF), and (c) the association between BMI, BF and physical fitness in adolescent soccer players.**

***Methods*:** **Members (n=136, aged 13.1±0.6 yr) of competitive soccer clubs were examined for physical and physiological characteristics.**

***Results*:** **Based on international BMI cut-off points, 19.9% (n=27) of participants were classified as overweight. BMI was highly correlated with BF (r=0.77, P<0.001). BMI and BF were in inverse relationship with aerobic power (r=-0.29, P<0.001; r=-0.44, P<0.001, respectively), maximal anaerobic power (r=-0.23, P=0.009; r=-0.47, P<0.001) and local muscular endurance (r=-0.36, P<0.001; r=-0.67, P<0.001).**

***Conclusions*:** **The strong relationship between BMI and BF suggest the further use of BMI in adolescent soccer players. The findings confirmed previous observations in the general population about the negative effect of overweight and fatness on physical fitness. The prevalence of overweightness among participants was similar with what is observed in general population. Therefore, sport participation cannot guarantee physiological body mass and body composition, and it is necessary to prescribe exercise targeting body mass and fat control.**

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INTRODUCTION

Obesity and overweightness in adolescence consist an important public health issue [1]; it has been suggested that they track from childhood and adolescence to adulthood, and are linked to many other diseases [2,3]. While sport is a promising setting for obesity prevention, the relevant research has revealed controversial results [4]. Although soccer is the most widely practiced sport in Europe [5], no study has been ever conducted so far to investigate the prevalence of overweightness and obesity in a youth male soccer population.

Body mass index (BMI) is employed globally to classify humans as normal, overweight and obese [6]. Compared with assessment methods of body fat percent (BF), it is inexpensive and easy to administer. However, its application in sport populations has been questioned [7], because it is associated with fat mass, as well as with fat free mass. For instance, as BMI is increased by high amounts of both fat and fat free mass, a very muscular athlete with low BF could be classified as overweight. Recent studies have shown that the relationship between BMI and BF is influenced by sex, age and sport [4,8,9]. Such relationship has not yet been identified in adult soccer. If BMI was in strong correlation with BF, it would offer to coach, trainer or other health-allied professional engaged in soccer training an important tool to develop proper exercise programs.

In addition to their implications for health, BF and BMI are associated with reduced physical fitness, as it was indicated by research conducted chiefly on general population. The comparison between groups with different BMI has revealed that the groups with lower or normal BMI perform better in physical fitness tests than overweight/obese or those with higher BMI [9-12]. However, such associations have not yet investigated in youth soccer. Therefore, the objectives of this study were to examine (a) the prevalence of overweightness/obesity, (b) the relationship between BMI and BF, and (c) the association between BMI, BF and physical fitness in young soccer players.

METHODS AND SUBJECTS

Procedures and participants:

In this investigation, a descriptive-correlation design was used to examine the association between BMI, BF and physical fitness. Young male soccer players (n=136, aged 13.1±0.6yr, weight 52.0±9.7 kg, height 1.61±0.10 m, BMI 19.9±2.3 $kg \cdot m^{-2}$ and BF 16.2±4.6%), all members of competitive sport clubs, volunteered for this study. Soccer clubs in the region of Athens, Greece, were invited to participate in this research. Most of the participants competed in nonclassified tournaments because there were no national tournaments for adolescent players. They had 4.8±2.3 yr training experience and were engaged in soccer training 3.3±0.8 days weekly with each session lasting 1.4±0.3 h, i.e. a total weekly training volume of 4.7±1.4 h. Oral and written informed consent was received from all participants or parents after verbal explanation of the experimental design and potential risks of study.

***Equipment and protocols*:**

Height, body mass and skin-folds were measured, BMI was calculated as the quotient of body mass (kg) to height squared (m^2), and BF was estimated from the sum of 10 skinfolds (cheek, wattle, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh and calf) according to the equation $BF=-41.32+12.59 \bullet \log_e x$, where x the sum of 10 skinfolds [13]. An electronic weight scale (HD-351 Tanita, Illinois, USA) was employed for body mass measurement (in the nearest 0.1 kg), a portable stadiometer (SECA, Leicester, UK) for stature (1 mm) and a caliper (Harpenden, West Sussex, UK) for skinfolds (0.5 mm). All participants performed the following physical fitness tests in the respective order:

(a) Sit-and-reach test (SAR).The SAR protocol [14] was employed for the assessment of low back and hamstring flexibility.

(b) Physical working capacity in heart rate 170 $beats{*}min^{-1}$ (PWC170). PWC170 was performed according to Eurofit guidelines [15] in a cycle ergometer (828 Ergomedic, Monark, Sweden). Based on the linear relationship between heart rate and power output, PWC170 was calculated as the power corresponding to heart rate 170 $beats{*}min^{-1}$ and expressed as $W{*}kg^{-1}$.

(c) Arm-swing countermovement vertical jump (CVJ). The participants performed two countermovement jumps [16]. Height of each jump was estimated using the Opto-jump (Microgate Engineering, Bolzano, Italy) and was expressed as cm.

(d) Handgrip muscle strength (HS). The participants were asked to stand with their elbow bent at approximately 90˚ and instructed to squeeze the handle of the handgrip dynamometer (Takei, Tokyo, Japan) as hard as possible for 5 seconds [15]. HMS was calculated as the sum of the best efforts for each hand divided by body mass and expressed as $kg{*}kg^{-1}$ of body mass.

(e) Force-velocity test (F-v). The F-v test was employed to assess maximal anaerobic power (Pmax expressed as $W{*}kg^{-1}$). This test employed various applied braking forces that elicit different pedalling velocities in order to derive Pmax [17]. The participants performed four sprints, each one lasting 7 sec, against incremental braking force (2, 3, 4 and 5 kg) on a cycle ergometer (Ergomedics 874, Monark, Sweden), interspersed by 5-min recovery periods.

(f) Wingate anaerobic test (WAnT). The WAnT [18] was performed in the same ergometer as the F-v did. Briefly, participants were asked to pedal as fast as

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Table 1: Anthropometric and physiological characteristics of BMI quartile groups (each group=34)

Parameter	Quartiles of BMI [mean (standard deviation)]				ANOVA	
	1st	2nd	3rd	4th	F	*P* value
Age (yr)	13.0(0.6)	13.1(0.6)	13.1(0.5)	13.1(0.5)	F3,132=0.37	0.8
Denotes Body Mass (kg)	42.7(6.4)	47.9(5.7)	56.5(6.0)	61.1(7.8)	F3,132=55.11	<0.001
Height (m)	1.57(0.10)	1.59(0.09)	1.66(0.08)	1.63(0.09)	F3,132=5.90	<0.001
BMI ($kg•m^{-2}$)	17.2(0.8)	18.9(0.5)	20.5(0.5)	23.0(1.2)	F3,132=310.41	<0.001
Body fat (%)	12.3(2.7)	14.6(3.6)	16.4(3.1)	21.3(3.6)	F3,132=46.80	<0.001
Sit-and-reach test (cm)	14.7(5.6)	17.3(5.9)	18.0(7.2)	19.6(6.1)	F3,132=3.69	0.01
PWC170 ($W*kg^{-1}$)	2.62(0.60)	2.6(0.62)	2.45(0.52)	2.15(0.51)	F3,117=4.45	0.005
CVJ (cm)	31.0(4.8)	34.3(7.5)	30.2(4.6)	29.8(7.0)	F3,89=2.71	0.05
Handgrip strength ($kg*kg^{-1}$)	1.22(0.19)	1.16(0.18)	1.10(0.17)	0.98(0.21)	F3,130=9.62	<0.001
Maximal power ($W*kg^{-1}$)	11.80(2.42)	11.84(2.61)	11.92(2.49)	10.60(2.61)	F3,127=1.97	0.1
Mean power ($W*kg^{-1}$)	7.60(0.88)	7.44(1.05)	7.66(0.86)	6.72(1.20)	F3,105=5.21	0.002

BMI: Body Mass Index; PWC170: Physical Working Capacity in Heart Rate 170 beats*min^{-1}; CVJ: Countermovement Vertical Jump

possible for 30 s against a braking force that was determined by the product of body mass in kg by 0.075. Mean power (Pmean), expressed in W*kg^{-1}, was the main outcome of this test.

Statistical analysis:

Statistical analyses were performed using IBM SPSS v.20.0 (SPSS, Chicago, USA). Data were expressed as mean and standard deviation. International cut-off points were employed to classify participants as normal, overweight or obese [19]. The association between BMI and BF was examined using Pearson's moment correlation coefficient (*r*). One-way analysis of variance (ANOVA) was employed to test differences in physical fitness between quartile groups of BMI and BF. The level of significance was set at α=0.05.

RESULTS

Anthropometric and physiological characteristics of BMI and BF quartile groups are shown in Table 1 and 2 respectively. As demonstrated in these tables, there was a trend toward decreased physical fitness in the highest quartile of BMI and BF. Based on international BMI cut-off points, 19.9% (n=27) of participants were classified as overweight, including one obese. BMI was highly correlated with BF (*r*=0.77, *P*<0.001), fat mass (*r*=0.89, *P*<0.001), as well as with fat free mass (*r*=0.63, *P*<0.001), and BMI quartiles differed significantly with regard to their BF (F3,132=46.80, *P*<0.001). BF could be predicted based on the equation BF=1.56*BMI–14.92 (standard error of estimate 2.96; Fig. 1).

BMI was in inverse relationship with PWC170

Table 2: Anthropometric and physiological characteristics of body fat quartile groups (each group=34)

Parameter	Quartiles of Body Fat [mean (standard deviation)]				ANOVA	
	1st	2nd	3rd	4th	F	*P* value
Age (yr)	13.2 (0.6)	13.2 (0.6)	13.0 (0.5)	13.0 (0.6)	F3,132 = 1.11	0.3
Denotes Body Mass (kg)	45.9 (7.5)	50.1 (8.8)	53.8 (8.0)	58.3 (9.8)	F3,132 = 12.66	<0.001
Height (m)	1.60 (0.10)	1.62 (0.10)	1.619 (0.09)	1.61 (0.10)	F3,132 = 0.25	0.8
Body Mass Index ($kg*m^{-2}$)	17.9 (1.3)	18.9 (1.7)	20.6 (1.5)	22.2 (1.9)	F3,132 = 48.60	<0.001
Body fat (%)	10.8 (1.3)	14.0 (0.7)	17.4 (1.4)	22.5 (2.6)	F3,132 =316.91	<0.001
Sit-and-reach test (cm)	17.5 (0.6)	15.3 (5.7)	18.8 (6.7)	18.0 (7.0)	F3,132 = 1.80	0.1
PWC170 ($W*kg^{-1}$)	2.66 (0.53)	2.64 (0.70)	2.39 (0.39)	2.09 (0.49)	F3,117 = 7.26	<0.001
CVJ (cm)	35.6 (5.9)	31.9 (4.9)	30.7 (7.0)	27.3 (4.6)	F3,89 = 9.37	
Handgrip strength ($kg*kg^{-1}$)	1.27 (0.18)	1.16 (0.16)	1.08 (0.17)	0.96 (0.19)	F3,130 = 18.42	<0.001
Maximal power ($W*kg^{-1}$)	12.51 (2.05)	12.25 (2.45)	11.66 (2.58)	9.69 (2.23)	F3,127 = 9.67	<0.001
Mean power ($W*kg^{-1}$)	7.89 (0.92)	7.68 (0.72)	7.55 (0.77)	6.32 (1.05)	F3,105 = 18.29	<0.001

PWC170 physical working capacity in heart rate 170 beats*min^{-1}, CVJ countermovement vertical jump

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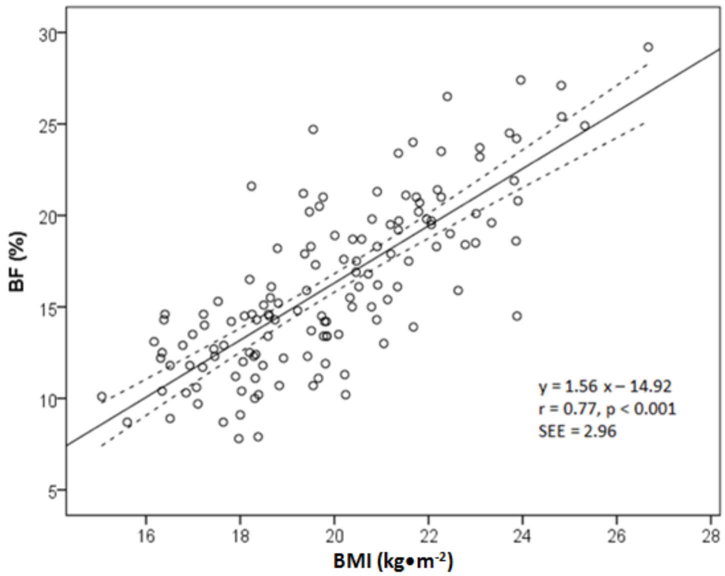

Fig. 1: Prediction of percentage of body fat (BF) from body mass index (BMI).
SEE = standard error of estimation. Dashed lines represent 95% confidence intervals.

(*r*= -0.29, *P*<0.001), Pmax (r=-0.23, *P*=0.009) and Pmean (*r*=-0.26, *P*=0.002). BF was in inverse relationship with PWC170 (*r*=-0.44, *P*<0.001), Pmax (*r*=-0.47, *P*<0.001) and Pmean (*r*=-0.67, *P*<0.001). Low or non-significant correlations were found between flexibility and BMI (*r*=0.24, *P*=0.005) or BF (*r*=0.09, *P*=0.3). Handgrip strength was in inverse relationship with BMI (*r*=-0.47, *P*<0.001), as well as with BF (*r*=-0.61, *P*<0.001). Arm-swing counter movement vertical jump was also inversely associated with BMI (*r*=-0.23, *P*=0.025) and BF (*r*=-0.53, *P*<0.001).

DISCUSSION

The prevalence of overweightness (19.9%) in our study was in agreement with findings in general population. A prevalence of 17.6% and 21.6% has been previously reported in 11-17 yr schoolchildren in France and Greece respectively [20,21] and 23% in schoolchildren 16-19 yr in Sweden [22]. Therefore, it is indicated that overweightness affects young soccer players in a similar extent as it does in general population. The participation in a sport per se cannot guarantee that an adolescent is not overweight and proper family-, sport club-, and school-based exercise interventions should target weight and body fat control. The increase in body mass results from the misbalance between energy intake (nutrition) and energy expenditure (physical activity), and an optimal intervention should consider both parameters, as well as genetic and environmental factors [20,23].

Even if the application of BMI in sport population has been questioned [7], it might be useful in youth soccer. Unlike sports where BMI could misclassify elite athletes as overweight or obese (e.g. American football [24]), soccer is a sport that is characterized by normal values of BMI (about 23 $kg \cdot m^{-2}$ in adults), as it has been shown by research on four elite European leagues [25]. In this context, the excess of body mass observed in our study was unexpected. Consequently, the current values of BMI found in our study should not be attributed to sport-specific physiological adaptations. It is unlikely that the high BMI in our study is due to a healthy increase in muscle mass alone and it may not be without health consequences. The high prevalence of overweightness in our sample warrants further investigation to determine the consequences of excessive weight in adolescent soccer

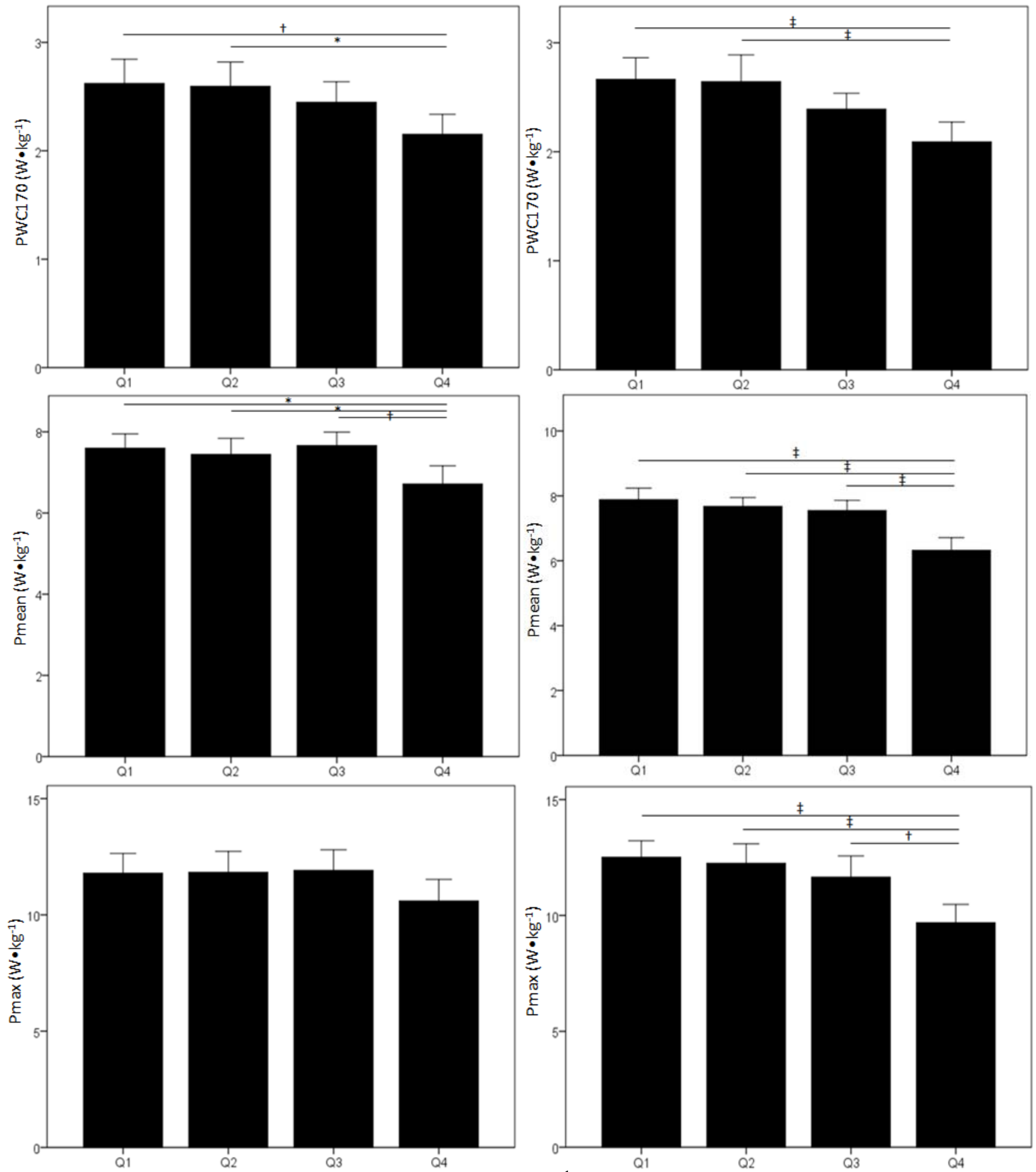

Fig. 2: Physical working capacity in heart rate 170 beats*min^{-1} (P170; upper row), mean power during the Wingate anaerobic test (Pmean; middle row) and maximal power estimated by a Force-velocity test (Pmax; lower row) for quartiles (Q1, Q2, Q3 and Q4) of body mass index (left) and body fat percent (right).

* P<0.05, † P<0.01, ‡ P <0.001.

players and to develop exercise intervention targeting weight management.

The results of this study indicate that BMI accounts for a large proportion of between-individual differences in BF; 59.8% of the variance in BF was explained by BMI. An important consideration was whether BF could be predicted from BMI in youth soccer. The strong relationship between BMI and BF, and the acceptable standard error of estimate of the former based on the latter, suggests the further use of BMI in adolescent soccer players. This correlation was comparable with findings in 5-19 yr boys (r=0.79,

$P<0.001$) [26]. It was also similar with what was found in Japanese general population aged 9-10 yr (r=0.78, $P<0.001$) and 12-13 yr (r=0.786, $P<0.001$) [27]; and higher than in the case of 4-11 yr boys (r=0.577, $P<0.01$) [8]. Thus, the use of BMI in youth soccer as a surrogate measure of BF is further recommended.

Based on previous studies on general population, it was hypothesized that there was an inverse relationship between BMI, BF and physical fitness in soccer players. The negative values of the correlation coefficient between these parameters confirmed our hypothesis. The most interesting finding derived from the comparison between BMI and BF quartiles (Fig. 2), which revealed that the highest BF quartile scored lower in all the tests. This suggests a threshold exists in BF, over which physical fitness is affected in great extent. These results emphasized the role of adiposity, but supported the role of BMI in youth soccer. We found associations between physical fitness and overweightness, whereby boys in higher BMI quartiles demonstrated reduced fitness compared with those in the lower quartiles. These relationships were even stronger between physical fitness and adiposity. These associations were not similar for all the parameters of physical fitness that were examined. Flexibility was a parameter that found to be in low or non-significant correlation with overweightness and adiposity, which came to terms with previous observations [9].

Our findings are encouraging and should be validated in countries with different prevalence of overweigh/obesity than Greece. Future work should focus on the identification of those sports in which children and adolescents are in risk to present such disease. An important question for future studies is to determine whether an optimal BMI for sport performance exists. Despite its inherent limitations (i.e. inability to discriminate between fat and fat-free mass), BMI association with physical fitness could be examined without difficulty by coaches and trainers in a variety of sport settings.

CONCLUSION

In conclusion, the prevalence of overweightness among participants was similar with what is observed in general population. The strong relationship between BF and BMI, and the acceptable standard error of estimate of the former based on the latter, suggests the further use of BMI in adolescent soccer players. Except for flexibility, BF was negatively associated with all the other physical fitness parameters under examination. A similar trend, but weaker, was noticed for BMI, too. These findings confirmed previous observations on general population about the negative effect of overweightness on physical fitness. Although the excess of body mass has weaker negative effect on physical fitness than BF does, its detrimental effect on sport performance and health should be considered in youth soccer clubs.

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Conflict of interests: None

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