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Association between body mass index, body fat per cent and muscle power output in soccer players

Research Article

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Abstract: The objectives of this study were to examine (a) the prevalence of overweight/obesity, (b) the relationship between body mass index (BMI) and body fat percent (BF), and (c) the association between BMI, BF and power output in adult male soccer players. Members of competitive soccer clubs (n=169, aged 22.7±4.2yr) were examined for anthropometric characteristics and body composition, and performed the physical working capacity in heart rate 170 min^{-1} test (PWC170), a force-velocity test (F-v) and the Wingate anaerobic test (WAnT). Based on international BMI cut-off points, 17.8% (n=30) of participants were classified as overweight. BMI was correlated with BF (r=0.67, p<0.001) and could be predicted based on the equation BF=1.193·BMI-12.24 (standard error of estimate 2.49). BMI and BF were in inverse relationship with mean power during WAnT (r=-0.30, p<0.001; r=-0.47, p<0.001, respectively). BF was also in inverse relationship with PWC170 (r=-0.26, p<0.001) and maximal power of the F-v test (r=-0.18, p=0.020).The prevalence of overweight among participants was lower than what is observed in general population. The findings confirmed previous observations on general population about the negative effect of overweight and fatness on selected parameters of physical fitness.

Keywords: *Body mass • Adiposity • Physical fitness • Sport*

1. Introduction

Obesity and overweight across the lifespan comprise 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, relevant research has revealed uneven results [4]. Although soccer is the most widely practiced sport in Europe [5], no study has been conducted to date to investigate the prevalence of overweight and obesity in an adult male soccer-playing population.

Body mass index (BMI) is employed globally to classify humans as normal, overweight or obese [6]. Compared with assessment methods usitilizing body fat percent (BF), it is inexpensive and easily to measure. 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 [7-9]. Such a relationship has not yet been identified in adult soccer players. If BMI were strongly correlated with BF, it would provide coaches, trainers or other health-allied professionals engaged in soccer training an important tool for development of proper exercise programs.

In addition to implications for health, BF and BMI are associated with lower physical fitness, as it has been indicated by research conducted chiefly on young populations. The comparison between groups with different BMI has revealed that groups with lower or normal BMI perform better in physical fitness tests than do the overweight/obese or those with higher BMI [10-14]. However, such associations have not yet been investigated in soccer players. Therefore, the objectives of this

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study were to examine (a) the prevalence of overweight/obesity; (b) the relationship between BMI and BF; and (c) the association between BMI, BF and physical fitness in adult male soccer players.

2. Materials and methods

2.1 Study design and participants

In this investigation, a non-experimental, descriptive-correlation design was used to examine the association between BMI, BF and physical fitness. Testing procedures were performed during the beginning of competitive period of seasons 2009-10, 2010-11 and 2011-12. The study protocol was performed in accordance with the ethical standards laid down in the Declaration of Helsinki in 1975 and approved by the local Institutional Review Board. Semi-professional soccer players (n=169, aged 22.7±4.2 years old, weight 74.8±7.8 kg, height 1.78±0.06 m, BMI 23.5±1.9 kg·m^{-2} and BF 15.8±3.3%, with playing experience 11.8±4.8 years and participation in weekly training 7.4±3.0 h), all members of competitive sport clubs, volunteered for this study. Oral and written informed consent was received from all participants after verbal explanation of the experimental design and potential risks of the study. Exclusion criteria included a history of any chronic medical condition and use of any medication. All participants visited our laboratory once and underwent a series of anthropometric and physiological measures.

2.2 Equipment and protocols

Height, body mass and skinfolds 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; BF = -41.32 + 12.59 • logex, where x the sum of 10 skinfolds) [15]. 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 (0.001 m) 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) Physical working capacity in heart rate 170 beats/min (PWC170). PWC170 was performed according to Eurofit guidelines [16] in a cycle ergometer (828 Ergomedic, Monark, Sweden). Seat height was adjusted to each participant's satisfaction, and toe clips with straps were used to prevent feet from slipping off the pedals. Participants were instructed before the tests that they should pedal with a steady cadence 80 revolutions per minute, which was given by both visual (ergometer's screen showing pedaling cadence) and audio means (metronome set at 80 beats per minute). This test consisted of three stages, each lasting 3 min, against an incremental braking force to elicit heart rate between 120 and 170 beats per minute. Based on the linear relationship between heart rate and power output, PWC170 was calculated as the power corresponding to heart rate 170 min^{-1} and expressed as W/kg.

(b) Force-velocity test (F-v). The F-v test was employed to assess maximal anaerobic power (P_{max} expressed as W/kg). This test employed various braking forces that elicit different pedaling velocities to derive P_{max} [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.

(c) Wingate anaerobic test (WAnT). The WAnT [18] was performed on the same ergometer as the F-v. Briefly, participants were asked to pedal as fast as possible for 30 s against a braking force that was determined by the product of body mass in kg by 0.075. Mean power (P_{mean}) was calculated as the average power during the 30 s period and was expressed as W/kg.

2.3 Statistical and data 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 of BMI were employed to classify participants as normal, overweight or obese [6]. Association between BMI and BF was examined using Pearson's moment correlation coefficient (r). Partial correlations, adjusted for the effect of age, were calculated between BMI, BF and physical fitness parameters. 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.

3. Results

Participants were categorized in quartile groups based on their BMI, where the first quartile (Q1) included those with values lower than 22.05 kg·m^{-2}, Q2 values ranged 22.05–23.39 kg·m^{-2}, Q3 23.40–24.46 kg·m^{-2} and Q4 values higher than 24.46 kg·m^{-2}. Participants were grouped in quartiles according to their BF as follows: Q1<13.1%, 13.1%≤Q2≤15.5%, 15.5%<Q3≤17.9% and Q4>17.9%. Anthropometric and physiological characteristics of BMI and BF quartile groups are shown in Tables 1 and 2, respectively. As shown in these tables, there was a trend

Table 1. Anthropometric and physiological characteristics of body mass index quartile groups.

	Quartiles of BMI				
	1st(n = 42)	2nd(n = 44)	3rd (n =41)	4th (n = 42)	ANOVA
Age (yr)	20.9 (2.4)	22.6 (4.3)	24.1 (4.5)	23.5 (4.5)	F3,165=4.92, p=0.003
BM (kg)	68.6 (5.6)	72.2 (4.8)	75.6 (5.0)	83.0 (7.4)	F3,165=47.21, p<0.001
Height (m)	1.79 (0.06)	1.78 (0.06)	1.78 (0.06)	1.79 (0.06)	F3,165=0.93, p=0.430
BMI (kg · m²)	21.3 (0.8)	22.8 (0.4)	23.9 (0.3)	25.9 (1.4)	F3,165=231.07, p<0.001
BF (%)	13.5 (2.5)	14.7 (2.3)	15.9 (2.4)	19.1 (3.2)	F3,165=35.58, p<0.001
PWC170 (W · kg⁻¹)	2.8 (0.5)	3.1 (0.5)	2.9 (0.5)	2.8 (0.6)	F3,149=2.16, p=0.096
P_{max} (W · kg⁻¹)	14.9 (2.6)	15.0 (2.1)	15.9 (3.5)	14.4 (2.2)	F3,156=1.95, p=0.124
P_{mean} (W · kg⁻¹)	8.8 (0.8)	9.0 (0.6)	9.0 (0.8)	8.4 (0.8)	F3,158=6.68, p<0.001

BM body mass, BMI body mass index, BF body fat percent, PWC170 physical working capacity in heart rate 170 beats/min, P_{max} maximal power output estimated by the Force-velocity test and P_{mean} mean power during the Wingate anaerobic test.

Table 2. Athropometric and physiological characteristics of body fat percent quartile groups.

	Quartiles of BMI				
	1st (n = 43)	2nd (n = 43)	3rd (n =43)	4th (n = 40)	ANOVA
Age (yr)	21.3 (3.4)	22.0 (3.5)	22.9 (3.6)	25.0 (5.2)	F3,165=6.52, p<0.001
BM (kg)	70.3 (6.8)	73.2 (5.6)	75.3 (6.8)	80.9 (8.3)	F3,165=17.29, p<0.001
Height (m)	1.78 (0.07)	1.78 (0.05)	1.78 (0.06)	1.79 (0.06)	F3,165=0.21, p=0.891
BMI (kg · m²)	22.2 (1.4)	23.0 (1.3)	23.6 (1.5)	25.2 (1.9)	F3,165=29.26, p<0.001
BF (%)	11.9 (1.1	14.5 (0.6)	16.8 (0.8)	20.3 (2.2)	F3,165=311.79, p<0.001
PWC170 (W · kg⁻¹)	3.0 (0.6)	2.9 (0.4)	3.0 (0.7)	2.6 (0.4)	F3,149=4.33, p=0.006
P_{max} (W · kg⁻¹)	15.1 (2.4)	15.9 (2.7)	15.1 (3.1)	14.1 (2.3)	F3,156=3.01, p=0.032
P_{mean} (W · kg⁻¹)	9.1 (0.8)	9.1 (0.5)	8.7 (0.7)	8.2 (0.8)	F3,158=15.84, p<0.001

BM body mass, BMI body mass index, BF body fat percent, PWC170 physical working capacity in heart rate 170 beats/min, P_{max} maximal power output estimated by the Force-velocity test and P_{mean} mean power during the Wingate anaerobic test.

toward decreased power output in the highest quartile of BMI, which was even clearer in the case of BM.

Based on international BMI cut-off points, 17.8% (n=30) of participants were classified as overweight, while among them one player was found to be obese. BMI was highly correlated with BF (r=0.67, p<0.001), fat mass (r=0.78, p<0.001), as well as with fat-free mass (r=0.61, p<0.001); BMI quartiles differed significantly with regard to their BF (F3,165=35.58, p<0.001). BMI could be predicted based on the equation BF=1.193·BMI–12.24 (standard error of estimate 2.49; Figure 1). BMI and BF were in inverse relationship with P_{mean} (r=-0.30, p<0.001; r=-0.47, p<0.001, respectively). BF was also in inverse relationship with PWC170 (r=-0.26, p<0.001) and P_{max} (r=-0.18, p=0.020). Low and non-significant correlations were found between BMI and PWC170 (r=-0.08, p=0.300), and P_{max} (r=-0.07, p=0.371).

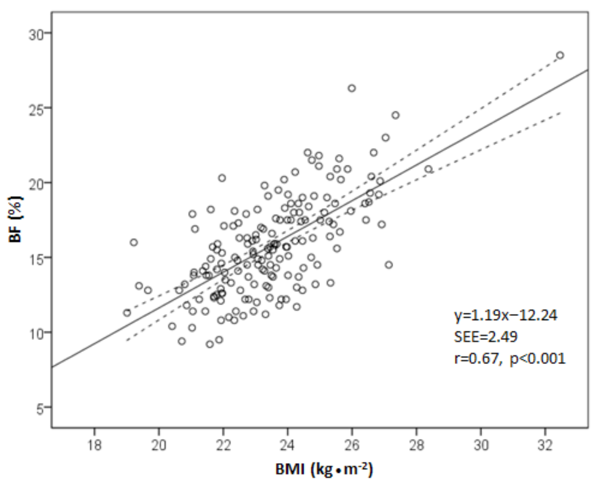

Figure 1. Prediction of percentage of body fat (BF) from body mass index (BMI). SEE = standard error of prediction. Dashed lines represent 95% confidence intervals.

4. Discussion

4.1 Prevalence of overweight

The prevalence of overweight (17.8%) in our study was lower than that in previous findings in general population. For instance, among male conscripts of the Greek army, 28.5% was overweight, and an additional 10.4% was obese [19]. Respective values from a study conducted on the general population of three Balkan countries were 31.4% and 12.4% [20]. Therefore, it is indicated that overweight affects soccer players in a lesser extent than it does the general population. Moreover, in our sample, only one participant was classified as obese. BMI was employed previously to estimate overweight and obesity in adult sport populations [7,21-23]. Prevalence of overweight/obesity was much lower in college athletes in various sports (17.8%) [22] in comparison with findings on American football players, among whom 45.0% were overweight and 42.6% were obese [21]. The high prevalence in American football in comparison with other sports was highlighted in other studies as well [7,23], suggesting its sport-dependence. With regard to the aforementioned studies, our sample had a lower prevalence of overweight and obesity than football players.

Nevertheless, the prevalence of overweight in our study was unexpected, given the optimal BMI of soccer players. In a recent comparison of four elite European leagues (English, Spanish, Italian and German), BMI ranged from 22.8±1.1 kg·m^{-2} to 23.2±1.1 kg·m^{-2} [24]. In terms of mean (23 kg·m^{-2}) and standard deviation (1.1 kg·m^{-2}), the aforementioned study indicated that 68.3% of elite players were in the range 21.9-24.1 kg·m^{-2}, while 95.4% were 20.8–25.2 kg·m^{-2}, demonstrating that approximately only 2.5% of players in the elite European leagues could be characterized as overweight. These findings suggested that soccer is not a sport characterized by excess of body mass. 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 prevalence of overweight in our sample warrants further investigation to determine the consequences of excessive weight in soccer players and to develop exercise intervention targeting weight management.

4.2 Relationship between BMI and body fat percent

The results of this study indicate that BMI accounts for a large proportion of between-individual differences in BF; 44.7% of the variance in BF was explained by BMI. An important consideration was whether BF could be predicted from BMI in soccer players. The direct 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 soccer players. In addition, BMI can differentiate clubs according to level of competency, with better clubs being characterized by lower mean values and variability scores of BMI. This further recommends the use of BMI in measurements of fitness in soccer players.

4.3 Association of BMI and body fat percent with physical fitness

Based on previous studies on the general youth 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 was that derived from the comparison between BMI and BF quartiles (Figure 2), which revealed that the highest BF quartile scored lower in all tests. This suggests that a threshold exists in BF, above which muscular power output is affected to a great extent. These results emphasized the role of adiposity, but supported the role of BMI in soccer as well. We found associations between power output and overweight whereby players in higher BMI quartiles demonstrated reduced P_{mean} compared with those in the lower quartiles. These relationships were even stronger between physical fitness and adiposity. These findings could be partially explained by the significant, but not strong, correlation between BMI and BF: both were associated with power output in the same direction, but with different magnitudes.

Participants performed the F-v test, the WAnT and the PWC170. With regard to the taxation of the human energy transfer systems, these tests describe short-term power output that relies mainly upon adenosine triphosphate-creatine phosphate (alactic anaerobic system), local muscular endurance capacity that depends on anaerobic glycolysis resulting in lactate production (lactic anaerobic system) and aerobic power that relies upon aerobic glycolysis, Krebs cycle and electron transport chain, respectively [16-18]. The contribution of these energy transfer systems to performance in soccer is well documented [25]. The association of short-term and aerobic power with BMI was statistically non-significant; on the other hand, a weak inverse relationship was observed, and this promising finding should be explored in a larger sample of soccer players. The significant negative correlation between BMI and local muscular endurance is a novel finding.

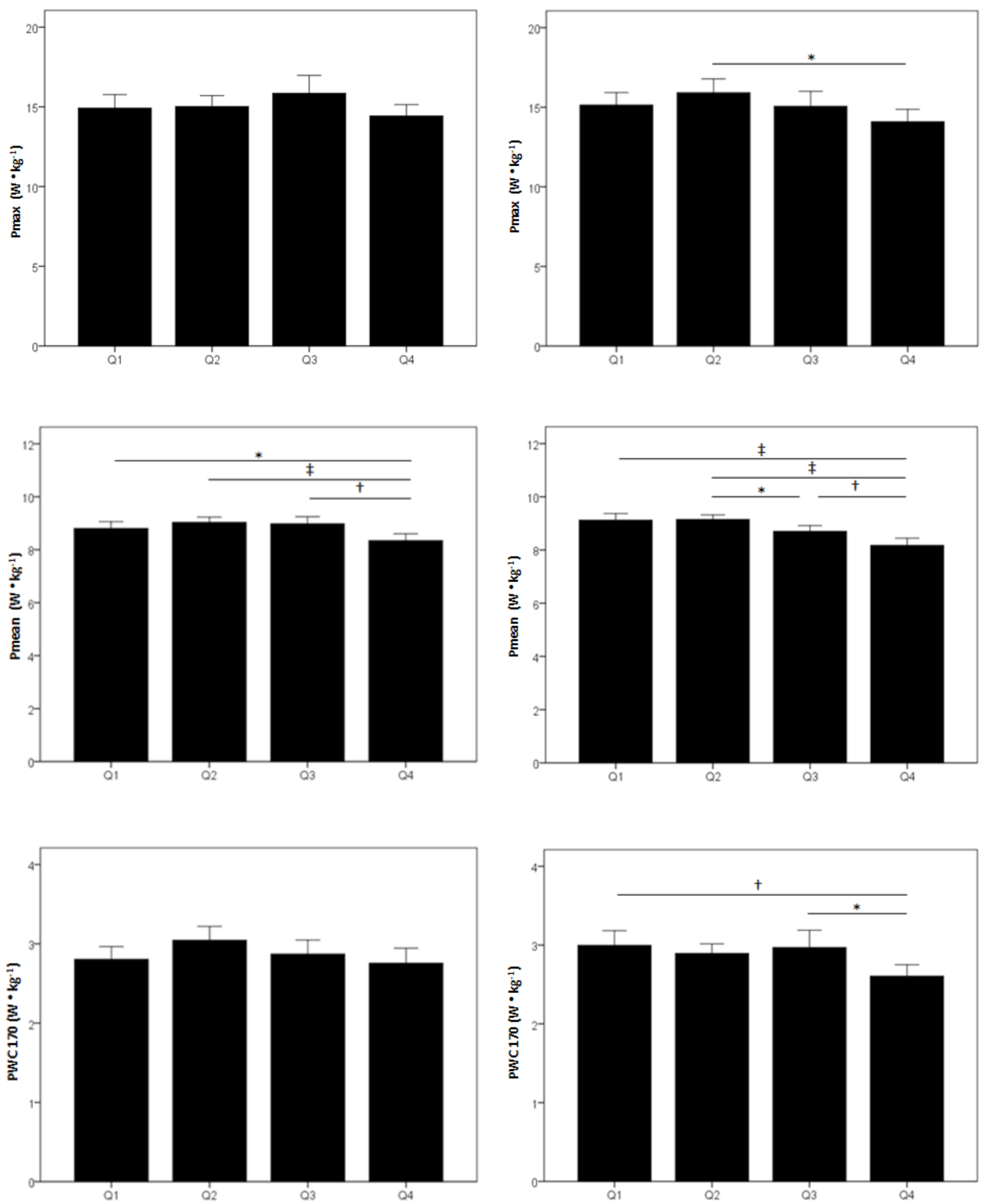

Figure 2. Maximal power output estimated by the Force-velocity test (Pmax, upper row), mean power during the Wingate anaerobic test (Pmean, middle row) and physical working capacity in heart rate 170 beats/min (PWC170; lower row) for quartiles (Q1, Q2, Q3 and Q4) of body mass index (left) and body fat percent (right).* $p < 0.05$, † $p < 0.01$, ‡ $p < 0.001$.

The main finding of this study is that the physical fitness tests employed show an association between BF, BMI and participants' power output, which in turns stresses the importance of weight control for sport performance. Therefore, soccer clubs, which commonly develop exercise training programs, should target optimal body mass and fat. The advantage of our research was the laboratory setting where measurements took place by the same experienced staff (PhD in exercise physiology), in contrast with the field methods employed to assess physical fitness in previous research [10-12,26]. The disadvantage was that because of the cross-sectional design of our research, it was not possible to infer causal relationships between BMI, BF and physical fitness, and therefore, results should be regarded with caution. However, it is reasonable to believe that soccer players with high values of BMI and especially of BF will have lower scores in physical fitness.

5. Conclusion

The prevalence of overweight among participants was lower than observed in the general population. It appears that the participation in soccer during adulthood plays a beneficial role in weight and body fat control. The statistically significant 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 soccer players. BF was negatively associated with all physical fitness parameters under examination. A similar trend, although weaker, was noticed for BMI. These findings confirmed previous observations on general population concerning the negative effect of overweight on physical fitness. Although an excess of body mass has a weaker negative effect on physical fitness than does BF, its detrimental effect on sport performance and health should be considered by soccer clubs.

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