ORIGINAL ARTICLE

Body mass index and body fat percentage are associated with decreased physical fitness in adolescent and adult female volleyball players

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Background: The objectives of this study were to examine (a) the prevalence of overweight/obesity, and (b) the relationship between body mass index (BMI), body fat percentage (BF) and physical fitness in adolescent and adult female volleyball players. **Materials and Methods:** Adolescent (n = 102, aged 15.2 ± 2.0 year) and adult (n = 57, 25.9 ± 5.0 year) players were examined for anthropometric characteristics and body composition, and performed the physical working capacity in heart rate 170 min^{-1} test, a force-velocity test, the Wingate anaerobic test (WAnT), sit-and-reach test (SAR), handgrip strength test (HST) and countermovement vertical jump (CVJ). **Results:** Based on international BMI cut-off points, 27.5% (n = 28) of adolescent and 12.3% (n = 7) of adult participants were classified as overweight, with the prevalence of overweight being higher in girls than in women (χ^2 = 4.90, P = 0.027). BMI was correlated with BF in both age groups (r = 0.72, P < 0.001 in girls; r = 0.75, P < 0.001 in women). Normal participants had superior certain physical and physiological characteristics than those who were overweight. For instance, normal girls and women had higher mean power during WAnT than their overweight counterparts (P = 0.003 and P = 0.009 respectively). Except for flexibility, BMI and BF were inversely related with physical fitness (e.g., BMI vs. HST r = -0.39, P < 0.001 in girls; BF vs. CVJ r = -0.45, P < 0.001 in women). **Conclusion:** The findings confirmed the negative effect of overweight and fatness on selected parameters of physical fitness. The prevalence of overweight in adolescent volleyball players was higher than in general population, which was a novel finding, suggesting that proper exercise interventions should be developed to target the excess of body mass in youth volleyball clubs.

Key words: Adiposity, age, muscular fitness, overweight, physical exercise, sport, volleyball

INTRODUCTION

Obesity and overweight across the lifespan is 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 volleyball is widely practiced sport worldwide, no study has been ever conducted to investigate the prevalence of overweight and obesity in a female volleyball population, and the association between body mass index (BMI), body fat percentage (BF) and physical fitness.

BMI is employed globally to classify humans as normal, overweight and obese.[5] Compared with assessment methods of body fat percentage (BF), it is inexpensive and easily to administer. However, its application in sport populations has been questioned,[6] 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.[6-8] Such relationship has not yet been identified in female volleyball. If BMI was in strong correlation with BF, it would offer to coach, trainer or other health-allied professional engaged in volleyball 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 has been indicated by research conducted chiefly on young populations. The comparison between the 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.[9-13] However, such associations have not yet investigated in volleyball. Therefore, the objectives of this 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 female volleyball players.

MATERIALS AND METHODS

Study design and participants

In this investigation, a non-experimental, descriptive-

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correlation design was used to examine the association between BMI, BF and physical fitness. Testing procedures were performed during the competitive period of seasons 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. Female volleyball players, divided into two groups, girls (n = 102, aged 15.2 ± 2.0 year, training experience 3.8 ± 2.2 year and weekly training volume 5.8 ± 1.7 h) and women (n = 57, 25.9 ± 5.0 year, 13.3 ± 5.9 year and 7.4 ± 3.0 h, respectively), all members of competitive sport clubs, volunteered for this study. Although, adolescence period is difficult to define in terms of chronological age due to its variation in time of onset and termination, it was suggested to range in age between 8 and 19 years in girls.[14] For the purpose of our study, we followed this definition about the range of adolescence.

Oral and written informed consent was received from all participants or their guardians, in the case of underage players, after verbal explanation of the experimental design and potential risks of study. Exclusion criteria included history of any chronic medical conditions and use of any medication. All participants visited our laboratory once and underwent a series of anthropometric and physiological measures.

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 skin-folds (cheek, wattle, chest I, triceps, subscapular, abdominal, chest II, suprailiac, thigh and calf; $BF = -41.32 + 12.59 \bullet \log_e x$, where x the sum of 10 skin-folds).[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 skin-folds (0.5 mm). A two-component model of body composition divided the body into fat mass (FM), calculated as the product of body mass by BF, and fat-free mass (FFM), estimated as the difference between body mass and FM. All participants performed the following physical fitness tests in the respective order:

- Sit-and-reach test (SAR).The SAR protocol[16] was employed for the assessment of low back and hamstring flexibility.
- Physical working capacity in heart rate 170 beats/min (PWC170). PWC170 was performed according to Eurofit guidelines[17] 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 the feet from slipping off the pedals. Participants were instructed before the tests that they should pedal with steady cadence 60 revolutions per minute, which was given by both visual (ergometer's screen showing pedaling cadence) and audio means (metronome set at 60 beats per minute). This test consisted by three stages, each lasting 3 min, against incremental braking force in order 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.
- Arm-swing countermovement vertical jump (CVJ). The participants performed two countermovement jumps.[18] Height of each jump was estimated using the Opto-jump (Microgate Engineering, Bolzano, Italy) and was expressed as cm.
- Handgrip strength test (HST). 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.[17] HMS was calculated as the sum of the best efforts for each hand divided by body mass and expressed as kg/kg of body mass.
- Force-velocity test (F-v). The F-v test was employed to assess maximal anaerobic power (Pmax expressed as W/kg). This test employed various braking forces that elicit different pedaling velocities in order to derive Pmax.[19] The participants performed four sprints, each one lasting 7 seconds, against incremental braking force (2, 3, 4 and 5 kg) on a cycle ergometer (Ergomedics 874, Monark, Sweden), interspersed by 5-min recovery periods.
- Wingate anaerobic test (WAnT). The WAnT[20] was performed in the same ergometer as the F-v did. Briefly, participants were asked to pedal as fast as possible for 30 seconds 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 seconds period and was expressed as W/kg.

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.[5,21] Due to the small number of obese participants (two girls and two women), overweight included obese. Chi-square examined differences in the prevalence of overweight between girls and women. Association between physical fitness, BMI and BF was examined using Pearson's moment correlation coefficient (r). Student independent t-test employed to test differences in physical fitness between normal and overweight participants for each age group. The level of significance was set at $\alpha = 0.05$.

RESULTS

Based on international BMI cut-off points, 27.5% (n = 28) of adolescent and 12.3% (n = 7) of adult participants were classified as overweight, with the prevalence of overweight being higher in girls than in women ($\chi^2 = 4.90$, $P = 0.027$). For both age groups, there was high correlation between BMI and BF (r = 0.72, $P < 0.001$; r = 0.75, $P < 0.001$, respectively). In girls, BMI was correlated with fat mass (r = 0.83, $P < 0.001$), as well as with fat-free mass (r = 0. 067, $P < 0.001$). Corresponding values for women were r = 0.78 ($P < 0.001$) and r =0.42 ($P = 0.001$). In girls, BF could be predicted based on the equation BF = BMI + 3.1 (standard error of estimate SEE = 2.7, coefficient of determination R^2 = 0.52), and in women, the respective equation was BF = 1.53·BMI-11.3 (SEE = 3.2, R^2 = 0.56).

The comparison between normal and overweight participants revealed differences with regard certain physical and physiological characteristics, in which normal participants scored better than those who were overweight [Table 1, Figure 1]. These findings came to terms with the outcome of the bivariate correlation analysis, which revealed negative association between BMI and physical fitness, except of flexibility [Table 2]. A similar trend was also observed in the correlation between BF and physical fitness.

Table 1: Physical and physiological characteristics of participants

Physical fitness component	Girls (n=102)		Women (n=57)	
	Normal (n=74)	Overweight (n=28)	Normal (n=50)	Overweight (n=7)
Age (year)	15.3±1.8	15.0±2.3	26.0±5.1	25.4±4.9
Body mass (kg)	59.1±8.3	72.0±11.2‡	65.9±6.7	80.7±6.8‡
Height (cm)	1.67±0.08	1.67±0.08	1.74±0.06	1.74±0.10
BMI (kg·m^{-2})	21.0±1.7	25.7±2.4‡	21.8±1.7	26.8±1.7‡
BF (%)	23.9±3.5	29.0±2.4‡	21.7±3.9	31.2±2.4‡
WHR	0.71±0.04	0.75±0.06‡	0.69±0.03	0.72±0.05*
PWC 170 (W kg^{-1})	1.97±0.50	1.84±0.51	2.34±0.55	2.51±1.17
Pmax (W·kg^{-1})	11.2±2.4	10.5±2.5	12.2±3.0	10.0±1.5
Pmean (W·kg^{-1})	6.48±0.71	5.97±0.80†	6.79±0.92	5.76±0.94†
SAR (cm)	26.4±6.2	26.3±5.7	25.9±7.6	24.3±5.2
HGS (kg·kg^{-1})	0.48±0.07	0.41±0.07‡	0.52±0.07	0.48±0.08†
CVJ (cm)	29.7±5.1	26.3±5.7	32.2±6.0	27.7±7.8

BMI=Body mass index; BF=Body fat percentage; WHR=Waist-to-hip ratio; PWC=170 Physical working capacity in heart rate 170 beats/min; Pmax maximal power output estimated by the Force-velocity test and Pmean mean power during the Wingate anaerobic test; SAR=Sit-and-reach test; HGS=Handgrip strength test and CVJ arm-swing countermovement vertical jump; *P<0.05; †P<0.01; ‡P<0.001. These values denote significance level of differences between normal and overweight participants using independent student t-test

Table 2: Correlation (Pearson coefficient r) between body mass index, body fat and physical fitness in adolescent and adult participants

Physical fitness component	Girls (n=102)		Women (n=57)	
	BMI	BF	BMI	BF
PWC 170	−0.07	−0.08	−0.13	−0.25
Pmax	−0.02	−0.13	−0.33*	−0.34*
Pmean	−0.20*	−0.33†	−0.40†	−0.42†
SAR	0.22*	0.03	0.11	−0.04
HGS	−0.39‡	−0.48‡	−0.56‡	−0.57‡
CVJ	−0.19	−0.24*	−0.40†	-0.45‡

BMI=Body mass index; BF=Body fat percentage=PWC170 Physical working capacity in heart rate 170 beats/min; Pmax maximal power output estimated by the Force-velocity test and Pmean mean power during the Wingate anaerobic test; SAR=Sit-and-reach test; HGS=Handgrip strength test and CVJ arm-swing Countermovement vertical jump. *P<0.05; † P<0.01; ‡P<0.001. These symbols denote significance level of correlation between normal and overweight participants using Pearson coefficient r

DISCUSSION

Prevalence of overweight in volleyball

The prevalence of overweight (27.5%) among adolescent volleyball players in our study was higher than previous findings in schoolchildren. For instance, this prevalence was 13.2% in 11-17 year,[22] 22.3% in 6-17 year[23] and 23.0% in 16-19 year.[24] This comparison indicated that overweight affects volleyball players in a higher extent than it does in general population. Moreover, in our sample only two adolescent participants were classified as obese, which was lower than the reference data we used. With regard to adult players, the occurrence of overweight (12.3%) was much lower than respective value from a study conducted on the general population of three Balkan countries, which had revealed 31.4% overweight and 12.4% obese adults.[25]

Nevertheless, the occurrence of overweight in our study's adolescents was unexpected given the current BMI of elite adult volleyball players. The comparison of the appearance of overweight between adolescent and adult participants revealed higher prevalence in the younger age group. In addition, BMI of adult volleyball players participating in our study was 22.4 ± 2.4 kg·m^{-2}, close to values reported by other studies on elite Greek players (21.7 ± 1.2 kg·m^{-2}[26] and 21.9 ± 1.9 kg·m^{-2}[27]). In terms of mean and standard deviation, these data indicated that only a small number of elite players should expect to be overweight. These findings suggested that volleyball is not a sport characterized by excess of body mass. Consequently, the current values of BMI found in our study's adolescent players should not be attributed to sport-specific physiological adaptations. It was unlikely that the high BMI in our study was due to a healthy increase in muscle mass alone and it might not be without health consequences. The prevalence of overweight in our sample warranted further investigation to determine the consequences of excessive weight in young volleyball players and to develop exercise intervention targeting weight management.

Relationship between body mass index and body fat percent

The results of this study indicated that BMI accounted for

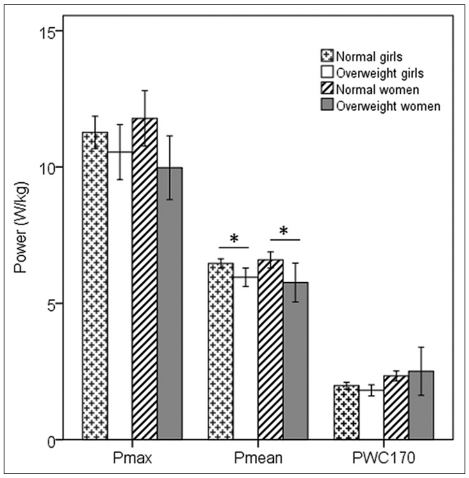

Figure 1: Maximal power output estimated by the Force-velocity test (Pmax), mean power during the Wingate anaerobic test (Pmean) and physical working capacity in heart rate 170 beats/min (PWC170) for normal and overweight girls and women. *$P < 0.01$

a large proportion of between-individual differences in BF; 51.8% and 56.1% of the variance in BF of adolescent and adult respectively was explained by BMI. An important consideration was whether BF could be predicted from BMI in volleyball. The direct relationship between BMI and BF, and the acceptable standard error of estimate of the former based on the latter (2.7% in girls and 3.2% in women), suggested the further use of BMI in volleyball players. In addition, there was stronger relationship between BMI and fat mass in girls and women than between BMI and fat-free mass, indicating that BMI is a better descriptor of fat mass than of fat-free mass. Thus, the use of BMI in volleyball was further recommended in volleyball as a tool of overweight/obesity evaluation.

Association of BMI and body fat percent with physical fitness

Based on previous studies on youth general population, it was hypothesized that there was also an inverse relationship between BMI, BF and physical fitness in volleyball players. The negative values of the correlation coefficient between these parameters, as well as the differences between normal and overweight participants confirmed our hypothesis. Our results emphasized the role of adiposity, but supported the role of BMI in volleyball, too. We found associations between power output and overweight, whereby overweight players demonstrated reduced Pmean compared with those in normal range of BMI. These relationships were similar as those between physical fitness and adiposity. The similar influence of BMI and BF on physical fitness might be partially attributed to the strong correlation between BMI and BF.

Participants performed the F-v test (Pmax), the WAnT (Pmean) and the PWC170, which with regard to the taxation of the human energy transfer systems describe (a) short-term power output that relies mainly upon adenosine triphosphate-creatine phosphate (alactic anaerobic system), (b) local muscular endurance capacity that depends on anaerobic glycolysis resulting in lactate production (lactic anaerobic system) and (c) aerobic power that relies upon aerobic glycolysis, Krebs cycle and electron transport chain, respectively.[18,20,21] Even if there were significant negative associations only between BMI and BF with Pmean (in both groups) and with Pmax (in women), the negative but not significant correlations, which were observed in the other cases, suggested a weak effect, which was in agreement with corresponding differences between normal and overweight participants.

The main finding of this study was that the employed tests showed an association between BF, BMI and participants' physical fitness, which in turns stresses the importance of weight control for sport performance. Therefore, volleyball clubs, which commonly develop exercise training programs, should target optimal body mass and fat. 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.[9-11,28] Disadvantage was that due to 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 looked with caution. However, it is reasonable to believe that volleyball players with high values of BMI and BF will have lower scores in physical fitness.

CONCLUSION

The prevalence of overweight among adolescent participants was higher than what is observed in general population. On the other hand, it seems that the participation in volleyball during adulthood plays a beneficial role in the weight and body fat control. Therefore, the development of exercise interventions targeting overweight adolescent players is recommended. 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 volleyball players. BMI and BF were negatively associated with most of the physical and physiological characteristics under examination. These findings confirmed the previous observations on general population about the negative effect of overweight on physical fitness.

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