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Associations between cardiorespiratory fitness and muscle strength with body composition among adults

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** Cardiorespiratory fitness (CRF) was reported to be associated with anthropometric measurements, including body mass, body mass index (BMI), fat mass (FM) and fat free mass (FFM). This study aimed to investigate the impact of FM and FFM on muscle strength and CRF.
Material and methods. This study was carried out on 270 randomly selected adults in Tehran, Iran. Anthropometric measurements, including weight, BMI, FM and FFM, were assessed using a bio-impedance analyzer (BIA) (InBody 720, Biospace, Tokyo, Japan). Muscle strength and CRF were assessed by handgrip dynamometer and Bruce graded treadmill protocol, respectively. The International Physical Activity Questionnaire (IPAQ) was used to measure health-related physical activity. A *p*-value less than 0.05 was statistically significant.
Results. Significant associations were found between maximum oxygen uptake (VO_2 max) and muscle strength with FM and FFM ($p < 0.001$). After adjusting for confounders, the association of VO_2 max with FFM remained significant ($p < 0.001$). Muscle strength was significantly associated with FM ($p = 0.036$) and FFM ($p < 0.001$) after adjustment for confounders.
Conclusions. High FM was associated with poor CRF, and low fat-free mass was related to poor muscle strength. FM and FFM can be good indices for CRF fitness in adults. Further longitudinal studies are needed to confirm these findings.
Key words: cardiorespiratory fitness, muscle strength, body composition.

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Background

Physical fitness is a state of functional capacity and well-being, and it is influenced by nutrition, physical fitness, muscle strength and aerobic capacity [1, 2]. Muscle strength and cardiorespiratory fitness (CRF) are the two best main measurements of evaluation of physical performance and fitness [3]. Lower levels of CRF and grip strength are reported to be directly related to an increase in all-cause mortality risk [4–7]. Aerobic capacity or CRF is related to the capacity of circulatory and respiratory systems, which supply oxygen to the muscles during moderate to intense exercises [8, 9]. VO_2 max, which is considered as a gold standard for measuring CRF, is the maximal rate of oxygen consumption that could be used in strenuous activities [10]. Moreover, the upper and lower limits of body strength significantly influence one's ability to perform physical activity [11, 12]. Handgrip strength is used in observational studies and clinical trials as an indicator of muscle strength [13].

On the other hand, anthropometric measurements, including BMI, fat mass (FM) and fat free mass (FFM), are indicators of body fitness [14–16]. The association between body composition with physiological traits, such as CRF and muscle grip, has been reported in several studies [17–20]. Most evidence has demonstrated that muscle mass is decreased with aging and leads to a decrease in muscle strength [20–22]. An inverse association was also found between body fat mass with muscular fitness and CRF [23–26]. Most studies have reported on the association between some certain measurements of body composition, such as BMI and waist circumference (WC), with physical performance [17, 27, 28]. There are limited studies which have investigated the association between FFM, FM and physical performance tests [29–32]. Thus, this study aimed to investigate the association of FM and FFM with CRF and muscle strength in Iranian adults.

Material and methods

Subjects

This cross-sectional study was carried out from May to September 2018 on 270 randomly selected Iranian adults (115 men and 155 women) from 18 to 70 years of age. The subjects were recruited from volunteers informed by advertisements through social media of the Tehran University of Medical Sciences. The sample size was calculated using the correlation coefficient between CRF and BF ($r = 0.31$), which was reported in a previous study [33]. Participants were excluded from the study if they: 1) were an alcoholic or drug addict; 2) had been diagnosed with certain diseases, including heart, kidney, liver and pulmonary diseases; 3) were pregnant or lactating women and had restricted conditions for graded exercise treadmill tests (including asthma, MI, inflammation, recent history of hospitalization, inability to walk, arthritis problems with limb and disability). All participants signed the consent form before participation in the study. We set a scheduled time to start some of the tests for each participant at the Tehran University of Medical Sciences (Public Health Laboratory). The study participants were residents in the same area in Tehran (Latitude: 35°44'N, Longitude: 51°30'E). Data collection included completion of physical measurements (physical fitness, physical activity and some anthropometric data).

Physical fitness measurements

Cardiorespiratory fitness

CRF was determined through VO_2 max, obtained from a graded exercise test on a treadmill utilizing the Bruce protocol [34]. The participants performed the Bruce graded treadmill protocol to complete exhaustion while the speed and incline of the treadmill were being increased every three minutes. The treadmill was started at 2.74 km/hr. (1.7 mph) and at an incline of 10%. At three-minute intervals, the incline of the treadmill was increased by 2%, and the speed was increased based on the Bruce protocol. The test stopped when the subject could not continue due to fatigue or pain or due to any other medical indications. Respiratory gases were analyzed during the exercise protocol by MetaLyzer3B. The analyzer recorded and displayed data every 10 seconds. The data collected was stored using the Cortex MetaLyzer3B program, which has been validated applying the Douglas bag technique as the criterion method [35]. CRF was determined as L/min and ml/kg/min with this program.

Muscle strength

Upper muscle strength was measured using an adjustable digital hand dynamometer in a normal sitting position. Grip strength is a reliable indicator of physical performance, especially muscle strength [36]. Handgrip strength is a predictor of upper body strength. Participants rotated their shoulders in a natural position and flexed their elbow to 90°. After obtaining proper settings for the arm and wrist in accordance with the protocol, force was exerted on a targeting sequence as hard as they could, three times for the right and left hands. The average of the tests in both hands was considered for analysis.

Physical activity

The short version of the International Physical Activity Questionnaire (IPAQ) was used to measure health-related physical activity [37]. The IPAQ questionnaires have been validated in 12 countries [38].

Anthropometric measurements and body composition

Height was measured with a calibrated tape line fastened to a wall and with the participant wearing no shoes by a stadiometer (Seca, Germany) with a precision of 0.5 cm. Weight, BMI, waist-hip ratio and WC were measured using a validated scale and tape line. Body composition, including body fat and body muscle percent, were also measured using a bio impedance analyzer (BIA) (InBody 720, Biospace, Tokyo, Japan). For this analysis, all patients were asked to follow these conditions before measurement: no food intake for at least 4 hours, no physical activity for at least 8 hours, no coffee or alcoholic beverage consumption for at least 12 hours, as well as with a restriction of no diuretic drugs use for at least 24 hours [39].

Statistical analyses

Analyses were carried out using the Statistical Package of the Social Sciences (SPSS version 25; SPSS Inc). Descriptive statistics of anthropometric measurements, physical fitness tests and body composition of the study samples were calculated as means and SDs and were also categorized into low, moderate and high groups. Analysis of variance was used to compare the mean of the variables across the tertiles of VO_2 max and muscle strength. Associations of body composition, maximal strength tests and maximal aerobic capacity were examined using Pearson correlation coefficients. Linear regression with parameter estimates was used to investigate the independent associations between VO_2 max and muscle strength, as independent variables, and body composition and anthropometric measurements, as dependent variables, which were adjusted according to age, sex, physical activity score and smoking in three different models. Model 1 was adjusted based on age and sex, model 2 was adjusted for age, sex and physical activity score, and model 3 was adjusted for age, sex, physical activity score and smoking. A p-value less than 0.05 was considered significant.

Ethical consideration

This study was approved by the local ethics review boards at the Tehran University of Medical Sciences (Ethic Number: R.TUMS.VCR.REC.1396.4306). All participants signed a written informed consent prior to the start of the study.

Results

The status of anthropometric measurements and physical fitness of the participants based on their level of CRF and muscle strength is shown in Table 1. Significant associations were found between levels of VO_2 max and height ($p < 0.001$), BMI ($p = 0.004$), FFM ($p < 0.001$), skeletal muscle mass (SMM) ($p < 0.001$), LBM ($p < 0.001$), FM ($p < 0.001$), BF% ($p < 0.001$), visceral fat area (VFA) ($p < 0.001$), waist hip ratio (WHR) ($p < 0.001$), basal metabolic rate (BMR) ($p < 0.001$), abdominal fat ($p < 0.001$), obesity degree ($p = 0.001$), WC ($p = 0.001$), respiratory exchange ratio (RER) ($p = 0.001$) and heart rate ($p = 0.004$). Moreover, significant associations were found between levels of muscular fitness with height ($p < 0.001$), weight ($p < 0.001$), FFM ($p < 0.001$), SMM ($p < 0.001$), LBM ($p < 0.001$), WC ($p < 0.001$), BMR ($p < 0.001$), BF% ($p < 0.001$), VFA ($p = 0.001$), BMI ($p = 0.008$), FM ($p = 0.006$), obesity degree ($p = 0.029$), WHR ($p = 0.004$) and RER ($p = 0.039$).

The correlation between demographic and anthropometric measurements with VO_2 max and muscle strength of the participants is presented in Table 2. Age was negatively correlated with VO_2 max ($r = -0.393$, $p = 0.001$), but it was not correlated with muscle strength ($r = -0.035$, $p = 0.562$). In addition, a significant correlation was found between VO_2 max with FFM ($r = 0.369$, $p < 0.001$), LBM ($r = 0.402$, $p < 0.001$) and SMM ($r = 0.390$, $p < 0.001$). In addition, muscle strength had a significant correlation with FM ($r = -0.155$, $p = 0.011$), BMI ($r = -0.155$, $p = 0.011$), VFA ($r = -0.232$, $p = 0.001$), WC ($r = -0.311$, $p = 0.001$), WHR ($r = -0.204$, $p = 0.011$), RER ($r = 0.171$, $p = 0.001$), BM ($r = 0.548$, $p = 0.001$), BF% ($r = -0.563$, $p = 0.001$), BMR ($r = 0.676$, $p = 0.001$), height ($r = 0.747$, $p = 0.001$), FFM ($r = 0.821$, $p = 0.001$), SMM ($r = 0.841$, $p = 0.001$) and LBM ($r = 0.834$, $p = 0.001$).

The association between anthropometric measurements with VO_2 max and muscular fitness after adjustments of age, sex, physical activity, and smoking are presented in Table 3. The association of VO_2 max (ml × min^{-1} × kg^{-1}) with FFM ($p = 0.164$), SMM ($p = 0.145$), LBM ($p = 0.691$), and BMR ($p = 0.262$) was disappeared after adjustments. However, the association of VO_2 max with other variables including FFM ($p < 0.001$), SMM ($p < 0.001$), LBM ($p < 0.001$), and BMR ($p < 0.001$) remained significant after adjustment for all confounders. In the case of muscle strength, adjustments disappeared its associations with FM ($p = 0.362$) and VFA ($p = 0.794$). Whereas, the association of muscle strength with BMI, WC, WHR, RER, BM, BF%, BMR, height, FFM, SMM, and LBM remained significant.

Table 1. Characteristics of participants according to VO_2 max and muscle strength categories

	VO_2 max, mL·kg^{-1}·min^{-1}				Muscular strength, kg			
	Low (*n* = 94)	Moderate (*n* = 123)	High (*n* = 53)	*p*	Low (*n* = 90)	Moderate (*n* = 90)	High (*n* = 90)	*p*
Age (year)	35 ± 12	38 ± 13	36 ± 14	0.265	38 ± 15	36 ± 13	37 ± 12	0.541
Height (cm)	165.84 ± 9.94	167.78 ± 9.24	173.15 ± 10.04	< 0.001	160.61 ± 6.6	166.94 ± 7.52	176.84 ± 8.02	< 0.001
Weight (kg)	73.7 ± 19.66	72.51 ± 14.81	71.68 ± 11.26	0.745	66.25 ± 14.81	68.64 ± 12.17	83.73 ± 15.31	< 0.001
BMI (kg/m^2)	26.58 ± 5.8	25.58 ± 4.05	23.95 ± 3.13	0.004	25.69 ± 5.65	24.56 ± 3.86	26.74 ± 4.2	0.008
FFM (kg)	47.05 ± 12.44	49.83 ± 12.44	56.37 ± 11.44	< 0.001	41.12 ± 6.85	46.7 ± 9.06	62.77 ± 9.92	< 0.001
SMM	25.81 ± 7.41	27.81 ± 7.14	31.61 ± 6.95	< 0.001	22.27 ± 4.11	25.96 ± 4.75	35.45 ± 5.9	< 0.001
LBM	43.83 ± 11.04	47.42 ± 11.18	53.17 ± 10.77	< 0.001	38.54 ± 6.22	44.45 ± 7.46	59.05 ± 8.88	< 0.001
FM (kg)	26.64 ± 10.93	22.33 ± 7.32	15.47 ± 6.02	< 0.001	25.11 ± 10.22	21.47 ± 7.66	21.06 ± 9.83	0.006
PBF (%)	35.3 ± 8.25	30.72 ± 7.76	21.75 ± 8.28	< 0.001	36.74 ± 7.71	30.57 ± 7.73	24.43 ± 8.31	< 0.001
VFA (cm^2)	127.57 ± 53.86	102.32 ± 38.81	67.62 ± 32.39	< 0.001	123.23 ± 51.7	97.89 ± 42.01	92.6 ± 46.65	< 0.001
Obesity degree	123.22 ± 26.49	117.39 ± 18.12	109.43 ± 13.96	0.001	119.51 ± 26.13	113.3 ± 17.61	121.4 ± 18.91	0.029
Abdominal fat (kg)	13.17 ± 5.17	11.4 ± 3.84	7.89 ± 3.35	< 0.001	12.2 ± 4.83	10.78 ± 4.01	11.1 ± 5.05	0.103
WC (cm)	92.02 ± 15.07	90.14 ± 11.3	84.26 ± 8.53	0.001	87.22 ± 13	87.1 ± 10.6	94.86 ± 12.67	< 0.001
WHR	0.92 ± 0.07	0.91 ± 0.06	0.86 ± 0.06	< 0.001	0.89 ± 0.06	0.9 ± 0.06	0.92 ± 0.07	0.004
BMR	1395.17 ± 274.39	1424.42 ± 308.09	1587.62 ± 246.99	< 0.001	1258.76 ± 147.78	1397.92 ± 179.69	1685.44 ± 330.86	< 0.001
Heart rate	166.89 ± 22.58	171.67 ± 18.86	178.5 ± 15.36	0.004	168.36 ± 21.31	172.49 ± 18.38	173.37 ± 20.47	0.235
RER	1.07 ± 0.05	1.09 ± 0.05	1.11 ± 0.05	0.001	1.08 ± 0.05	1.09 ± 0.05	1.1 ± 0.05	0.039
Sex M	21 (17.9%)	57 (48.7%)	39 (33.3%)	< 0.001	4 (3.4%)	28 (23.5%)	87 (73.1%)	< 0.001
Sex F	73 (47.7%)	66 (43.1%)	14 (9.2%)		86 (57%)	62 (41.1%)	3 (2%)	
Activity score L	43 (43 %)	47 (47%)	10 (10%)	< 0.001	38 (38.8%)	33 (33.7%)	27 (27.6%)	0.009
Activity score M	39 (35.1%)	51 (45.9%)	21 (18.9%)		38 (33.6%)	41 (36.3%)	34 (30.1%)	
Activity score V	10 (18.2%)	23 (41.8%)	22 (40%)		10 (18.2%)	16 (29.1%)	29 (52.7%)	

BMI – body mass index, FFM – fat free mass, SMM – skeletal muscle mass, LBM – lean body mass, PBF – percent body fat, VFA – visceral far area, WC – waist circumference, WHR – waist hip ratio, BMR – basal metabolic rate, RER – respiratory exchange ratio, M – male, F – female, Y – yes, N – no, L – low, M – moderate, V – vigorous.

Table 2. Pearson correlation between the anthropometric and body composition characteristics of participants with VO_2 max and muscle strength

Variables	Physical fitness tests			
	VO_2 max, mL · kg^{-1} · min^{-1}		Muscular fitness, kg	
	r	*p*	*r*	*p*
Age (year)	-0.393	0.001	-0.035	0.562
Height (cm)	0.500	0.001	0.747	0.001
Weight (kg)	-0.68	0.267	0.548	0.001
BMI (kg/m^2)	-0.405	0.001	0.155	0.011
FFM (kg)	0.369	0.001	0.821	0.001
SMM	0.390	0.001	0.841	0.001
LBM	0.402	0.001	0.834	0.001
FM (kg)	-0.608	0.001	-0.155	0.011
PBF (%)	-0.748	0.001	-0.563	0.001
VFA (cm^2)	-0.653	0.001	-0.232	0.001
Obesity degree	0.449	0.001	0.101	0.098
Abdominal fat (kg)	-0.581	0.001	-0.066	0.277
WC (cm)	-0.318	0.001	0.311	0.001
WHR	-0.381	0.001	0.204	0.001
BMR	0.309	0.001	0.676	0.001
Heart Rate	0.417	0.001	0.119	0.064
RER	0.312	0.001	0.171	0.005

BMI – body mass index, FFM – fat free mass, SMM – skeletal muscle mass, LBM – lean body mass, PBF – percent body fat, VFA – visceral far area, WC – waist circumference, WHR – waist hip ratio, BMR – basal metabolic rate, RER – respiratory exchange ratio.

Table 3. Multiple linear regression analysis of the anthropometric measures and body composition characteristics of participants with VO_2 max and muscle strength

	Physical fitness tests											
	VO_2 max, mL · kg^{-1} · min^{-1}						Muscular fitness, kg					
	Model 1		Model 2		Model 3		Model 1		Model 2		Model 3	
	ß (95% CI)	*p*	*ß* (95% CI)	*p*	*ß* (95% CI)	*p*	*ß* (95% CI)	*p*	*ß* (95% CI)	*p*	*ß* (95% CI)	*p*
Age (year)	-0.26 (-0.31, -0.2)	< 0.001	-0.25 (-0.3, -0.19)	< 0.001	-0.24 (-0.29, -0.19)	< 0.001	-0.1 (-0.17, -0.03)	0.004	-0.09 (-0.16, -0.02)	0.011	-0.08 (-0.15, -0.01)	0.02
Height (cm)	0.03 (-0.08, 0.15)	0.549	0.04 (-0.08, 0.15)	0.531	0.03 (-0.08, 0.14)	0.575	0.45 (0.31, 0.58)	< 0.001	0.46 (0.33, 0.6)	< 0.001	0.46 (0.33, 0.6)	< 0.001
Weight (kg)	-0.17 (-0.22, -0.12)	< 0.001	-0.17 (-0.22, -0.12)	< 0.001	-0.16 (-0.21, -0.12)	< 0.001	0.18 (0.11, 0.24)	< 0.001	0.18 (0.12, 0.25)	< 0.001	0.19 (0.13, 0.26)	< 0.001
BMI (kg/m^2)	-0.6 (-0.75, -0.45)	< 0.001	-0.6 (-0.74, -0.45)	< 0.001	-0.58 (-0.73, -0.43)	< 0.001	0.28 (0.07, 0.49)	0.01	0.29 (0.07, 0.5)	0.008	0.32 (0.1, 0.53)	0.005
FFM (kg)	-0.06 (-0.15, 0.03)	0.211	-0.07 (-0.16, 0.02)	0.121	-0.07 (-0.16, 0.03)	0.164	0.52 (0.42, 0.62)	< 0.001	0.52 (0.42, 0.62)	< 0.001	0.52 (0.42, 0.63)	< 0.001
SMM	-0.09 (-0.25, 0.07)	0.267	-0.13 (-0.29, 0.03)	0.108	-0.12 (-0.28, 0.04)	0.145	0.97 (0.8, 1.14)	< 0.001	0.97 (0.8, 1.15)	< 0.001	0.98 (0.81, 1.16)	< 0.001
LBM	-0.01 (-0.11, 0.09)	0.871	-0.03 (-0.14, 0.07)	0.51	-0.02 (-0.12, 0.08)	0.691	0.61 (0.5, 0.71)	< 0.001	0.61 (0.5, 0.72)	< 0.001	0.62 (0.51, 0.74)	< 0.001
FM (kg)	-0.36 (-0.43, -0.29)	< 0.001	-0.35 (-0.42, -0.28)	< 0.001	-0.35 (-0.42, -0.28)	< 0.001	0.02 (-0.09, 0.12)	0.769	0.03 (-0.07, 0.14)	0.524	0.05 (-0.06, 0.16)	0.362
PBF (%)	-0.47 (-0.55, -0.39)	< 0.001	-0.46 (-0.54, -0.37)	< 0.001	-0.45 (-0.54, -0.37)	< 0.001	-0.18 (-0.31, -0.05)	0.005	-0.16 (-0.29, -0.03)	0.019	-0.14 (-0.28, -0.01)	0.036
VFA (cm^2)	-0.08 (-0.09, -0.06)	< 0.001	-0.07 (-0.09, -0.06)	< 0.001	-0.07 (-0.09, -0.06)	< 0.001	-0.01 (-0.03, 0.01)	0.451	-0.004 (-0.025, 0.017)	0.68	-0.003 (-0.024, 0.019)	0.794
Obesity degree	-0.14 (-0.17, -0.11)	< 0.001	-0.14 (-0.17, -0.11)	< 0.001	-0.14 (-0.17, -0.1)	< 0.001	0.05 (0.002, 0.1)	0.04	0.05 (0.003, 0.097)	0.036	-0.06 (0.007, 0.102)	0.026
Abdominal fat (kg)	-0.74 (-0.87, -0.61)	< 0.001	-0.72 (-0.85, -0.59)	< 0.001	-0.71 (-0.85, -0.57)	< 0.001	0.09 (-0.12, 0.3)	0.401	0.13 (-0.08, 0.34)	0.238	0.16 (-0.06, 0.38)	0.148
WC (cm)	-0.26 (-0.31, -0.2)	< 0.001	-0.25 (-0.3, -0.2)	< 0.001	-0.25 (-0.3, -0.19)	< 0.001	0.12 (0.05, 0.2)	0.002	0.13 (0.06, 0.21)	0.001	0.15 (0.07, 0.23)	< 0.001
WHR	-49.95 (-59.71, -40.19)	< 0.001	-48.87 (-58.67, -39.08)	< 0.001	-48.41 (-58.53, -38.29)	< 0.001	12.31 (-2.55, 27.18)	0.104	15.52 (0.44, 30.59)	0.044	17.29 (1.75, 32.82)	0.029
BMR	-0.002 (-0.005, 0.002)	0.312	-0.002 (-0.005, 0.002)	0.252	-0.002 (-0.005, 0.001)	0.262	0.011 (0.007, 0.02)	< 0.001	0.011 (0.007, 0.02)	< 0.001	0.011 (0.007, 0.015)	< 0.001
Heart rate	0.11 (0.07, 0.15)	< 0.001	0.11 (0.07, 0.15)	< 0.001	0.11 (0.07, 0.15)	< 0.001	0.06 (0.005, 0.11)	0.033	0.06 (0.004, 0.11)	0.035	0.06 (0.002, 0.12)	0.041
RER	25.01 (11.38, 38.64)	< 0.001	25.31 (11.81, 38.82)	< 0.001	23.92 (10.32, 37.53)	0.001	17.78 (-0.31, 35.87)	0.054	19.28 (1.02, 37.55)	0.039	19.05 (0.56, 37.54)	0.044

Model 1 – adjusted for age and sex, Model 2 – adjusted for age, sex and physical activity score, Model 3 – adjusted for age, sex, physical activity score and smoking.
BMI – body mass index, FFM – fat free mass, SMM – skeletal muscle mass, LBM – lean body mass, PBF – percent body fat, VFA – visceral far area, WC – waist circumference, WHR – waist hip ratio, BMR – basal metabolic rate, RER – respiratory exchange ratio.

Discussion

The results of this study revealed that CRF was negatively associated with BMI, FM, VFA, abdominal fat, obesity degree, WC, WHR and age before and after adjustment and was positively associated with height, FFM, BMR, RER and maximal heart rate. There was a significant association between absolute VO_2 max (l × min^{-1}) and FFM, SMM, LBM and BMR, even after adjustment for all confounders. Similar to these results in adults, several studies have reported that overweight children are categorized at a poor VO_2 max level compared to healthy weight children [40, 41]. The association observed between maximal oxygen uptake and body composition measurements was in line with a recently published report by Goran et al. in older adults [42]. They revealed that participants with higher body FM appear to have a lower aerobic capacity. Rump et al. [43], in a birth-cohort among young prepubescent children, identified that FM was negatively associated with VO_2 max and was positively associated with submaximal heart rate. Fat-free mass was positively related to absolute oxygen uptake. Moreover, they observed a significant association between the relative value of CRF and weight, BMI and WC [44]. Brand et al. reported a significant association between CRF and overweight and obesity in boys, while this association was marginally insignificant in girls. An increase in body fat percentage, especially visceral fat, may impair the proper functioning of the cardiovascular system, regardless of the status of BMI. The higher prevalence of "apple" shaped obesity in men (i.e. central obesity) may explain the stronger relationship we observed between FM and VO_2 max in men. Moreover, the effects of BF on CRF can be mediated by mean arterial pressure (MAP). A higher percentage of BF is associated with higher MAP [45]. However, some other factors, such as genetics and gender, may have an influence on the status of body composition and CRF [31, 46–49].

Moreira et al. [31] indicated that BMR and VFA significantly affect the variety of CRF, regardless of menopause and age. The presence of CRF levels > 30.94 ml/kg/min was related to low FM and ameliorated muscle status, and postmenopausal women with VO_2 max < 26.87 ml/kg/min had higher VFA. Mota et al. [50] found a significant difference in the CRF of an obese group of females, while the association was not significant in males. Kim et al. [51], in a longitudinal study, reported that CRF was significantly related with the risk of overweight in girls but not in boys. This may be due to a higher BMI and muscle mass in boys than in girls.

In the present study, maximal strength was also positively associated with height, weight, BMI, FFM, SMM, LBM, WC, WHR and BMR. There are positive significant relationships among these parameters, even after adjusting for confounding factors. Nevertheless, we found a negative association between muscular fitness and FM, BF% and VFA, which disappeared after adjustments. Vaara et al. [29] concluded that muscle strength index had low correlations with BM, WC, BMI and FM. However, FFM had a positive moderate association with maximal strength test scores. In contrast, Woo et al., in a cross sectional study on 4,000 men and women ≥ 65 years of age, indicated that fat mass and BMI are main factors contributing to physical performance [52].

Another study [53] indicated that LBM was positively associated with muscular strength. A 1 kg increase in birth weight corresponded in men to a 4.1 kg (95% CI: 3.1, 5.1) and in women to a 2.9 kg (2.1, 3.6) increase in adult lean mass. BF% was negatively associated with muscle strength in men. Ageing and smoking were other factors which related to poor muscular fitness.

In line with our findings, Payette et al. [54] revealed that grip strength was significantly correlated with FFM in frail elderly women, particularly in those without any pain. Likewise, Estrada et al. [55] reported that muscular handgrip strength was related to lower-limb, upper-limb and total SMM, even considering the impact of body mass or height.

In the present study, men showed better and longer aerobic power and gained greater maximal oxygen consumption along with higher muscle strength than women. The differences could be explained by sex-related discrepancies in body composition, FM and FFM [56, 57].

Several studies have indicated that the higher muscular strength in men may result from the fact that women have lower lean tissue mass. Furthermore, the higher muscle strength in men may be caused by larger muscular fibers, which derive from a biological difference rather than a difference in activity score [58].

However, the present study had some limitations. First, this study was a cross-sectional study with a relatively small sample size. More accurate CRF tests could be used, but they require expensive equipment, take too much time and may cause some risks for older adults [59].

Conclusions

Relative VO_2 max was related to FM and BF%. Muscular fitness was associated with FM. It can be concluded that the body composition analysis may be essential to predict CRF and muscle strength test results. High FM was associated with poor CRF, and low fat-free mass was related to poor muscle strength. The differences between the VO_2 max and muscle strength of men and women can be explained by differences in body composition, especially in FFM.

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