Estimated health-related physical fitness in Taiwan and itsimplications for body mass index distribution and overweight/obesity risk: Results from the Taiwan Scientific Physical Fitness Testing Program

Yun-Tsung Chen
National Taiwan Normal University
Po-Fu Lee
National Ilan University
Chang-Tsen Hung
Yuanpei University of Medical Technology
Chi-Fang Lin
National Taiwan Normal University
Chen-Te Hsu
Shu Te University
Yi-Tien Lin
Graduate Institute of Business Administration, Fu Jen Catholic University
Hsueh-Yi Lin
National Ilan University
Chien-Chang Ho (093703@mail.fju.edu.tw)
Fu Jen Catholic University

Research Article

Keywords: physical fitness, body composition, BMI, adiposity, 3MPKS

Posted Date: April 6th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-1514010/v1

Abstract

Background: Health-related physical fitness reduces the risk of chronic disease, promotes quality of life and has enormous economic benefits considering the global health care costs resulting from obesity. However, relatively limited information is available regarding the dose–response relationship between health-related physical fitness and obesity risk. This study aimed to determine the associations of health-related physical fitness with body mass index (BMI) distribution and overweight/obesity risk among adults aged 23-64 years in Taiwan.

Methods: We conducted a cross-sectional study and reviewed the data derived from the Scientific Physical Fitness Testing Program, Sports Administration, Ministry of Education in Taiwan. Responses from 16,939 participants (7,761 men; 9,178 women) aged 23-64 years from the database were collected in this study. Each participant completed a series of health-related physical fitness measurements, including cardiorespiratory fitness (3-min progressive knee-up and step [3MPKS] test), muscular fitness (hand grip strength), and flexibility (sit-and-reach test). Anthropometric measurements included body height, weight, and BMI. The quartiles of health-related physical fitness results were identified as the dependent variable in the multiple linear and multiple logistic regression analysis to determine the associations of the health-related physical fitness measurements with the BMI distribution and the overweight/obesity risk as well as the dose–response relationship.

Results: The 3MPKS test and relative hand grip strength were significantly negatively associated with BMI and overweight/obesity risk with a dose–response relationship in both men and women. However, the sit-and-reach test was partially related to BMI and overweight/obesity risk in adults.

Conclusions: Higher levels of the 3MPKS test and relative grip strength were associated with lower BMI and overweight/obesity risk in both sexes. Cardiorespiratory fitness and muscular fitness were effective predictors of BMI distribution and overweight/obesity risk in Taiwanese adults.

Background

The World Health Organization (WHO) recently reported that more than 1.9 billion adults worldwide were overweight, and at least 650 million of them were classified as obese [1]. Obesity has reached the global epidemic dimension, and it is associated with an increased risk of cardiovascular disease (CVD), hypertension, diabetes, osteoarthritis and cancers, thereby reducing the quality of life and increasing the risk of premature death [2, 3]. Notably, 44% of Taiwanese adults were recently classified as overweight and obese [3]. Therefore, the successful prediction of future risk for overweight and obesity and subsequent weight management are important topics in Taiwan.

Body mass index (BMI) is commonly used to classify the obese status in adults. The WHO suggested cutoff points for overweight and obesity of greater than 25 kg/m^2 and 30 $kg/m^{2,}$ respectively [1]. Studies have found that BMI is a good predictor of multiple health outcomes, such as heart disease, diabetes, osteoarthritis and anxiety [4, 5]. In addition, health-related physical fitness, including cardiorespiratory fitness, muscle strength and endurance, flexibility and body composition, is related to health [6]. It has been shown that higher levels of cardiovascular fitness and muscle strength are associated with lower risks of CVD, metabolic syndrome (MS), stroke and osteoporosis [7]. Flexibility has positive effects on the joint range of motion, body stability and relaxation and reduces sports injury and MS risks [8–10].

The standard measurement of cardiorespiratory fitness is maximal oxygen uptake (VO_2max), which may be obtained from direct measurements or indirect estimates [6]. Compared with direct testing in a laboratory setting, the 3-min progressive knee-up and step (3MPKS) test is a more time-efficient and valid method for predicting VO_2max; it does not require expensive metabolic equipment or the need to exercise to exhaustion [11]. Moreover, grip strength is a good predictor of overall body strength [12] and has been shown to be associated with physical performance, cardiometabolic health and quality of life [13, 14]. A study reported that relative grip strength (e.g., kilograms divided by body weight or BMI) was more strongly associated with CVD and MS risks than absolute grip strength [15, 16]. Thus, health-related physical fitness reduces the risk of chronic disease, promotes quality of life and has enormous economic benefits considering the global health care costs resulting from

obesity [17]. However, relatively limited information is available regarding the dose–response relationship between health-related physical fitness and obesity risk.

To provide obesity prevention strategies, detailed knowledge of health-related physical fitness levels in the Taiwanese population is necessary. Therefore, the present study aimed to assess the 3MPKS test, relative hand grip strength and sit-and-reach of the Taiwanese population and their impact on BMI distribution and overweight/obesity risk.

Methods

Study design and participants

This cross-sectional study is based on de-identified data from the Taiwan's Scientific Physical Fitness Testing Program (TSPFTP). The TSPFTP was conducted by the Sports Administration, Ministry of Education in Taiwan, to obtain annual data on health-related physical fitness tests of Taiwanese adults aged 23 to 64 years. The design of this survey used convenience sampling. Participants were recruited from 18 physical fitness test stations in Taiwan. This survey included face-to-face interviews followed by a standardized structural questionnaire, anthropometric measurements, and physical fitness tests conducted by trained examiners and medical specialists (usually nurses or doctors). This study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Institutional Review Board of Fu Jen Catholic University in Taiwan (FJU-IRB C110113).

Data collection

The data collection took place from September to November 2017 and contained three different approaches. First, trained examiners and medical specialists preliminarily checked the participants' resting heart rate and their systolic and diastolic blood pressure, as well as assessing their potential safety risks by the Physical Activity Readiness Questionnaire (PAR-Q). All participants were required to pass the preliminary safety assessment and then they were allowed to proceed to the next test step. Second, participants were requested to fill out (or verbally answer the questions) the demographic questionnaire, as well as to complete the anthropometric measurements. After completing the second step, the participants were instructed to warm up (dynamic and static muscle stretching) for approximately 10 minutes. Then, a series of physical fitness measurements were performed, and interval breaks were permitted for 2–4 minutes between measurements. For this study, we finally included a total of 16,939 participants (7,761 men and 9,178 women) in the analysis who passed the potential safety risk assessment, completed the questionnaire and underwent the physical fitness measures.

Demographic characteristics

A standardized, structured questionnaire was used to collect the data on demographic characteristics (i.e., age and gender), socioeconomic status (i.e., education, monthly income, marital status, and relationship status), and the residence zip code through face-to-face interviews. Education was divided into elementary school or lower, junior or senior school, and college or higher. Currently employed status was divided into yes, no, and other. Monthly income was divided into ≦ 20,000 NTD (new Taiwan dollar), 20,001–40,000 NTD, and ≧ 40,001 NTD. Marital status was divided into married, never married, and divorced/separated/widowed. Relationship status was divided into living with someone and not living with someone.

Anthropometric measures

Anthropometric measurements included body height, weight, and BMI, taken after the participants were asked to remove their shoes and heavy clothes and stand in a normal posture. Body weight and height were recorded in meters to the nearest 0.1 kg and 0.1 cm with an electronic height-weight scale. In addition, BMI was calculated based on body weight and height (weight [kg]/height [m]^2), and according to the Health Promotion Administration in Taiwan [18], BMI categories such as normal weight, overweight, and obesity were defined as a BMI of 18.5 ≦ BMI < 24 kg/m^2, 24 ≦ BMI < 27 kg/m^2, and BMI ≧ 27 kg/m^2, respectively.

Health-related Physical Fitness Measurements

The following tests of physical fitness were conducted: cardiorespiratory fitness was measured via the 3MPKS test (ml/kg/min) [11, 19], muscular fitness was measured via hand grip strength (kg) [20], and flexibility was measured via the sit-and-reach test (cm) [21]. Hand grip strength was measured with an electronic hand grip dynamometer by taking the average of the two dominant handgrip attempts. The sit-and-reach test needed to be performed twice with a sit-and-reach box with a measuring scale, where 30 cm was at the level of the feet, and the average distance from the two attempts was used for analysis.

Participants were asked to avoid any other vigorous- or moderate-intensity physical activity before performing these tests. A 10-min warm-up was introduced by the examiner, and the participant did this before the physical fitness assessment. All participants performed the tests in the following order with a sufficient break period (3–5 min) between tests: hand grip strength, sit-and-reach test, and 3MPKS test.

Statistical Analyses

All statistical analyses were performed with SAS version 9.4 software (SAS Institute, Cary, NC, USA). Differences in demographic characteristics, anthropometric variables and health-related physical fitness measurements between BMI categories were analyzed using one-way analysis of variance (ANOVA) or chi-square tests. When a significant F value was found ($p < 0.05$), Tukey's post-hoc test was performed to determine the differences between the pairs of means. Multiple linear regression analysis with health-related physical fitness measurements as the dependent variable was used to examine the associations between health-related physical fitness measurements and BMI after adjustment for potential confounders such as age, education, occupation, monthly income, marital status, and relationship status. To examine the dose–response relationship of health-related physical fitness performance with BMI and obesity status, four different categories (quartiles) were applied for each health-related physical fitness measurement according to gender. The low quartile was comprised of participants who had the best performances on each physical fitness measurement, and it was assigned as the reference group for further analysis. Unconditional logistic regression analyses were conducted to evaluate the linear association among cardiorespiratory fitness, muscle fitness, or flexibility, and obesity risks. All regression models were adjusted for age, education, occupation, monthly income, marital status, relationship status and other health-related physical fitness measurements. Then, the adjusted odds ratios (ORs) with 95% confidence intervals (CIs) were calculated. All data are expressed as the means ± standard deviation (SD) or frequency (percentage). The significance level adopted to reject the null hypothesis was $p < 0.05$.

Results

Demographic characteristics of the study participants

In total, 7,761 men and 9,178 women were included in this study. Participants aged 23 to 64 years with complete data were included from the TSPFTP. Table 1 lists their demographic characteristics according to obesity status among adults in Taiwan. The highest proportion of participants had a normal weight (56%). All participants were divided into a normal body group, an overweight group and an obese group, separated by sex. There were significant differences among the normal weight, overweight, and obesity groups on all related variables except height for men ($p = 0.221$). For women, there were significant differences among the normal weight, overweight, and obesity groups on all related variables except relationship status ($p = 0.236$).

Table 1

Demographic characteristics of the study participants according to obesity status among adults in Taiwan[a]

Variables	Men (*N* = 7,761)				Women (*N* = 9,178)			
	OB (*n* = 1,627)	OW (*n* = 2,495)	NW (*n* = 3,639)	*p*	OB (*n* = 865)	OW (*n* = 1,711)	NW (*n* = 6,602)	*p*
Age (years)	38.94 ± 10.26	39.07 ± 11.25	35.83 ± 11.10	< 0.0001*	39.78 ± 11.36	40.61 ± 11.57	37.07 ± 10.90	< 0.0001*
Height (cm)	171.66 ± 6.50	171.46 ± 6.25	171.75 ± 6.44	0.221	159.37 ± 6.18	159.24 ± 6.17	159.90 ± 5.66	< 0.0001*
Body weight (kg)	86.71 ± 8.89	74.69 ± 6.07	64.92 ± 6.13	< 0.0001*	74.42 ± 7.33	64.17 ± 5,45	54.18 ± 5.21	< 0.0001*
BMI (kg/m^2)	29.38 ± 1.95	25.37 ± 0.86	21.99 ± 1.39	< 0.0001*	29.26 ± 1.67	25.27 ± 0.83	21.17 ± 1.46	< 0.0001*
Education (%)				< 0.0001*				< 0.0001*
Elementary school or lower	0.7	0.8	0.3		1.2	2.9	1.2	
Junior or senior school	11.4	9.5	7.6		20.3	16.9	10.1	
College or higher	87.9	89.7	92.1		78.5	80.2	88.8	
Currently employed (%)				< 0.0001*				0.022*
Yes	92.1	91.3	88.0		83.6	83.3	85.7	
No	4.8	5.7	8.9		14.0	14.1	11.5	
Other	3.1	3.0	3.1		2.4	2.5	2.7	
Income level (%)				< 0.0001*				< 0.0001*
≦ 20,000 NTD	5.7	7.9	9.2		15.5	14.3	11.3	
20,001–40,000 NTD	25.4	23.2	25.1		39.9	36.6	35.8	
≧ 40,001 NTD	68.9	68.9	65.7		44.6	49.1	52.8	
Marital status (%)				< 0.0001*				0.005*
Never married	38.2	35.2	48.1		38.8	36.4	40.6	
Married	57.2	58.4	46.1		53.4	57.6	53.3	
Divorced/separation/widowed	4.5	6.4	5.8		7.7	6.0	6.1	
Relationship status (%)				< 0.0001*				0.148

Abbreviations: BMI, body mass index; NTD, new Taiwan dollar; NW, normal weight; OB, obesity; OW, overweight; UW, underweight.

[a]Values expressed as the means ± standard deviation or percentage (%). Obesity, BMI ≧ 27 kg/m^2; Overweight, 27 > BMI ≧ 24 kg/m^2; Normal weight, 24 > BMI ≧ 18.5 kg/m^2.

*$p < 0.05$.

Variables	Men (*N* = 7,761)			Women (*N* = 9,178)		
Living with someone	83.5	82.4	78.3	88.0	85.2	86.0
Not living with someone	16.5	17.6	21.7	12.0	14.8	14.0

Abbreviations: BMI, body mass index; NTD, new Taiwan dollar; NW, normal weight; OB, obesity; OW, overweight; UW, underweight.

[a]Values expressed as the means ± standard deviation or percentage (%). Obesity, BMI ≧ 27 kg/m^2; Overweight, 27 > BMI ≧ 24 kg/m^2; Normal weight, 24 > BMI ≧ 18.5 kg/m^2.

*$p < 0.05$.

Health-related physical fitness distribution according to obesity status

Table 2 presents the comparison of obesity status differences by various health-related physical fitness measurements among adults in Taiwan. All obesity groups had significant differences in all health-related physical fitness measurements between men and women, and the obesity group had the lowest scores among all measurements.

Table 2
Health-related physical fitness measurements according to different obesity statuses among adults in Taiwan

Variables	OB	OW	NW	*p*	Tukey's Post-Hoc Test
Men (*N* = 5,764)					
3MPKS (ml/kg/min)	39.56 ± 4.02	41.23 ± 4.73	43.30 ± 5.39	< 0.0001*	OB < OW < NW
Grip strength/BW	0.50 ± 0.10	0.56 ± 0.11	0.63 ± 0.13	< 0.0001*	OB < OW < NW
Sit-and-reach test (cm)	20.61 ± 9.38	21.94 ± 9.85	21.64 ± 9.79	< 0.0001*	OB < OW, NW
Women (*N* = 7,639)					
3MPKS (ml/kg/min)	32.37 ± 5.21	32.82 ± 4.26	35.20 ± 4.97	< 0.0001*	OB, OW < NW
Grip strength/BW	0.37 ± 0.08	0.41 ± 0.09	0.47 ± 0.10	< 0.0001*	OB < OW < NW
Sit-and-reach test (cm)	26.25 ± 9.49	27.72 ± 9.70	27.51 ± 10.67	0.002*	OB < OW, NW

Associations of health-related physical fitness measurements with BMI

Table 3 presents the regression coefficients for predicting the BMI using different health-related physical fitness measurements. In men, adjusted for age, education, occupation, monthly income, marital status, relationship status and other physical fitness measurements, the power was decreased on the 3MPKS test (β = -0.127) and sit-and-reach test (β = -9.421) and increased for grip strength (β = -0.002). However, for women, after adjusting for several variables, the power was decreased on the 3MPKS test (β = -0.127) and grip strength (β = -9.421).

Table 3
Regression coefficients for predicting the BMI using different health-related physical fitness measurements

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	β	SE	*p*	*β*	SE	*p*
Men						
3MPKS (ml/kg/min)	-0.116	0.277	< 0.0001*	-0.127	0.008	< 0.0001*
Grip strength/BW	-8.970	0.264	< 0.0001*	-9.421	0.271	< 0.0001*
Sit-and-reach test (cm)	-0.005	0.003	0.120	-0.002	0.003	0.522
Women						
3MPKS (ml/kg/min)	-0.108	0.006	< 0.0001*	-0.111	0.007	< 0.0001*
Grip strength/BW	-10.227	0.284	< 0.0001*	-10.096	0.285	< 0.0001*
Sit-and-reach test (cm)	0.007	0.003	0.007*	0.007	0.003	0.006*

Table 4 presents the results of the regression coefficients for predicting BMI using different quartiles of health-related physical fitness measurements. The results indicated that there was a significant relationship between BMI and physical fitness ($p < 0.05$). In men, adjusted for age, education, occupation, monthly income, marital status, relationship status and other physical fitness measurements, the power showed a significant difference and had the highest increase with the 3MPKS test in the third level (β = 1.900) and the highest decrease in grip strength in the first level (β = -0.922). On the sit-and-reach test, the second level had a significant decrease (β = 0.178). However, in women, after adjusting for several variables, the power was significantly different and had the highest increase with the 3MPKS test in the third level (β = 1.454) and grip strength in the first level (β = -1.309) and the highest decrease in the sit-and-reach test in the first level (β = 0.230).

Table 4
Regression coefficients for predicting BMI using different quartiles of health-related physical fitness measurements

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	β	SE	*p*	*β*	SE	*p*
Men						
3MPKS (ml/kg/min)						
> 45.43	Ref.	—	—	Ref.	—	—
41.62–45.43	1.078	0.092	< 0.0001*	1.079	0.095	< 0.0001*
38.26–41.61	1.524	0.094	< 0.0001*	1.594	0.102	< 0.0001*
< 38.26	1.749	0.095	< 0.0001*	1.900	0.117	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Grip strength/BW						
< 0.50	Ref.	—	—	Ref.	—	—
0.50–0.58	-0.814	0.090	< 0.0001*	-0.922	0.091	< 0.0001*
0.59–0.67	-1.758	0.093	< 0.0001*	-1.865	0.094	< 0.0001*
> 0.67	-3.011	0.097	< 0.0001*	-3.108	0.099	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Sit-and-reach test (cm)						
> 28.00	Ref.	—	—	Ref.	—	—
21.01-28.00	0.043	0.091	0.633	-0.004	0.091	0.961
14.50–21.00	0.227	0.090	0.012*	0.178	0.090	0.048*
< 14.50	-0.024	0.092	0.795	-0.082	0.092	0.371
Test for trend	*p* = 0.576			*p* = 0.888		
Women						
3MPKS (ml/kg/min)						
> 37.59	Ref.	—	—	Ref.	—	—
34.24–37.59	0.528	0.080	< 0.0001*	0.555	0.081	< 0.0001*
31.12–34.23	0.864	0.081	< 0.0001*	0.882	0.085	< 0.0001*
< 31.12	1.484	0.082	< 0.0001*	1.454	0.096	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Grip strength/BW						
< 0.38	Ref.	—	—	Ref.	—	—
0.38–0.45	-1.349	0.078	< 0.0001*	-1.309	0.079	< 0.0001*
0.46–0.51	-2.206	0.085	< 0.0001*	-2.161	0.085	< 0.0001*

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	β	SE	*p*	*β*	SE	*p*
> 0.51	-2.810	0.084	< 0.0001*	-2.759	0.085	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Sit-and-reach test (cm)						
> 34.50	Ref.	—	—	Ref.	—	—
27.01–34.50	0.231	0.080	0.004*	0.230	0.080	0.004*
20.00–27.00	0.207	0.080	0.010*	0.209	0.080	0.009*
< 20.00	-0.186	0.080	0.020*	-0.185	0.080	0.021*
Test for trend	*p* = 0.022*			*p* = 0.025*		

Associations of health-related physical fitness measurements with overweight risk

Table 5 presents the multivariate adjusted ORs for overweight in relation to the quartiles of physical fitness measurements after adjustment for potential confounders. In men, after adjusting for potential confounders, all the levels of the 3MPKS test, grip strength, and sit-and-reach test were associated with the risk of overweight compared with the reference group. In the 3MPKS test, the third level (< 38.26 ml/kg/min) had the highest risk of overweight (OR = 2.117, 95% CI: 1.734–2.586) compared with the reference group. Regarding grip strength, the first level (0.50–0.58 kg) had the highest risk of overweight (OR = 0.806, 95% CI: 0.687–0.946) compared with the reference group. In the sit-and-reach test, the second level (14.50–21.00 kg) had the highest risk of overweight (OR = 0.849, 95% CI: 0.729–0.988) compared with the reference group.

Table 5
Multivariate adjusted ORs for overweight in relation to quartiles of physical fitness measurements after adjustment for potential confounders (n = 14,447)

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	OR	95% CI	*p*	OR	95% CI	*p*
Men						
3MPKS (ml/kg/min)						
> 45.43	Ref.	—	—	Ref.	—	—
41.62–45.43	2.272	1.955–2.641	< 0.0001*	2.063	1.766–2.410	< 0.0001*
38.26–41.61	2.423	2.074–2.832	< 0.0001*	2.056	1.731–2.442	< 0.0001*
< 38.26	2.655	2.263–3.115	< 0.0001*	2.117	1.734–2.586	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Grip strength/BW						
< 0.50	Ref.	—	—	Ref.	—	—
0.50–0.58	0.850	0.727–0.994	0.042*	0.806	0.687–0.946	0.008*
0.59–0.67	0.750	0.643–0.874	< 0.0001*	0.697	0.595–0.817	< 0.0001*
> 0.67	0.305	0.258–0.361	< 0.0001*	0.278	0.234–0.330	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Sit-and-reach test (cm)						
> 28.00	Ref.	—	—	Ref.	—	—
21.01-28.00	0.843	0.725–0.980	0.026*	0.810	0.696–0.942	0.006*
14.50–21.00	0.872	0.750–1.014	0.074	0.849	0.729–0.988	0.035*
< 14.50	0.816	0.701–0.950	0.009*	0.781	0.670–0.911	0.002*
Test for trend	$p = 0.074$			$p = 0.015$*		
Women						
3MPKS (ml/kg/min)						
> 37.59	Ref.	—	—	Ref.	—	—
34.24–37.59	1.930	1.605–2.320	< 0.0001*	1.959	1.625–2.361	< 0.0001*
31.12–34.23	2.562	2.141–3.066	< 0.0001*	2.542	2.107–3.067	< 0.0001*
< 31.12	3.299	2.759–3.945	< 0.0001*	3.036	2.467–3.738	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Grip strength/BW						
< 0.38	Ref.	—	—	Ref.	—	—
0.38–0.45	0.645	0.561–0.741	< 0.0001*	0.667	0.580–0.767	< 0.0001*
0.46–0.51	0.384	0.326–0.451	< 0.0001*	0.398	0.338–0.469	< 0.0001*

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	OR	95% CI	*p*	OR	95% CI	*p*
> 0.51	0.218	0.182–0.262	< 0.0001*	0.228	0.190–0.274	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Sit-and-reach test (cm)						
> 34.50	Ref.	—	—	Ref.	—	—
27.01–34.50	1.195	1.022–1.397	0.025*	1.192	1.019–1.394	0.028*
20.00–27.00	1.080	0.922–1.263	0.340	1.085	0.927–1.272	0.310
< 20.00	0.787	0.669–0.925	0.004*	0.794	0.675–0.934	0.005*
Test for trend	*p* = 0.002*			*p* = 0.003*		

In women, after adjusting for potential confounders, all levels of the 3MPKS test and hand grip strength were associated with a risk of overweight compared with the reference group. In 3MPKS, the third level (< 31.12 ml/kg/min) had the highest risk of overweight (OR = 3.036, 95% CI: 2.467–3.738) compared with the reference group. Regarding grip strength, the first level (0.50–0.58 kg) had the highest risk of overweight (OR = 0.667, 95% CI: 0.580–0.767) compared with the reference group. In the sit-and-reach test, 27.01–34.50 cm and < 20.00 cm were associated with a risk of overweight (OR = 1.192, 95% CI: 1.019–1.394; OR = 0.798, 95% CI: 0.675–0.934) compared with the reference group.

Associations of health-related physical fitness measurements with obesity risk

The results of the logistic regression models for the risk of obesity are shown in Table 6. After adjusting for potential confounders, the results showed that participants who performed the 3MPKS test and had high handgrip strength all had a risk of obesity, and the third level of the 3MPKS test (OR = 6.530, 95% CI: 5.008–8.513) and the first level of grip strength (OR = 0.528, 95% CI: 0.446–0.624) had the highest risk of obesity in men. Performance at the second level on the sit-and-reach test was associated with a higher risk of obesity (OR = 1.376, 95% CI: 1.132–1.673) than the reference group in men.

Table 6
Multivariate adjusted ORs for obesity in relation to quartiles of physical fitness measurements after adjustment for potential confounders (n = 12,733)

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	OR	95% CI	*p*	OR	95% CI	*p*
Men						
3MPKS (ml/kg/min)						
> 45.43	Ref.	—	—	Ref.	—	—
41.62–45.43	3.488	2.757–4.412	< 0.0001*	3.557	2.798–4.522	< 0.0001*
38.26–41.61	5.375	4.277–6.757	< 0.0001*	5.747	4.509–7.326	< 0.0001*
< 38.26	5.760	4.580–7.243	< 0.0001*	6.530	5.008–8.513	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Grip strength/BW						
< 0.50	Ref.	—	—	Ref.	—	—
0.50–0.58	0.593	0.504–0.697	< 0.0001*	0.528	0.446–0.624	< 0.0001*
0.59–0.67	0.237	0.197–0.286	< 0.0001*	0.206	0.169–0.250	< 0.0001*
> 0.67	0.056	0.043–0.073	< 0.0001*	0.049	0.037–0.064	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Sit-and-reach test (cm)						
> 28.00	Ref.	—	—	Ref.	—	—
21.01-28.00	1.054	0.865–1.284	0.602	0.981	0.803–1.198	0.847
14.50–21.00	1.443	1.191–1.748	< 0.0001*	1.376	1.132–1.673	0.001*
< 14.50	0.983	0.809–1.195	0.865	0.900	0.737–1.099	0.303
Test for trend	$p = 0.405$			$p = 0.986$		
Women						
3MPKS (ml/kg/min)						
> 37.59	Ref.	—	—	Ref.	—	—
34.24–37.59	0.900	0.696–1.163	0.419	0.958	0.739–1.242	0.745
31.12–34.23	1.289	1.016–1.635	0.037*	1.431	1.116–1.833	0.005*
< 31.12	2.633	2.116–3.277	< 0.0001*	3.238	2.505–4.187	< 0.0001*
Test for trend	$p < 0.0001$*			$p < 0.0001$*		
Grip strength/BW						
< 0.38	Ref.	—	—	Ref.	—	—
0.38–0.45	0.344	0.290–0.408	< 0.0001*	0.351	0.296–0.417	< 0.0001*
0.46–0.51	0.126	0.098–0.161	< 0.0001*	0.129	0.100-0.166	< 0.0001*

Variables	Model 1 (unadjusted)			Model 2 (adjusted[a])		
	OR	95% CI	*p*	OR	95% CI	*p*
> 0.51	0.052	0.037–0.073	< 0.0001*	0.051	0.036–0.072	< 0.0001*
Test for trend	*p* < 0.0001*			*p* < 0.0001*		
Sit-and-reach test (cm)						
> 34.50	Ref.	—	—	Ref.	—	—
27.01–34.50	1.408	1.119–1.773	0.004*	1.396	1.108–1.758	0.005*
20.00–27.00	1.470	1.172–1.844	0.001*	1.429	1.138–1.794	0.002*
< 20.00	1.061	0.842–1.337	0.614	1.035	0.820–1.305	0.774
Test for trend	*p* = 0.950			*p* = 0.868		

For women, the second and third levels on the 3MPKS test were associated with a risk of obesity, and the third level had a higher risk of obesity (OR = 3.238, 95% CI: 2.505–4.187) than the reference group. Participants who performed the grip strength test all had a risk of obesity, and the first level of grip strength (OR = 0.351, 95% CI: 0.296–0.417) had the highest risk of obesity in women. In the first and second levels, the 3MPKS test was associated with a risk of obesity, and the second level had a higher risk of obesity (OR = 1.429 95% CI: 1.138–1.794) than the reference group in women.

Discussion

In this study, we analyzed the relationship between health-related physical fitness and BMI and overweight/obesity risk using data from 7,761 men and 9,178 women. The main findings of this study were as follows: (1) higher levels of 3MPKS and relative grip strength were each associated with lower BMI, overweight and obesity with a dose–response relationship in both men and women; (2) sit-and-reach was partially negatively associated with BMI and was not a good predictor for overweight/obesity in adults.

A previous study found that Caucasians having the same body fat percentage, age and sex have an approximately 3 kg/m^2 higher BMI than Asians [22]. Thus, in the present study, obesity was defined by a BMI greater than or equal to 27 kg/m^2 instead of the WHO recommendation of 30 kg/m^2. Notably, we observed that the proportions of overweight (32% vs. 19%) and obesity (21% vs. 9%) were higher in men than in women. In contrast, the global prevalence of overweight (40% vs. 39%) and obesity (15% vs. 11%) is higher in women than in men [23]. We suggest that women have more efficient weight management than men in Taiwan, which may reduce their future risk of chronic diseases and enhance their quality of life.

Cardiovascular fitness is closely associated with many health outcomes, but it is impractical to assess all populations in a laboratory setting because the assessment requires expensive metabolic equipment and the evaluation of VO_2max takes time and space and could be difficult for the participants. In contrast, the 3MPKS test is a simple and validated (r = 0.79) method for predicting VO_2max in adults [11]. In the present study, we found that 3MPKS performance was significantly negatively associated with BMI and overweight/obesity risk with a dose–response relationship in both sexes. Furthermore, men and women with a VO_2max lower than 45.4 ml/kg/min and 34.2 ml/kg/min might have an increased risk of obesity by 3.5-6.5 times and 1.4–3.2 times, respectively. A similar study indicated that low VO_2max levels (35.0 vs. 20.1 ml/kg/min; measured by cycle ergometer) might increase the risk of developing obesity by 2.9 times as compared with high VO_2max levels in adults [24]. In addition, higher cardiorespiratory fitness (measured by a nine-minute run/walk) was associated with a lower risk for overweight/obesity in children [25]. Therefore, the American College of Sports Medicine recommends that adults engage in moderate-intensity aerobic training (e.g., walking, running and cycling) for ≥ 150 min/week or vigorous-intensity aerobic training for ≥ 75 min/week to improve their cardiovascular fitness and weight management [7, 26].

Grip strength is a good predictor of overall body strength (i.e., a sum of shoulder abductors, hip flexors and ankle dorsiflexors) in children and young adults [12]. A study indicated that relative grip strength was negatively associated with the waist circumference (an indicator of abdominal obesity) in young adults [27]. In the present study, we observed that a lower relative grip strength was associated with a higher BMI and overweight/obesity risk with a dose–response relationship in both sexes. In addition, men and women with a relative grip strength lower than 0.67 and 0.51, respectively, might have an increased risk of overweight/obesity. A similar study indicated that a lower relative grip strength was associated with a higher risk of MS in young and elderly adults [14, 16]. Thus, we suggest that relative grip strength is a good predicator of overweight/obesity, abdominal obesity and MS risks in young and older adults.

In this study, we found that sit-and-reach was higher in the overweight group than in the obese group, whereas it did not differ between the overweight and normal weight groups in men and women. In addition, sit-and-reach was partially negatively associated with BMI and overweight/obesity risk in both sexes. Similar studies indicated that sit-and-reach was not affected by BMI or overweight/obesity status among children and adolescents [25, 28]. Therefore, we suggest that sit-and-reach is not a good predictor of the BMI distribution and overweight/obesity risk.

Conclusions

This study demonstrated that adults with higher cardiorespiratory fitness and muscle strength had a lower BMI and overweight/obesity risk with a dose–response relationship. All men and women with a $VO_2max < 45$ and 34 ml/kg/min or relative grip strength < 0.67 and 0.51, respectively, might have an increased risk of overweight/obesity. The sit-and-reach test was not a good predictor of BMI distribution and overweight/obesity risk in either sex.

Abbreviations

3MPKS
3-min progressive knee-up and step
ANOVA
analysis of variance
BMI
body mass index
CI
confidence interval
CVD
cardiovascular disease
MS
metabolic syndrome
OR
odds ratio
PAR-Q
Physical Activity Readiness Questionnaire
SD
standard deviation
TSPFTP
Taiwan's Scientific Physical Fitness Testing Program
TWD
New Taiwan dollar
VO_2max
maximal oxygen uptake

WC
waist circumference
WHO
World Health Organization.

Declarations

Ethics approval and consent to participate

This study was conducted with a secondary database provided by the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan. All consents obtained from the study participants were written prior the data collection. This study's design and analysis procedure was approved by the Ethical Committee of Fu Jen Catholic University (FJU-IRB C110113).

Consent for publication

Not applicable.

Availability of data and materials

The data that support the findings of this study are available from [the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan] but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available. Data are however available from the authors upon reasonable request and with permission of [the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan].

Competing interests

The authors declare that they have no competing interests.

Funding

This study was supported by a grant from the Ministry of Science and Technology (MOST 109-2410-H-030-059).

Authors' contributions

YTC and CCH participated in the design, conducted the statistical analyses, interpreted the data, and drafted the manuscript. PFL and CTH supervised the study, assisted in data interpretation, and critically reviewed the manuscript. CFL and CTH helped in conducting the study and revising the manuscript. YTL and HYL helped to manage and analyze the data. All authors read and approved the final manuscript.

Acknowledgements

This study is based in part on data from the National Physical Fitness Survey provided by the Sports Cloud: Information and Application Research Center of Sports for All, Sport Administration, Ministry of Education in Taiwan. The interpretation and conclusions contained herein do not represent those of Sport Administration, Ministry of Education in Taiwan.

Authors' information

[1]Department of Physical Education and Sport Science, National Taiwan Normal University, Taipei City 106, Taiwan; [2]Department of Leisure Industry and Health Promotion, National Ilan University, Yilan County 260, Taiwan; [3]Department of Health and Leisure Management, Yuanpei University of Medical Technology, Hsinchu City 306, Taiwan; [4]Department of Recreation and Sport Management, Shu Te University, Kaohsiung City 82445, Taiwan; [5]Graduate Institute of Business

Administration, Fu Jen Catholic University, New Taipei City 242, Taiwan; [6]Department of Physical Education, Fu Jen Catholic University, New Taipei City 24205, Taiwan; [7]Research and Development Center for Physical Education, Health and Information Technology, College of Education, Fu Jen Catholic University, New Taipei City 24205, Taiwan; [8]Office of Physical Education, Fu Jen Catholic University, New Taipei City 24205, Taiwan.

References

1. Lim HJ, Xue H, Wang Y. Global trends in obesity. Handbook of Eating and Drinking: Interdisciplinary Perspectives 2020; 1217–1235.
2. Stiegler P, Cunliffe A. The role of diet and exercise for the maintenance of fat-free mass and resting metabolic rate during weight loss. Sports Med. 2006; 36(3): 239–62.
3. Schaller N, Seiler H, Himmerich S, Karg G, Gedrich K, Wolfram G, Linseisen J. Estimated physical activity in Bavaria, Germany, and its implications for obesity risk: Results from the BVS-II Study. Int J Behav Nutr Phys Act. 2005; 2: 6.
4. Green MA. Do we need to think beyond BMI for estimating population-level health risks? J Public Health (Oxf). 2016; 38(1): 192–3.
5. Mertens E, Deforche B, Mullie P, Lefevre J, Charlier R, Knaeps S, Huybrechts I, Clarys P. Longitudinal study on the association between three dietary indices, anthropometric parameters and blood lipids. Nutr Metab. 2015; 12: 47.
6. Whaley MH, Brubaker PH, Otto RM, Armstrong LE. *ACSM's guidelines for exercise testing and prescription*; Lippincott Williams & Wilkins: Philadelphia, Pa., 2006.
7. Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Nieman DC, Swain DP. American College of Sports Medicine position stand. Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc. 2011; 43(7): 1334–59.
8. Costa PB, Graves BS, Whitehurst M, Jacobs PL. The acute effects of different durations of static stretching on dynamic balance performance. J Strength Cond Res. 2009; 23(1): 141–7.
9. Cornelius WL. FLEXIBILITY EXERCISE: Benefits from Flexibility Exercise. Strength Cond J. 1990; 12: 61–4.
10. Chang KV, Hung CY, Li CM, Lin YH, Wang TG, Tsai KS, Han DS. Reduced flexibility associated with metabolic syndrome in community-dwelling elders. PLoS One. 2015; 10(1): e0117167.
11. Chung YC, Huang CY, Wu HJ, Kan NW, Ho CS, Huang CC, Chen HT. Predicting maximal oxygen uptake from a 3-minute progressive knee-ups and step test. PeerJ. 2021; 9: e10831.
12. Wind AE, Takken T, Helders PJM, Engelbert RHH. Is grip strength a predictor for total muscle strength in healthy children, adolescents, and young adults? Eur J Pediatr. 2010; 169(3): 281–7.
13. Stevens PJ, Syddall HE, Patel HP, Martin HJ, Cooper C, Aihie Sayer A. Is grip strength a good marker of physical performance among community-dwelling older people? J Nutr Health Aging. 2012; 16(9): 769–74.
14. Churilla JR, Summerlin M, Richardson MR, Boltz AJ. Mean combined relative grip strength and metabolic syndrome: 2011–2014 national health and nutrition examination survey. J Strength Cond Res. 2020; 34(4): 995–1000.
15. Lee WJ, Peng LN, Chiou ST, Chen LK. Relative handgrip strength is a simple indicator of cardiometabolic risk among middle-aged and older people: A nationwide population-based study in Taiwan. PLoS One. 2016; 11(8): e0160876.
16. Chun SW, Kim W, Choi KH. Comparison between grip strength and grip strength divided by body weight in their relationship with metabolic syndrome and quality of life in the elderly. PLoS One. 2019; 14(9): e0222040.
17. Tremmel M, Gerdtham UG, Nilsson PM, Saha S. Economic burden of obesity: A systematic literature review. Int J Environ Res Public Health. 2017; 14(4): 435.
18. Health Promotion Administration, Ministry of Health and Welfare. Check your body weight every day. [https://www.hpa.gov.tw/Home/Index.aspx].

19. Li F, Chang CH, Chung YC, Wu HJ, Kan NW, ChangChien WS, Ho CS, Huang CC. Development and validation of 3 min incremental step-in-place test for predicting maximal oxygen uptake in home settings: A submaximal exercise study to assess cardiorespiratory fitness. Int J Environ Res Public Health. 2021; 18(20): 10750.
20. Bohannon RW, Magasi SR, Bubela DJ, Wang YC, Gershon RC. Grip and knee extension muscle strength reflect a common construct among adults. Muscle Nerve. 2012; 46(4): 555–8.
21. Ayala F, Sainz de Baranda P, De Ste Croix M, Santonja F. Absolute reliability of five clinical tests for assessing hamstring flexibility in professional futsal players. J Sci Med Sport. 2012; 15(2): 142–7.
22. Gurrici S, Hartriyanti Y, Hautvast J, Deurenberg P. Relationship between body fat and body mass index: differences between Indonesians and Dutch Caucasians. Eur J Clin Nutr. 1998; 52(11): 779–83.
23. WHO. Obesity and overweight. [https://www.who.int/en/news-room/fact-sheets/detail/obesity-and-overweight#].
24. Ortega R, Grandes G, Sanchez A, Montoya I, Torcal J. Cardiorespiratory fitness and development of abdominal obesity. Prev Med. 2019; 118: 232–7.
25. Casonatto J, Fernandes RA, Batista MB, Cyrino ES, Coelho-e-Silva MJ, de Arruda M, Vaz Ronque ER. Association between health-related physical fitness and body mass index status in children. J Child Health Care. 2016; 20(3): 294–303.
26. Donnelly JE, Blair SN, Jakicic JM, Manore MM, Rankin JW, Smith BK. American College of Sports Medicine Position Stand. Appropriate physical activity intervention strategies for weight loss and prevention of weight regain for adults. Med Sci Sports Exerc. 2009; 41(2): 459–71.
27. Díez-Fernández A, Martínez-Vizcaíno V, Torres-Costoso A, Cañete García-Prieto J, Franquelo-Morales P, Sánchez-López M. Strength and cardiometabolic risk in young adults: The mediator role of aerobic fitness and waist circumference. Scand J Med Sci Sports. 2018; 28(7): 1801–17.
28. Dumith SC, Ramires VV, Souza MA, Moraes DS, Petry FG, Oliveira ES, Ramires SV, Hallal PC. Overweight/obesity and physical fitness among children and adolescents. J Phys Act Health. 2010; 7(5): 641–8.