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Brief communication (Original)

Body mass index and percentage of body fat determined physical performance in healthy personnel

Duangporn Thong-Ngam, Maneerat Chayanupatkul, Vikit Kittisupamongkon
Department of Physiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand

Background: Body mass index (BMI) and percentage of body fat may be linked to physical performance. However, the nature and extent of such association is not known. In addition, it is unknown whether BMI is a good reflection of body fat.
Objectives: We measured the impact of obesity on physical performance and to determine the association between BMI, body fat, and various parameters of physical performance. Therefore, we tested whether BMI could be used as a good reflection of body fat.
Methods: Three hundred people (126 men and 174 women) attending Chula Medical Exposition 2008 were included in this study. All participants underwent various measurements including percentage of body fat by Lange skinfold caliper, submaximal cycle ergometer test, handgrip strength, leg and back dynamometer, and flexibility determination. They were classified by BMI Asian criteria into normal (BMI <23 kg/m^2), overweight (BMI 23-24.9 kg/m^2), and obesity (BMI >25 kg/m^2). The body fat categorized was into satisfied (body fat <16.9%) and unsatisfied (body fat ≥16.9%). Differences in physical performance between groups were calculated by unpaired *t*-test and analysis of covariance using SPSS for windows version 16.0.
Results: Subjects with normal BMI had significantly higher handgrip strength than overweight and obese group (p = 0.007 and p <0.001 respectively). Regarding percentage of body fat, subjects in unsatisfied group were found having significantly less aerobic power and muscular strength when compared with satisfied group (p <0.001 in all aspects). The present study showed significant correlation between BMI and body fat (r = 0.33, p <0.001), body fat and aerobic power (r = -0.18, p = 0.002), body fat and handgrip strength (r = -0.65, p <0.001), and body fat and leg muscular strength (r = -0.52, p <0.001).
Conclusions: Increased BMI and body fat tended to inversely affect physical performance in both cardiorespiratory fitness and muscular strength. Body fat seemed to have a stronger correlation with impaired physical performance. It could not be fully replaced by BMI in determination of aerobic power and muscular strength.

Keywords: Body fat, BMI, physical performance

Changing lifestyle and increasing popularity in junk food have contributed to the growing prevalence of obesity in Thai population. Obesity is known to be associated with various medical problems, such as diabetes mellitus, hypertension, dyslipidemia, coronary heart disease, metabolic syndrome, and osteoarthritis of the knee [1-4]. Many recent studies have reported the impact of obesity on physical functioning and performance especially in older adults [5-8]. BMI has been widely used for an assessment of health risk and has been demonstrated to be related to morbidity and mortality in population of different culture and ethnicity [9-10]. Regarding physical function, body composition measurement is considered to give more accurate picture compared with BMI. In this study, we determined the association between different BMI categories and percentage of body fat with physical performance, namely cardiorespiratory fitness, muscular strength, and flexibility. We also examined whether BMI could be used as an appropriate reflection of fat mass in determination of these performance.

Correspondence to: Duangporn Thong-Ngam, MD, Department of Physiology, Faculty of Medicine, Chulalongkorn University, Bangkok 10330, Thailand. E-mail: dr.duangporn@gmail.com

Methods

The study population recruited 126 men and 174 women from people attending physical performance measurement session in Chula Medical Exposition. All participants were at age of 15-60. People who

had heart disease, uncontrolled asthma, and any disability precluding test performance were excluded from the study. As required by the University Ethic Committee, all subjects were notified of study purpose and procedures. Informed consent was obtained from each participant. Information regarding demographic data, the presence of medical disease based on subjects' report of diagnosis, and frequency and method of exercise was gathered by a self-administration questionnaire. Subjects' knowledge on exercise was determined by a set of 10 questions concerning basic knowledge of exercise.

Body weight was measured to the nearest of 0.01 kg on an electronic scale (Yamato Scale CO., LTD., Hyogo, Japan). Height was measured to the nearest of 0.1 cm with stadiometer. The measurement of skinfold thickness over the triceps, biceps, subscapularis, and suprailiac regions by Lange skinfold caliper (Beta Technology Inc., CA, USA.) were added together to give the sum of skinfold, and percentage of body fat was determined using standard table modified from Durnin J.V. and Womerslay J. [11].

Physical performance presented in this study included aerobic power assessment, muscular strength, and flexibility. Aerobic power was measured using submaximal cycle ergometer test following YMCA Cycle Ergometry Protocol. We used average heart rate in each stage of exercise to predict workload at age-related maximal heart rate to determine maximal oxygen uptake (VO_2max). Handgrip strength was determined by Takei A5402 digital handgrip dynamometer (Takei Scientific Instrument CO., LTD., Niigata, Japan), and leg and back muscular strength was measured by Takei A5402 leg and trunk dynamometer (Takei Scientific Instrument CO., LTD., Niigata, Japan). Body flexibility was measured in centimeters by Sit and Reach Box technic.

Statistical analysis

Subjects were classified into different BMI categories using Asian criteria [12], as normal (BMI <23 kg/m^2), overweight (BMI 23-24.9 kg/m^2) and obesity (BMI ≥25 kg/m^2). Participants were also grouped into satisfied body fat mass (body fat <16.9%) and unsatisfied body fat mass (body fat ≥16.9%). The differences of aerobic power, muscular strength, and flexibility between groups of different BMI, body fat, and gender were determined using unpaired *t*-test and analysis of covariance. Correlation between BMI, percentage of body fat mass, and physical performance was examined using Pearson Correlation. All values were expressed in mean□SEM. All statistical analysis were performed using SPSS for windows (version 16.0, SPSS Inc., Chicago, IL, USA).

Results

Three hundred people (42% men and 58% women) were enrolled in this study with average age of 20.70±10.14. The differences between BMI, percentage of body fat, muscular strength, and times spending on exercise per week between male and female participants were presented in **Table 1**. Male subjects had significantly higher physical performance concerning aerobic power and muscular strength but not flexibility. Female subjects had significantly higher percentage of body fat comparing with male subjects regardless of different BMI.

Table 1. Differences in BMI, percentage of body fat, physical performance, and times spent in exercise per week in male and female subjects.

	Male (n=126)	**Female** (n=174)	***p*-value**
BMI	21.61±0.29	21.07±0.23	NS
VO_2max (ml/kg/min)	41.04±1.45	36.52±1.16	0.014
hand grip (kg)	0.64±0.01	0.46±0.01	<0.001
leg strength (kg)	1.64±0.06	0.89±0.04	<0.001
body fat (%)	4.48±0.29	16.24±0.36	<0.001
Flexibility (cm)	3.93±0.80	4.68±0.62	NS
Exercise time (hr) /wk	2.63±0.16	1.92±0.13	0.001

Comparing of percentage of body fat, aerobic power, muscular strength, and flexibility between different BMI groups were shown in **Table 2**. Percentage of body fat increased in concordance with rising BMI. There was no significant difference in aerobic power among BMI subgroups. Subjects with normal BMI tended to have more handgrip strength than overweight and obese counterparts (0.56±0.01 vs. 0.49±0.02 and 0.47±0.02 kg, $p = 0.007$ and $p < 0.001$), respectively. As far as back and leg muscular strength were concerned, we only found significant difference between normal and obese groups (1.25±0.05 vs. 1.04±0.09 kg, $p = 0.044$). In addition, overweight subjects had significantly higher flexibility than normal (6.50±1.08 vs. 3.78±0.60 cm, $p = 0.03$).

Categorizing percentage of body fat into satisfied (body fat <16.9%) and unsatisfied (body fat ≥16.9%) groups, we compared BMI, aerobic power, muscular strength, and flexibility among groups. The results were demonstrated in **Table 3**. Subjects in unsatisfied group had significantly higher BMI with less aerobic power and less muscular strength (VO_2max 42.9±1.88 vs. 32.97±1.52 ml/kg/min, $p < 0.001$; handgrip 0.57±0.01 vs. 0.43±0.01 kg, $p < 0.001$; leg strength 1.33±0.45 vs. 0.84±0.05 kg $p < 0.001$, respectively). Flexibility tends to be higher in unsatisfied body fat group.

We also calculated the correlation between BMI and percentage of body fat with different parameters of physical performance, as seen in **Table 4**. There were significant positive correlation between BMI and body fat ($R = 0.33$, $p < 0.001$), BMI and age ($R = 0.28$, $p < 0.001$), and body fat and age ($R = 0.195$, $p = 0.001$). Body fat was inversely correlated with VO_2max ($R = -0.176$, $p = 0.002$), and muscular strength (handgrip; $R = -0.648$, $p < 0.001$ leg strength; $R = -0.502$, $p < 0.001$). BMI was negatively associated with VO_2max and muscular strength but there was no statistical significance. Flexibility was found to be positively associated with BMI ($p = 0.016$) and body fat. **Figure 1** showed linear regression curve between BMI and percentage of body fat.

Table 2. Differences in BMI, percentage of body fat, and physical performance among BMI groups**.**

Physical performance	Normal (BMI <23) n=225	Overweight (BMI 23-24.9) n=42	Obesity (BMI ≥25) n=23
body fat (%)	10.27±0.43	12.99±1.17[a]	16.88±1.27[b,d]
VO_2max (ml/kg/min)	40.26±1.22	38.63±4.40	44.33±9.23
hand grip (kg)	0.56±0.01	0.49±0.02[a]	0.47±0.02[b]
leg strength (kg)	1.25±0.05	1.12±0.09	1.04±0.09[c]
flexibility (cm)	3.78±0.60	6.50±1.08[a]	3.95±1.51

All values were presented as mean±SEM. [a] $p < 0.005$ when compared with normal BMI, [b] $p < 0.001$ when compared with normal BMI, [c] $p < 0.005$ when compared with normal BMI, [d] $p < 0.005$ when compared with overweight

Table 3. Differences in BMI and physical performance between satisfied and unsatisfied groups.

	satisfied (body fat <16.9%) n=227	unsatisfied (body fat ≥16.9%) n=73	*p*-value
BMI	20.68±0.20	22.99±0.37	<0.001
VO_2max (ml/kg/min)	42.9±1.88	32.97±1.52	<0.001
hand grip (kg)	0.57±0.01	0.43±0.01	<0.001
leg strength (kg)	1.33±0.47	0.84±0.05	<0.001
flexibility (cm)	3.81±0.59	5.32±0.92	NS

All values were presented as mean±SEM

Table 4. Correlation between BMI and percentage of body fat with different parameters of physical performance.

	BMI		Percentage of body fat	
	R	***p*-value**	**R**	***p*-value**
age	0.28	<0.001	0.195	0.001
BMI	1		0.33	<0.001
VO_2max (ml/kg/min)	-0.1	NS	-0.176	0.002
hand grip (kg)	-0.25	<0.001	-0.648	<0.001
leg strength (kg)	-0.09	NS	-0.522	<0.001
flexibility (cm)	0.14	0.016	0.067	NS
body fat (%)	0.33	<0.001	1	

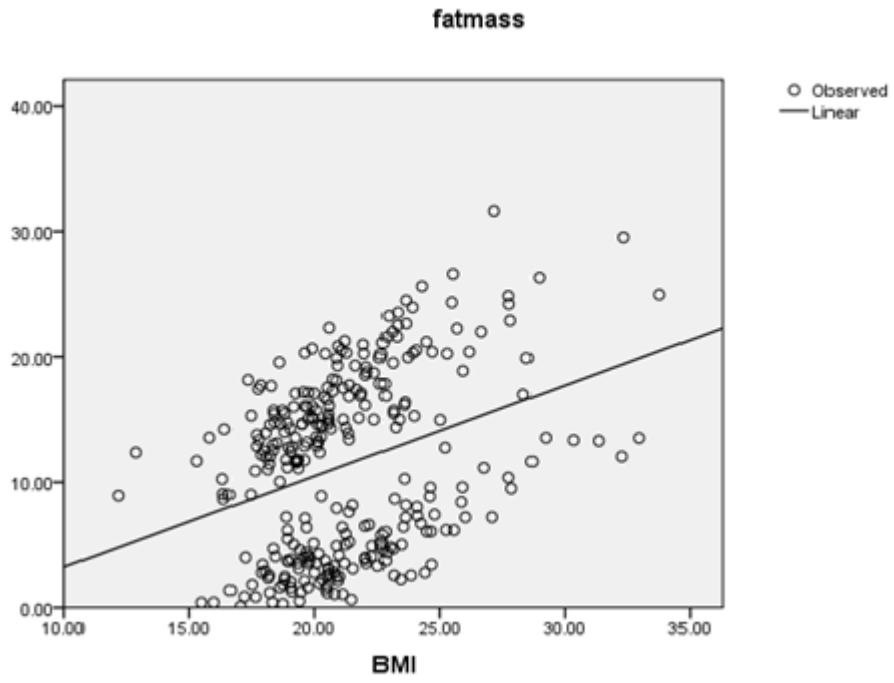

Figure 1. Linear regression curve between BMI and percentage of body fat**.**

Discussion

Recent studies have shown the adverse effect of increased fat mass and obesity on physical performance and functions [5, 7, 8, 10, 13]. Most of these studies focused on the impact of obesity in geriatric population. In the present study, most subjects were young adults with average age of 20.07. Therefore, we might determine whether obesity negatively affected physical performance in young adults as in elderly group. Moreover, BMI was cheaper, easier, and more convenient to obtain compared with percentage of body fat. We tried to show if BMI was well correlated with physical performance and could be used as a good reflection of body fat.

The study showed that subjects with higher BMI tended to have less muscular strength. There was no difference in aerobic power among BMI subgroups, and overweight subjects appeared to have higher flexibility than normal. The "Sit and Reach Box" was used to determine flexibility. Body flexibility might not be affected by increased BMI and body fat. This study demonstrated significant negative correlation between BMI and handgrip strength, and positive

correlation between BMI and flexibility. When dividing subjects into satisfied and unsatisfied fat mass group using percentage of body fat, we found that participants with higher body fat had significantly lower physical performance both aerobic power and muscular strength. The study also showed significantly inverse correlation between percentage of body fat and aerobic power, hand strength and leg muscular strength. The percentage of body fat seemed to be superior to BMI with respect to the correlation with physical performance. Although there was significant correlation between BMI and percentage of body fat, the R-value was only 0.33. This finding could imply that BMI might be acceptable as a good representative of body fat mass, since BMI included both fat mass and fat-free mass. Muscular persons might have higher BMI with lower fat mass, and could perform better both in cardiorespiratory fitness and muscle power.

The finding observed in this study emphasized the negative impact of obesity on physical performance apart from increasing the risk of various diseases. The more weight they gain, the lower physical performance they have. With declining physical performance, they tend to have functional limitation, to be less physically active, and will consequently gain more weight. In order to stop this undesirable cycle, we should start encouraging people to be more concerned about prudent diet, and adequate exercise. Even though studies regarding the effect of weight reduction intervention on physical performance were limited, some of them have shown significant improvement in physical performance and functional limitation after weight reduction [14, 15].

There were limitations in the present study, including its cross-sectional design, aerobic power measurement with indirect method, and body fat determination with skinfold caliper. In spite of the limitations, this study confirmed the adverse effect of increased BMI and percent body fat on physical performance and supported the idea that body fat mass was a better determinant of cardiorespiratory fitness and muscular strength, and could not be fully replaced by BMI. Further study with more subjects and longitudinal design could give us more information about association between BMI, percent body fat mass and physical performance, and might show the benefit of weight reduction program on physical performance.

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