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Associations between muscular fitness and metabolic syndrome: Cross-sectional study of Japanese women and men

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ABSTRACT

Metabolic syndrome (MetS) is a complex interrelated risk factor for cardiovascular disease and type 2 diabetes mellitus. High cardiorespiratory fitness is known to contribute to prevention of MetS. However, little is known regarding the association between muscular fitness and MetS in Japanese adults. The purpose of this study was to examine the associations between muscular fitness and MetS in Japanese women and men. This cross-sectional study included 335 women and 209 men aged 30 - 79 y. MetS was determined according to the 2009 criteria of the International Diabetes Federation. Muscular fitness was evaluated by muscular fitness composite score (MFS), which was determined using Z scores from grip strength and sit-ups. Participants were classified by MFS tertile into low, middle, and high MFS groups. We used multiple logistic regression analysis to estimate odds ratios for the incidence of MetS in each group. The prevalence of MFS was 27.2% in women and 27.3% in men. Adjusted odds ratios for MetS prevalence in the low, middle, and high MFS groups, after adjusting for age, smoking status, alcohol intake, and exercise habits, were 1.0 (referent), 0.90 (95% confidence interval [CI], 0.50 - 1.62), and 0.49 (95% CI, 0.25 - 0.94; *P* for trend = 0.03) in women; in men, they were 1.0 (referent), 0.49 (0.23 - 1.04), and 0.42 (0.18 - 0.97; *P* for trend = 0.04), respectively. Muscular fitness is inversely associated with the prevalence of MetS in Japanese women and men.

Keywords: Muscle Strength; Muscle Endurance; Muscular Fitness; Metabolic Syndrome

1. INTRODUCTION

Metabolic syndrome (MetS) is a clustering of central obesity and cardiovascular disease (CVD) risk factors, including abnormal blood pressure, lipids, and blood glucose [1]. Insulin resistance occurring as a result of visceral fat accumulation is a key factor in MetS and is considered a strong predictor of CVD events [2]. Over the past 2 decades, the prevalence of MetS has increased in Japan as well as in Western countries. Because individuals with MetS have an elevated risk of developing type 2 diabetes [3,4] and CVD [5,6], strategies to prevent an epidemic of this syndrome are urgently required [7].

The primary management approach for MetS is healthy lifestyle promotion such as increased physical activity and diet modification [8]. Because physical fitness (*i.e.*, cardiorespiratory fitness [CRF] and muscular fitness) is primarily determined by physical activity, high physical fitness is thought to be effective for improving MetS. Previous studies have demonstrated an inverse association between CRF and MetS prevalence and suggested that CRF is an independent predictor of MetS incidence [9-11]. Compared with CRF, fewer studies have been conducted on the association between muscular fitness and MetS. While an inverse relationship between muscular strength and MetS has been previously illustrated in American [12,13], Australian [14], and European populations [15], this relationship has not been well studied in populations of Japanese adults [16-18], especially Japanese women. The purpose of this study was to examine the associations between muscular fitness and MetS in Japanese women and men.

2. METHODS

2.1. Subjects

The subjects were 335 women and 209 men, aged 30 -

79 y, who underwent a baseline preventive medical examination and physical fitness tests between 2006 and 2010 and were recruited to participate in a training program for health promotion at Fujisawa City Health and Medical Center. All subjects provided written informed consent before enrollment in the study. This study was approved by the Ethics Committee of Waseda University and conducted in accordance with the spirit of the Declaration of Helsinki.

2.2. Clinical Examination

All subjects received preventive medical examinations at the medical institution in Fujisawa City The exam included a measurement of height, body weight, waist circumference (WC), blood chemistry analyses (triglycerides, TG; high-density lipoprotein, HDL-c; fasting blood glucose, FPG), and resting blood pressure (BP; systolic blood pressure, SBP; diastolic blood presser, DBP). Body mass index (BMI) was calculated as body weight (kg) divided by height squared (m^2), and WC was measured at the umbilicus with subjects in the standing position.

2.3. Criteria for MetS

MetS was defined as meeting 3 or more of the following criteria [19]: abdominal obesity (WC ≥ 80 cm in women, WC ≥ 90 cm in men); high TG (≥150 mg/dL or taking medicine to lower TG); low HDL-c (<50 mg/dL in women, <40 mg/dL in men); high BP (SBP ≥ 130 mmHg or DBP ≥ 85 mmHg, or taking medicine to lower BP); and high FPG (≥100 mg/dL or taking medicine to lower FPG).

2.4. Muscular Fitness

Grip strength test, used as a proxy for overall strength [20], was assessed using a handgrip dynamometer (ED-D100PNR, Yagami, Nagoya, Japan) [21]. The subject stood with the arm completely extended and squeezed the dynamometer with maximum isometric effort. Grip strength was measured twice on each side. The best of the 4 grip measurements was use to characterize maximum muscle strength. To account for differences in body size, total handgrip was adjusted for body weight (kg).

Abdominal muscle endurance was evaluated by a sit-up test [21]. The subject started in a lying position with hands crossed over the chest, knees bent at a 90˚ angle, and heels and feet flat on the floor. The subject had to rise to a position with the elbows pointed forward until they touched the thighs. The total number of correctly performed and completed sit-ups within 30 s was counted.

Muscular fitness was evaluated by muscular fitness composite score (MFS), which was determined using Z scores from grip strength and sit-ups.

2.5. Confounding Variables

Several confounding variables were included in the analyses: age (y), smoking status (current, former, never), daily alcohol intake (g/day), and exercise habits (never, once/wk, 2 - 3 times/wk, 4 - 5 times/wk, 6 - 7 times/wk). These variables were assessed by means of a questionnaire.

2.6. Statistical Analysis

Measured and calculated values are presented as mean ± SD or number (%). Participants were classified by MFS tertile into low, middle, and high MFS groups. Analysis of variance was used for continuous variables with a normal distribution, the Kruskal-Wallis test was used for continuous variables with a non-normal distribution, and the chi-square test was used for categorical variables. The association of muscular fitness with the risk of having MetS was estimated using multiple logistic regression analysis adjusted for age (Model 1), and further adjusted for smoking status, alcohol intake, and exercise habits (Model 2). The data were analyzed with SPSS 19.0 for Windows (IBM Japan, Tokyo, Japan). The statistical significance level was set at $P < 0.05$.

3. RESULTS

Table 1 shows the characteristics of individuals according to MFS level. Women with the highest MFS demonstrated a significantly lower body weight, BMI, WC, SBP, DBP, and TG level ($P < 0.05$) and a higher Grip strength, Sit-ups, and HDL-c level ($P < 0.01$). Men with the highest MFS were significantly younger and had a lower body weight, BMI, WC, and TG level ($P < 0.05$) and higher Grip strength, Sit-ups, and HDL-c level ($P < 0.05$). Women in the highest MFS tertile, but not men, had a lower prevalence of MetS.

Adjusted odds ratios (ORs) for MetS prevalence in the low, middle, and high MFS groups, after adjusting for age, were 1.0 (referent), 0.92 (95% confidence interval [CI]: 0.51 - 1.63), and 0.53 (95% CI, 0.28 - 0.99) (*P* for trend = 0.04) in women; in men, they were 1.0 (referent), 0.48 (95% CI, 0.23 - 1.01), and 0.42 (95% CI, 0.19 - 0.90) (*P* for trend = 0.02), respectively (**Figure 1**, Model 1). In addition, after further adjusting for smoking status, alcohol intake, and exercise habits, adjusted ORs were 1.0 (referent), 0.90 (95% CI, 0.50 - 1.62), and 0.49 (95% CI, 0.25 - 0.94) (*P* for trend = 0.03) in women; in men, they were 1.0 (referent), 0.49 (95% CI, 0.23 - 1.04), and 0.42 (95% CI, 0.18 - 0.97) (*P* for trend = 0.04), respectively (**Figure 1**, Model 2).

Table 2 shows age-adjusted and multivariate-adjusted ORs. In women, MFS was inversely associated with HDL-c and WC. Age-adjusted ORs for the highest versus lowest tertiles were 0.17 (95% CI, 0.05 - 0.60; *P* for

Table 1. The characteristics of individuals across MFS tertiles.

	Women (n = 335)			
	Low (n = 111)	Middle (n = 112)	High (n = 112)	
Age (y)	60.5 ± 8.8	60.6 ± 7.2	58.8 ± 7.1	
Height (cm)	155.3 ± 5.1	155.1 ± 5.1	156.2 ± 4.5	
Body weight (kg)	58.5 ± 8.2	54.6 ± 6.5	51.8 ± 5.6	**
BMI (kg/m^2)	24.3 ± 3.1	22.7 ± 2.5	21.2 ± 2.1	**
WC (cm)	86.1 ± 8.8	81.5 ± 7.7	77.4 ± 7.2	**
SBP (mmHg)	126.2 ± 14.4	127.2 ± 16.7	121.9 ± 17.2	*
DBP (mmHg)	76.6 ± 9.4	77.6 ± 11.2	74.0 ± 10.8	*
HDL-c (mg/dL)	63.6 ± 14.3	68.7 ± 16.1	74.6 ± 17.4	**
TG (mg/dL)	113.4 ± 68.9	112.6 ± 62.7	90.5 ± 48.7	**
FPG (mg/dL)	96.3 ± 13.7	93.2 ± 8.3	94.7 ± 14.7	
Grip strength (kg/BW)	0.41 ± 0.06	0.47 ± 0.05	0.57 ± 0.07	**
Sit-ups (times/30s)	7.7 ± 4.5	13.3 ± 3.2	17.4 ± 3.5	**
Prevalence of metabolic syndrome	36 (39.6)	34 (37.4)	21 (23.1)	*
Alcohol intake (g/day)	1.1 ± 2.5	1.4 ± 2.6	1.1 ± 2.2	
Smoking status				
Current	1 (16.7)	4 (66.7)	1 (16.7)	
Former	14 (37.8)	7 (18.9)	16 (43.2)	
Never	96 (32.9)	101 (34.6)	95 (32.5)	
Exercise habits (times/wk)				**
6 - 7	4 (25.0)	4 (25.0)	8 (50.0)	
4 - 5	6 (24.0)	11 (44.0)	8 (32.0)	
2 - 3	31 (26.5)	39 (33.3)	47 (40.2)	
1	33 (30.0)	39 (35.5)	38 (34.5)	
0	37 (55.2)	19 (28.4)	11 (16.4)	
	Men (n = 209)			
	Low (n = 69)	Middle (n = 70)	High (n = 70)	
Age (y)	66.6 ± 7.4	65.5 ± 6.9	62.7 ± 9.6	*
Height (cm)	167.3 ± 5.7	166.9 ± 5.9	165.8 ± 4.8	
Body weight (kg)	69.6 ± 10.0	67.5 ± 6.6	63.8 ± 8.5	**
BMI (kg/m^2)	24.9 ± 3.3	24.2 ± 1.9	23.2 ± 2.5	**
WC (cm)	88.4 ± 7.8	86.8 ± 5.6	81.5 ± 7.0	**
SBP (mmHg)	130.3 ± 17.1	132.0 ± 16.6	129.6 ± 15.4	
DBP (mmHg)	80.4 ± 10.6	80.5 ± 9.6	78.8 ± 11.6	
HDL-c (mg/dL)	54.8 ± 13.8	58.9 ± 12.8	62.5 ± 17.9	*
TG (mg/dL)	155.9 ± 72.1	120.4 ± 54.8	136.3 ± 82.5	*
FPG (mg/dL)	102.7 ± 16.9	98.2 ± 15.6	99.5 ± 13.3	
Grip strength (kg/BW)	0.50 ± 0.07	0.59 ± 0.06	0.69 ± 0.08	**
Sit-ups (times/30s)	11.9 ± 3.7	16.6 ± 2.7	21.2 ± 4.3	**
Prevalence of metabolic syndrome	26 (45.6)	16 (28.1)	15 (26.3)	
Alcohol intake (g/day)	4.9 ± 6.6	6.2 ± 5.6	5.5 ± 4.8	
Smoking status				
Current	12 (40.0)	10 (33.3)	8 (26.7)	
Former	39 (31.5)	45 (36.3)	40 (32.3)	
Never	18 (32.7)	15 (27.3)	22 (40.0)	
Exercise habits (times/wk)				**
6 - 7	1 (7.7)	3 (23.1)	9 (69.2)	
4 - 5	10 (23.8)	15 (35.7)	17 (40.5)	
2 - 3	19 (33.3)	20 (35.1)	18 (31.6)	
1	17 (29.8)	17 (29.8)	23 (40.4)	
0	22 (55.0)	15 (37.5)	3 (7.5)	

Data are mean ± SD or number (%). $^*P < 0.05$; $^{**}P < 0.01$; BMI: body mass index; WC: waist circumference; SBP: systolic blood pressure; DBP: diastolic blood pressure; HDL-c: high-density lipoprotein cholesterol; TG: triglyceride; FPG: fasting plasma glucose; BW: body weight.

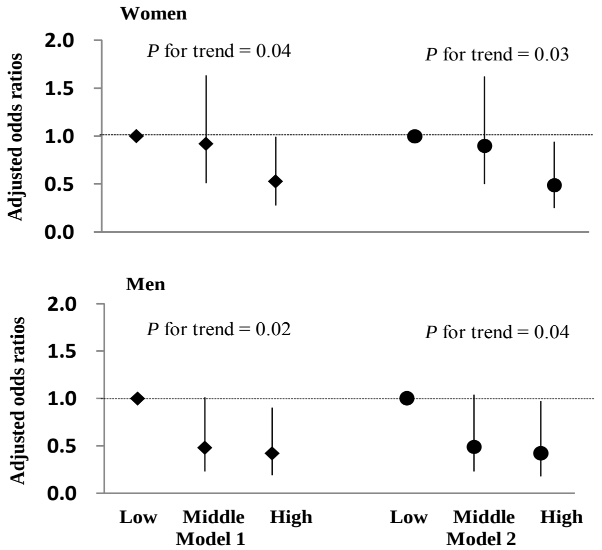

Figure 1. Adjusted odds ratios (ORs) for MetS prevalence in the low, middle, and high muscular fitness composite score (MFS) groups. Results are adjusted for age (Model 1), and additionally adjusted for smoking status, alcohol intake, and exercise habits (Model 2). Vertical bars indicate 95% CIs. Low: Low MFS; Middle: Middle MFS; High: High MFS.

trend < 0.01) for HDL-c and 0.18 (95% CI, 0.10 - 0.32; *P* for trend < 0.001) for WC; multivariate-adjusted ORs for the highest versus lowest tertiles were 0.15 (95% CI, 0.04 - 0.55; *P* for trend < 0.01) for HDL-c and 0.17 (95% CI, 0.09 - 0.32; *P* for trend < 0.001) for WC. In men, MFS was inversely associated with TG and WC: age-adjusted ORs for the highest versus lowest tertiles were 0.39 (95% CI, 0.19 - 0.79; *P* for trend < 0.01) for TG and 0.06 (95% CI, 0.02 - 0.22; *P* for trend < 0.001) for WC. However, the MFS-TG relationship was attenuated after further adjustment for smoking status, alcohol intake, and exercise habits; multivariate-adjusted ORs for the highest versus lowest tertiles were 0.54 (95% CI, 0.25 - 1.14; *P* for trend < 0.09) for TG and 0.07 (95% CI, 0.02 - 0.25; *P* for trend < 0.001) for WC.

4. DISCUSSION

In this cross-sectional study, we examined the association between MFS levels and the prevalence of MetS and MetS risk factors in Japanese women and men. The primary findings of this study were that 1) low MFS levels were associated with greater risk of incident MetS

Table 2. Adjusted odds ratios (95% CIs) for MetS risk factors across MFS tertiles.

	Women (n = 335)					
	Low (n = 111)	Middle (n = 112)		High (n = 112)		
		ORs	95%Cl	ORs	95%Cl	*P* for trend
BP						
Model 1	1.00	0.98	(0.57 - 1.67)	0.61	(0.36 - 1.05)	0.07
Model 2	1.00	0.94	(0.54 - 1.62)	0.58	(0.33 - 1.02)	0.06
HDL-c						
Model 1	1.00	0.85	(0.38 - 1.90)	0.17	(0.05 - 0.60)	<0.01
Model 2	1.00	0.84	(0.37 - 1.88)	0.15	(0.04 - 0.55)	<0.01
TG						
Model 1	1.00	1.26	(0.72 - 2.20)	0.86	(0.48 - 1.54)	0.60
Model 2	1.00	1.30	(0.74 - 2.30)	0.87	(0.48 - 1.59)	0.62
FPG						
Model 1	1.00	0.46	(0.24 - 0.87)	0.62	(0.33 - 1.15)	0.10
Model 2	1.00	0.44	(0.23 - 0.84)	0.56	(0.30 - 1.06)	0.06
WC						
Model 1	1.00	0.38	(0.21 - 0.68)	0.18	(0.10 - 0.32)	<0.001
Model 2	1.00	0.37	(0.21 - 0.68)	0.17	(0.09 - 0.32)	<0.001
	Men (n = 209)					
	Low (n = 69)	Middle (n = 70)		High (n = 70)		
		ORs	95%Cl	ORs	95%Cl	*P* for trend
BP						
Model 1	1.00	1.50	(0.74 - 3.04)	1.16	(0.57 - 2.33)	0.68
Model 2	1.00	1.28	(0.62 - 2.65)	0.84	(0.39 - 1.81)	0.70
HDL-c						
Model 1	1.00	0.98	(0.27 - 3.57)	0.98	(0.26 - 3.64)	0.98
Model 2	1.00	1.27	(0.33 - 4.87)	0.90	(0.21 - 3.79)	0.80
TG						
Model 1	1.00	0.27	(0.13 - 0.54)	0.39	(0.19 - 0.79)	0.01
Model 2	1.00	0.30	(0.15 - 0.62)	0.54	(0.25 - 1.14)	0.09
FPG						
Model 1	1.00	0.36	(0.18 - 0.74)	0.68	(0.34 - 1.34)	0.24
Model 2	1.00	0.36	(0.17 - 0.74)	0.73	(0.35 - 1.54)	0.38
WC						
Model 1	1.00	0.69	(0.34 - 1.43)	0.06	(0.02 - 0.22)	<0.001
Model 2	1.00	0.72	(0.34 - 1.51)	0.07	(0.02 - 0.25)	<0.001

Model 1 is adjusted for age; Model 2 is adjusted for age, smoking status, alcohol intake, and exercise habits; BP: blood pressure; HDL-c: high-density lipoprotein cholesterol; TG: triglyceride; FPG: fasting plasma glucose; WC: waist circumference.

in women and men; and 2) low MFS levels were associated with higher prevalence of several MetS risk factors after adjustment for age, smoking status, alcohol intake, and exercise habits.

The inverse association between muscle strength and the prevalence of MetS found in the present study is consistent with the results of previous investigations [12-14]. Jurca *et al.* reported this association in adult men using a study of cross-sectional design. They found that muscle strength (measured by one repetition maximal leg press and bench press) was associated with a significantly lower risk of developing MetS in men [12]. Further longitudinal analyses in adult men obtained comparable results [13]. In addition, Atlantis *et al.* reported an inverse association between muscle strength (handgrip strength per lean mass of the arm) and the prevalence of MetS in men [14]. The present study has extended the previous results by revealing inverse associations between MFS and the prevalence of MetS in both women and men.

By contrast, other previous studies have reported a relationship between muscle strength and MetS risk factors [15,22]. Wijndaele *et al.* reported that muscular strength assessed by measuring isometric knee extension and flexion peak torque was associated with the MetS risk factors of TG, HDL-c, and clustered MetS risk factors in women, and associated with clustered MetS risk factors in men [15]. Aoyama *et al.* examined the relationship between grip strength and individual and clustered MetS risk factors in Japanese men and women and found that grip strength was inversely associated with plasma glucose levels and clustered MetS risk factors in women [18]. Similar to previous studies, MFS was also associated with lipid profiles and WC in this study.

Although their results are not directly comparable with ours, Katzmarzyk *et al.* found a significant inverse relationship between musculoskeletal fitness composite score (calculated from the scores for sit-ups, push-ups, grip strength, and trunk flexibility) and all-cause mortality [22] and the incidence of type 2 diabetes among a Canadian population [23]. In addition, Sawada *et al.* observed a significant inverse relationship between muscular and performance fitness index composite scores (summed Z scores of sit-ups, side step, and functional reach) and the incidence of type 2 diabetes in Japanese men [24]. In their previous study, a significant inverse relationship was observed between muscular fitness and all-cause mortality and type 2 diabetes. These results suggest that maintaining a high level of MFS may prevent the development of MetS and reduce the risk of type 2 diabetes and mortality.

Strength training may lower MetS risk, including improvement in TG and HDL-c [25], BP [26], central adiposity and body composition [27], and whole-body insulin action and glucose uptake [28,29]. The metabolic effects of reduced muscle mass secondary to aging, decreased physical activity, or both contribute to the presence of obesity, insulin resistance, type 2 diabetes, dyslipidemia, and hypertension [30]. Skeletal muscle, the primary tissue for glucose and triglyceride metabolism, is a determinant of resting metabolic rate, and changes in muscle mass may reduce multiple CVD risk factors [31]. Therefore, with the maintenance of high muscle strength, such as that achieved by resistance training, may prove effective for the prevention and treatment of MetS.

This study has some limitations. First, the causality of relationships cannot be determined due to its cross-sectional design. Longitudinal or interventional studies are required to demonstrate this association further. Second, our sample size is small. In order to better clarify these relationships, future research should be done to increase the sample size.

In conclusion, this study suggests that muscular fitness is inversely associated with MetS in Japanese women and men aged 30 - 79 y. This finding may indicate a protective effect of muscular fitness on MetS. Furthermore, muscle fitness was associated with a better profile for several risk factors of MetS.

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