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Original Article

Increasing Leg Strength per Body Weight is Associated with Improvements in Metabolic Syndrome in Japanese Men

Nobuyuki Miyatake [1)], Motohiko Miyachi [2)], Takeyuki Numata [1)]

1) Okayama Southern Institute of Health, Okayama 700-0952, Japan
2) National Institute of Health and Nutrition, Shinjuku, Tokyo, 162-8636, Japan

Abstract

Objectives: The link between changes in leg strength per body weight and metabolic syndrome was evaluated in Japanese men with a 1-year follow up.

Subjects and Methods: We used data for 136 Japanese men (45.5 ± 8.5 years) with a 1-year follow up. All subjects were given instructions by well-trained medical staff on how to change their lifestyle. Metabolic syndrome has been defined by a new criterion in Japan. The association between changes in leg strength per body weight and metabolic syndrome was evaluated.

Results: With a 1-year follow up, body weight, abdominal circumference, systolic blood pressure, diastolic blood pressure and triglyceride were significantly reduced. Leg strength and leg strength per body weight and HDL cholesterol were significantly increased. The prevalence of metabolic syndrome was significantly reduced. There was significant relationship between changes in metabolic syndrome and changes in leg strength per body weight. The prevalence of metabolic syndrome was significantly reduced in subjects with an increase in leg strength per body weight (Group I) compared to subjects without such an increase (Group D). In addition, there were remarkable differences in delta abdominal circumference (delta represents positive changes in parameters) between Group I and Group D.

Conclusion: An increase in leg strength per body weight may be associated with improving metabolic syndrome and abdominal circumference in Japanese men.

KEY WORDS: metabolic syndrome, muscle strength, leg strength

Introduction

Metabolic syndrome, characterized by abdominal obesity has become a common disorder in Japan [1)]. We have preciously reported that, using the new criterion developed in Japan [2)], 30.7% of men and 3.6% of women have been diagnosed as having metabolic syndrome. Subjects with metabolic syndrome have an increased risk of cardiovascular disease [3)], elevation of hepatic enzymes [4)], and proteinuria [5)]. Lifestyle modifications, especially exercise, are considered to be critical for preventing and improving metabolic syndrome.

Aerobic exercise is generally accepted as a useful method for improving metabolic syndrome [6-8)] and we have also reported that lower aerobic exercise levels were characteristic in subjects with metabolic syndrome [9)]. In addition, lower levels of muscle strength are also associated with metabolic syndrome [10,11)]. We have solely reported in a cross-sectional study that lower levels of leg strength per body weight were characteristic in subjects with metabolic syndrome [12)]. However, whether an increase in leg strength per body weight is beneficial for improving metabolic syndrome, and what effects this will have on metabolic syndrome remains to be investigated in a longitudinal study.

In this study, we evaluate the link between increases in leg strength per body weight and metabolic syndrome in Japanese men with a 1-year follow up.

Subjects and Methods

Subjects

We used data for 136 Japanese men, aged 45.5±8.5 years, retrospectively from a database of 14,345 subjects who met the following criteria: (1) received an annual health check-up at baseline from June 1997 to March 2006, (2) received an annual health check-up every year with a follow up duration of 1-year, (3) received anthropometric and leg strength measurements, a fasting blood examination and blood pressure measurements as part of the annual health check-up, (4) received no medications for diabetes, hypertension, and/or dyslipidemia, and (5) provided written informed consent (***Table 1***).

At the first annual health check-up, all subjects were given instructions by well-trained medical staff on how to change their lifestyle according to the results. *i.e.* not to eat too much, consider balance when they eat and increase their daily steps.

Ethical approval for the study was obtained from the Ethical Committee of Okayama Health Foundation.

Nobuyuki Miyatake,
Okayama Southern Institute of Health, 408-1 Hirata, Okayama, 700-0952, Japan.
Tel: +81-86-246-6250 / Fax: +81-86-246-6330 / E-mail: center@okakenko.jp

Table 1 Clinical profiles and changes in parameters with 1-year follow up

	Baseline	Follow up	*p*
Number of subjects	136		
Height (cm)	169.0 ± 5.3		
Body weight (kg)	75.2 ± 11.3	73.8 ± 10.7	**<0.0001**
Abdominal circumference (cm)	88.2 ± 9.7	86.3 ± 9.1	**<0.0001**
Leg strength (kg)	69.6 ± 15.7	72.3 ± 15.0	**0.0100**
Leg strength per body weight	0.93 ± 0.21	0.99 ± 0.20	**<0.0001**
Systolic blood pressure (mmHg)	130.9 ± 14.5	124.0 ± 13.0	**<0.0001**
Diastolic blood pressure (mmHg)	82.2 ± 11.5	77.5 ± 9.6	**<0.0001**
Triglyceride (mg/dl)	152.8 ± 105.7	122.6 ± 78.0	**0.0005**
HDL cholesterol (mg/dl)	53.2 ± 14.3	55.3 ± 14.4	**0.0189**
Blood sugar (mg/dl)	103.1 ± 20.1	103.8 ± 27.2	0.6069

Mean ± SD

Anthropometric and body composition measurements

Anthropometric and body compositions were evaluated based on the following parameters: height, body weight and abdominal circumference. Body mass index (BMI) was calculated by weight / [height]^2 (kg/m^2). Abdominal circumference was measured at the umbilical level in standing subjects after normal expiration[1].

Blood pressure measurements at rest

Resting systolic and diastolic blood pressure were measured indirectly using a mercury sphygmomanometer placed on the right arm of the seated participant after at least 15 minutes of rest.

Blood sampling assays

Overnight fasting serum levels of high density lipoprotein (HDL) cholesterol, triglycerides (L Type Wako Triglyceride・H, Wako Chemical, Osaka) and plasma glucose were measured.

Definition of metabolic syndrome

Men with a waist circumference in excess of 85 cm were defined as having metabolic syndrome if they also had two or more of the following components: 1) Dyslipidemia: triglycerides ≥ 150 mg/dl and/or HDL cholesterol < 40 mg/dl, 2) High blood pressure: blood pressure ≥ 130/85 mmHg, 3) Impaired glucose tolerance: fasting plasma glucose ≥ 110 mg/dl[1].

Measurement of muscle strength

To assess muscle strength, leg strength was measured. Leg strength was measured using a COMBIT CB-1 dynamometer (MINATO, Osaka, Japan). Isometric leg strength was measured as follows: the subject sat in a chair, grasping the armrest in order to fix the body position. The dynamometer was then attached to the subject's ankle joint by a strap, and they extended the leg to 60 degrees[13]. In addition, to standardize the influence of total body weight, we calculated muscle strength (kg) per body weight (kg)[14], the level of which "over 1.0" is recommended for daily activity[13].

Statistical analysis

All data are expressed as mean ± standard deviation (SD) values. A statistical analysis was performed using a paired *t* test, an unpaired *t* test, χ^2 test, one-factor ANOVA and logistic regression analysis: $p<0.05$ was considered to be statistically significant. Pearson's correlation coefficients were calculated and used to test the significance of the linear relationship among continuous variables.

Results

The clinical parameters at the baseline and the 1-year follow up are summarized in ***Table 1***. Leg strength and leg strength per body weight significantly increased after one year. Body weight, abdominal circumference, systolic blood pressure, diastolic blood pressure and triglyceride levels were significantly reduced. HDL cholesterol was significantly increased. The prevalence of metabolic syndrome was also significantly reduced even after adjusting for age (Baseline: 41 men, Follow up: 28 men) (***Table 2***). We evaluated the relationship between changes in metabolic syndrome and changes in muscle strength. There were significant differences in delta (delta represents positive changes in parameters) leg strength per body weight among the four groups. However, there were no significant differences in leg strength among the four groups by one-factor ANOVA analysis (***Table 3***).

Table 2 Changes in the prevalence of metabolic syndrome

Metabolic syndrome (Baseline)	Metabolic syndrome (Follow up) (−)	(+)	*p*	After adjusting for age *p*
(−)	89	6	**<0.0001**	**<0.0001**
(+)	19	22		

Table 3 Relationship between changes in metabolic syndrome and changes in muscle strength

	Metabolic syndrome (−)→(+)	(−)→(+)	(+)→(−)	(+)→(+)	*p*
Number of subjects	89	6	19	22	
Delta leg strength (kg)	1.2 ± 11.3	1.6 ± 10.9	5.8 ± 12.5	6.6 ± 13.9	0.1666
Delta leg strength per body weight	0.03 ± 0.15	0.01 ± 0.12	0.14 ± 0.17	0.10 ± 0.15	**0.0272**

Eighty one men increased their leg strength per body weight by the time of the 1-year follow up. We investigated the changes in the prevalence of metabolic syndrome amongst men who had different levels of increased leg strength per body weight [Group I: Delta leg strength per body weight > 0, Group D: Delta leg strength per body weight ≤ 0](***Table 4***). The prevalence of subjects with metabolic syndrome at baseline and without metabolic syndrome at follow up was higher (15 men, 18.5%) in Group I than those in Group D (4 men, 7.3%) (p=0.0433).

Table 4 Relationship between changes in leg strength per body weight and metabolic syndrome

Metabolic syndrome Baseline	Follow up	Leg strength per body weight Group I	%	Group D	%	*p*	After adjusting for age *p*
(−)	(−)	48	59.3	41	74.5		
(−)	(+)	2	2.5	4	7.3		
(+)	(−)	15	18.5	4	7.3	0.0593	**0.0433**
(+)	(+)	16	19.8	6	10.9		
Total		81	100.0	55	100.0		

Group I : Delta leg strength per body weight > 0
Group D : Delta leg strength per body weight ≤ 0

Seventy four men increased their leg strength by the time of the 1-year follow up. We investigated the changes in the prevalence of metabolic syndrome amongst men who had different levels of increased leg strength [Group IL: Delta leg strength > 0 kg, Group DL: Delta leg strength ≤ 0 kg](***Table 5***). The prevalence of subjects with metabolic syndrome at baseline and without metabolic syndrome at follow up in Group IL was similar to those in Group DL (p=0.3357).

Table 5 Relationship between changes in leg strength and metabolic syndrome

Metabolic syndrome Baseline	Follow up	Leg strength Group IL	%	Group DL	%	p	After adjusting for age p
(−)	(−)	44	59.5	45	72.6		
(−)	(+)	3	4.1	3	4.8		
(+)	(−)	12	16.2	7	11.3	0.3615	**0.3357**
(+)	(+)	15	20.3	7	11.3		
Total		74	100.0	62	100.0		

Group IL : Delta leg strength > 0kg
Group DL : Delta leg strength ≤ 0kg

We further compared parameters at baseline and changes in each parameter at baseline and follow up between Group I and Group D (**Table 6**). At baseline, significant differences were noted in leg strength and leg strength per body weight. After 1-year follow up, there were also significant differences in delta leg strength and delta abdominal circumference between the two groups. However, other delta parameters in Group I were similar to those in Group D.

Table 6 Comparison of Clinical parameters at baseline and changes in parameters with 1-year follow up

	Group I	Group D	p
Number of subjects	81	55	
Age	46.2 ± 8.5	44.5 ± 8.5	0.2682
Abdominal circumference (cm)	88.1 ± 10.3	88.4 ± 8.8	0.8279
Leg strength (kg)	65.7 ± 16.6	75.3 ± 12.4	**0.0004**
Leg strength per body weight	0.89 ± 0.22	1.00 ± 0.18	**0.0029**
Systolic blood pressure (mmHg)	130.4 ± 15.9	131.5 ± 12.2	0.6683
Diastolic blood pressure (mmHg)	81.7 ± 12.5	83.0 ± 9.9	0.5338
Triglyceride (mg/dl)	151.4 ± 101.4	154.7 ± 112.8	0.8595
HDL cholesterol (mg/dl)	55.1 ± 14.7	50.5 ± 13.2	0.0655
Blood sugar (mg/dl)	101.7 ± 14.9	105.0 ± 26.0	0.3499
Delta leg strength (kg)	9.8 ± 9.4	−7.7 ± 6.6	**<0.0001**
Delta leg strength per body weight	0.15 ± 0.12	−0.09 ± 0.08	
Delta abdominal circumference (cm)	−2.6 ± 5.3	−0.9 ± 3.8	**0.0413**
Delta systolic blood pressure (mmHg)	−6.7 ± 13.8	−7.0 ± 11.7	0.9179
Delta diastolic blood pressure (mmHg)	−4.3 ± 11.1	−5.3 ± 10.6	0.6113
Delta triglyceride (mg/dl)	−34.0 ± 95.4	−24.5 ± 102.8	0.5801
Delta HDL cholesterol (mg/dl)	2.0 ± 10.8	2.1 ± 8.8	0.9172
Delta blood sugar (mg/dl)	1.9 ± 20.3	−0.8 ± 12.2	0.3833

Mean ± SD
Group I : Delta leg strength per body weight > 0
Group D : Delta leg strength per body weight ≤ 0

Finally, we evaluated the relationship between delta leg strength per body weight and each delta parameter of metabolic syndrome by a simple correlation analysis. Leg strength per body weight was weakly correlated with delta abdominal circumference (r=−0.239, p=0.0051) (**Table 7**).

Table 7 Simple correlation analysis between changes in (delta) leg strength per body weight

	r	p
Delta abdominal circumference (cm)	−0.239	**0.0051**
Delta systolic blood pressure (mmHg)	−0.005	0.9513
Delta diastolic blood pressure (mmHg)	−0.018	0.8331
Delta triglyceride (mg/dl)	−0.133	0.1223
Delta HDL cholesterol (mg/dl)	0.105	0.2233
Delta blood sugar (mg/dl)	0.123	0.1548

Discussion

We explored, using the Japanese criterion, whether an increase in leg strength per body weight can improve metabolic syndrome and its components in Japanese men.

In addition to aerobic exercise[6-8], some cross sectional studies show that metabolic syndrome is inversely associated with muscle strength[10,15]. Jurca *et al*. have reported examining the associations for muscle strength and cardiorespiratory fitness with the prevalence of metabolic syndrome by cross sectional study[10]. They concluded that muscle strength has an inverse association with metabolic syndrome prevalence using the National Cholesterol Education Program (NCEP) definition. Benson *et al*. have also reported that they evaluated 126 children and adolescents, and upper body strength and abdominal circumference were the only independent predictors of insulin resistance[15]. We also previously showed that lower leg strength per body weight was characteristic in Japanese men with metabolic syndrome[12]. It seems difficult for subjects with lower leg strength per body weight to support their entire body's weight; it seems also difficult for subjects with lower leg strength per body weight to carry out aerobic exercise *i.e*. walking and jogging. It is reasonable to suggest that simply moving from a lower to a higher leg strength per body weight might result in the amelioration of metabolic syndrome in some Japanese men. However, these were cross sectional studies and the hypothesis that metabolic syndrome may be associated with lower leg strength per body weight cannot be accurately proven.

In turn, few longitudinal studies have been carried out to prove a link between metabolic syndrome and muscle strength. Jurca *et al*. concluded that muscle strength has an inverse association with metabolic syndrome, but the association was attenuated when further adjusted for cardiorespiratory fitness[11]. In the present study, using the criterion developed in Japan, increasing leg strength per body weight was associated with improvement of metabolic syndrome in Japanese men with a 1-year follow up. In addition, a clinical impact on abdominal circumference was also noted. These findings suggest that, in subjects with metabolic syndrome, a low level of leg strength per body weight seems to accelerate metabolic syndrome. Holten *et al*. reported that strength training for the legs increases insulin-mediated glucose uptake and insulin receptors[16]. Although aerobic exercise has been advocated as most suitable to decrease metabolic syndrome[6-8,17], a combination of aerobic exercise and resistance training might be considered for preventing and improving metabolic syndrome. It is especially important for metabolic syndrome patients to maintain or maximize the muscle strength of their lower limbs as well as to carry out aerobic exercise.

Potential limitations still remain in this study. First, the 14,345 subjects in our study voluntarily underwent the annual health check-up; they were, therefore, probably more health-conscious than the average person. The selected 136 subjects underwent an annual health check-up every year with a follow-up duration of 1-year and received no medication; they were, therefore, probably even more health-conscious than most of the subjects in the database, and the small sample size makes it difficult to infer association between increasing leg strength per body weight and decreasing metabolic syndrome. Second, leg strength and leg strength per body weight were significantly lower in subjects in Group I than those subjects in Group D at baseline.

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