Table 2 Muscle strength as classified by age group

	Men				Women			
	Mean ± SD	Minimum	Maximum	Median	Mean ± SD	Minimum	Maximum	Median
Grip strength (right) (kg)								
20-29	46.8 ± 7.6	11.7	74.1	46.5	26.8 ± 5.2	10.3	77.6	26.7
30-39	46.6 ± 7.3	22.7	73.3	46.1	27.4 ± 4.9[a]	4.7	46.4	27.3
40-49	46.0 ± 7.5	9.8	71.6	45.4	27.7 ± 5.1[a]	6.1	52.2	27.6
50-59	42.9 ± 7.2[abc]	13.6	65.2	42.8	24.5 ± 4.8[abc]	5.3	38.6	24.5
60-69	38.2 ± 6.5[abcd]	8.7	53.7	38.7	23.0 ± 4.6[abcd]	11.8	39.9	22.8
Total	45.3 ± 7.8	8.7	74.1	45.1	26.4 ± 5.2	4.7	77.6	26.4
Grip strength (left) (kg)								
20-29	44.2 ± 7.4	11.9	68.9	43.5	25.3 ± 4.7	8.4	45.2	25.0
30-39	44.4 ± 7.1	15.4	71.3	44.2	26.1 ± 4.8[a]	8.8	44.0	25.9
40-49	44.0 ± 7.1	20.5	69.3	43.6	26.4 ± 4.8[a]	4.0	48.5	26.5
50-59	41.0 ± 6.6[abc]	14.5	59.4	41.4	23.6 ± 4.6[abc]	3.3	39.4	23.4
60-69	36.7 ± 6.4[abcd]	17.5	55.7	36.8	22.0 ± 4.3[abcd]	11.0	38.9	21.7
Total	43.1 ± 7.4	11.9	71.3	43.0	25.2 ± 4.9	3.3	48.5	25.1
Leg strength (kg)								
20-29	72.3 ± 16.7	32.1	152.0	71.0	43.3 ± 9.9	9.0	93.9	42.6
30-39	71.4 ± 16.9	31.0	161.4	69.4	43.4 ± 9.8	13.5	85.9	42.7
40-49	68.4 ± 15.5[ab]	27.0	124.4	67.3	43.4 ± 9.7	10.5	82.2	43.0
50-59	61.9 ± 14.4[abc]	27.2	109.6	62.4	40.1 ± 9.1[abc]	10.1	79.8	39.9
60-69	54.9 ± 12.5[abcd]	26.3	92.0	54.0	36.6 ± 8.3[abcd]	11.0	65.2	36.1
Total	68.1 ± 16.8	26.3	161.4	67.1	42.3 ± 9.8	9.0	93.9	41.8
Leg strength per body weight								
20-29	1.05 ± 0.22	0.48	1.80	1.04	0.83 ± 0.17	0.21	1.59	0.82
30-39	1.00 ± 0.22[a]	0.50	1.75	0.99	0.81 ± 0.18	0.28	1.55	0.80
40-49	0.96 ± 0.20[ab]	0.41	1.67	0.96	0.77 ± 0.17[ab]	0.23	1.60	0.77
50-59	0.90 ± 0.19[abc]	0.34	1.58	0.89	0.72 ± 0.16[abc]	0.23	1.45	0.71
60-69	0.84 ± 0.19[abcd]	0.42	1.49	0.83	0.68 ± 0.16[abcd]	0.21	1.23	0.67
Total	0.98 ± 0.22	0.34	1.80	0.97	0.78 ± 0.18	0.21	1.60	0.77

[a]$p<0.05$ vs age 20-29, [b]$p<0.05$ vs age 30-39, [c]$p<0.05$ vs age 40-49, [d]$p<0.05$ vs age 50-59.

Table 3 Prevalence of subjects with exercise habits in Japanese

	Exercise habits (+)		Exercise habits (−)	
Age	Number of subjects	%	Number of subjects	%
Men				
20-29	240	29.4	577	70.6
30-39	254	28.0	652	72.0
40-49	235	36.1	416	63.9
50-59	157	35.3	288	64.7
60-69	98	49.2	101	50.8
Total	984	32.6	2,034	67.4
Women				
20-29	341	16.7	1,705	83.3
30-39	297	17.7	1,381	82.3
40-49	373	25.0	1,122	75.1
50-59	395	34.4	752	65.6
60-69	258	50.1	257	49.9
Total	1,664	24.2	5,217	75.8

jects with and without exercise habits as classified by age group (Table 4). In men, right grip strength under the age of 50, left grip strength in 20's, leg strength under the age of 40 and the ratio of leg strength to body weight under the age of 50 were significantly higher in subjects with exercise habits than in those without. In women, right grip strength under the age of 40, left grip strength in 20's, 30's and 50's, leg strength in 20's, 30's and 50's, and the ratio of leg strength to body weight in 20's, 30's and 50's were significantly higher in subjects with exercise habits than in those without.

Discussion

In this study, we explored muscle strength and its

Table 4 Comparison of muscle strength between Japanese with and without exercise habits as classified by age group

	Men			Women		
Age	Exercise habits (+)	Exercise habits (−)	*p*	Exercise habits (+)	Exercise habits (−)	*p*
Grip strength (right) (kg)						
20-29	47.9 ± 7.9	46.3 ± 7.4	0.0082	27.8 ± 5.2	26.6 ± 5.2	0.0003
30-39	47.5 ± 7.4	46.3 ± 7.2	0.0300	28.1 ± 5.1	27.3 ± 4.9	0.0094
40-49	46.9 ± 7.3	45.4 ± 7.5	0.0156	28.1 ± 5.3	27.5 ± 5.0	0.0590
50-59	43.4 ± 7.2	42.7 ± 7.3	0.4444	24.9 ± 4.9	24.3 ± 4.7	0.0602
60-69	37.8 ± 6.4	38.6 ± 6.6	0.3840	23.0 ± 4.7	23.0 ± 4.5	0.9198
Grip strength (left) (kg)						
20-29	45.2 ± 7.1	43.8 ± 7.4	0.0146	25.9 ± 4.9	25.1 ± 4.6	0.0103
30-39	45.1 ± 7.5	44.1 ± 6.9	0.0520	26.8 ± 5.0	26.0 ± 4.7	0.0065
40-49	44.6 ± 6.8	43.6 ± 7.2	0.0833	26.7 ± 5.2	26.3 ± 4.7	0.1737
50-59	41.5 ± 7.0	40.8 ± 6.3	0.2822	24.0 ± 4.6	23.4 ± 4.5	0.0459
60-69	36.6 ± 6.2	36.8 ± 6.7	0.8076	21.9 ± 4.4	22.1 ± 4.1	0.7156
Leg strength (kg)						
20-29	75.4 ± 16.8	70.9 ± 16.4	0.0004	45.9 ± 10.3	42.8 ± 9.7	<0.0001
30-39	73.5 ± 17.4	70.5 ± 16.6	0.0155	45.0 ± 9.8	43.1 ± 9.8	0.0033
40-49	69.2 ± 15.4	67.9 ± 15.5	0.3057	44.0 ± 9.8	43.2 ± 9.7	0.1479
50-59	63.4 ± 14.4	61.1 ± 14.4	0.1101	40.9 ± 9.8	39.7 ± 8.7	0.0397
60-69	55.0 ± 11.3	54.8 ± 13.6	0.9202	37.0 ± 8.0	36.2 ± 8.6	0.3203
Leg strength per body weight						
20-29	1.09 ± 0.22	1.03 ± 0.22	0.0006	0.87 ± 0.18	0.82 ± 0.17	<0.0001
30-39	1.04 ± 0.24	0.99 ± 0.21	0.0013	0.85 ± 0.19	0.81 ± 0.18	0.0007
40-49	0.99 ± 0.20	0.95 ± 0.20	0.0206	0.79 ± 0.17	0.77 ± 0.17	0.0765
50-59	0.92 ± 0.20	0.89 ± 0.14	0.0658	0.74 ± 0.17	0.71 ± 0.15	0.0031
60-69	0.85 ± 0.20	0.82 ± 0.17	0.2406	0.68 ± 0.16	0.67 ± 0.16	0.3496

Mean ± SD

relation to exercise habits in Japanese. This information gathered should serve as a quite useful database for evaluating muscle strength in Japanese subjects.

The prevalence of subjects with exercise habit in Japan was reported to be 30.2% of men and 28.1% of women by the National Nutrition Survey in Japan. The definition of duration (3 months) in our study was shorter than in the survey definition, and we eliminated subjects who took medications. The subjects enrolled in our study undertook annual health check-ups and they might therefore be more careful of their own health than subjects in the National Nutrition Survey. However, our results by analysis of subjects without medications were comparable to those in the survey. The prevalence of exercise habits in subjects with medications is higher than that in subjects without medications in both sexes (data not shown).

It has been well reported that there is significant loss in muscle strength with aging [6, 7]. Aging is associated with alterations in body composition; there is an increase in body fat percentage and a concomitant decline in lean body mass [8]. Aging, therefore, results in substantial alterations in body composition, with a marked reduction in skeletal muscle mass. Loss of muscle strength may be an important cause of the age-related loss in bone strength resulting in osteoporosis and can also influence the ability to perform simple tasks such as sitting on a chair or visiting the toilet [9]. In frail, institutionalized men and women, muscle strength is a determinant factor for exercise capacity; *e.g.* it is highly related to habitual walking speed. Especially, leg strength is closely related to the speed of walking up stairs, the speed of standing up from a chair, and gait speed. We have previously reported that the ratio of leg strength to body weight in subjects with metabolic syndrome was significantly lower than that in subjects without the syndrome [4] and that increasing the ratio of leg strength to body weight is important in subjects with metabolic syndrome.

In this study, age-related loss of muscle strength was noted as in previous studies using a large sample of subjects not taking any medications. Grip strength was significantly decreased with age in subjects of both sexes over the age of 50. However, the ratio of leg strength to body weight was significantly decreased with age in male subjects over 30 and female subjects over 40. Age-related changes in the ratio of leg strength to body weight were noted in young adults. It seems difficult for subjects with a low ratio of leg strength to body weight to support their entire body's weight; it also seems difficult for such subjects to perform aerobic exercise *e.g.* walking and jogging.

Although muscle strength in subjects with exercise habits was significantly higher than that in subjects without exercise habits after adjusting for age, no significant differences in muscle measurements were noted over the age of 60. According to the National Nutrition Survey in Japan, the prevalence of subjects with exercise habits increases with age, while daily step counts decrease with age (http://www.mhlw.go.jp/houdou/2008/04/dl/h0430-2g.pdf accessed on Jan 20, 2009). Lower exercise intensity and shorter exercise time in elderly adults as well as the small sample size may make it difficult to infer causality between exercise habits and muscle strength in this group. However, lower and declining muscle strength has been associated with increased mortality, independent of physical activity and muscle mass [1]. Tammelin *et al.* reported that men having a heavy physical work score had higher grip strength [10]. Fujita *et al.* also reported that activity of daily living was closely linked to grip strength in community-dwelling elderly after hip fracture [11]. Taken together, it seems reasonable to suggest that simply improving muscle strength by promoting exercise habits might result in decreased mortality in some Japanese.

Further prospective investigation studies to evaluate the relationship between exercise habits and muscle strength are needed in Japanese.

Acknowledgments. This research was supported in part by Research Grants from the Ministry of Health, Labor, and Welfare, Japan.

References

1. Metter EJ, Talbot LA, Schrager M and Conwit R: Skeletal muscle strength as a predictor of all-cause mortality in healthy men. J Gerontol A Biol Sci Med Sci (20002) 57: B359-B365.
2. Rhodes EC, Martin AD, Taunton JE, Donnelly M, Warren J and Elliot J: Effect of one year of resistance training on the relation between musclar strength and bone density in elderly women. Br J Sports Med (2000) 34: 18-22.
3. Geliebter A, Mahaer MM, Gerace L, Gutin B, Heymsfield SB and Hashim SA: Effects of strength or aerobic training on body composition, resting metabolic rate, and peak oxygen consumption in obese dieting subjects. Am J Clin Nutr (1997) 66: 557-563.
4. Miyatake N, Wada J, Nishikawa H, Saito T, Takenami S, Miyachi M, Makino H and Numata T: Comparison of muscle strength between Japanese men with and without metabolic syndrome. Acta Med Okayama (2007) 66: 99-102.
5. Kigawa A, Yamamoto T, Koyama Y, Kageyama S and Arima K: Evaluation of knee extensor strength for prevention of sports injury. Japan Ortho Soc Sports Med (1987) 6: 141-145 (in Japanese).
6. Larsson L and Karlsson J: Isometric and dynamic endurance as a function of age and skeletal muscle characteristics. Acta Physiol Scand (1978) 104: 129-136.
7. Young A, Stokes M and Crowe M: Size and strength of the quadriceps muscles of old and young women. Eur J Clin Invest (1984) 14: 282-287.
8. Rogers MA and Evans WJ: Changes in skeletal muscle with aging: effects of exercise training. Exerc Sports Sci Rev (1993) 21: 65-102.
9. Rantanen T, Guralnik JM, Sakari-Rantala R, Leveille S, Simonsick EM, Ling S and Fried LP: Disability, physical activity, and muscle strength in older women: the Women's Health Aging Study. Arch Phys Med Rehabil (1999) 80: 130-135.
10. Tammelin T, Nayha S, Rintamaki H and Zitting P: Occupational physical activity is related to physical fitness in young workers. Med Sci Sports Exerc (2002) 34: 158-165.
11. Fujita H, Shiomi T, Arahata K and Ishibashi H: Relationship between activity of daily living and motor function in the community-dwelling elderly after hip fracture. Nippon Ronen Igakkai Zasshi (2006) 43: 241-245.

ANTI-AGING MEDICINE

Received: Jun 1, 2009
Accepted: Jul 8, 2009
Published online: Jul 17, 2009

Original Article

Body Fat Percentage Measured by Dual Energy X-ray Absorptiometry is Associated with Maximal Oxygen Uptake in Japanese

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Abstract

Objective: Both aerobic exercise level and body composition are associated with aging. In addition, lower aerobic exercise level and excess of body fat are risk for atherosclerosis. Therefore, the link between maximal oxygen uptake and anthropometric, body composition parameters was investigated.
Subjects and Methods: We used data for 300 Japanese (150 men: 44.2±14.1 years, 150 women: 44.4±14.1 years) in a cross sectional analysis. Maximal oxygen uptake was measured by breath-by-breath method and body composition was evaluated by dual energy X-ray absorptiometry (DEXA).
Results: Maximal oxygen uptake was significantly decreased with age over the age of 40. Body fat percentage measured by DEXA was significantly correlated with maximal oxygen uptake (men: r=−0.622, women: r=−0.604). In addition, the significant relationships between body fat percentage and clinical parameters *i.e.* triglyceride, high density lipoprotein (HDL) cholesterol, blood sugar, insulin and homeostasis model assessment (the HOMA index) were also noted.
Conclusion: Lower maximal oxygen uptake may be characteristic in subjects with higher body fat percentage and aerobic exercise should be recommended for preventing lifestyle-related disease.

KEY WORDS: maximal oxygen uptake, dual energy X-ray absorptiometry (DEXA), body fat percentage, abdominal circumference

Introduction

Regular physical activity has been shown to increase high density lipoprotein (HDL) cholesterol and reduce resting blood pressure, triglycerides, abdominal fat, fasting blood sugar, and insulin responses to oral glucose challenge test [1-5)]. Some cross sectional studies show that metabolic syndrome is significantly correlated with physical fitness [6-8)]. In addition, Sandvik L *et al.* reported that physical fitness was a graded, independent, long-term predictor of mortality from cardiovascular causes in healthy, middle-aged men [9)].

Maximal oxygen uptake is generally considered an accurate and reliable parameter. In the Exercise and Physical Activity Reference for Health Promotion 2006, established by the Ministry of Health Labour and Welfare Japan in 2006, maximal oxygen uptake was considered to be the most significant element of physical fitness related to health promotion and the recommended reference value for maximal oxygen uptake to prevent lifestyle-related disease was reported [10)]. In general, maximal oxygen uptake is considered to reduce with aging and lower maximal oxygen uptake is characteristic in subjects with lifestyle-related disease *i.e.* metabolic syndrome and also in subjects without exercise habits. Body composition *i.e.* visceral fat accumulation and excess of body fat is closely linked to metabolic syndrome and accelerated the atherosclerosis [11)]. Taken together, maximal oxygen uptake may be useful marker of aging and body composition may be also useful marker of atherosclerosis. Therefore, to evaluate the relationship between maximal oxygen uptake and body composition may promise us a quite useful data for anti aging in Japanese general population.

In this study, we measured maximal oxygen uptake and its relation to anthropometric, body composition parameters in Japanese.

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Subjects and Methods

Subjects

We used data for 150 Japanese men and 150 Japanese women, aged 20-69 years, at Okayama Southern Institute of Health with written informed consent (*Table 1*). No subjects received any medications for diabetes, hypertension, and/or dyslipidemia.

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

Anthropometric Measurements

The anthropometric measurements were performed by using the following parameters such as height, body weight, body mass index (BMI), abdominal circumference and hip circumference. BMI was calculated by weight/[height]^2 (kg/m^2). The abdominal circumference was measured at the umbilical level and the hip circumference was measured at the widest circumferences over the trochanter in standing subjects after normal expiration [1,5].

Body Composition Measurements

Body composition was measured by dual energy X-ray absorptiometry (DEXA) (QDR4500, Hologic Inc., Waltham, MA, USA), which is used as accurate standard [12]. The DEXA measurement consisted of a whole body scan using an array beam [13]. Subjects removed all metal objects and were positioned in the supine position with hands placed prone on either side of the body and with legs held 10 cm apart according to the specifications of the manufacturer. All scans were analyzed according to manufacturer's instructions [14].

Blood Sampling and Hormone Assays

After subjects fasted overnight for 10 to 12 hours, we collected blood samples in order to determine serum levels of HDL cholesterol, triglycerides (L Type Wako Triglyceride • H, Wako Chemical, Osaka), insulin and plasma glucose. Serum insulin was measured by immunoradiometric assay (IRMA) using INSULIN RIABEAD II (DAINABOT, Tokyo, Japan). Plasma glucose was measured by using the glucose-oxidant method. The insulin resistance was evaluated using the homeostasis model assessment, the HOMA index [fasting plasma glucose (mg/dl)×fasting serum insulin (μU/ml)/405], according to the method developed by Matthews et al [15].

Blood Pressure Measurements

Blood pressure of each participant was measured after resting at least 15 minutes in the sitting position.

Exercise testing

Maximal oxygen uptake was measured using a maximal graded exercise test with bicycle ergometers (Excalibur V2.0, Lode BV, Groningen, Netherlands). The initial work load was 30-60 watt, and the work rate was increased thereafter by 15 watt/min until the subject could not maintain the required pedaling frequency (60 rpm) [16]. During the latter stages of the test, each subject was verbally encouraged by the test operators to give a maximal effort. In addition, ECG was monitored continuously together with the recording of heart rate (HR). Expired gas was collected and rates of oxygen consumption (VO_2) and carbon dioxide production (VCO_2) were measured breath-by-breath using a cardiopulmonary gas exchange system (Oxycon Alpha, Mijnhrdt b.v., Netherlands). Achievement of maximal oxygen uptake was accepted if two of the following conditions were met: subject's maximal HR was > 95% age-predicted maximal HR (220 − age), and the VO_2 curve showed a leveling off.

Statistical Analysis

Data are expressed as mean ± standard deviation (SD) values. A comparison of parameters was performed by ANOVA and Scheffe's F test: $p<0.05$ was considered to be statistically significant. The Pearson's correlation coefficients were calculated to test for the significance of the linear relationship among continuous variables. Further more stepwise multiple regression analysis was performed to determine what factors correlated with maximal oxygen uptake. Statistical analysis was performed with Statview 5.0 (SAS Institute Inc., Cary, NC).

Table 1 Clinical profiles in subjects

	Men				Women			
	Mean ± SD	Minimum	Median	Maximum	Mean ± SD	Minimum	Median	Maximum
Number of subjects		150				150		
Age	44.2 ± 14.1	21.0	44.0	69.0	44.4 ± 14.1	20.0	46.0	69.0
Height (cm)	170.2 ± 5.6	158.1	170.1	187.3	157.9 ± 5.7	146.0	157.5	175.1
Body weight (kg)	66.5 ± 8.8	48.3	65.2	96.4	52.7 ± 7.5	35.3	51.8	73.4
Body mass index (kg/m^2)	23.0 ± 2.9	17.2	22.8	34.7	21.2 ± 3.0	13.3	20.6	31.3
Body fat percentage (%)	19.7 ± 5.5	8.9	19.5	34.7	26.9 ± 5.9	8.5	26.5	39.5
Body fat (kg)	13.3 ± 4.9	4.8	12.5	32.8	14.5 ± 4.5	3.2	13.5	26.6
Lean body mass (kg)	52.9 ± 5.9	39.0	52.3	75.3	38.9 ± 5.0	28.5	38.0	66.5
Muscle mass (kg)	50.6 ± 5.6	37.5	50.2	72.2	36.8 ± 5.2	11.7	36.1	63.8
Abdominal circumference (cm)	81.3 ± 8.0	63.9	80.4	104.9	76.0 ± 9.0	59.6	73.8	96.9
Hip circumference (cm)	93.5 ± 5.3	79.1	93.2	110.5	90.3 ± 5.4	76.8	90.2	108.5
Systolic blood pressure (mmHg)	130.0 ± 14.6	101.0	127.0	180.0	118.8 ± 15.3	89.0	117.5	162.0
Diastolic blood pressure (mmHg)	80.6 ± 10.8	48.0	80.0	111.0	72.3 ± 10.9	52.0	71.0	97.0
Blood sugar (mg/dl)	93.1 ± 9.9	61.0	92.0	146.0	88.3 ± 8.9	59.0	87.0	133.0
Triglyceride (mg/dl)	99.5 ± 57.6	33.0	83.0	434.0	72.3 ± 41.2	24.0	61.0	298.0
Log triglyceride (mg/dl)	1.94 ± 0.21	1.51	1.92	2.63	1.80 ± 0.20	1.38	1.79	2.47
HDL cholesterol (mg/dl)	57.4 ± 16.4	31.0	54.5	149.0	68.3 ± 14.3	40.0	69.0	103.0
Insulin (mU/ml)	5.1 ± 3.3	0.7	4.2	28.2	4.4 ± 2.0	0.5	4.2	16.1
HOMA index	1.2 ± 0.9	0.2	0.9	7.2	1.0 ± 0.5	0.1	0.9	4.0
Maximal oxygen uptake (ml/kg/min)	37.2 ± 8.7	16.5	35.5	61.9	30.8 ± 6.7	17.6	30.2	49.8
Maximal work rate (watt)	200.5 ± 49.1	91.0	196.0	354.0	141.2 ± 34.2	80.0	136.0	260.0
Maximal heart rate (beat/min)	178.4 ± 23.3	106.0	197.5	230.0	172.8 ± 17.9	117.0	173.0	214.0

Results

Maximal oxygen uptake as classified into age groups was summarized in *Table 2*. Maximal oxygen uptake was significantly decreased with age over the age of 40 in both sexes.

We evaluated the relationship between maximal oxygen uptake and clinical parameters *i.e.* age, anthropometric and body composition parameters (*Table 3*). Maximal oxygen uptake was significantly correlated with age (men: r=−0.559, women: r=−0.549). Maximal oxygen uptake was negatively correlated with body weight, BMI, body fat percentage, body fat and abdominal circumference and positively correlated with lean body mass and muscle mass in both sexes. In women, weak relationship between maximal oxygen uptake and hip circumference was also noted. Correlation coefficient rate between maximal oxygen uptake and body fat percentage was highest (men: r=−0.622, women: r=−0.604) (*Figure 1*). Single regression lines were expressed as follows [men: y (maximal oxygen uptake: ml/kg/min) = 56.609 − 0.983x (body fat percentage: %), women: y = 49.208 − 0.685x]. We also used stepwise multiple regression analysis to evaluate the effect of anthropometric, body composition parameters on maximal oxygen uptake and we found that body weight, body fat percentage and abdominal circumference was independently related to maximal oxygen uptake at a significant level in both sexes [men: (maximal oxygen uptake)=71.407+0.461(body weight)−0.671(body fat percentage)−0.634(abdominal circumference), r^2=0.512, p<0.001, women: (maximal oxygen uptake)=51.747+0.343(body weight)−0.584(body fat percentage)−0.307(abdominal circumference), r^2=0.444, p<0.0001].

To exclude the effect of aging on both maximal oxygen uptake and body fat percentage, we further evaluated the relationship between maximal oxygen uptake and body fat percentage as classified by age group (*Table 4*). Significant relationships between maximal oxygen uptake and body fat percentage, except 20's in women, were noted.

Table 2 Maximal oxygen uptake (ml/kg/min) as classified into age groups

	Men					Women				
Age	Number of subjects	Mean ± SD	Minimun	Median	Maximum	Number of subjects	Mean ± SD	Minimun	Median	Maximum
20-29	30	44.0 ± 9.0	28.3	45.8	61.9	30	36.1 ± 7.8	17.6	35.2	49.8
30-39	30	40.2 ± 7.2	26.2	41.3	50.3	30	32.5 ± 5.4	22.7	33.1	41.4
40-49	30	36.8 ± 8.2 a	23.7	36.9	54.4	30	31.4 ± 5.3 a	21.8	30.6	45.2
50-59	31	34.1 ± 6.9 ab	16.5	32.9	48.8	30	28.5 ± 5.6 a	18.1	28.0	39.5
60-69	29	30.8 ± 6.1 ab	17.2	31.5	45.2	30	25.6 ± 4.3 abc	18.7	25.1	35.9

a: p<0.05 vs age 20-29 b: p<0.05 vs age 30-39 c: p<0.05 vs age 40-49

Table 3 Simple correlation analysis between maximal oxygen uptake and anthropmetric, body composition parameters

	Men		Women	
	r	p	r	p
Age	−0.559	**<0.0001**	−0.549	**<0.0001**
Body weight (kg)	−0.169	**0.0392**	−0.174	**0.0328**
Body mass index (kg/m^2)	−0.287	**0.0004**	−0.360	**<0.0001**
Body fat percentage (%)	−0.622	**<0.0001**	−0.604	**<0.0001**
Body fat (kg)	−0.544	**<0.0001**	−0.519	**<0.0001**
Lean body mass (kg)	0.205	**0.0119**	0.205	**0.0119**
Muscle mass (kg)	0.192	**0.0184**	0.169	**0.0390**
Abdominal circumference (cm)	−0.560	**<0.0001**	−0.488	**<0.0001**
Hip circumference (cm)	−0.152	0.0640	−0.205	**0.0118**

Table 4 Simple correlation analysis between maximal oxygen uptake and body fat percentage as classified by age group

	Men		Women	
	r	p	r	p
20-29	−0.814	**<0.0001**	−0.084	0.6584
30-39	−0.545	**0.0019**	−0.514	**0.0036**
40-49	−0.726	**<0.0001**	−0.808	**<0.0001**
50-59	−0.564	**0.0010**	−0.737	**<0.0001**
60-69	−0.446	**0.0154**	−0.667	**<0.0001**

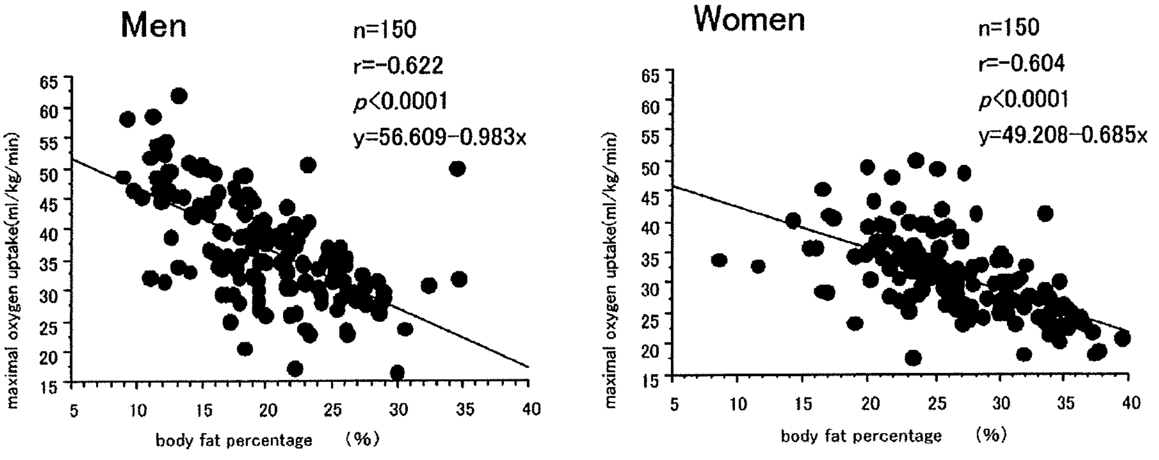

Fig. 1. Simple correlation analysis between maximal oxygen uptake and body fat percentage measured by DEXA in Japanese.

We investigated the link between body fat percentage measured by DEXA and clinical parameters (*Table 5*). Body fat percentage was weakly correlated with triglyceride, log triglyceride, HDL cholesterol, blood sugar, insulin and the HOMA index in both sexes. In women, body fat percentage was also weakly correlated with systolic and diastolic blood pressure.

It is well known that abdominal obesity is closely linked to hypertension, dyslipidemia and glucose intolerance. Therefore, we also investigated the link between abdominal circumference and clinical parameters (*Table 6*). Abdominal circumference was also weakly correlated with triglyceride, log triglyceride, HDL cholesterol, blood sugar, insulin and the HOMA index in both sexes. In women, abdominal circumference was weakly correlated with systolic blood pressure. However, correlation coefficient rates between body fat percentage measured by DEXA and clinical parameters, except blood sugar in men, were higher than those between abdominal circumference and clinical parameters.

Table 5 Simple correlation analysis between body fat percentage and clinical parameters

	Men		Women	
	r	*p*	r	*p*
Systolic blood pressure (mmHg)	0.080	0.3310	0.257	**0.0015**
Diastolic blood pressure (mmHg)	0.039	0.6325	0.165	**0.0442**
Blood sugar (mg/dl)	0.207	**0.0111**	0.289	**0.0003**
Triglyceride (mg/dl)	0.333	**<0.0001**	0.383	**<0.0001**
Log troglyceride (mg/dl)	0.381	**<0.0001**	0.428	**<0.0001**
HDL cholesterol (mg/dl)	−0.311	**0.0001**	−0.264	**0.0011**
Insulin (mU/ml)	0.390	**<0.0001**	0.445	**<0.0001**
HOMA index	0.373	**<0.0001**	0.458	**<0.0001**

Table 6 Simple correlation analysis between abdominal circumference and clinical parameters

	Men		Women	
	r	*p*	r	*p*
Systolic blood pressure (mmHg)	0.140	0.0881	0.254	**0.0017**
Diastolic blood pressure (mmHg)	0.075	0.3614	0.089	0.2806
Blood sugar (mg/dl)	0.283	**0.0005**	0.229	**0.0049**
Triglyceride (mg/dl)	0.306	**0.0001**	0.279	**0.0006**
Log troglyceride (mg/dl)	0.335	**<0.0001**	0.320	**<0.0001**
HDL cholesterol (mg/dl)	−0.311	**0.0001**	−0.207	**0.0110**
Insulin (mU/ml)	0.348	**<0.0001**	0.354	**<0.0001**
HOMA index	0.360	**<0.0001**	0.372	**<0.0001**

Discussion

In this study, maximal oxygen uptake was closely linked to body fat percentage measured by DEXA in Japanese.

DEXA is a technique applied to body composition assessment and was originally used for the measurement of total body bone mineral or the lumber spine bone mineral content [12]. It is thought to be a suitable method for in-vivo measurements. A low radiation dosage enables us to repeat the trials and was useful for monitoring the changes in body composition *i.e.* body fat percentage and muscle mass. However, it is expensive, bulky and is not suitable for field studies.

It has been well reported that there is significant loss in oxygen uptake at ventilatory threshold (VT), which is also considered accurate and reliable parameter of aerobic exercise level [17], with aging [18,19]. Miura reported that oxygen uptake at VT was significantly correlated with age (men: r=−0.626, women: r=−0.578) in 610 Japanese [18]. Sanada *et al* reported that negative correlation was noted between oxygen uptake at VT and age in 1463 Japanese [19]. There are few reports of maximal oxygen uptake, which was directly measured, in healthy Japanese. Ohta *et al* reported that maximal oxygen uptake was significantly decreased with age in 832 apparently healthy subjects [20] and single regression formula were y (ml/kg/min) = 46.6 − 0.36×age (r=0.447) in men and y = 35.3 − 0.23×age (r=0.407) in women. In this study, age-related decreasing of maximal oxygen uptake was noted as previous studies in Japanese without taking any medications. This mean value also promises us one of quite useful database for evaluating maximal oxygen uptake in Japanese subjects.

In some literature, the relationship between maximal oxygen uptake and body composition was reported. Significant relationships between maximal oxygen uptake and body fat percentage were noted in Japanese junior high school boys and girls [21], Danish women [22] and African-American adolescents [23]. Although we could not infer causality between maximal oxygen uptake and body fat percentage, an excess of body fat, which is expressed as body fat percentage (%), may be an excess weight and plays a critical role for determining maximal oxygen uptake. In this study, we found that body fat percentage measured by DEXA was closely linked to maximal oxygen uptake. In addition, the correlation coefficient rates between body fat percentage and clinical parameters of blood examination were higher than those between abdominal circumference and clinical parameters. These suggest that body fat percentage measured by DEXA may be one of good predictor for estimating maximal oxygen uptake in Japanese.

Potential limitations still remain in this study. First, we could not demonstrate the mechanism the link between maximal oxygen uptake and body fat percentage measured by DEXA. Second, we have previously reported that visceral adipose tissue area was negatively correlated with oxygen uptake at VT (r=−0.400) [24] and we could not directly measure visceral fat area by computed tomography (CT) in this study. Although correlation coefficient rate between maximal oxygen uptake and body fat percentage measured by DEXA was higher than that between maximal oxygen uptake and abdominal circumference and that between oxygen uptake at VT and visceral fat area in our previous report, comparison between body fat percentage measured by DEXA and visceral fat area directly measured by CT is urgently required to determine what factors correlated with maximal oxygen uptake. Third, body fat percentage measured by DEXA is less feasible for use in certain clinical applications because of the cost of and technical requirements for its use. Therefore, the relationship between maximal oxygen uptake and body fat percentage measured by other method *i.e.* impedance method also must be evaluated.

In conclusion, we found that body fat percentage measured by DEXA was closely related to maximal oxygen uptake. Lower aerobic exercise level may be characteristic in subjects with higher body fat percentage and aerobic exercise should be recommended. Maximal oxygen uptake may be important marker for preventing and improving lifestyle-related disease in addition to aging and aerobic exercise level.

Acknowledement

This research was supported in part by Research Grants from the Ministry of Health, Labor, and Welfare, Japan (19160101).

References

1) Miyatake N, Takahashi K, Wada J *et al*: Daily exercise lowers blood pressure and reduces visceral fat in overweight Japanese men. Diabetes Res Clin Prac 62; 149-157, 2003
2) Yamanouchi K, Shinozaki T, Chikada K *et al*: Daily walking combined with diet therapy is a useful means for obese NIDDM patients not only to reduce body weight but also to improve insulin sensitivity. Diabetes Care 18; 775-778, 1995
3) Oshida Y, Yamanouchi K, Hayamizu S *et al*: Long-term mild jogging increases insulin action despite no influence on body mass index or VO2 max. J Appl Physiol 66; 2206-2210, 1989
4) Barnard RJ, Ugianskis EJ, Martin DA *et al*: Role of diet and exercise in the management of hyperinsulinemia and associated atherosclerotic risk factors. Am J Cardiol 69; 440-444, 1992
5) Miyatake N, Nishikawa H, Morishita A *et al*: Daily walking reduces visceral adipose tissue areas and improves insulin resistance in Japanese obese subjects. Diabetes Res Clin Prac 58; 101-107, 2002
6) Caroll S, Cooke CB, Butterly RJ. Metabolic clustering, physical activity and fitness in non smoking, middle-aged men. Med Sci Sports Exerc 32; 2079-2086, 2000
7) Nagano M, Kai Y, Zou B *et al*: The contribution of cardiorespiratory fitness and visceral fat to the risk factors in the Japanese patients with impaired glucose tolerance and type 2 diabetes mellitus. Metabolism 53; 644-649, 2004
8) Kullo IJ, Hensrud DD, Allison TG. Relation of low cardiorespiratory fitness to the metabolic syndrome in middle-aged men. Am J Cardiol 90; 795-797, 2002
9) Sandvik L, Erikssen J, Thaulow E *et al*: Physical fitness as a predictor of mortality among healthy, middle-aged Norwegian men. N Engl J Med 25; 533-537, 1993
10) Ministry of Health Labour and Welfare Japan (2007) Exercise and physical activity reference for health promotion 2006. pp9-10 (http://www.mhlw.go.jp/bunya/kenkou/undou01/pdf/data.pdf accessed on Jan 29, 2009)
11) Definition and the diagnostic standard for metabolic syndrome —Committee to Evaluate Diagnostic Standards for Metabolic Syndrome, Nippon Naika Gakkai Zasshi 94; 794-809, 2005 (in Japanese)
12) Wang J, Heymsfield SB, Aulet M *et al*: Body fat from body density: underwater weighing vs. dual-photon absorptiometry. Am J Physiol 256; E829-E834, 1989
13) Gustafsson L, Jacobson B, Kusoffsky L: X-ray spectrophotometry for bon-mineral determinations. Med Biol Eng 12; 113-119, 1974
14) Herd RJM, Blake GM, Parker JC *et al*: Total body studies in normal British women using dual energy X-ray absorptiometry. Br J Radiol 66; 303-308, 1993
15) Matthews DR, Hosker JP, Rudenski AS *et al*: Homeostasis model assessment: insulin resistance and β-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 28; 412-419, 1985
16) Miyachi M, Tanaka H, Yamamoto K *et al*: Effects of one-legged endurance training on femoral arterial and venous size in healthy humans. J Appl Physiol 90; 2439-2444, 2001
17) Wasserman K, Whipp BJ, Koyl SN *et al*: Anaerobic threshold and respiratory gas exchange during exercise. J Appl Physiol 35; 236-243, 1973
18) Miura K: Ventilatory threshold in Japanese-as the basis for exercise prescription for health promotion. Nippon Koshu Eisei Zasshi 43; 220-230, 1996 (in Japanese)
19) Sanada K, Kuchiki T, Miyachi M *et al*: Effect of age on ventilatory threshold and peak oxygen uptake normalized for regional skeletal mass in Japanese men and women aged 20-80 years. Eur J Appl Physiol 99; 475-483, 2006
20) Ohta T, Zhang J, Ishikawa K *et al*: Peak oxygen uptake, ventilatory threshold and leg extension power in apparently healthy Japanese. Nippon Koshu Eisei Zasshi 46; 289-297, 1999 (in Japanese)
21) Watanabe K, Nakadomo F, Maeda K: Relationship between body composition and cardiorespiratory fitness in Japanese junior high school boys and girls. Ann Physiol Anthropol 13; 167-174, 1994
22) Andersen LB, Haraldsdottir J: Maximal oxygen uptake, maximal voluntary isometric contraction and physical activity in young Danish adults. Eur J Appl Physiol Occup Physiol 67; 315-320, 1993
23) Drinkard B, McDuffie J, McCann S *et al*: Relationship between walk/run performance and cardiorespiratory fitness in adolescents who are overweight. Phys Ther 81; 1889-1896, 2001
24) Miyatake N, Takenami S, Kawasaki Y *et al*: Relationship between visceral fat accumulation and physical fitness in Japanese women. Diabetes Res Clin Prac 64; 173-179, 2004

INTERNAL MEDICINE

□ ORIGINAL ARTICLE □

Changes in Metabolic Syndrome and Its Components with Lifestyle Modification in Japanese Men

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Abstract

Objective Changes in metabolic syndrome and its components with lifestyle modification were evaluated in Japanese men.

Methods We used data for 160 Japanese men (45.6±8.8 years) with a 1-year follow up. Anthropometric, blood examination and blood pressure measurements were evaluated. Metabolic syndrome was defined by using a criterion in Japan. All subjects were given instructions by well-trained medical staff on how to change their lifestyle.

Results With a 1-year follow-up, anthropometric parameters, blood pressure (BP), triglyceride and HDL cholesterol were significantly improved and the prevalence of metabolic syndrome was significantly reduced. The number of subjects with abdominal obesity at baseline and at follow-up was higher (81 men) than that of subjects with other components at baseline and at follow-up. Parameters at baseline were significantly correlated with changes in parameters for one year. With lifestyle modification, the level of 163 mmHg in systolic BP (SBP), 115 mmHg in diastolic BP (DBP), 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications with a 1-year follow up.

Conclusion Lifestyle modification is useful for improving metabolic syndrome and its components. However, items of metabolic syndrome were improved, even when the abdominal circumference was greater than the normal value for Japanese men.

Key words: lifestyle modification, metabolic syndrome, blood pressure

(Inter Med 49: 261-265, 2010)
(DOI: 10.2169/internalmedicine.49.2900)

Introduction

Metabolic syndrome, characterized by abdominal obesity, has become a public health challenge and common disorder in Japan (1). For example, we have previously described that 30.7% of men and 3.6% of women were diagnosed as having the metabolic syndrome (2). Metabolic syndrome is closely related to elevated hepatic enzymes (3), uric acid (4), reduced exercise capacity (5, 6) and cardiovascular disease (7). Therefore, proper management of metabolic syndrome is urgently required.

The recommendation for medication for hypertension is based on the following from the Japanese Society of Hypertension (http://www.jpnsh.org/, accessed on June 15, 2009.): blood pressure (BP)≧140/90 mmHg, dyslipidemia is defined as triglyceride≧150 mg/dL, LDL cholesterol≧140 mg/dL, HDL cholesterol<40 mg/dL from the Japan Atherosclerosis Society (http://jas.umin.ac.jp/, accessed on July 15, 2009) and diabetes mellitus≧126 mg/dL in fasting plasma glucose from the Japan Diabetes Society (http://www.jds.or.jp/, accessed on July 15, 2009). In addition, lifestyle modification has been considered as useful and an essential method for preventing and improving these disorders. However, whether a lifestyle modification is beneficial for improving metabolic syndrome and its components, and what

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Received for publication September 14, 2009; Accepted for publication October 29, 2009
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Table 1. **Clinical Profiles and Changes in Parameters with Lifestyle Modification with a 1-year Follow Up in Japanese Men**

	Baseline	Follow up	p
Number of subjects	160		
Age	45.6 ± 8.8		
Height (cm)	168.7 ± 5.5		
Body weight (kg)	74.9 ± 11.1	73.5 ± 10.2	<0.0001
Body mass index (kg/m²)	26.3 ± 3.7	25.8 ± 3.3	<0.0001
Abdominal circumference (cm)	88.2 ± 9.9	86.5 ± 9.1	<0.0001
Hip circumference (cm)	96.7 ± 5.7	95.9 ± 5.2	<0.0001
SBP (mmHg)	130.8 ± 14.8	123.4 ± 12.4	<0.0001
DBP (mmHg)	82.5 ± 10.9	77.5 ± 9.3	<0.0001
Triglyceride (mg/dL)	145.2 ± 94.0	119.8 ± 76.5	0.0005
HDL cholesterol (mg/dL)	50.1 ± 14.4	56.1 ± 15.1	0.0109
Blood sugar (mg/dL)	102.0 ± 19.2	102.4 ± 25.6	0.7478

Mean ± SD
SBP: Systolic blood pressure
DBP: Diastolic blood pressure

effects such a modification has on metabolic syndrome and its components remain to be investigated in a longitudinal analysis. In this study, we evaluated the effect of lifestyle modification on metabolic syndrome and its components in Japanese men with a 1-year follow up.

Subjects and Methods

Subjects. We used data for 160 Japanese men, aged 45.6±8.8 years who met the following criteria: 1) received an annual health check-up every year with a follow up duration of 1-year, 2) received no medications for diabetes, hypertension, and/or dyslipidemia, and 3) provided written informed consent (Table 1).

In 2008, the Ministry of Health, Labor, and Welfare of Japan started to undertake a specific health check-up and special health guidance for preventing lifestyle-related diseases (http://www.mhlw.go.jp/bunya/shakaihosho/iryouseido01/info02a.html, accessed on Oct 11, 2009). At the first annual health check-up, all subjects were given instructions by well-trained medical staff on how to change their lifestyle as the special health guidance. Nutritional instruction was provided with a well-trained nutritionist, who planned the diet for each subject based on their data and provided simple instructions (i.e. not to eat too much and to consider balance when they eat). Exercise instruction was also provided by a well-trained physical therapist, who encouraged each subject to increase their daily amount of steps walked. At the second health check-up, medical staff subjectively evaluated changes in their lifestyle and the subjects with an evaluation of over the level of recommendation for medications were encouraged to receive medications.

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

Anthropometric and body composition measurements. Anthropometric and body compositions were evaluated based on the following parameters: height, body weight, abdominal circumference and hip circumference. Body mass index (BMI) was calculated by weight /[height]^2(kg/m^2). Abdominal circumference was measured at the umbilical level and hip circumference was measured at the widest circumference over the trochanter in standing subjects after normal expiration (8).

BP measurements at rest. Resting systolic and diastolic BP (SBP and DBP) 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 and assays. Overnight fasting serum levels of high density lipoprotein (HDL) cholesterol, triglycerides (L Type Wako Triglyceride·H, Wako Chemical, Osaka) and serum 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).

Statistical analysis. All data are expressed as mean ± standard deviation (SD) values. A statistical analysis was performed using a paired t test and χ^2 test: $p<0.05$ was considered to be statistically significant. Simple correlation analysis was used to test the significance of the linear relationship among continuous variables.

Results

Clinical profiles and changes in parameters with lifestyle modification are summarized in Table 1. Body weight, BMI, abdominal circumference and hip circumference were significantly reduced after one year. SBP, DBP and triglyceride were also significantly reduced and HDL cholesterol was significantly increased with lifestyle modification. However, blood glucose at baseline was similar to that at follow up, and abdominal circumference was over the level of 85 cm at follow up.

We also evaluated the changes in prevalence of metabolic syndrome and its components (Table 2). Prevalence of metabolic syndrome and its components i.e. abdominal obesity, hypertension, dyslipidemia and impaired glucose tolerance was significantly reduced with a 1-year follow up. The number of subjects with abdominal obesity [81 men (50.6%)] at

Table 2. **Changes in Metabolic Syndrome and Its Components with Lifestyle Modification after One Year**

		Follow up		p
		Abdominal circumference (−)	Abdominal circumference (+)	
	Abdominal circumference (−)	54	7	<0.0001
	Abdominal circumference (+)	18	81	
		Hypertension (−)	Hypertension (+)	
	Hypertension (−)	53	11	<0.0001
	Hypertension (+)	48	48	
		Dyslipidemia (−)	Dyslipidemia (+)	
Baseline	Dyslipidemia (−)	88	9	<0.0001
	Dyslipidemia (+)	32	31	
		Impaired glucose tolerance (−)	Impaired glucose tolerance (+)	
	Impaired glucose tolerance (−)	129	3	<0.0001
	Impaired glucose tolerance (+)	8	20	
		Metabolic syndrome (−)	Metabolic syndrome (+)	
	Metabolic syndrome (−)	110	5	<0.0001
	Metabolic syndrome (+)	25	20	

Table 3. **Simple Correlation Analysis between Parameters at Baseline and Changes in Parameters with Lifestyle Modification with a 1-year Follow Up**

	r	p	Single regression line	Recommendation for medication	Baseline level without medications calculated by formula
SBP (mmHg)	−0.596	<0.0001	y=−0.492x+56.951	y+x=140	163
DBP (mmHg)	−0.626	<0.0001	y=−0.618x+45.959	y+x=90	115
Triglyceride (mg/dL)	−0.654	<0.0001	y=−0.626x+54.488	y+x=150	226
HDL cholesterol (mg/dL)	−0.270	0.0005	y=−0.187x+12.101	y+x=39	33
Blood sugar (mg/dL)	0.052	0.5118			

y: changes in parameters
x: parameters at baseline

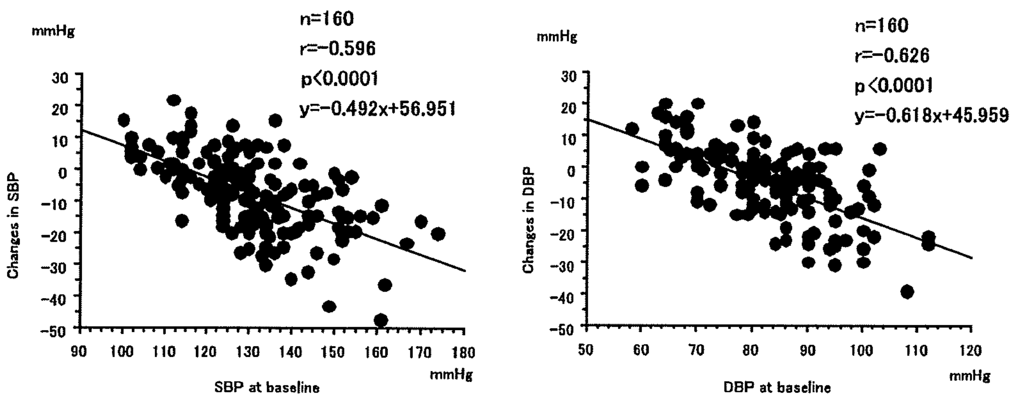

Figure 1. **Simple correlation analysis between BP at baseline and changes in BP with a 1-year follow-up in Japanese men.**

baseline and at follow up was higher than that of subjects with other components [hypertension: 48 men (30.0%), dyslipidemia: 31 men (19.4%), impaired glucose tolerance: 20 men (12.5%)]at baseline and at follow up. Therefore, abdominal obesity was persisted but metabolic parameters were improved.

We further investigated the link between parameters at baseline and changes in parameters (Table 3, Fig. 1). SBP, DBP, Triglyceride and HDL cholesterol at baseline were significantly correlated with changes in each parameter. The recommendation for medications was 140 mmHg in SBP, 90 mmHg in DBP, 150 mg/dL in triglyceride, 39 mg/dL in HDL cholesterol and 126 mg/dL in fasting plasma glucose. Therefore, the baseline level without medications was calculated by single regression line. The level of 163 mmHg in SBP, 115 mmHg in DBP, 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications with a 1-year follow up.

Discussion

In this study, the prevalence of metabolic syndrome and its components was significantly reduced with lifestyle modification with a 1-year follow up. In addition, the metabolic parameters were improved without normalized abdominal circumference.

There are some reports that show the link between lifestyle modification and metabolic syndrome and its components in a longitudinal analysis. Katzmarzyk et al reported on the effects of 20 weeks supervised aerobic training program on the prevalence of metabolic syndrome in 621 men and women who were enrolled in the HERITAGE Study. 30.5% of the participants with metabolic syndrome at baseline were classified as not having the syndrome after the intervention (9). Ekelund et al reported that the energy expenditure of physical activity predicts progression to metabolic syndrome independent of aerobic fitness, obesity, and other confounding factors followed by 5.6 years (10). The Kuopio Ischemic Heart Disease Risk Factor Study (11) followed several hundred men without the syndrome at baseline. After four years, subjects in the upper one-third of VO_2max at baseline were 75% less likely than unfit men to develop metabolic syndrome. Muzio et al reported that metabolic syndrome was effectively treated by long-term diet (~500 calorie/day deficit) and lifestyle therapy alone in 37% of obese, nondiabetic patients (12). By using the criterion developed in Japan, Okura et al recently reported that 67 women with metabolic syndrome were treated with a 14-week weight loss program, which included a low-calorie diet and aerobic exercise. The adjusted odds ratios for metabolic syndrome improvement in the two interventions with diet alone and diet plus exercise were 1.0 and 3.68. In addition, $\dot{V}O_2max$ in subjects on the low-calorie diet and aerobic exercise treatment was 22.9±3.2 mL/kg/min at baseline and 27.0±3.8 mL/kg/min after intervention ($p<0.001$) (13). In this study, although the difference of blood sugar between at baseline and at follow up was not noted, we found that the prevalence of metabolic syndrome and its components including impaired glucose tolerance was significantly reduced with lifestyle modification after one year. Abdominal obesity, which is one of the targets for management of metabolic syndrome, was not improved to the normal range. However, the metabolic parameters were improved without normalized abdominal circumference. The diagnosis of metabolic syndrome is a caution for the general people to be careful in the healthy life, and these are not criteria for diagnosis of a definite disease to be treated with drug administration or with specific medication (14, 15). Taken together, these changes in metabolic components with lifestyle modification would be expected to reduce the risk of cardiovascular diseases or glucose metabolism.

The Japan Society of Hypertension recommends that lifestyle modification is essential for improving hypertension and medications should be considered after one or three months' lifestyle modification in subjects with low or moderate risk. Medications are immediately recommended in subjects with high risk (http://www.jpnsh.org/, accessed on June 15, 2009).

The Japan Atherosclerosis Society and the Japan Diabetes Society also recommended that lifestyle modification is essential in the first place. We explored that the clinical parameters i.e. BP, triglyceride and HDL cholesterol at baseline were closely correlated with changes in these parameters in subjects without medications with a 1-year follow up. In addition, by using single regression line and the recommendation for medications, the baseline level of parameters without medications was calculated. The level of 163 mmHg in SBP, 115 mmHg in DBP, 226 mg/dL in triglyceride and 33 mg/dL in HDL cholesterol at baseline was estimated to improve to the level without medications after one year. Through the concept of metabolic syndrome, the significance of encouraging a reduction of abdominal obesity by lifestyle modification as the first step for the management of individuals with abdominal obesity has become strengthened (14). Although these results may be affected by higher values and limited in the difference of parameters, the estimated level in this study may be one of reference data for improving metabolic syndrome with lifestyle modification in preference to medications in some Japanese men. Further intervention studies are necessary to test the effect of lifestyle modification on metabolic syndrome.

Potential limitations still remain in this study. First, the selected 160 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 more health-conscious than most of the average person. Second, the small sample size makes it difficult to infer causality between lifestyle modification and metabolic syndrome. Third, blood sugar did not significantly reduce and blood sugar at baseline was not also associated with changes in blood sugar with a 1-year follow up. These results suggest that an improvement of metabolic risk factors may be different according to the level of lifestyle modification.

Acknowledgement

This research was supported in part by Research Grants from the Ministry of Health, Labor, and Welfare, Japan.

References

1. Committee to Evaluate Diagnostic Standards for Metabolic Syndrome. Definition and the diagnostic standard for metabolic syndrome. Nippon Naika Gakkai Zasshi **94**: 794-809, 2005 (in Japanese).
2. Miyatake N, Kawasaki Y, Nishikawa H, Takenami S, Numata T. Prevalence of metabolic syndrome in Okayama prefecture, Japan. Intern Med **45**: 107-108, 2006.
3. Miyatake N, Matsumoto S, Makino H, Numata T. Comparison of hepatic enzymes between Japanese men with and without metabolic syndrome. Acta Med Okayama **61**: 31-34, 2007.
4. Numata T, Miyatake N, Wada J, Makino H. Comparison of serum uric acid levels between Japanese with and without metabolic syndrome. Diabetes Res Clin Prac **80**: e1-e5, 2008.
5. Miyatake N, Saito T, Wada J, et al. Comparison of ventilatory threshold and exercise habits between Japanese men with and without metabolic syndrome. Diabetes Res Clin Prac **77**: 314-319, 2007.
6. Miyatake N, Wada J, Saito T, et al. Comparison of muscle strength between Japanese men with and without metabolic syndrome. Acta Med Okayama **61**: 99-102, 2007.
7. Wilson PW, Kannel WB, Silbershatz H, D'Agostino RB. Clustering of metabolic factors and coronary heart disease. Arch Intern

Med **159**: 1104-1109, 1999.

8. Miyatake N, Wada J, Kawasaki Y, Matsumoto S, Makino H, Numata T. Relationship between metabolic syndrome and proteinuria in the Japanese population. Intern Med **45**: 599-603, 2006.
9. Katzmarzyk PT, Lenon AS, Wilmore JH, et al. Targeting the metabolic syndrome with exercise: evidence from the HERITAGE Family Study. Med Sci Sports Exerc **35**: 1703-1709, 2003.
10. Ekelund U, Brage S, Franks PW, Hennings S, Emms S, Wareham NJ. Physical activity energy expenditure predicts progression toward the metabolic syndrome independently of aerobic fitness in middle-aged healthy Caucasians: the Medical Research Council Ely Study. Diabetes Care **28**: 1195-1200, 2005.
11. Laaksonen DE, Lakka HM, Salonen JT, Niskanen LK, Rauramaa R, Lakka T. Low levels of leisure-time physical activity and cardiorespiratory fitness predict development of the metabolic syndrome. Diabetes Care **25**: 1612-1618, 2002.
12. Muzio F, Mondazzi L, Sommariva D, Branchi A. Long-term effects of low-calorie diet on the metabolic syndrome in obese nondiabetic patients. Diabetes Care **28**: 1485-1486, 2005.
13. Okura T, Nakata Y, Ohkawara K, et al. Effects of aerobic exercise on metabolic syndrome improvement in response to weight reduction. Obesity (Silver Spring) **15**: 2478-2484, 2007.
14. Teramoto T, Sasaki J, Ueshima H, et al. Metabolic syndrome. J Atheroscler Thromb **15**: 1-5, 2008.
15. Zimmet P, Magliano D, Matsuzawa Y, Alberti G, Shaw J. The metabolic syndrome: a global public health problem and a new definition. J Atheroscler Thromb **12**: 295-300, 2005.

Paper : Epidemiology

Age and Sex Differences in the Levels of Muscular Activities during Daily Physical Actions

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[Received April 4, 2008; Accepted July 29, 2008; Published online February 20, 2009]

The present study aimed to clarify age and gender differences in the electromyographic (EMG) activity levels of lower limb muscles during daily physical actions. Forty young and 22 elderly individuals performed five physical actions, i.e. normal walking, ascending and descending stairs, standing up from and sitting onto a chair, and a calf raise exercise. The surface electromyograms (EMGs) during these actions were recorded from the vastus medialis, rectus femoris, vastus latelalis, lateral gastrocnemius, medial gastrocnemius, and soleus muscles using a portable EMG recording apparatus. For the prescribed actions, the mean activity levels of the quadriceps femoris (QF%EMG) and triceps surae (TS%EMG) muscles were quantified and expressed as the relative values (%EMG) to that during the maximal voluntary isometric contraction (MVC). The %EMG values of QF and TS significantly differed among actions, with significant influences of age and gender. The %EMG of each of QF and TS was negatively correlated to MVC torque relative to body weight, developed in knee extension and ankle plantar flexion, suggesting that the observed age and gender differences in %EMG could be partially attributed to those in torque generation capabilities. Thus, the present findings indicate that the individuals with lower maximal isometric joint torque per body weight demonstrate higher muscular activity levels during daily physical actions. For these populations, the daily physical actions examined here may be resistance exercises for improving the torque generation capability of lower limb muscles.

Keywords: daily action, resistance exercise, surface electromyograms, age, gender

[International Journal of Sport and Health Science Vol.6, 169-181, 2008]

1. Introduction

It is well known documented that muscle mass and strength decrease with age (Vandervoot & Macmas, 1986; Lexell, 1995; Hurley, 1995; Lynch et al., 1999; Janssen et al., 2000). In particular, decline with the lower limbs muscles is to a greater degree (Hurley et al., 1995; Miyatani et al., 2003; Kubo et al., 2003a). Since the ability of executing daily physical actions is based on force-generating capacity of lower limb muscles, the age-related loss of lower limb muscle mass and strength result in the difficulty of performing them for the elderly individuals. On the other hand, it is well-known that muscle mass and strength in the middle-aged and elderly individuals are increased by resistance training (Häkkinen et al., 1998; Kubo et al., 2003b; Kamen & Knight, 2004; Andersen et al., 2005). Most of previous studies that have examined the effect of resistance training in the middle-aged and elderly individuals have adopted a resistance exercise program mainly consisting of high intensity exercises. However, Rook et al. (1997) have pointed out whether elderly people could perform such a program in daily life is questionable. Recently, some studies have attempted to examine the effect of resistance training employing daily physical actions e.g. walking (Rook et al., 1997), ascending and descending stairs (de Vreede et al., 2005), and standing up from and sitting down onto a chair (Kubo et al., 2003b). These previous findings on the effect of muscle strength have been divided into affirmation (Aniansson & Gastafsson, 1981; Kubo et al., 2003b) and denial (Rook et al., 1997; de Vreede et al., 2005). This may be because the levels of muscular activities during training exercise differed among actions adopted as exercises. As noted in the principle of overload (Hettinger, 1968), gain of muscle mass and strength through resistance training require more than certain ratio levels of muscular activities relative to maximal muscle strength. Therefore, to discuss the effectiveness of daily physical actions as resistance exercises, the muscular activity levels during daily physical actions adopted as training exercises should be determined.

Another reason of discrepancy among the previous findings on the effect of muscle strength may be considered to be involved the differences in maximal muscle strength among the studied subjects. In other words, the load for exercising muscles during daily physical actions is only one's body weight. Thus, the muscular activity levels during the actions may depends on the maximal muscle strength per body weight, which is also presumed to affect whether the training is effective. The findings of previous studies on the muscular activity levels during daily physical actions using surface electromyography (EMG) demonstrated gender (Sawai et al., 2006) and age (Landers et al., 2001; Hortobágy et al., 2003) differences and indicated that the gender and age differences might be affected by those in maximal muscle strength (Landers et al., 2001; Sawai et al., 2006). Although these findings support dependence of maximal muscle strength on the muscular activity levels during daily physical actions, there are no studies determined association the muscular level of lower limb with age, gender, and maximal muscle strength in each daily physical action.

The purpose of this study were to quantify the muscular activity level of lower limb muscles during daily physical actions and to investigate the association it with age, gender, and maximal muscle strength in the young, middle-aged and elderly individuals.

2. Methods

2.1. Subjects

A total of 62 subjects were participated in this study. The young group consisted of 21 men and 19 women aged 19 to 36 years and the elderly group consisted of 8 men and 14 women aged 58 to 72 years. The means and standard deviations of age, height, and body weight are shown in **Table 1**.

The present study was carried out with the approval of the ethical committee of the Faculty of Sport Sciences, Waseda University. Written informed consent to participate was obtained from the subjects after explaining them of the study purpose and measurement items.

2.2. Measured actions

Five daily physical actions, i.e. standing up from and sitting down onto a chair (SS), calf raise (CR), normal walking (NW), ascending the stairs (AS), and descending the stairs (DS) were performed in this study. The specific action types are shown in **Table 2**. For SS and CR, all subjects performed 10 repetitions at tempo of once every 4 sec. An electronic metronome (SQ100-77, Seiko, Japan) was used for control of action tempo. Before the measurement of these actions, the subjects practiced these actions so that they could

Table 1 Physical characteristics of subjects.

	Young group		Elderly group	
	Men (n=21)	Women (n=19)	Men (n=8)	Women (n=14)
Age (yrs)	23.9±2.7	25.4±4.1	68.3±2.3	63.6±3.2
Height (cm)	170.7±4.8	162.8±5.6[a]	167.1±3.2	153.2±2.6[a,b]
Body weight (kg)	66.5±7.8	55.8±7.1[a]	67.1±5.7	50.3±6.0[a]

n: the number of subjects.
a: significantly different between the men and women within the same generation at $p<0.05$.
b: significantly different between the young and elderly within the same gender at $p<0.05$.

Table 2 Types of the actions taken for the EMG measurements.

Action type	Description of each action
Standing up from and sitting down onto a chair (SS)	Repeatedly standing up from and sitting down in a chair with a 40 cm seat height.
Calf raise (CR)	Raising heels from upright standing position, and putting down heels repeatedly.
Normal walking (NW)	Walking 10 m on a flat surface outdoors at natural speed while wearing shoes.
Ascending the stairs (AS)	Ascending 14 stairs with 14.5 cm step height and 40 cm depth outdoors at natural speed wearing shoes.
Descending the stairs (DS)	Descending 14 stairs with 14.5 cm stpe height and 40 cm depth outdoors at natural speed wearing shoes.

perform at a constant tempo. A digital video camera (NV-DJ100, Panasonic, Japan) was used to determine the beginning and end of the actions. The sampling frequency was set at 30 Hz. The SS and CR were recorded in the sagittal plane by the video camera set 5 m away from the subjects. For NW, AS, and DS, the subjects were instructed to perform at their pace which they performed in their daily life. In the analytical zone, the acceleration and deceleration phases were not included. For NW, the subjects were instructed to begin to walk just (about 5 m) in front of the analytical zone and then to walk through the 10 m point where was the end point of the analytical zone. For AS and DS, the subjects were instructed to begin to walk about 3 m in front of the first stair step and to continue walking through the last step. Another instruction for these actions was to ascend and descend the stairs one step at a time. For NW, the motion of the lower limb was recorded by the video camera set up 5 m away laterally from the subjects along the center of the analytical zone, as described above; for AS and DS, the motions of the lower limb were recorded by an examiner with the video camera who stood laterally from the subject. The velocity and tempo of the actions calculated from the recorded pictures were described just below. the velocity of NW was 1.49±0.19 m/s in the young group and 1.51±0.15 m/s in the elderly group. The tempo of AS and DS was 1.83±0.15 step/s and 2.00±0.21 steps/s in the young group, and 1.84±0.14 steps/s and 2.11±0.27 steps/s in the elderly group. It should be noted that those in the young group were expressed as means and standard deviations of the 9 young subjects who were measurable for action velocity. No significant differences were observed in the velocity and tempo of all actions between both groups.

2.3. Measurement of maximal voluntary isometric contraction (MVC) torque

MVC torques during knee extension and ankle plantar flexion were measured using static myometers (VTK-002R/L, VTF-002R/L, Vine, Japan). The posture of the subjects in the measurement of knee extension (KE) was sitting position with hip and knee angles of 90° (a full extension position angle: 0°). The ankle was firmly attached to the lever arm of myometer with a strap and secured with the knee joint angle flexed at 90°. The lumber was fixed with a strap to prevent the hip angle from fluctuating. The posture of the subjects in the measurement of ankle plantar flexion (PF) was the sitting position with knee and ankle angles of 0° and 90° (anatomical zero), respectively. The foot was securely fixed with a strap to prevent ankle joint angle from moving. The thigh was secured with a strap to prevent knee joint angle from moving. The measurement side was the right leg. It should be noted that the joint angle in measurement of KE and PF yielded the highest voluntary activation of the nervous system during MVC (Kubo et al., 2004) without age-related difference (Hurley et al., 1998; Morse et al., 2005). Prior to the measurement trials, all subjects performed warm-up trail. The trial consisted of muscle strength exertion subjectively perceived as 50% (2 or 3 repetitions), 80% (2 or 3 repetitions) and 100% (1 or 2 repetitions) of MVC. The subjects were instructed to exert fully for about 4 sec. To exclude the influence of fatigue, a rest interval was set between trials at least 3 min. The MVC torque of each action was measured twice or three. The torque data of each trial was amplified by a strain amplifier (DPM-611A, Kyowa, Japan). Afterwards, the obtained signals through an A/D converter (Power Lab/16SP, ADInstruments, Australia), and then recorded on a personal computer (ThinkPad, IMB, Japan) at 100 Hz sampling frequency and processed with a low-pass filter (cutoff frequency: 10 Hz). And then the maximal value in the torque curve was evaluated as the MVC torque (**Fig. 1**). In two or

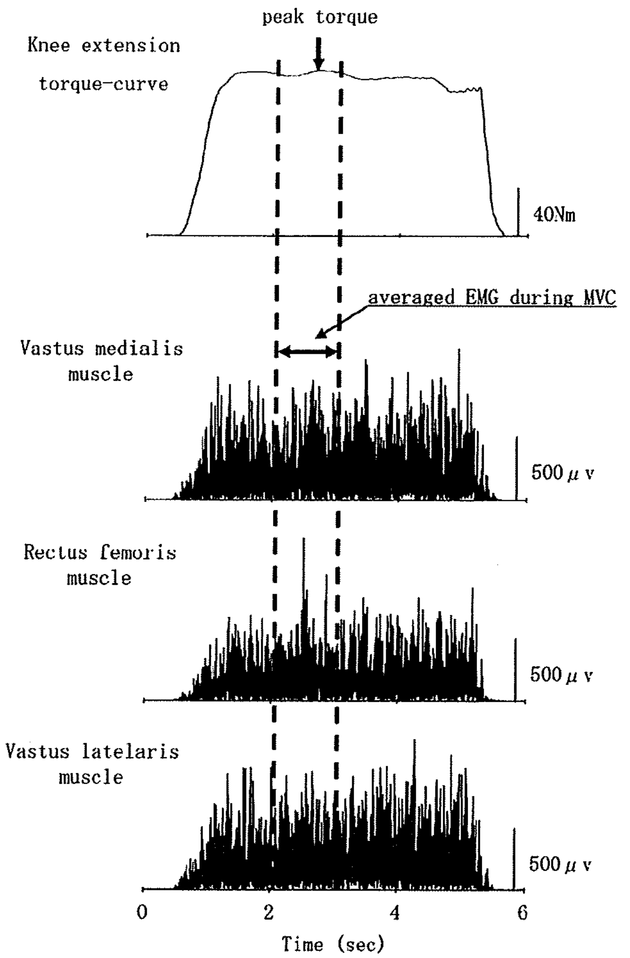

Figure 1 A typical example of knee extension torque-curve and rectified EMGs during MVC.

three torque measurements, the highest value was adopted. Furthermore, to exclude the influence of body size, MVC torque was divided by body weight (KE/BW and PF/BW).

2.4. Measurement of surface electromyograms (EMGs)

The EMGs during MVC and the prescribed daily physical actions were measured by a bipolar lead method using a portable EMG recording apparatus (ME6000T8, MEGA Electronics Ltd, Finland). The studied muscles were the following; the vastus medialis, rectus femoris, vastus latelalis, lateral gastrocnemius, medial gastrocnemius, and soleus muscles of right leg. Ag/AgCl electrodes of 15 mm diameter (N-00-S, Blue sensor, Ambu, Denmark) were attached over the bellies of the 6 muscles with an interelectrode distance of 20 mm for the measurements.

Before application of the electrodes, the skin area was shaved, cleaned with isopropyl alcohol, and abraded with coarse tape in order to reduce skin impedance and ensure good adhesion of the electrodes. One electrode functioned as a gland electrode as well as a preamplifier. After the signals of EMG were amplified 412-fold through the preamplifier, they were A/D converted through a band-pass filter (8-500 Hz/3 dB), at a sampling frequency of 1000 Hz, and stored in a built-in memory card. After the trials, EMG data were downloaded onto the personal computer (ThinkPad, IMB, Japan). Furthermore, the EMG signals and the recorded video pictures were synchronized through a synchronization unit (PH-100A synchronizer, DKH Co. Ltd., Japan) so that the digital video camera could capture rays of light.

All obtained EMGs data were full-wave rectified, and then averaged integrated EMGs during MVC and the measured actions were each calculated from them, respectively. For MVC, the averaged integrated EMGs were calculated over 1 sec including the point when the torque was maximal (**Fig. 1**). For SS and CR, the beginning and end of the actions were confirmed on the video pictures and the integrated EMGs were averaged over the 10 repetitions. For NW, the averaged integrated EMGs were calculated over a 10-meter walk; for AS and DS, those were calculated over a 14-step stairs while ascending or descending. The averaged integrated EMGs during the actions were quantified and normalized as the relative values (%EMG) to that during MVC. In the present study, the %EMGs of the quadriceps femoris muscles were calculated for each of the three constituent muscles, i.e. the vastus medialis, rectus femoris, and vastus latelalis muscles, and then the averaged value of the %EMG for them was evaluated as the level of muscular activities of the quadriceps femoris muscles (QF%EMG). Likewise, the %EMGs of the triceps surae muscles were calculated for each of the three constituent muscle, i.e. the latelal gastrocnemius, medial gastrocnemius, and soleus muscles, and the averaged value of %EMGs for these three muscles were evaluated as the level of muscular activities of the triceps surae muscles (TS%EMG).

2.5. Statistical analysis

All measurement results were expressed as means± standard deviations. The differences in age, height, body weight, and MVC torque were analyzed using a two-way ANOVA (age×gender). When a significant interaction (age×gender) was found, a one-way ANOVA was performed. For QF%EMG and TS%EMG, the effects of action type, age and gender on QF%EMG and TS%EMG were analyzed using a three-way ANOVA (action×age×gender), respectively. When a significant interaction (action×age×gender) was found, a two-way ANOVA (action×group; young men, young women, elderly men, and elderly women) was performed to examine the main effects and interaction. When the F value was significant, a post-hoc test was performed by Tukey's HSD. When the differences among the actions were examined, the four actions of NW, AS, DS, and SS were selected regarding QF%EMG and the four actions of NW, AS, DS, and CR were selected regarding TS%EMG. Pearson product-moment correlation coefficient (r) was calculated to determine the association between %EMG during each action and each of KE/BW and PF/BW. In addition, after adjustment for age, a partial correlation was examined between %EMG and MVC torque per body weight. For the present statistical processing, a statistical analysis software was used (SPSS12.0J, SPSS Japan, Japan). In all analyses, the significant level was set at $p<0.05$.

3. Results

3.1. MVC torque

Table 3 shows MVC torque in the young and elderly groups. For both men and women, KE and PF in the young group were significantly greater than those in the elderly group; in both age groups, those of men were significantly higher than those of women. Similarly, the age differences within the same gender and the gender differences within the same age group were significant in KE/BW and PF/BW, except for the gender difference in PF/BW of the elderly group.

3.2. Relationship between %EMG and MVC torque per body weight

Figure 2 shows typical examples of full-wave rectified EMG during all actions for one young and one elderly man. In both individuals, the muscular activities patterns of the quadriceps femoris muscles and the triceps surae muscles during the actions were similar. However, the elderly individuals exhibited higher %EMG than the young individuals.

The relationships between KE/BW and QF%EMG and between PF/BW and TS%EMG are shown in **Figure 3** and **4**, respectively. For all actions, the QF%EMG and TS%EMG were significantly correlated with KE/BW and PF/BW, respectively. The MVC torque per body weight and %EMG were also significantly correlated with age (KE/BW: $r=-0.559$, PF/BW: $r=-0.495$, QF%EMG: $r=0.308\sim0.673$, TS%EMG: $r=0.445\sim0.523$, all $p<0.05$). After adjustment for age, the corresponding relationships were still significant (QF%EMG and KE/BW: $r=-0.273\sim0.315$, TS%EMG and PF/BW: $r=-0.403\sim-0.482$, all $p<0.05$).

3.3. Age and gender differences in QF%EMG and TS%EMG

Table 4 shows QF%EMG and TS%EMG values during each action. The results of three-way ANOVA (action×age×gender) showed an interaction between gender and age. Thus, a two-way ANOVA (action×group) were performed, resulting in no interactions between action and group for QF%EMG and TS%EMG.

Table 3 Descriptive data on joint torque and joint torque per body weight.

	Young group		Elderly group	
	Men	Women	Men	Women
Joint torque (Nm)				
KE	184.5±41.2	111.6±21.2[a]	140.6±25.8[b]	72.9±12.3[a,b]
PF	187.2±34.7	137.2±27.1[a]	152.7±19.3[b]	100.6±19.4[a,b]
Joint torque per body weight (Nm/kg)				
KE/BW	2.78±0.52	2.01±0.30[a]	2.11±0.44[b]	1.46±0.23[a,b]
PF/BW	2.82±0.45	2.48±0.50[a]	2.28±0.29[b]	2.03±0.47[b]

KE: knee extension, PF: ankle plantar flexion, BW: body weight.
a: significantly different between the men and women within the same generation at $p<0.05$.
b: significantly different between the young and elderly within the same gender at $p<0.05$.

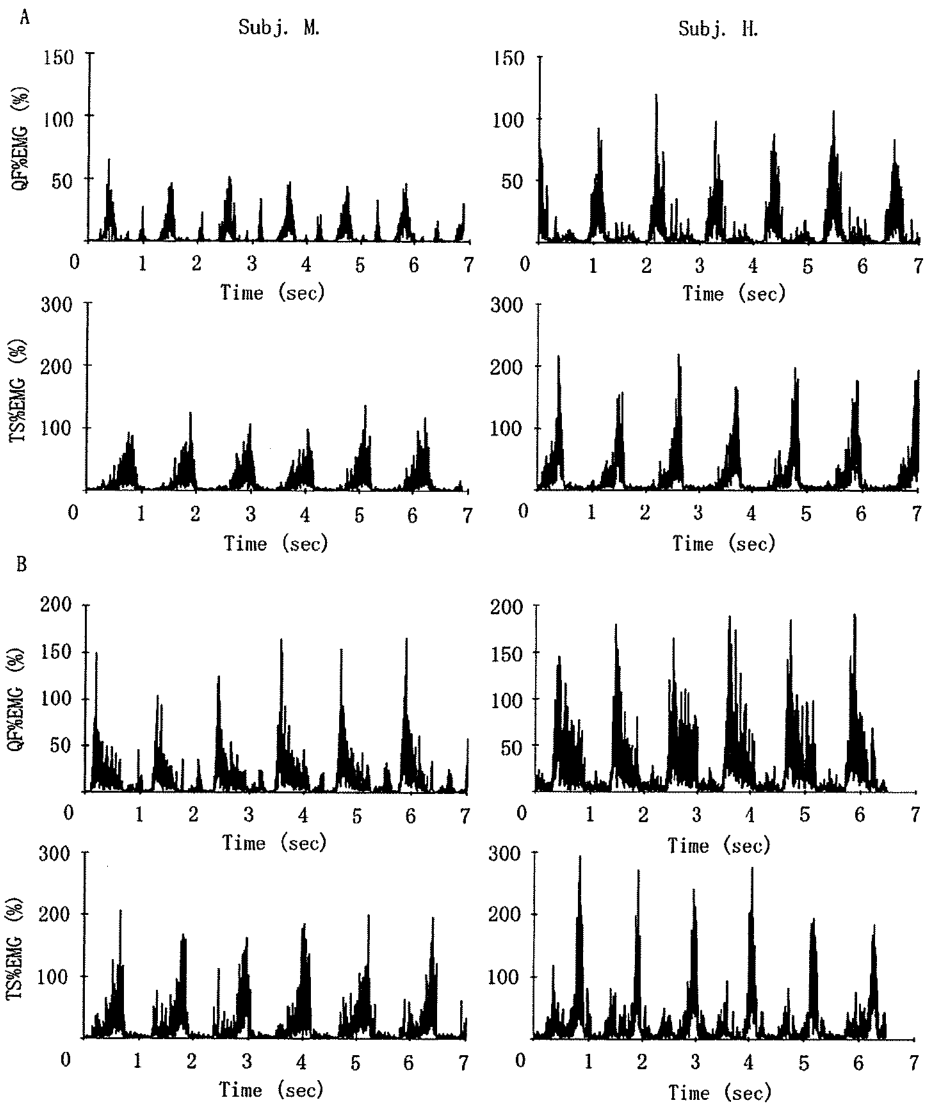

Figure 2 A typical example of EMG during measured actions in a young man (left panel) and elderly man (right panel). The level of muscular activity in QF and TS were expressed by averaged values of three constituent muscles.
A: normal walking, **B**: ascending the stairs, **C**: descending the stairs, **D**: standing up from and sitting onto a chair, **E**: calf raise.
Subj. M, 21 yrs, KE/BW: 2.82 Nm/kg, PF/BW: 3.57 Nm/kg.
Subj. H, 67 yrs, KE/BW: 1.96 Nm/kg, PF/BW: 2.58 Nm/kg.

The QF%EMG of NW was significantly lower than those of other actions, regardless of age and gender (all $p<0.001$). The QF%EMG of DS was significantly lower than those of SS ($p<0.001$). The TS%EMG in NW and DS were significantly lower than those in AS and CR.

For both men and women, QF%EMG and TS%EMG in the elderly group were significantly higher values than those in the young group (all $p<0.05$). The percentage of QF%EMG values of young group relative to those of elderly group ranged from 31% (NW) to 65% (SS) in men and from 57% (NW) to 98% (SS) in women. The corresponding values of TS%EMG were between 45% (DS) and 67% (CR) in men and between 55% (NW) and 70% (CR) in women.

In the young group, QF%EMG and TS%EMG in men were significantly lower values than those in women (all $p<0.05$). The percentage of %EMG of young women relative to those of young men ranged from 58% (NW) to 75% (SS) in QF%EMG, and from 69% (AS) to 89% (CR) in TS%EMG. In the elderly group, No gender differences in QF%EMG and TS%EMG were observed in all actions.

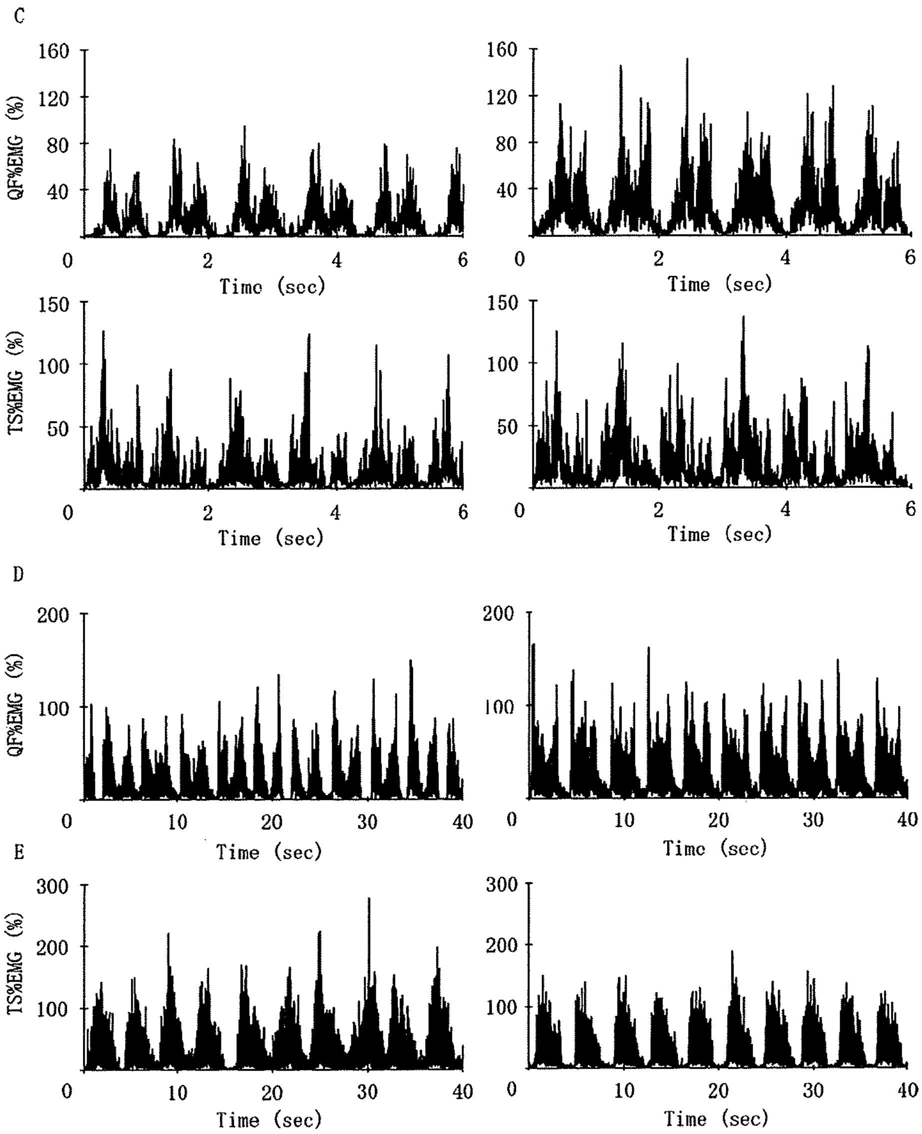

Figure 2

4. Discussion

The present findings were that 1) age and gender differences were observed in QF%EMG and TS%EMG during daily physical actions, and 2) the QF%EMG and TS%EMG were negatively correlated with KE/BW and PF/BW, respectively. The relationships were still significant, after the influence of age was excluded, suggesting that the levels of muscular activities during daily physical actions were influenced by MVC torque per body weight regardless of age.

4.1. Age difference in the levels of muscular activities during daily physical actions

Age differences in the levels of muscular activities during daily physical actions were observed in this study. In terms of the average values in both age groups, however, the age differences in the MVC torques were not consistent with those in the levels of muscular activities during daily physical actions. Namely, the %EMG for both men and women in this study did not correspond to the values calculated by following: the %EMG multiplied by MVC torque per body weight in the elderly group, and divided by MVC torque per body weight in the young group. The obtained values (men: 13.4~24.8% for QF%EMG,