Relationship between extremity muscle mass and physical fitness in obese middle-aged and elderly women

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Summary

The present study investigated the relationship between physical fitness and muscle mass for different body segments in obese elderly women ranging from 50 to 64 years of age. The results showed that the physical fitness of these women was generally low at scores of 3-4 on a 10-point scale. Regarding the relationship between physical fitness and muscle mass, grip strength was significantly correlated with the muscle mass of the arm, leg, and extremity. Also, the arm/leg muscle mass ratio exhibited a significant correlation to the 20 m shuttle run. In terms of arm/leg muscle mass balance, the greater the leg muscle mass, the greater the systemic endurance. For young people, muscle mass is correlated with various physical fitness parameters; however, in the present study, muscle mass only correlated to grip strength and the 20 m shuttle run. The reason for this was primarily excessive fat mass, and the effect of excessive fat mass was particularly high for movements requiring active muscle power.

Ⅰ Introduction

In 2004, the total fertility rate in Japan reached its lowest level at 1.29 [5], while the size of the elderly population continues to increase. Because of this phenomenon, the declining birthrate and the growing proportion of elderly people continue to advance. Furthermore, the health problems associated with aging and an aging society are diverse and place a great deal of pressure on society to provide care and treat diseases. Under these circumstances, a ten-year project called "Healthful Japan 21" was implemented in 2000. "Healthful Japan 21" emphasizes primary prevention of diseases, specifically lifestyle disease, and its goals are to reduce late middle age mortality and allow people to remain healthy for a longer portion of their lives. One measure is to reduce obesity. Increased body weight and abnormal endocrine function caused by obesity result in physical stress, which is closely related to such diseases as hypertension, diabetes, and hyperlipidemia [1,7,15]. Also, obesity in women is common after menopause, and the incidence of obesity for women in their 50s and 60s has been reported at 23.8% and 30.3%, respectively [5]. Such people continue to be obese, and in order to facilitate their awareness of the effects of obesity on daily living, it appears necessary to present goals and design concrete programs.

At present, in collaboration with Osaka Prefecture University, the city of Habikino, and the Osaka

Table 1　Age and physical characteristics of subjects

	Mean ± SD	Range
Age, yr	60.0 ± 3.0	51-64
Height, cm	153.0 ± 5.8	142.5-161.8
Weight, kg	57.9 ± 10.2	46.8-85.0
Fat, %	33.3 ± 2.6	30.2-37.8
Fat, kg	19.5 ± 4.8	14.2-30.3
FFM, kg	38.4 ± 5.5	32.5-54.7

n=19

Insured Persons Council, we are developing a health promotion program called the "diabetes prevention program", which is based on nutrition, exercise, and oral health for prediabetics (hemoglobin A1c:=5.5 to <6.1) living in Habikino. The objectives of the program are to: 1) conduct a fact-finding survey on the nutrition, exercise habits, and oral health of prediabetics; 2) analyze guidance programs in each area and establish their contents; 3) provide individual guidance; and 4) foster health promotion leaders among participants.

The present study assessed physical fitness and the muscle mass of different body segments in order to design and present exercise therapy for prediabetics. Furthermore, the present study investigated the relationship between physical fitness and muscle mass and their correlations to daily living, and gathered basic data for developing more appropriate exercise guidance programs.

Ⅱ　Methods

1. Subjects

Subjects were 19 elderly women with hemoglobin A1c values from 5.5 to less than 6.1 (**Table 1**). Informed consent was obtained following an explanation of the study objectives and measurement methods. All but one subject was right-handed.

2. Measurement of extremity muscle mass, fat percentage, and fat-free mass (FFM) by the bioelectrical impedance (BI) method

For estimation of body composition, including extremity muscle mass, a 12-lead BI muscle analyzer (Muscle-α, 50 kHz, 500 μA: Art Heaven 9, Kyoto, Japan) and disposable electrocardiogram (ECG) electrodes (RedDot 2339: 3M, U.S.A) were used.

Table 2　Muscle mass of body segments and extremity estimated by the BI method

	Mean ± SD	Range
Forearm, kg		
Left	0.38 ± 0.06	0.30-0.50
Right	0.40 ± 0.06*	0.33-0.53
Upper arm, kg		
Left	0.42 ± 0.07	0.32-0.56
Right	0.42 ± 0.07	0.30-0.54
Arm, kg		
Left	0.80 ± 0.12	0.65-1.03
Right	0.83 ± 0.12*	0.66-1.04
a	1.63 ± 0.24	1.33-2.07
Thigh, kg		
Left	2.85 ± 0.48	2.25-3.86
Right	2.84 ± 0.47	2.21-3.78
Lower leg, kg		
Left	1.38 ± 0.22	0.96-1.76
Right	1.43 ± 0.27	0.81-2.04
Leg, kg		
Left	4.23 ± 0.63	3.21-5.62
Right	4.27 ± 0.66	3.09-5.82
a	8.51 ± 1.28	6.30-11.44
Extremity, kg		
b	10.13 ± 1.48	7.64-13.47

n=19
Arm: forearm + upper arm
Leg: thigh + lower leg
a: right + left, b: arm + leg
＊: $p < 0.05$

Impedance (Z) was continuously measured using 2 induction methods: distal induction (first test); and proximal induction (second test)[12,26]. Current injecting electrodes were placed on the dorsal centers of the left and right hands and feet. In the first Z test by distal induction, a voltage sensing electrode was placed on the center of the ulnar and radial styloid processes and the center of the medial and lateral malleoli bilaterally. In the second Z test by proximal induction, current injecting electrodes were placed in the same manner as the first test, while a voltage sensing electrode was placed on the radial and tibial (outer) points. With these electrode arrangements, Z of bilateral arms and legs was measured in the first test and Z of bilateral upper arms and thighs was measured in the second test. The Z of bilateral forearms and lower legs was calculated as the difference between the first and second Z tests. Muscle mass of the following body

Table 3 Physical fitness measurements of subjects

	Mean ± SD	(Point)	Range (Max-Min)	
Grip strength, kg	22.0 ± 4.6	(2.9 ± 1.7)	13.6-31.7	(1-7)
Sit-ups, times	10.6 ± 2.7	(4.3 ± 0.8)	5.0-15.0	(3-6)
Sit-and-reach, cm	39.3 ± 9.3	(4.6 ± 2.1)	20.0-57.0	(1-9)
Side step, times	33.6 ± 4.2	(4.0 ± 1.1)	28.0-42.0	(3-6)
20 m shuttle run, times	13.6 ± 5.7	(3.3 ± 1.2)	8.0-29.0	(2-6)
Standing long jump, cm	120.1 ± 12.8	(3.0 ± 0.9)	95.0-146.0	(1-5)

n=19
( ) Point of ten stage assessment.

segments was estimated bilaterally: forearms; thighs; lower legs; arms (forearm plus upper arm); legs (thigh plus lower leg); and all extremities (arms plus legs). Furthermore, fat percentage and FFM were estimated.

3. Physical fitness measurement

Grip strength (average of left and right sides), sit-up, sit-and-reach, side step, 20 m shuttle run, and standing long jump were measured according to the methods established by the Ministry of Education, Culture, Sports, Science and Technology [11].

4. Statistical analysis

Measured values were expressed as mean ± standard deviation. A paired t-test was used to compare left- and right-side measurements. Pearson's product-moment correlation coefficients were used to analyze correlations among measurements. Statistical significance was established at the $p<0.05$ level.

Ⅲ Results and Discussion

Table 1 shows the physical characteristics of the subjects. Subjects' mean fat percentage was 33%, and all subjects were obese with a fat percentage = 30%. Therefore, the subjects of the present study were obese due to energy imbalance. In addition, because the subjects' elevated level of hemoglobin A1c, they were at a higher risk for developing glucose metabolism disorders and required early intervention based on health guidance. **Table 2** shows the extremity muscle

Table 4 Correlation coefficient matrix

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1 Grip strength , kg	1.000																
2 Sit-ups, times	−0.173	1.000															
3 Sit-and-reach, cm	−0.319	−0.239	1.000														
4 Side step, times	0.273	0.411	−0.044	1.000													
5 20 m shuttle run, times	−0.163	0.307	−0.126	0.337	1.000												
6 Standing long jump, cm	0.437	0.208	−0.131	0.356	0.078	1.000											
7 Fat, %	0.424	−0.409	0.153	−0.033	−0.484	−0.285	1.000										
8 Fat, kg	0.579	−0.252	0.005	0.107	−0.330	−0.007	0.886	1.000									
9 FFM, kg	0.626	−0.096	−0.130	0.216	−0.172	0.205	0.678	0.939	1.000								
10 Forearm (kg)	0.447	−0.116	0.204	0.099	−0.407	0.048	0.606	0.763	0.773	1.000							
11 Upper arm (kg)	0.632	−0.162	0.035	0.089	−0.223	0.087	0.687	0.858	0.877	0.771	1.000						
12 Arm (kg)	0.576	−0.149	0.125	0.100	−0.332	0.073	0.688	0.862	0.878	0.938	0.944	1.000					
13 Thigh (kg)	0.561	−0.030	−0.126	0.251	−0.228	0.079	0.704	0.904	0.937	0.819	0.854	0.889	1.000				
14 Lower leg (kg)	0.241	−0.102	0.001	0.106	0.235	−0.112	0.388	0.600	0.680	0.394	0.651	0.559	0.600	1.000			
15 Leg (kg)	0.501	−0.060	−0.092	0.223	−0.080	0.016	0.659	0.885	0.938	0.746	0.867	0.859	0.955	0.810	1.000		
16 Extremity (kg)	0.522	−0.075	−0.060	0.208	−0.112	0.025	0.676	0.898	0.946	0.791	0.896	0.897	0.963	0.786	0.997	1.000	
17 Arm/Leg	0.128	−0.136	0.326	−0.206	−0.456	0.132	−0.015	−0.115	−0.176	0.263	0.063	0.171	−0.205	−0.549	−0.354	−0.278	1.000

FFM: Fat Free Mass
10-15: muscle mass (right + left)

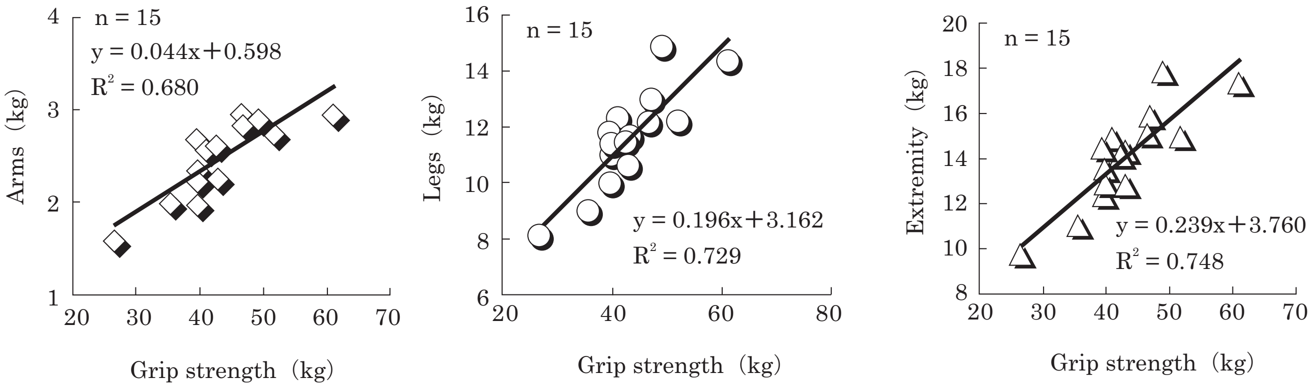

Fig.1　Relationship between grip strength and muscle mass.

mass and the muscle mass of body segments as measured by the BI method. Left and right differences were observed in the forearm and arm, with a significantly higher muscle mass on the right side than on the left side. The reason for this was because all subjects but one were right-handed, thus, the muscles of the dominant hand were more developed through activities of daily living (ADL). There were no left-right differences for the other body segments, and left-right balance was maintained. **Table 3** shows the results of a physical fitness test for the subjects. According to a 10-point scale, the mean score for each physical fitness parameter was generally low at 3-4. These results clarified that, of the various parameters, it is important to improve muscle strength, endurance, and agility.

In the past, many studies investigated the relationship of ADL in the elderly to muscle strength (muscle mass), physical fitness, and motor ability [4,6,8,9,14,17-19,27]. Most studies have focused on the muscle strength of the legs, which play an important role in body movements [8,9,14,19]. Grimby [4] studied muscle strength and aerobic power in the elderly and reported that these parameters decreased in proportion to the amount of muscle mass due to daily inactivity, in particular, decreased motor unit output. Also, Rolland et al. [14] reported that there was no correlation between muscle strength and obesity in elderly women and that the leg muscle strength of active obese elderly women was greater than that of inactive obese elderly women. The subjects of the present study were obese elderly women who did not exercise regularly, and because there was no control group comprised of active elderly women, a comparison similar to that performed by Rolland et al.[14] was not possible; however, the mean score for the standing long jump, which indicates leg muscle strength, was low at 3 on a 10-point scale.

Furthermore, the present study investigated the correlation of physical fitness to body composition, such as muscle mass, (**Table 4**). In the past, we investigated the correlation of muscle mass to muscle strength and aerobic power in young men[24]. The results showed that there was a significant correlation between muscle mass and various physical fitness parameters and it was concluded that muscle mass is an important indicator of ADL. In the present study, grip strength exhibited a significant correlation to arm muscle mass, leg muscle mass, extremity muscle mass(**Fig 1**), and FFM. The same findings were obtained in our past study on young men. This suggests that grip strength may be a useful variable for indirectly assessing the muscle mass of not only the arm, but also the leg and extremity. A negative correlation existed between the 20 m shuttle run and fat percentage or arm/leg muscle mass ratio. The score for the 20 m shuttle run, a test for systemic endurance, was particularly low for severely obese women. Also, arm/leg muscle mass ratio has exhibited a negative correlation with maximum oxygen uptake (an indicator of endurance) [24], and similar findings were observed for the obese elderly women in the present study. In terms of the balance between arm muscle mass and leg muscle mass, the greater the leg muscle mass, the greater the endurance. Unlike in young people, muscle mass was not correlated to the various parameters of physical fitness and motor ability in obese elderly women. A significant corre-lation was observed only between grip strength and muscle mass and between arm/leg muscle mass ratio and fat percentage or 20 m shuttle run. The reasons for this include decreased muscle strength caused by aging or inactive lifestyle, in particular, delayed re-action due to reduced neurological function[19]. Previous studies have shown that the FFM for obese people is higher than that for non-obese people[10,22,23]. As FFM appears to be an appropriate indicator for muscle mass[10], the subjects' leg muscle mass, which supports body weight, may be greater than that of non-obese people. In general, muscle strength is proportionally corre-lated with muscle cross sectional area, but as is the case with the present study, in obese people, excessive fat weight acts as a negative factor, and the relationship between muscle mass and physical fitness does not necessarily apply. Simply, excessive fat accumulation is a negative factor for physical fitness and motor ability[2,3,13,22,23]. Therefore, it may be possible to improve physical fitness and motor ability simply by reducing excess fat in obese individuals.

The relationship of muscle mass to physical characteristics and physical fitness was investigated in obese elderly women, and the results clarified that inactive lifestyle and excessive fat accumulation contribute to poor physical fitness. Furthermore, since the subjects of the present study were prediabetics, it will be necessary to design exercise programs that 1) improve glucose metabolism and 2) reduce excessive fat mass. Sano[16] reported that aerobic exercise with an intensity of 40-70% $\dot{V}O_2max$ was effective in improving glucose metabolism, lipid metabolism, and obesity. Irie et al. [6] reported that improving muscle power and balance was effective in maintaining ADL and preventing falls in the elderly [6]. Furthermore, Toji and Kaneko[21] clarified that high intensity 8-10 repetition strengthening training was effective in increasing the muscle power of the elderly. Therefore, with our diabetes prevention program, it will be necessary to prescribe strengthening training and aerobic exercise with an intensity of 40-70% $\dot{V}O_2max$ in order to improve the metabolism of sugar and fat and neurological function.

In advanced age, the deterioration of psychological and physiological functions becomes marked. While aging can not be avoided, it is possible to maintain quality of life (QOL) by maintaining physical and psychological function. If QOL can be maintained, the level of stress is reduced for not only the elderly individual, but also their family members who care for them. In addition, maintaining QOL can reduce medical costs. Takenaka et al. [20] reported that QOL was high for the elderly who were active in everyday life. Also, Yaguchi et al. [25] reported that the subjective happiness scores for individuals who exercised were higher than those for individuals who did not exercise; therefore, it is considered important for the elderly to exercise.

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肥満中高年女性の体力と四肢筋量との関連

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本研究は，肥満中高年女性の体力と四肢筋量との関連について検討した。体力は全般に低く，10 段階評価で平均 3-4 点であった。体力と筋量の関連に関しては，握力が腕，下肢および四肢筋量との相関が高かった。また，腕／脚筋量比は 20 m シャトルランとの相関が認められた。つまり，腕／脚筋量比では，脚筋量が発達している者ほど持久力が高いことを示している。青年層に関しては，筋量は種々の体力との関連が高かったが，本研究では唯一握力と 20 m シャトルランにのみ筋量との関連がみられた。この要因として，過剰な脂肪の影響が考えられ，特に瞬発的な動作ではその影響が大きかった。

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