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Relationship between Fat-Free Mass and Muscle Strength, Nutrient Intakes, Exercise Habits in Male Aged

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ABSTRACT

This study was performed for the purpose of finding the relationship between fat-free mass (FFM), which mainly represents muscle mass change, and muscle strength. The correlation between diet and exercise behaviors and FFM in healthy elderly men over age 55 was also investigated. FFM and corresponding hand grip strength declined significantly with increasing age. However, the concentration of serum albumin, the indicator of protein nutritional status, showed no change with increases in age. The subjects were categorized into three groups according to FFM tertiles. Anthropometry such as height, BMI, circumferences of waist and hips, body fat mass percent and hand grip strength decreased significantly in the lowest FFM group. But albumin level showed no change relative to FFM level. FFM showed a significant relationship to nutrient intake such as energy and fat. However, no association was found with exercise behavior, probably because there were no instances of resistance exercise habits among the subjects studied. The variance in FFM could be attributed 86.2% to height and age. The variance of height-adjusted FFM could be attributed only 40.6% to age and fat intake. In conclusion, decreases in FFM may cause reductions in muscle strength in elderly men. Increasing energy and fat intake were associated with increased FFM and may protect elderly men from the risk of sarcopenia. FFM had no association with endurance exercise habits.

KEY WORDS: fat-free mass, muscle strength, nutrient intake, exercise behavior.

INTRODUCTION

Adults at an advanced age experience profound changes in body composition, increased whole body fat, and decreased body protein and bone mass, resulting in decreased lean body mass (LBM, fat-free mass). Accumulation of body fat and abdominal fat is known to be associated with increased risk of cardiovascular diseases like diabetes, hypertension, and dyslipidemia. Loss of LBM is associated with increased risk of sarcopenia and osteoporosis. Decreased LBM is known to occur primarily as a result of losses in skeletal muscle mass.[1] Muscle is the most prominent determinant of differences in LBM and total body water between different age groups[2] for the following reasons: ① high proportion of weight to body mass, ②dramatic decrease of weight with age, ③ high proportion of body cell mass in muscle.[3] The loss of muscle mass and muscle strength with increased age is termed sarcopenia.[4]

Reductions in muscle mass can be accurately assessed by measuring the muscle cross-sectional area using computer tomography.[5] Computer tomography has shown that from the thirties, muscle cross-sectional area decreases due to fat accumulation within muscle and declination of muscle density.[5][6] Sarcopenia due to aging causes not only muscular strength loss[7] but also influences bone metabolism, like bone density. Both are attributes of the frequent fragility in the elderly.[8][9] Reductions in LBM and muscle mass also cause declination of basal metabolism and activity, resulting in reduced energy expenditure. As a result of decreased dietary intake and nutritional deficiency, the aging process is accelerated. The loss of muscle strength with age occurs irrespective of muscle location (upper vs. lower extremities) and function.[1] Starting and progression of muscle strength showed differences between men and women.[10] The percentage reduction in total strength is higher in men than women. Declines in lower extremity strength and grasping power are well known. Reductions in muscular strength with aging result in a loss of the ability to perform basic daily activities. The main cause of weakness and the vegetative state in older people is the loss of muscular strength.[4] The loss of muscular strength with aging results in decreased basal activities, which causes accelerated weakness, disability and loss of mental sharpness.[11][12] Cross-sectional or longitudinal studies and grasping power (= hand grip dynanometry), which represent the muscular strength vari-

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ation between different age groups due to muscle mass and LBM change, are frequently used to test elderly people[12,16] because they can be performed in a short period of time at low cost.

Dietary intake seems to be one of the most important components in the prevention of muscle and LBM loss with aging, but there have been no consistent reports on the effects of nutrition. Nutritional imbalance or nutritional deficiencies are reported to accelerate the loss of LBM and muscle mass, so that energy and protein intake should be increased above RDA in older people.[17,18] In contrast, there are reports that reduced physical activity and LBM in the elderly causes a decline in resting metabolism and daily activity energy expenditure, resulting in a reduced energy requirement.[19] In animal experiments, it has been shown that excess protein intake could not prevent the loss of LBM, and reductions in dietary intake have been shown to delay the lowering of protein synthesis rate and muscle mass in older rats.[20] However, there have been no reports on the relationship between the loss of LBM or muscle mass and dietary intake in elderly Koreans, other than the study by Lee[21] on elderly women.

Physical activity is well known to be associated with LBM and muscle mass. Among the various types of exercise, progressive resistance training like weight training promotes muscle protein synthesis and is effective in preventing the loss of muscle mass and LBM. It is thus safe for elderly people.[4,22] Recently, dumbbell exercises, a low intensity and aerobic-resistance exercise, have been successful with the elderly.[12]

As mentioned above, the prevention of age-related loss of muscle mass and LBM is reported to be very important for the health of older people. However, it has been seldom investigated in relation to lifestyle factors such as dietary intake, exercise habits, LBM, and muscle mass in elderly Koreans. In this study, using LBM as a proxy indicator of muscle mass and grasping power as an indicator of muscular strength, the relationship between fat-free mass and muscular strength with the elderly was analyzed. Also, the relationship between fat-free mass and nutritional intake, exercise habits and protein nutritional state was investigated. Finally, the primary components that could explain variances in fat-free mass with the elderly were studied.

SUBJECTS AND METHODS

A nutritional survey of elderly Korean adults was conducted at a public health center in Seoul. Male adults over 55 and without chronic diseases such as diabetes($n = 40$), were selected. Dietary intake, anthropometric characteristics and grasping power were measured. Dietary food intake was assessed using the 24-hour recall method and nutrient intake was calculated using the Can-pro program.

The subjects were asked about their exercise habits, such as frequency and duration of exercise. From these data, the average daily duration of exercise was calculated. Energy expenditure for exercise was calculated using frequency of performance, mean duration and energy cost per kg body weight for various sports and body weights.

Anthropometric measurements included height, weight, body composition, circumferences of waist and hips and WHR. Fat-free mass, fat mass and fat mass percent in the entire body were measured using Inbody 3.0 (Biospace, Korea). Grasping power was measured using digital handgrip dynanomometer (KKK. 5101, Takei Scientific Co, Japan).

Blood samples were taken early in the morning from the antecubital vein following a 12-hour fast. Blood samples were centrifuged at 2000rpm, 4℃, for 10 min and were stored frozen at −32℃ until analysis. The concentration of serum albumin was analyzed using a blood analyzer (DT60, Johnes and Johnes, USA).

Statistical analysis was conducted using SAS program (Version 6.12). The subjects were divided into three age groups according to age category: 55 − 64 years old, 65 − 74 years old and over 75 years old. Changes in fat-free mass and other anthropometric variables and serum albumin concentration as well as grasping power according to age category were analyzed using general linear model. The subjects were also divided according to FFM into tertiles: low FFM, medium FFM and high FFM. The differences in grasping power, anthropometric measurements and concentrations of serum albumin among the three FFM groups was analyzed using Duncan's multiple comparison method after ANOVA analysis. Predictors that can explain the variances in FFM without interactive effect among analyzing factors were sought using adjusted multiple stepwise regression analysis.

RESULTS

1. General characteristics and daily nutrient intake, exercise habits of the subjects

The mean age and BMI of the subjects was 67.1 years and 24.0 kg/m^2, respectively. Table 1 shows the mean nutrient intake of the subjects in comparison to Korean

RDA. Intake of nutrients differed from Korean RDA in a range from 67.8% to 159.7%. Daily intake of protein, a nutrient known to be closely associated with muscle mass and fat-free mass, was above Korean RDA, which is 1.11 g per kg body weight. But intake of other nutrients was below Korean RDA, especially vitamin B_2 and Ca, which were shown to be in a state of nutritional deficiency.

Exercise habits are presented in Table 2. The proportion of subjects without regular exercise habits was 43%. Of types of exercise, the proportion engaging in endurance exercise with mild resistant characteristics such as climbing, exercising at a health center or walking accounted for 55%. Thus, the exercise habits of the subjects were mainly of the endurance variety.

The results showed that the proportion of subjects performing exercise more frequently than 4 days per week was 42.5%. Most of the subjects were exercising less than once every two days. The average daily energy expenditure was above 200 kcal. The mean exercise duration time per day calculated with exercise time per performance and frequency per week was lower than thirty minutes, which is well below the exercise time required for health maintenance.

The average daily energy expenditure was above 200 kcal, which was 2.5 times that of the female subjects in our previous report.

Table 1. Nutrient intakes of elderly (n = 40)

Variables	Mean ± SD	RDA%
Energy (Cal)	1709 ± 461	83.2 ± 22.7
Protein (g)	72.3 ± 35.1	110.5 ± 55.2
(%)	16.4 ± 4.6	
Fat (g)	36.6 ± 17.9	
(%)	18.7 ± 6.8	
Carbohydrate (g)	269.2 ± 75.7	
(%)	64.0 ± 10.5	
Dietary fiber (g)	7.7 ± 7.0	
Vit. A (μg RE)	946.7 ± 2415	135.2 ± 345.1
Vit. B1 (mg)	1.38 ± 1.21	130.2 ± 121.1
Vit. B2 (mg)	1.05 ± 1.24	84.0 ± 103.8
Niacin (mg NE)	16.2 ± 7.6	119.2 ± 59.3
Vit. C (mg)	100.3 ± 104.4	143.2 ± 149.2
Ca (mg)	474.6 ± 297.7	67.8 ± 42.5
P (mg)	1117.6 ± 567.6	159.7 ± 81.1
Fe (mg)	12.2 ± 8.1	102.0 ± 67.8

Table 2. Exercise behavior of subjects

Variables		Frequency, %(n)
Exercise	YES	57.5(23)
	NO	42.5(17)
Exercise type	NO	42.5(17)
	Walking, Aerobics, Tennis, Swimming, Golf	22.5(9)
	Climing, Health	32.5(13)
	Others	2.5(1)
Frequency/week	less than 1	45.0(18)
	2 - 3	12.5(5)
	more than 4	42.5(17)
Variables		Mean ± SD[1)]
Exercise time(hour/day)		0.46 ± 0.56
Energy expenditure for exercise(Cal/day)		207.0 ± 286.9

1) Mean ± SD = Mean ± standard deviation

2. Anthropometric variables, serum albumin concentration and handgrip strength according to age

Anthropometric variables and serum albumin concentration by age of the subjects are presented in Table 3. Height, BMI, body fat mass, fat mass percent and circumference of waist and hips did not show any significant differences according to age. However, weight and fat-free mass were found to decrease with increasing age.

Serum albumin level is acknowledged to be an indicator of protein nutritional status. Serum albumin concentration is not influenced by increasing age. Handgrip strength, a proxy indicator of muscular strength, decreased significantly with increasing age.

3. Fat-free mass and anthropometric variables, handgrip strength, serum albumin level

In this study, the subjects were also categorized into three groups according to tertiles of fat-free mass distribution: low FFM, medium FFM and high FFM. Comparison of anthropometry, handgrip strength and serum

Table 3. Anthropometry, grip strength, serum albumin concentration by age category (Mean ± SD)

Variables \ Age group	55 ≤ Age < 65	65 ≤ Age < 75	75 ≤ Age
Age (year)	58.5 ± 2.4^{a*}	68.4 ± 2.8^{a}	79.4 ± 2.9^{a}
Weight (kg)	69.5 ± 11.0^{a}	66.1 ± 6.4^{ab}	58.9 ± 9.2^{b}
Height (cm)	167.7 ± 5.7	165.7 ± 7.4	160.6 ± 11.5
BMI (kg/m²)	24.6 ± 2.8	24.1 ± 1.8	22.8 ± 2.2
Fat-free mass (kg)	52.9 ± 4.9^{a}	50.6 ± 6.4^{ab}	45.5 ± 7.8^{b}
Fat mass (kg)	16.6 ± 6.6	15.5 ± 3.8	13.4 ± 3.5
Fat mass (%)	23.2 ± 5.4	23.5 ± 5.5	22.9 ± 5.3
Waist circum.[1] (cm)	86.6 ± 8.9	86.9 ± 6.4	83.2 ± 7.0
Hip circum. (cm)	95.9 ± 7.7	93.1 ± 4.3	91.4 ± 5.2
WHR	0.90 ± 0.06	0.94 ± 0.05	0.91 ± 0.06
Right GP[2] (gps)	35.8 ± 5.3^{a}	32.2 ± 5.7^{ab}	29.7 ± 8.4^{b}
Left GP (gps)	34.8 ± 6.4^{a}	30.1 ± 5.8^{ab}	26.4 ± 7.3^{b}
Mean GP[3] (gps)	35.3 ± 5.6^{a}	31.2 ± 4.8^{ab}	28.0 ± 7.7^{b}
Albumin (g/dl)	4.6 ± 0.5	4.4 ± 0.8	4.2 ± 0.5

1) Circum.: circumference
2) GP: hand grip strength
3) Mean GP: Mean of right and left grip strength
*: Means with different letters within a row are significantly different from each other at $p < 0.05$

albumin concentration according to FFM category is presented in Table 4. Weight and height were found to decrease with increasing FFM. BMI was highest in the high FFM group. Waist circumference, which is often used as an indicator of central obesity, increased with increasing FFM. Since hip circumference showed a similar pattern, no difference was found in waist-hip ratio according to FFM.

Table 4. Anthropometry, grip strength, serum albumin concentration by fat-free mass category (Mean ± SD)

Variables	Low FFM	Medium FFM	High FFM
Weight (kg)	58.4 ± 7.4^{ab*}	63.5 ± 2.5^{b}	75.0 ± 8.7^{a}
Height (cm)	158 ± 9.3^{c}	165.3 ± 2.4^{b}	172.0 ± 4.7^{a}
BMI (kg/m^2)	23.4 ± 2.2^{b}	23.3 ± 1.2^{b}	25.3 ± 2.9^{a}
Fat mass (%)	26.0 ± 5.3^{a}	20.4 ± 3.2^{b}	23.8 ± 5.8^{ab}
Fat mass (kg)	15.3 ± 4.2^{ab}	13.0 ± 2.6^{b}	18.2 ± 6.3^{a}
Waist circum. (cm)	82.7 ± 7.3^{b}	84.1 ± 5.3^{b}	91.1 ± 7.3^{a}
Hip circum. (cm)	91.3 ± 3.5^{b}	90.8 ± 4.0^{b}	99.2 ± 6.0^{a}
WHR	0.91 ± 3.5	0.93 ± 0.07	0.92 ± 0.06
Right GP[1)] (gps)	26.5 ± 6.5^{b}	34.6 ± 4.1^{a}	36.6 ± 4.7^{a}
Left GP (gps)	26.0 ± 6.6^{b}	31.3 ± 5.7^{ab}	35.4 ± 5.8^{a}
Mean GP[2)] (gps)	26.2 ± 6.6^{b}	32.9 ± 4.3^{a}	36.0 ± 4.2^{a}
Albumin (g/dl)	4.3 ± 0.7	4.5 ± 0.5	4.4 ± 0.7

1) Circum. = circumference 2) GP = hand grip strength
3) Mean GP = Mean of right and left grip strength
*: Means with different letters within a row are significantly different from each other at $p < 0.05$

Grasping power represents a loss of muscular strength through muscle mass loss. The grip strength of the right and left hands was significantly higher in the highest FFM group. Serum albumin concentration showed no significant differences according to FFM level.

4. Fat-free mass and nutrient intake, exercise behavior

The relationship between fat-free mass and nutrient intake are presented with correlation coefficients in Tables 5 and 6. Nutrient balance and protein intake are known to be important factors for the prevention of loss of muscle mass and muscular strength with aging.[17)18)23)] In this study, energy and fat intake was significantly related to fat free

Table 5. Correlation coefficients between nutrient intakes and fat-free mass

Variables	Fat-free mass
Energy (kcal)	0.433*
Protein (g)	0.217
Fat (g)	0.422*
Carbohydrate (g)	0.313
Cholesterol (mg)	-0.030
Fiber (g)	0.229
Ca (mg)	-0.004
P (mg)	0.146
Fe (mg)	0.134
Na (mg)	0.095
K (mg)	0.137
Vitamin A (ug R.E.)	0.199
Vitamin B_1 (mg)	0.303
Vitamin B_2 (mg)	0.219
Niacin (mg NE)	0.178
Vitamin C (mg)	0.176

*: Significant at $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

Table 6. Correlation coefficients between intakes of animal and vegetable nutrient and fat free mass

Variables	Fat-free mass
Animal protein (g)	0.052
Vegetable protein (g)	0.229
Animal fat (g)	0.260
Vegetable fat (g)	0.345*
Animal Ca (mg)	-0.058
Vegetable Ca (mg)	0.061
Animal Fe (mg)	0.055
Vegetable Fe (mg)	0.135

*: Significant at $p < 0.05$ **: $p < 0.01$, ***: $p < 0.001$

Table 7. Correlation coefficients between exercise activity variables and fat-free mass

Variables	Fat-free mass
Energy expenditure for Exercise (Cal/day)	0.231
Hour spended for Exercise (hour/day)	0.208
Daily hour for sitting (hour/day)	0.326

*: Significant at $p < 0.05$ **: $p < 0.01$ ***: $p < 0.001$

Table 8. Predictors for fat-free mass

Dependent variable	Independent variables	b	SE(b)	t-test	p-value	Beta	Beta × r × 100
Fat-free mass	Intercept	-54.6134	12.2791	-4.448	0.0001		
	Height	0.6894	0.0608	11.331	0.0001	0.8543	78.0
	Age	-0.1320	0.0613	-2.153	0.0401	-0.1624	8.2
						R2 of model (%) = 86.2	
						Adjusted R^2 (%) = 85.6	
Height-adjusted FFM	Intercept	0.3915	0.0352	11.13	0.0001		
	Age	0.0006	0.0002	2.694	0.0118	0.3892	25.3
	Fat intake	-0.002	0.0005	-3.282	0.0028	-0.4743	15.3
						R^2 of model (%) = 40.6	
						Adjusted R^2 (%) = 38.5	

r: Pearson correlation coefficient

mass, but protein intake did not show any association with fat-free mass.

The correlation coefficients between fat-free mass and weekly exercise duration, daily energy expenditure for exercise and time spent sitting are presented in Table 7. The results showed no association of these parameters with fat-free mass.

5. Predictors explaining variances in fat-free mass

Multiple stepwise regressional analysis was conducted to determine predictors that can explain variances in fat-free mass using nutrient intake, exercise behaviors, age and anthropometric variables such as independent variables and fat free mass as dependent variables (Table 8). Height and age can explain 86.2% of the variances in fat-free mass. After adjusting for height, the variances in fat-free mass can be explained 40.6% by age and fat intake. This result shows that changes in fat-free mass are determined mainly by physical condition and age. Excluding the influences of height, age and nutrient intake are important factors in fat-free mass changes. However 60% of the height adjusted fat-free mass variances cannot be explained in this study.

DISCUSSION

In this study, factors related to the loss of fat-free mass with advancing age, which accelerate the aging process, were investigated in male adults over 55.

With increasing age, weight and fat-free mass were found to decrease, although height and other anthropometric variables did not fall. The fat-free mass of the subjects over 75 was 14% lower than that of the subjects who were 55 – 65 years old. It was reported that fat-free mass showed a maximum value in the mid-thirties and declined thereafter so that the difference between age 25 and age 70 was 16%.[25] Results from the anthropometry and whole body scanning[5] demonstrated that variations in body composition between men of different ages and the significant difference in weight between the middle-aged and older groups was largely a result of differences in lean body weight rather than fat. Analysis of covariance indicated that the weight and body composition difference between younger and older men was not explained by the observed height differences.

Overall, lean body weight in the older men was 88% that of the middle-aged men, a similar percentage difference being found in the CT areas as well (leg 88%, abdomen 91%, chest 98%, arm 88%). Compared with the results of our previous report, fat-free mass reduction in elderly Korean men seems to occur more rapidly than in women. With the passing of 10 years, mean fat-free mass of the elderly men decreased ca. 3.7 kg, which is more than was reported with elderly Korean women. This result confirmed the more rapid declination of fat-free mass with increasing age in men than women. Although the loss of fat-free mass was influenced generally both by bone mass loss and muscle mass loss, the reduction of muscle mass resulting from body cell mass loss is the main determinant of fat-free mass loss with increasing age. With aging, RNA activity and muscle capacity declines, so the protein synthesis rate in muscle decreases more dramatically than in the other organs. Yarasheski *et al.*[26] and Welle *et al.*[27] have demonstrated that muscle protein synthesis is reduced in the elderly at the whole body level. Thus the decreases in muscle strength and power with aging are probably due to reduced muscle mass and muscle quality, which might alter the intrinsic contractile properties.[28] The variation of fat-free mass between genders in this report and our previous report suggests that the loss of muscle mass was the main contributing factor to fat-free mass reduction with aging. Muscle atrophy seems to occur in accordance with the progressive decline in whole muscle fibers,[29] and selective changes in myofibrillar type 2 fibers[30] and myosine heavy chain composition.[31]

Serum albumin concentration was not influenced by age increases in our study, which is consistent with the results of other reports with elderly Korean women.[21][32][33] According to Fu and Nair,[34] there is no age-related change in synthesis rate and concentration of human serum albumin, in contrast to muscular protein synthesis rates. Animal studies have shown, however, a generalized decline in protein synthesis in the liver.[35]

Handgrip strength decreased with increasing age, as reported by other researchers.[10][12] Handgrip strength is an essential indicator of strength for performing basic daily activities such as moving, taking a shower, bathing, changing clothes, grooming and washing.[12] The loss of grasping power makes old people dependent on helpers in their daily lives. According to Suzuki,[12] for their independent daily activities the aged need a minimum of 13 kg gps. In our study all the age groups had higher grasping power. The loss of muscular strength with aging results in a decrease in basal activities like walking ability, frequent fragility and a decrease in ability to perform all basic activities, causing accelerated weakness, disability and loss of mental sharpness.[11][12] Generally, muscle strength reaches peak value at age 20 – 30, remaining constant until age 45 – 50, and declining 12 – 15% every 10 years after that.[1)14)36)] Thus, the muscle strength of those in their sixties and seventies is reduced ca. 30 – 39% compared with the strength in their twenties.[1)37)38)] In this study, mean handgrip strength of those over 75 year decreased ca 20% compared to those aged 55 – 64. Although this reduction was lower than the results seen in other reports, it was larger than our previous study with elderly women. This result was consistent with the argument of Hurley[10)] that muscle strength decreases more rapidly in men than in women.

Waist circumference, which is often used as an indicator of central obesity, increased with increasing FFM. Thus, it can be supposed that the risk of loss of FFM and consequently the risk of sarcopenia will increase in the event of a body weight and waist circumference reduction. As a result, for adults over 55, the effort to reduce obesity or central obesity should be very carefully conducted. In sedentary adults, the main determinant of energy expenditure is fat-free mass. In many elderly people, declining energy needs are not matched by an appropriate decline in energy intake, the ultimate result being increased body fat content and high BMI with advancing age. Increased body fat in the abdominal region is thought to be directly linked to the greatly increased incidence of type II diabetes and syndrome x among the elderly.[4)]

Handgrip strength increased with high FFM level: grip strength was higher in all of the FFM groups compared with those of the elderly women in our previous report.[21)] Lower grasping power represents the loss of muscular strength through muscle mass loss. The loss of muscle mass in the elderly occurs due to declines in muscle fiber numbers and size after adulthood, resulting in muscle atrophy with advancing age. With aging, connective tissues and collagen increase while elasticity decreases, resulting in a decline in muscular strength.[20)] In many studies it was reported that muscle mass is the major determinant of the age and sex related differences in muscular strength.[1)4)] The decrease in grip strength seen in this study, which was due to fat-free mass reduction and higher levels of fat-free mass compared with that of the elderly women[21)] was consistent with the results of other studies.

Serum albumin concentration showed no differences according to FFM, confirming the results of other reports that various organs are differently influenced by aging and that changes in visceral protein level are independent of changes in muscular protein with aging.[34)23)]

Many studies stressed that nutrient balance and protein intake are important factors in the prevention of loss of muscle mass and muscular strength with aging.[17)18)23)] In this study, energy and fat intake were found to be significantly related to fat free mass, although protein intake showed little association. Starling *et al.*[23)] showed that increments of protein intake under the required level could prevent the loss of muscle mass and strength.

Furthermore, according to our previous report with elderly women whose protein intake was below RDA, fat-free mass showed a significant correlation with protein intake. The higher protein intake than RDA in the elderly men in this study may be one reason that there was no association with fat-free mass.

Limiting caloric intake is known to delay the aging process. Ricketts *et al.*[19)] reported that with animals, reductions in food intake can delay aging and declines in body protein synthesis rate. However, our study with elderly men does not support that argument, probably because the subjects had lower energy intakes than RDA. With aging, the energy oxidation system is known to undergo changes such as declines in the enzyme activities of glycolysis,[20)] thus resulting in a greater dependence on the energy supply from oxidation. This may favor utilization of fat oxidation to carbohydrates. This could be one of the reasons for the association of fat intake with fat-free mass, although more research on the subject is needed.

There was no association between fat-free mass and weekly exercise duration, daily energy expenditure for exercise and time spent sitting. Yarasheki *et al.*[26)] observed that resistance exercises can increase protein synthesis without changing proteolysis in the elderly. Also, Klitgard *et al.*[31)39)] observed that previous aerobic exercise could not prevent the loss of fat-free mass and muscle mass in the elderly. Campbell *et al.*[40)] showed that in the elderly, fat-free mass and energy expenditure increased after 12 weeks of resistance training. For the prevention of decline of fat-free mass and muscle mass, resistance exercises such as weight training are more effective, according to many studies, than endurance training, which can increase energy expenditure and decrease body fat and result in an improvement in cardiovascular disease risk.[4)12)41)] However, the elderly in this study seldom performed resistance exercises. This may be the cause of the fact that no association of fat -free mass with exercise behavior in the elderly was found in this study.

Multiple stepwise regression analysis showed that age and physical condition such as height and nutrient intake are the main factors determining fat-free mass changes. However, the 60% of height adjusted fat-free mass variances cannot be explained in this study. The loss of muscle mass and fat-free mass with increasing age are known to be influenced not only by extrinsic factors like dietary intake, exercise and sedentary habits, but also by intrinsic factors such as growth hormone, sex hormone and growth factor. The unexplained variances in fat-free mass may be attributed to genetic factors or endocrinal factors. Furthermore, the variances could also be attributed to the fact that the subjects in this study didn't engage in resistance exercises and that those engaged in regular exercise may find themselves reducing physical activities of other kinds due to increases in fatigue. According to this study, protein intake and serum albumin concentration, indicators of protein nutritional status, were not closely associated with fat-free mass. This can be attributed to the fact that the subjects?protein intake level in this study was above RDA.

In conclusion, the loss of fat-free mass with advancing age stimulated the loss of muscular strength in the elderly. The loss of fat-free mass had no association with protein nutritional status or with aerobic exercise habits. Further research is needed with a larger number of elderly people to identify the influence of protein nutritional status. Investigation of energy expenditure in larger numbers of elderly people, or investigation of people who engage in resistance exercises should be conducted to allow the application of the above results to elderly Koreans in general.

Literature cited

1) Frontera WR, Hughes VA, Luty KJ, Evans WJ. A cross-sectional study of muscle strength and mass in 45-78-year-old men and women. *J Appl Physiol* 71: 644-650, 1991
2) Steen B. Body composition and aging. *Nutr Rev* 46(2): 45-52, 1988
3) Kucymarski RJ. Need for body composition information in elderly subjects. *Am J Clin Nutr* 50: 1150-1155, 1989
4) Evans WJ. Nutrition, exercise and healthy aging. In: Proceedings of Good Nutrition for All, 8th Asian Congress of Nutrition, pp.100-108, 1999
5) Borkan GA, Hults DA, Gerzof SG, Robbins AH, Silbert CK. Age changes in body composition revealsed by computed tomography. *J Gerontol* 38(6): 673-677, 1983
6) Kuczmarski RJ. Need for body composition information in elderly subjects. *Am J Clin Nutr* 50: 1150-1155, 1989
7) Evans WJ. Functional and metabolic consequence of sarcopenia. *J Nutr* 127: 998S-1003S, 1997
8) Bevier WC, Wiswell RA, Pyka G, Kozak KC, Newhall KM, Marcus R. Relationship of body composition, muscle strength and aerobic capacity to bone mineral density in older men and women. *J Bone Miner Res* 4: 421-432, 1989
9) Snow-Harter C, Bouxsein M, Lewis B, Charlette S, Weinstein P, Marcus R. Muscle strength as a predictor of bone mineral density in young women. *J Bone Miner Res* 5: 589-595, 1990
10) Hurley, BF. Age, gender, and muscular strength. *J Gerontol Series A* 50A(Special issues): 41-44, 1995
11) Dutta C. Significance of sarcopenia in the elderly. *J Nutr* 127: 992s-993s, 1997
12) Suzuki M., Exercise and nutrition to prevent sarcopenia and osteopenia of elderly people. In: The implication of foods and supplements for exercise performance. Proceedings of 2000 International Congress on Exercise Nutrition. *Kor Soc Exer Nutri* 95-110, 2000
13) Bassey EJ, Harries UJ Normal values for handgrip strength in 920 men and women aged over 65 years, and longitudinal changes over 4 years in 620 survivors. *Clin Sci* 84: 331-337, 1993
14) Bemben, MG, Massey BH, Bemben DA, Misner JE, Boileau RA. Isometric muscle force production as a function of age in healthy 20-74-yr-old men. *Med Sci Sports Exerc* 11: 1302-1310, 1991
15) Era P, Lyyra AL, Viitasalo JT, Heikkinen E. Determinants of isometric muscle strength in men of different ages. *Eur J Appl Physiol* 64: 84-91, 1992
16) Rantanen T, Era P, Heikinen E. Maximal isometric strength and mobility among 75-year old men and women. *Age Aging* 23: 132-137, 1994
17) Robert AB, Dallal GE. Effects of age on energy balance. *Am J Clin Nutr* 68(suppl): 975s-979s, 1998
18) Volpi E, Ferrando AA, Yeckel CW, Tipton KD, Wolfe RR. Exogenous amino acids stimulate net protein muscle protein synthesis. *J Clin Invest* 101: 2000-2007, 1998
19) Ricketts WG, Birchenall-Sparks MC, Hardwidk JP, Richardson A. Effect of dietary restriction on protein synthesis by isolated kidney cells. *J Cell Physiol* 125: 492-499, 1985
20) Kim SH, Kim HY. Aging, Daewoo Scientific Publication Series, pp.313-346, 1995
21) Lee OH. Relationship between fat-free mass and grip strength, nutrient intakes, exercise behavior in middle- and old-aged women. *Kor J Nutr* 34(4): 2001
22) Roubenoff R. Sarcopenia and its implications for the elderly. *Eur J Clin Nutr* 54(s3): s40-s47, 2000
23) Starling RD, Ades PA, Poehlman ET. Physical activity, protein intake, and appendicular skeletal muscle mass in older men. *Am J Clin Nutr* 70: 91-96, 1999
24) Lee RD, Nieman DC. Nutritional assessment 2nd ed. Mosby-Year Book, Inc., 1996
25) Heymsfield SB, Wang J, Lichtman S, Kamen Y, Kehayias J, Pierson RN. Body composition in elderly subjects: a critical approach of clinical methodology. *Am J Clin Nutr* 50: 1167-1172, 1989
26) Yaraheski KE, Zachwieja JJ, Bier DM. Acute effects of resistance exercise on muscle protein synthesis rate in young and elderly men and women. *Am J Physiol* 265(2 pt 1): E210-E214, 1993
27) Welle S, Josefwicz R, Statt M Myofibrillar protein synthesis in young and old men. *Am J Physiol* 264(Endocrinol. Metab 27): E693-E698, 1993
28) Coggan AR. Muscle biopsy as a tool in the study of aging. *J Gerontol Series A* Vol 50A (special issue): 30-34, 1995

29) Lexell J, Henniksson-Larssen K, Wimbold B, Sjostrom M. Distribution of different fiber types in human skeletal muscles: effects of aging studied in whole muscle cross sections. *Muscle Nerve* 6: 588-595, 1983

30) Larsson L. Histocchemical characterstics of human skeletal muscle during aging. *Acta Physiol Scand* 117: 469-471, 1983

31) Klitgaard H, Zhou M, Schiaffino S, Betto R, Salviati G, Saltin B. Ageing alters the myosin heavy chain composition of single fibers from human skeletal muscle. *Acta Physiol Scand* 140: 55-62, 1990

32) Mosoni L, Valluy MC, Serrurier B, Prugnaud J, Obled C, Guezennec CZ, Mirand PP. Altered response of protein synthesis to nutritional state and endurance training in old rats. *Am J Physiol* 268(2 pt 1): E 328-E335, 1995

33) Gersovitz M, Munro Hn, Udall J, Young VR. Albumin synthesis in young and elderly subjects using a new stable isotope methodology: response to level of protein intake. *Metabolism* 29(11): 1075-1086, 1980

34) Fu A, Nair KS. Age effect on fibrinogen and albumin synthesis in humans. *Am J Physiol* 275(Endocrinol. Metab 38): E1023-E1030, 1998

35) Ward W, Richardson A. Effect of age on liver protein synthesis and degradation. *Hepatol* 14: 935-948, 1991

36) Era P, Lyra AL, Vitasalo JT, Heikinen E. Determinants of isometric muscle strength in men of different ages. *Eur J Appl Physiol* 64: 84-91, 1992

37) Young A, Stokes M, Crowe M. Size and strength of the quadriceps muscles of old and young women. *Eur J Clin Invest* 14: 282-287, 1984

38) Murray MP, Duthie EH, Jr, Gambert SR, Sepic SB, Mollinger LA. Age-related differences in knee muscle strength in nominal women. *J Gerontol* 40: 275-280, 1985

39) Klitgard H, Mantoni M, Schiaffino S. Function, morphology and protein expression of aging skeletal muscle: a cross-sectional study of elderly men with different training background. *Acta Physiol Scand 140*: 41-54, 1990

40) Campbell WW, Crim MC, Young VR, Evans W. Increased energyy requirements and changes in body composition with resistance training in older adults. *Am J Cin Nutr* 60: 167-175, 1994

41) Hersey WC 3rd, Graves JE, Pollock Ml, Gingrich R, Shireman RB, Heath GW, Spierto F, McCole SD, Hagberg JM. Endurance exercise training improves body composition and plasma insulin response in 70- to 79-years-old men and women. *Metabol* 43(7): 847-854, 1984