보건학 석사학위논문

비만인 사람에서 근육량과 관련된 생활습관 요인: 한국 쌍둥이 코호트

Lifestyle factors associated with muscle mass among obese population: The Healthy Twin study, Korea

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Abstract

Lifestyle factors associated with muscle mass among obese population: The Healthy Twin study, Korea

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Introduction

Sarcopenia was defined as the loss of skeletal muscle mass due to aging. Sarcopenic obesity, characterized by the loss of muscle mass and the increase of fat tissue, showed a synergistic effect on chronic diseases. Lifestyle factors were regarded as risks for sarcopenic obesity; therefore, we tried to investigate the lifestyle factors associated with muscle mass among obese population in the Healthy Twin study, Korea.

Method

We gathered informations, including DEXA from the healthy twin study of Korea and included those with a body mass index (BMI) $\geq 25 kg/m^2$. Multiple linear regression between muscle mass and lifestyle factors such as age, smoking, alcohol consumption, physical activity, BMI, proportion of protein intake, and proportion of carbohydrate intake were used, and co-twin control analysis was analyzed among monozygotic (MZ) twins.

The muscle mass indices were weight-adjusted appendicular skeletal mass (ASM), height-adjusted ASM, and skeletal muscle mass index (SMMI) acquired from DEXA.

Results

In total, 919 participants were included, and 74 pairs of MZ twin data were used for co-twin control analysis. Increased physical activity and the proportion of protein intake were positively associated with muscle mass in men. BMI was positively associated with

height-adjusted ASM and negatively with both weight-adjusted ASM and SMMI. In co-twin control analysis, physical activity and the proportion of carbohydrate intake were positively related with muscle mass. The proportion of protein intake was associated with muscle mass with marginal significance.

Discussion

We suggest that physical activity and both carbohydrate and protein intake could positively influence muscle mass among the obese population. To prevent sarcopenic obesity, an increase of physical activity and proportion of carbohydrate and protein intake should be encouraged.

keywords
: sarcopenic obesity, muscle mass, lifestyle factors

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Introduction

As the proportion of society who elderly increases, more attention is being paid to the loss of muscle mass, which is defined as sarcopenia. Sarcopenia is associated with physical disability [1], falls [1] and even mortality [2, 3]. In particular, links have been found between sarcopenic obesity and metabolic syndrome [4]. Lim et al. reported that the risk of metabolic syndrome was higher with sarcopenic obesity than with either sarcopenia or obesity alone [5]. Recently, a higher association has been found between sarcopenic obesity and a risk of hypertension than sarcopenia or obesity alone [6].

Aging was related with a loss of muscle mass, quality and power, and lead to sarcopenia. Sarcopenia is defined as the loss of skeletal muscle mass associated with aging, and the loss of muscle power, aerobic capacity, and function [7]. Skeletal muscle mass constitutes a maximum of 50% of bodyweight among young adults [8], and decreases by 1 – 2% per year after 50 years [9], and constitutes 25% at 80 years of age[8]. Moreover, skeletal muscle mass is twice that of fat mass in young men however, this ratio reverses in elderly men [10]. Aging was also related with an increase of visceral fat, and it increases the risk of metabolic syndrome, type II DM, and cerebrovascular disease. The combined effect of sarcopenia and visceral obesity might influence the synergistic effect of chronic metabolic diseases and physical disability [11].

The mechanisms of sarcopenia were explained in several ways. Loss of hormone levels such as growth hormone (GH), insulin-like growth factor (IGF)-I, insulin, sex hormone (androgens, estrogens), corticosteroids [12], and the cytokines that are related with inflammation [13], vitamin D [14], C-reactive protein [15] were suggested as possible mechanisms. The environmental factors associated with sarcopenia were the loss of physical activity [16, 17] and of protein intake [18]. Genetic factors were also related with sarcopenia, a recently reported candidate for polymorphism was the angiotensin converting enzyme (ACE) gene I/D, α-actinin-3(ACTN3) R577X, and myostatin (MSTN) K153R [19]. Mikkola et al. showed that cross-sectional areas of the lower leg were influenced by all environmental factors and genetic factors among old female-twin pairs [20]. However, they do not reflect the appendicular skeletal mass (ASM), and were not adjusted by height and weight, and the population was limited to aged females.

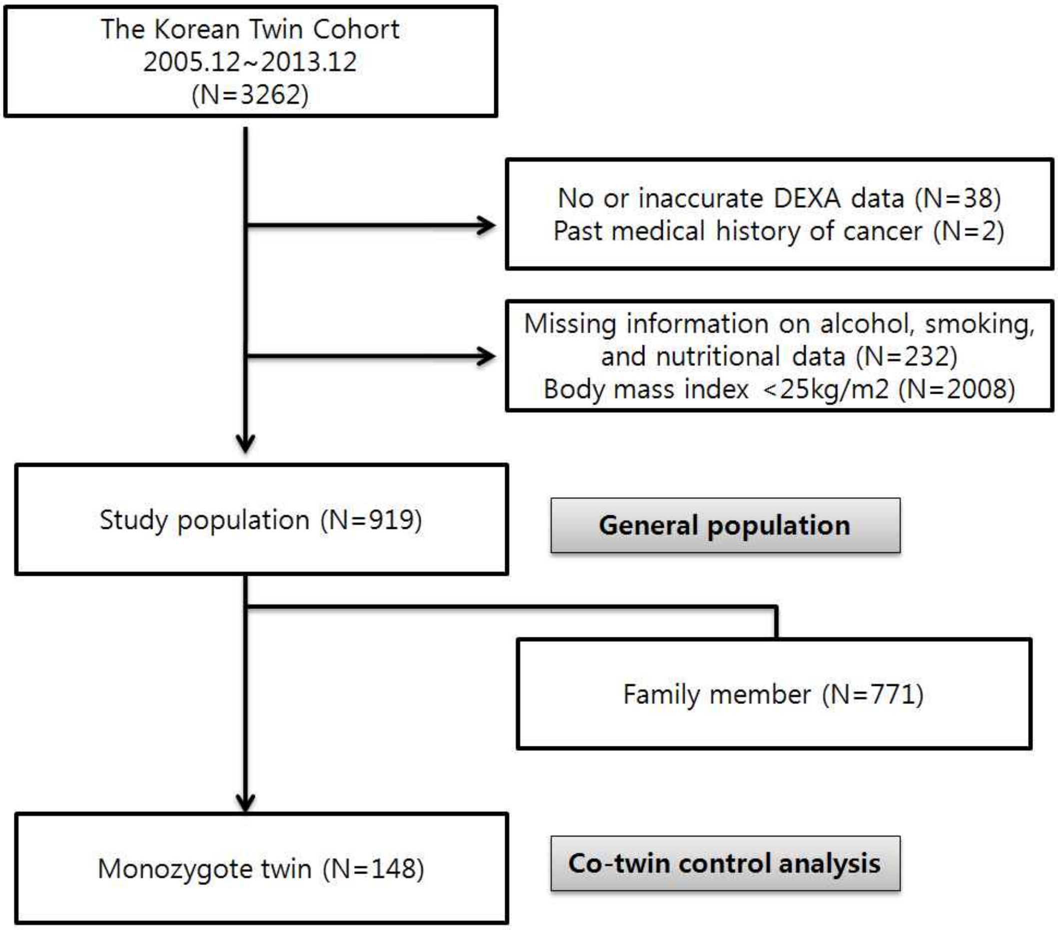
In this study, we tried to examine the factors associated with muscle mass in a Korean twin cohort, compare it with previous reports, and evaluate the risk factors among monozygote (MZ) twins to estimate the effects of non-genetic factors on muscle mass among the obese population in males and females.

Materials and Methods

Study population

We used data from the Korean twin cohort, a part of the Korean Genome and Epidemiology Study, KoGES, for those who had completed the questionnaire and examination between December, 2005 and December, 2013 (N=3,262). We excluded 272 participants, who were missing data on DEXA (dual-energy X-ray absorptiometry), had a past medical history of cancer, or had missing data on smoking, drinking, or their 24-hour dietary recall. We excluded those with a BMI (body mass index) of less than 25kg/m^2 to investigate the factors related to muscle mass in obesity. In total, 919 participants were included in the study. Of those, 148 participants (74 pairs) were mozygote twins (Fig 1).

Figure 1. Flowchart of participants inclusion



Measurements

Whole and regional body composition was measured by DEXA, muscle mass was acquired through DEXA, and the appendicular skeletal muscle was calculated as the sum of skeletal muscle in upper and lower arms and legs, assuming that all non-bone and non-fat elements were skeletal muscles. Three muscle mass indices were calculated as follows: Height-adjusted ($ASM/height^2$) [1], Weight-adjusted ASM (ASM/weight) [5], and skeletal muscle mass index (SMMI) (skeletal muscle mass (kg)/ wt (kg) x100) [21].

Demographic information on smoking status, alcohol consumption, and regular exercise were assessed using a structured questionnaire. Smoking status was classified into three categories: Current smoker, former smoker, and never smoker. Drinking status was also classified into current drinker, past drinker,and non-drinker. Physical activity was assessed by the questionnaire about average number of exercise activities per week, average time spent exercising per activity, and type of exercise. These were divided into 3 tertiles according to their MET score: First tertile, second tertile, third tertile, and "no answer."

BMI was calculated using the following formula: Weight (kg)/height (m^2).

The percentages of protein and carbohydrate intake were calculated as follows: Daily protein intake (g) x4kcal/g x100/ daily energy intake and daily carbohydrate intake (g) x4 kcal/g x100/ daily energy intake. Daily nutrient intake data was acquired by 24 hour dietery recall data.

Statistical methods

The baseline characteristics were expressed as means (SD) or as an absolute number (%), according to gender. The chi-square test and t-test were respectively used to compare categorical variables and continuous variables for both genders. The linear regression model was used to describe the factors associated with muscle mass. The beta-coefficients (SD) were estimated according to gender. We used a multiple linear regression model after adjusting for potential confounders such as age, BMI, smoking status, drinking status, level of physical activity, proportion of protein intake, and proportion of carbohydrate intake. We also analyzed by co-twin control analysis to investigate non-genetic factors among the MZ twin among combined sexes because of small numbers. 148 participants (74 pairs) were selected for co-twin control analysis using Generalized Estimating Equations (GEE). Regression modeling provides tools for examining associations while allowing for the confounding effects of other factors or interaction effects. Twin data provides the paired structure of the data, so the methods described below were used as John B et al recommended [22].

Y denotes the outcome, X the covariate of immediate interest, I index twin pairs, and j=1 or 2 to index the individual twins within the pairs [22],

(1) The regression on X alone (treating twins "as individuals," ignoring the paired structure of the data [22].

$E(Y_{ij})=\beta_0+\beta_c X_{ij}$ [22]

It has several problems: First, the ordinary least squares (OLS) for the standard error (SE) is not correct for MZ twin data, because it ignores the paired structure of the data [22]. The generalized least squares (GLS) approach allowing for the correlation structure might provide a valid SE [22]. Second problem is related with using the properties of the OLS estimations of the regression coefficients [22]. The paired nature of the twin data can provide additional information contributing for a better straight-line fit [22]. The GLS method of estimation applies differential weight to the data [22]. The third problem relates to the methods that use the fitting model: The specification of the expected value of Yij is inadequate [22]. Thus, a more general regression model that allows the covariate effect to differ within and between pairs is needed [22]. An acceptable formulation for a general model is recommended as follows [22] :

(2) Multiple regression: Including the co-twin X value in the model [22].

$E(Y_{ij})=\beta_0+\beta_w\ (X_{ij}-X_{i.})-\beta_b X_i$ [22]

In this study, we used both (1) and (2) methods.

STATA software 12.0 (Stata Corp.) was used for statistical analysis, and P values <0.05 were considered to be statistically significant.

Results

Baseline characteristics of study participants

In total, 919 participants were included in the study. Among those, 484 were male, and 435 were female.

Table 1 shows the baseline characteristics of the study participants. The mean (SD) of ages were 44.65 (13.51) for males, and 50.37 (12.67) for females. The number (%) of current smokers and current drinkers were 185 (38.22) and 392 (80.99) for the males, 19 (4.37) and 191 (44.01) for the females. The proportion of 3rd tertile of physical activity (MET) was 31.61% for the males, and 31.49% for the females. The mean (SD) of BMI were 27.29 (2.23) and 27.68 (2.49) for males and females, respectively. The respective proportions of protein and carbohydrate intake were 14.27 (4.05) and 66.60 (10.34) for males, and 14.45 (4.16) and 68.66 (10.47) for females.

The mean (SD) of weight-adjusted ASM, height-adjusted ASM, and SMMI were 325.72 (42.44), 8.87 (1.23), and 3.68 (0.47) for males, and 249.76 (30.78), 6.88 (0.83), and 2.82 (0.34) for females, respectively.

Table 1. Baseline characteristics of study participants

	Male (N=484)	Female (N=435)
General informations		
Age (years)	44.65 (13.51)	50.37 (12.67)
Number of monozygote twin	90 (45 pairs)	56 (28 pairs)
Lifestyle factors		
Smoker [1]		
Non-smoker	118 (24.38)	406 (93.33)
Past smoker	181 (37.40)	10 (2.30)
Current smoker	185 (38.22)	19 (4.37)
Drinking [2]		
Non drinker	57 (11.78)	206 (47.47)
Past drinker	35 (7.23)	37 (8.53)
Current drinker	392 (80.99)	191 (44.01)
Physical activity [3]		
First tertile	136 (28.10)	112 (25.75)
Second tertile	124 (25.62)	123 (28.28)
Third tertile	153 (31.61)	137 (31.49)
No answer	71 (14.67)	63 (14.48)
Body mass index (kg/m^2)	27.29 (2.23)	27.68 (2.49)
Nutritional intake		
Protein intake (%) [4]	14.27 (4.05)	14.45 (4.16)
Carbohydrate intake (%) [5]	66.60 (10.34)	68.66 (10.47)
Muscle mass [6]		
Weight-adjusted appendicular skeletal mass (ASM)	325.72 (42.44)	249.76 (30.78)
Height-adjusted ASM	8.87 (1.23)	6.88 (0.83)
Skeletal muscle mass index (SMMI)	3.68 (0.47)	2.82 (0.34)

Datas were expressed as number (%) or mean (SD)

[1] Smoking was classifid into 3 categories: current, former, and never-smokers

[2] Drinking status was also classified into current, past and non-drinker

[3] Physical activity was assessed by the questionnaire about average number of exercise per week, average time consuming on exercise per number, and type of exercise, and were divided into tertile according to MET score

[4] Calculated as follow : Daily protein intake (g) x4kcal/g x100/ daily energy intake

[5] Calculated as follow : Daily carbohydrate intake (g) x4 kcal/g x100/ daily energy intake

[6] Calculated as follow: Height-adjusted ASM (appendicular skeletal mass)/height^2), Weight-adjusted ASM (ASM/weight), and skeletal muscle mass index (SMMI) (skeletal muscle mass (kg)/ wt (kg) *100)

Factors associated with muscle mass among obese population

Tables 2-1, 2-2, and 2-3 show factors associated with muscle mass using multiple linear regression models. We showed factors associated with weight-adjusted ASM, height-adjusted ASM, and SMMI in tables 2-1, 2-2, and 2-3, respectively.

For each gender, age was inversely associated with all three muscle mass indices (ß (95% CI) of the weight-adjusted ASM, height-adjusted ASM and SMMI = -0.466 (-0.767, -0.164), -0.012 (-0.021, -0.004), and -0.005 (-0.008, -0.002), respectively among males, and -0.446 (-0.692, -0.201), -0.013 (-0.019, -0.006), and -0.005 (-0.008, -0.002), respectively among females). Neither smoking nor drinking was associated with muscle mass in obese men or women. Physical activity was associated with muscle mass for obese men (ß (95% CI) of the 3rd tertile as a reference of the 1sttertile = 15.792 (6.063, 25.520), 0.402 (0.135, 0.669), and 0.178 (0.069, 0.288) for weight-adjusted ASM, height-adjusted ASM, and SMMI, respectively), not in obese women (ß (95% CI) of the 3rd tertile as reference of the 1st tertile = 2.426 (-4.821, 9.672), 0.057 (-0.136, 0.251), and 0.027 (-0.054, 0.109) for weight-adjusted ASM, height-adjusted ASM, and SMMI, respectively). BMI were negatively associated with weight-adjusted ASM and SMMI, and positively associatedwith height-adjusted ASM for both men and women. The proportion of protein intake was associated with the muscle mass with marginal significance in males but not in females (ß (95% CI) for weight-adjusted ASM, height-adjusted ASM, and SMMI= 1.763 (-0.307, 3.836), 0.563 (-0.253, 1.379), and 0.045 (-0.012, 0.102) among males, respectively, 0.337 (-1.018, 1.692), 0.238 (-0.303, 0.779), and 0.010 (-0.026, 0.046) among females, respectively).

Table 2-1. Factors associated with weight-adjusted appendicular skeletal mass using multiple linear regression

	Male (N=484)	Female (N=435)
Age (years)	-0.466 (-0.767, -0.164)	-0.446 (-0.692, -0.201)
Smoker		
Non-smoker	Reference	Reference
Past smoker	1.366 (-8.558, 11.290)	-5.060 (-23.448, 13.328)
Current smoker	4.259 (-5.556, 14.075)	2.510 (-11.492, 16.513)
Drinking		
Non drinker	Reference	Reference
Past drinker	-10.971 (-28.836, 6.895)	0.598 (-9.806, 11.002)
Current drinker	-7.078 (-18.863, 4.707)	0.300 (-6.076, 6.673)
Physical activity		
First tertile	Reference	Reference
Second tertile	6.163 (-4.004, 16.331)	-6.461 (-13.884, 0.961)
Third tertile	15.792 (6.063, 25.520)	2.426 (-4.821, 9.672)
No answer	12.491 (0.203, 24.779)	1.452 (-7.632, 10.535)
Body mass index (kg/m^2)	-3.644 (-5.315, -1.974)	-3.978 (-5.089, -2.867)
Protein intake (%)	1.763 (-0.307, 3.836)	0.337 (-1.018, 1.692)
Carbohydrate intake (%)	0.563 (-0.253, 1.379)	0.238 (-0.303, 0.779)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 2-2. Factors associated with height-adjusted appendicular skeletal mass using multiple linear regression

	Male (N=484)	Female (N=435)
Age (years)	-0.012 (-0.021, -0.004)	-0.013 (-0.019, -0.006)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.035 (-0.236, 0.308)	-0.126 (-0.618, 0.365)
Current smoker	0.129 (-0.140, 0.400)	-0.078 (-0.295, 0.453)
Drinking		
Non drinker	Reference	Reference
Past drinker	-0.314 (-0.804, 0.177)	0.018 (-0.260, 0.300)
Current drinker	-0.221 (-0.545, 0.102)	0.001 (-0.169, 0.171)
Physical activity		
First tertile	Reference	Reference
Second tertile	0.167 (-0.112, 0.446)	-0.183 (-0.382, 0.015)
Third tertile	0.402 (0.135, 0.669)	0.057 (-0.136, 0.251)
No answer	0.372 (0.034, 0.709)	0.029 (-0.213, 0.271)
Body mass index (kg/m^2)	0.199 (0.154, 0.245)	0.119 (0.090, 0.149)
Percent of protein intake (%)	0.045 (-0.012, 0.102)	0.010 (-0.026, 0.046)
Percent of carbohydrate intake (%)	0.015 (-0.007, 0.038)	0.006 (-0.007, 0.021)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 2-3. Factors associated with skeletal muscle index using multiple linear regression

	Male (N=484)	Female (N=435)
Age (years)	-0.005 (-0.008, -0.002)	-0.005 (-0.008, -0.002)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.015 (-0.097, 0.127)	-0.057 (-0.265, 0.151)
Current smoker	0.048 (-0.062, 0.159)	0.028 (-0.130, 0.187)
Drinking		
Non drinker	Reference	Reference
Past drinker	-0.123 (-0.326, 0.078)	0.007 (-0.111, 0.124)
Current drinker	-0.080 (-0.213, 0.053)	0.003 (-0.069, 0.075)
Physical activity		
First tertile	Reference	Reference
Second tertile	0.069 (-0.045, 0.184)	-0.073 (-0.157, 0.011)
Third tertile	0.178 (0.069, 0.288)	0.027 (-0.054, 0.109)
No answer	0.141 (0.002, 0.280)	0.016 (-0.086, 0.119)
Body mass index (kg/m^2)	-0.041 (-0.060, -0.022)	-0.045 (-0.058, -0.032)
Percent of protein intake (%)	0.020 (-0.003, 0.043)	0.004 (-0.012, 0.019)
Percent of carbohydrate intake (%)	0.006 (-0.003, 0.015)	0.003 (-0.003, 0.008)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Subgroup analysis: Factors associated with muscle mass among obese population using multiple linear regression according to age <65 years and age ≥ 65 years

Table 3-1, 3-2, and 3-3 show the factors associated with muscle mass using a multiple linear regression model according to age (<65 years and age ≥65 years). A significant association of age with muscle mass was observed in females aged less than 65 years. Neither smoking nor drinking status was related with weight-adjusted ASM, height-adjusted ASM, or SMMI. A higher physical activity level was positively associated with muscle mass in males aged less than 65 years (ß (95% CI) for weight-adjusted ASM and SMMI= 16.051 (5.199, 26.902) and 0.407 (0.109, 0.705) among males, respectively)). As previously described, BMI was negatively associated with weight-adjusted ASM and SMMI, and positively associated with height-adjusted ASM with at least marginal significance. The proportions of protein and carbohydrate intake were not related with muscle mass for any group.

Table 3-1-1. Subgroup analysis: factors associated with weight-adjusted appendicular skeletal mass using multiple linear regression according to age <65 and age ≥65 among male

	Weight-adjusted ASM (Beta-coefficient (SD))	
	Age <65 years (N=422)	Age ≥65 years (N=62)
Age (years)	-0.285 (-0.724, 0.154)	-1.654 (-3.692, 0.383)
Smoker		
Non-smoker	Reference	Reference
Past smoker	3.057 (-8.680, 14.793)	-7.628 (-24.516, 9.260)
Current smoker	5.273 (-5.837, 16.383)	-6.901 (-27.091, 13.278)
Drinking		
Non drinker	Reference	Reference
Past drinker	-17.476 (-39.989, 5.036)	2.534 (-20.740, 25.809)
Current drinker	-9.862 (-23.325, 5.560)	8.091 (-11.390, 27.571)
Physical activity		
First tertile	Reference	Reference
Second tertile	7.592 (-3.748, 18.931)	0.399 (-20.081, 20.879)
Third tertile	16.051 (5.199, 26.902)	12.296 (-6.506, 31.098)
No answer	13.169 (-0.339, 26.676)	-8.622 (-39.094, 21.850)
Body mass index (kg/m^2)	-3.634 (-5.428, -1.840)	-5.891 (-10.925, -0.857)
Protein intake (%)	2.119 (-0.274, 4.512)	-1.813 (-5.573, 1.947)
Carbohydrate intake (%)	0.731 (-0.199, 1.661)	-1.076 (-2.726, 0.574)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 3-1-2. Subgroup analysis: factors associated with weight-adjusted appendicular skeletal mass using multiple linear regression according to age <65 and age ≥65 among female

	Weight-adjusted ASM (Beta-coefficient (SD))	
	Age <65 years (N=381)	Age ≥ 65 years (N=53)
Age (years)	-0.531 (-0.844, -0.218)	-0.822 (-2.330, 0.686)
Smoker		
Non-smoker	Reference	Reference
Past smoker	5.033 (-19.493, 29.561)	-16.290 (-39.196, 6.614)
Current smoker	2.455 (-12.567, 17.376)	6.738 (-41.570, 55.047)
Drinking		
Non drinker	Reference	Reference
Past drinker	0.249 (-11.007, 11.505)	-2.146 (-33.311, 29.018)
Current drinker	0.070 (-6.799, 6.939)	-5.469 (-25.751, 14.823)
Physical activity		
First tertile	Reference	Reference
Second tertile	-7.255 (-15.658, 1.149)	-3.414 (-19.302, 12.474)
Third tertile	1.404 (-6.757, 9.565)	12.431 (-5.554, 30.415)
No answer	0.038 (-10.272, 10.347)	4.963 (-13.076, 23.001)
Body mass index (kg/m^2)	-0.833 (-5.027, -2.638)	-5.137 (-8.430, -1.843)
Protein intake (%)	0.602 (-0.921, 2.124)	-1.667 (-4.574, 1.240)
Carbohydrate intake (%)	0.377 (-0.215, 0.969)	-1.141 (-2.545, 0.264)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 3-2-1. Subgroup analysis: factors associated with height-adjusted appendicular skeletal mass using multiple linear regression according to age <65 and age ≥65 among male

	Height-adjusted ASM (Beta-coefficient (SD))	
	Age <65 years (N=422)	Age ≥ 65 years (N=62)
Age (years)	-0.009 (-0.021, 0.003)	-0.050 (-0.105, 0.006)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.091 (-0.231, 0.413)	-0.201 (-0.662, 0.261)
Current smoker	0.164 (-0.141, 0.469)	-0.203 (-0.755, 0.348)
Drinking		
Non drinker	Reference	Reference
Past drinker	-0.514 (-1.132, 0.104)	0.096 (-0.040, 0.732)
Current drinker	-0.308 (-0.678, 0.062)	0.239 (-0.293, 0.771)
Physical activity		
First tertile	Reference	Reference
Second tertile	0.205 (-0.106, 0.516)	0.003 (-0.556, 0.563)
Third tertile	0.407 (0.109, 0.705)	0.313 (-0.201, 0.827)
No answer	0.395 (0.024, 0.766)	-0.217 (-1.409, 0.616)
Body mass index (kg/m^2)	0.199 (0.150. 0.249)	0.145 (0.008, 0.283)
Protein intake (%)	0.055 (-0.010, 0.121)	-0.052 (-0.155, 0.051)
Carbohydrate intake (%)	0.020 (-0.005, 0.046)	-0.030 (-0.075, 0.015)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 3-2-2. Subgroup analysis: factors associated with height-adjusted appendicular skeletal mass using multiple linear regression according to age <65 and age ≥65 among female

	Height-adjusted ASM (Beta-coefficient (SD))	
	Age <65 years (N=381)	Age ≥ 65 years (N=53)
Age (years)	-0.015 (-0.024, -0.007)	-0.019 (-0.060, 0.023)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.159 (-0.494, 0.813)	-0.479 (-1.110, 0.151)
Current smoker	0.070 (-0.327, 0.468)	0.319 (-1.011, 1.650)
Drinking		
Non drinker	Reference	Reference
Past drinker	0.010 (-0.290, 0.310)	-0.059 (-0.092, 0.799)
Current drinker	-0.004 (-0.187, 0.179)	-0.165 (-0724, 0.394)
Physical activity		
First tertile	Reference	Reference
Second tertile	-0.203 (-0.427 0.021)	-0.095 (-0.533, 0.342)
Third tertile	0.033 (-0.018, 0.250)	0.335 (-0.160, 0.831)
No answer	-0.008 (-0.282, 0.267)	0.116 (-0.381, 0.613)
Body mass index (kg/m^2)	0.123 (0.091, 0.155)	0.009 (-0.002, 0.180)
Protein intake (%)	0.018 (-0.022, 0.059)	-0.045 (-0.125, 0.035)
Carbohydrate intake (%)	0.011 (-0.005, 0.026)	-0.030 (-0.007, 0.009)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 3-3-1. Subgroup analysis: factors associated with skeletal muscle mass index using multiple linear regression according to age <65 and age ≥65 among male

	SMMI (Beta-coefficient (SD))	
	Age <65 years (N=422)	Age ≥ 65 years (N=62)
Age (years)	-0.003 (-0.008, 0.002)	-0.019 (-0.042, 0.004)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.035 (-0.098, 0.167)	-0.086 (-0.277, 0.105)
Current smoker	0.060 (-0.066, 0.185)	-0.078 (-0.306, 0.150)
Drinking		
Non drinker	Reference	Reference
Past drinker	-0.197 (-0.452, 0.057)	0.029 (-0.234, 0.292)
Current drinker	-0.111 (-0.263, 0.041)	0.091 (-0.129, 0.312)
Physical activity		
First tertile	Reference	Reference
Second tertile	0.086 (-0.042, 0.214)	0.005 (-0.227, 0.236)
Third tertile	0.181 (0.059, 0.304)	0.139 (-0.074, 0.351)
No answer	0.149 (-0.004, 0.301)	-0.097 (-0.442, 0.247)
Body mass index (kg/m^2)	-0.041 (-0.061, -0.021)	-0.067 (-0.123, -0.009)
Protein intake (%)	0.024 (-0.003, 0.051)	-0.020 (-0.063, 0.022)
Carbohydrate intake (%)	0.008 (-0.002, 0.019)	-0.012 (-0.031, 0.006)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Table 3-3-2. Subgroup analysis: factors associated with skeletal muscle mass index using multiple linear regression according to age <65 and age ≥65 among female

	SMMI (Beta-coefficient (SD))	
	Age <65 years (N=381)	Age ≥ 65 years (N=53)
Age (years)	-0.006 (-0.010, -0.002)	-0.009 (-0.026, 0.008)
Smoker		
Non-smoker	Reference	Reference
Past smoker	0.057 (-0.220, 0.334)	-0.184 (-0.442, 0.074)
Current smoker	0.027 (-0.141, 0.196)	0.077 (-0.468, 0.622)
Drinking		
Non drinker	Reference	Reference
Past drinker	0.003 (-0.124, 0.130)	-0.024 (-0.376, 0.328)
Current drinker	0.001 (-0.077, 0.078)	-0.062 (-0.291, 0.168)
Physical activity		
First tertile	Reference	Reference
Second tertile	-0.082 (-0.177, 0.013)	-0.039 (-0.218, 0.141)
Third tertile	0.016 (-0.077, 0.108)	0.140 (-0.063, 0.344)
No answer	0.001 (-0.116, 0.117)	0.056 (-0.148, 0.260)
Body mass index (kg/m^2)	-0.043 (-0.57, -0.029)	-0.068 (-0.095, -0.021)
Protein intake (%)	0.007 (-0.010, 0.024)	-0.019 (-0.052, 0.014)
Carbohydrate intake (%)	0.004 (-0.002, 0.011)	-0.013 (-0.029, 0.003)

Datas were expressed as Beta-coefficient (SD)

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Factors associated with muscle mass in MZ twin

We analyzed co-twin control analysis using GEE with MZ twins. The relationship between lifestyle factors and muscle mass among combined sexes are shown in Table 4. Females had less muscle mass compared to males. Physical activity levels were positively associated with muscle mass (ß (95% CI) in weight-adjusted ASM, height-adjusted ASM and SMMI=15.214 (-1.804, 32.232), 0.455 (-0.040, 0.951) and 0.172 (-0.020, 0.364) respectively, for both sexes)). BMI was positively associated with height-adjusted ASM with statistical significance, but not with weight-adjusted ASM and SSMI. The proportion of protein intake was positively associated with all muscle indices with marginal significance. The proportion of carbohydrate intake was significantly associated with all three muscle mass indices.

Table 4. Factors associated with muscle mass (weight-adjusted ASM (appendicular skeletal mass), height-adjusted ASM, and Skeletal muscle mass index (SMMI)) using generalized estimating equations among monozygote twin (N=144)

	Weight-adjusted ASM	Height-adjusted ASM	SMMI
Age (years)	-0.955	-0.027	-0.011
	(1.920, 0.010)	(-0.054, 0.001)	(-0.022, 0.000)
Gender			
Female	Reference	Reference	Reference
Male	90.561	2.521	1.023
	(73.194, 107.927)	(2.027, 3.015)	(0.827, 1.220)
Smoker			
Non-smoker	Reference	Reference	Reference
Past smoker	5.973	0.194	0.067
	(-12.453, 24.389)	(-0.342, 0.729)	(-0.141, 0.276)
Current smoker	-4.823	-0.118	-0.054
	(-21.427, 11.782)	(-0.598, 0.362)	(-0.242, 0.133)
Drinking			
Non drinker	Reference	Reference	Reference
Past drinker	-9.754	-0.287	-0.110
	(-34.257, 14.750)	(-1.002, 0.429)	(-0.387, 0.167)
Current drinker	-11.147	-0.334	-0.126
	(-26.765, 4.470)	(-0.893, 0.114)	(-0.302, 0.051)
Physical activity			
First tertile	Reference	Reference	Reference
Second tertile	3.764	0.169	0.043
	(-10.669, 18.197)	(-0.254, 0.591)	(-0.121, 0.206)
Third tertile	15.214	0.455	0.172

	(-1.804, 32.232)	(-0.040, 0.951)	(-0.020, 0.364)
No answer	24.695	0.834	0.279
	(4.645, 44.746)	(0.250, 1.418)	(0.052, 0.506)
Body mass index (kg/m^2)	-2.410	0.204	-0.027
	(-5.165, 0.345)	(0.125, 0.284)	(-0.058, 0.004)
Protein intake	-2.718	0.082	0.031
(%)	(-0.425, 5.862)	(-0.001, 0.174)	(-0.005, 0.066)
Carbohydrate	1.468	0.044	0.017
intake (%)	(0.271, 2.664)	(0.009, 0.079)	(0.003, 0.030)

Datas were expressed as Beta-coefficient (SD) using generalized estimating equations among obese monozygote twin

Multiple linear regression was adjusted for age, smoking status (non, past and current), drinking status (non, past, and current), physical activity (1st, 2nd, 3rd tertile, and no answer), body mass index, percent of protein intake, and percent of carbohydrate intake

Discussion

In the present study, age was negatively associated with muscle mass among obese populations, increased physical activity was positively associated with muscle mass in men, and the proportion of protein intake was related with muscle mass with marginal significance for men. Neither smoking nor drinking was associated with muscle mass in the obese population. In co-twin control analysis, physical activity and the proportion of carbohydrate intake were related with muscle mass for both genders. The proportion of protein intake was related with muscle mass with marginal significance.

Sarcopenia is the progressive loss of skeletal muscle mass and strength with multiple contributing factors in the aging process [16]. Age-related changes influencing sarcopenia include the reduction in anabolic hormones such as testosterone, estrogen, growth hormone, and insulin-like growth factor-1 (IGF-1), inflammatory activity, and oxidative stresses associated with muscle catabolism [23]. Genetic factors may also affect the progression of sarcopenia. The genetic component of sarcopenia is complex and driven by many genes several genes have been identified that contribute to variations of skeletal muscle mass and strength, including IGF-1 and vitamin D receptor genes [24]. It is also known that sarcopenia progression is affected by lifestyle factors. Lifestyle factors are important, because they have more controllable characteristics than age-related systemic changes and genetic factors. Those suggested as sarcopenia-related lifestyle factors were physical activity, exercise, protein intake, alcohol consumption, and cigarette smoking. As previous studies have reported, a loss of muscle mass was associated with advanced age, decreased physical activity, BMI, and protein intake among obese population in this study. However, smoking and alcohol consumption were not significantly associated with muscle mass. Moreover, when analyzed by age (age ≥65 years and age <65 years), the significant associations between muscle mass, physical activity, and protein intake were only observed in males aged less than 65 years. We suggested that the loss of muscle mass could be the result of lifestyle when young, so the muscle mass in older groups might not reflect the lifestyle factors of the present young population.

It is known that low protein intake is related with sarcopenia. Aging is termed as the "anorexia of aging," which is associated with reduced appetite and low food intake [25]. The consumption of inadequate dietary protein (0.45 g/kg/d) compared to adequate intake (0.92 g/kg/d) for six weeks led to the loss of lean body mass in a small randomized study of postmenopausal women [18]. In this study, the relationship between protein intake and muscle mass was shown only in males, not in females. The mechanisms of this discrepancy should be further investigated.

It is also known that sarcopenia is associated with weight and body mass index [23]. Older people with a normal BMI may be at risk of sarcopenia and weight loss when older, which may lead to a loss of muscle mass [26]. In this study, weight-adjusted ASM and SMMI were negatively associated with BMI, because it was calculated by dividing into weight. On the other hand, height-adjusted ASM showed a positive relationship with BMI. Obese elderly people have a higher muscle mass than non-obese; however, the muscle quality of the obese was suggested to be poor due to increased intramuscular adipose tissue, frailty, and disability [26]. However, muscle mass indices using muscle mass cannot measure the strength and function of the muscle.

Physical activity has been reported as a factor associated with an increase of muscle mass. A sedentary lifestyle has been shown to be arisk factor for chronic disease, frailty, and sarcopenia [28]. Both aerobic and resistance training can improve the rate of loss of muscle mass and strength with age [29]. Inactivity exacerbates ongoing muscle loss [17] and increases the proportion of body fat mass [30].

This study has many limitations. First, we cannot judge the causal relationship because of the cross-sectional nature of its design. Second, we cannot adjust for all confounding factors. Third, the number of elderly and MZ twin were small. To be able to derive the exact relationship between non-genetic factors and muscle mass, a large number of participants would be required.

However, to the best of our knowledge, this is the first study that has investigated the factors associated with muscle mass using a twin cohort. Further studies might be needed after gathering more population and data that are more detailed.

We suggest that physical activity and protein and carbohydrate intake could be a positive influence on muscle mass among the obese population. To prevent sarcopenic obesity, an increase of physical activity and intake of proportion of both protein and carbohydrate could be encouraged.

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국 문 초 록

배경

근감소증이란 노화와 관련된 골격근의 감소를 말하며, 근감소성 비만은 골격근량의 감소와 비만조직의 증가를 특징으로 하며 만성질환 위험에 상승효과가 있는 것으로 알려져 있다. 근감소성 비만과 생활습관 요인의 관련성은 지속적으로 연구되어 왔으며, 이 논문에서는 한국 쌍둥이 코호트를 이용하여 비만인 사람에서 근육량과 관련된 생활습관 요인들에 대하여 연구하고자 하였다.

방법

2005-2013년에 모집된 한국 쌍둥이 코호트에서 DEXA (dual-energy X-ray absorptiometry) 를 시행하고 변수에 결측치가 없는 체질량 지수 $25kg/m^2$ 이상인 대상자에 대하여 근육량과 생활습관 요인 (나이, 흡연, 음주, 신체활동, 체지량지수, 단백질 및 탄수화물 섭취율) 에 대해 다중 선형회귀모형을 이용하여 분석하였으며, co-twin control analysis 를 이용하여 일란성 쌍둥이 내에서의 상기 관련성에 대하여 분석하였다. 근육량은 DEXA 를 이용하여 체중보정 골격근량, 키 보정 골격근량, 골격근량인덱스로 나타내었다.

결과

총 919명이 연구에 포함되었으며 co-twin control analysis를 위해 총 74쌍의 일란성 쌍둥이 데이터를 이용하였다. 신체활동량과 단백질 섭취량은 남성에서 근육량과 양의 상관관계가 있었다. 남녀 모두에서 연령이 증가할수록 근육량은 감소하였고, 체질량지수는 키 보정 골격근량과 양

의 관계를 보였고, 체중 보정 골격근량 및 골격근량인덱스와는 음의 상관관계를 보였다. co-twin control analysis 에서는 신체활동량 및 탄수화물 섭취율이 근육량과 양의 상관관계가 있었으며, 총 단백질 섭취율 섭취율은 한계 의의를 보였다.

결론
이 연구에서는 신체활동량의 증가 및 단백질, 탄수화물, 지방의 섭취가 비만인 남성의 근육량에 영향을 끼침을 보여주었다. 따라서, 근감소성 비만을 줄이기 위해서는 신체활동량의 증가 및 주요 영양소 섭취 비율을 증가시키는 것이 추천될 수 있겠다.

주요어 : 근감소성 비만, 근육량, 생활습관 요인
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