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The relationship between skeletal muscle mass and the KOSHA cardiovascular risk in obese male workers

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Abbreviations
BMI: body mass index; CI: confidence interval; CVD: cardiovascular disease; DBP: diastolic blood pressure; KOSHA: Korea Occupational Safety and Health Agency; HbA1c: hemoglobin A1c; HDL: high-density lipoprotein; LDL: low-

ABSTRACT

Background: Efforts for the prevention and management of cardiovascular diseases (CVDs) in workers have been actively pursued. Obesity is one of the important risk factors related to CVDs. Obesity has various metabolic characteristics, and some individuals can be metabolically healthy. Body composition including skeletal muscle mass is known to have protective effect in obesity. The study aims to investigate the association between skeletal muscle mass and Korea Occupational Safety and Health Agency (KOSHA) CVD risk among obese male manufacturing workers in Korea and to identify appropriate indicators of skeletal muscle mass for predicting risk of CVDs.
Methods: The study was conducted on 2,007 obese male workers at a manufacturing industry aged more than 19 years. Skeletal muscle mass, skeletal muscle index (SMI), skeletal muscle mass percent (SMM%) and skeletal muscle to body fat ratio (MFR) were used to evaluate body composition and these indicators were divided into quartiles. The odds ratios (ORs) and 95% confidence intervals (CIs) for the KOSHA CVD risk groups according to quartiles of skeletal muscle mass indicators were estimated using ordinal logistic regression analysis.
Results: The OR for the KOSHA CVD risk groups in the highest quartile of SMI was 1.67 (95% CI: 1.42–1.92), while the ORs for the KOSHA CVD risk groups in the highest quartiles of SMM%, SMM/body mass index (BMI), and MFR were 0.47 (95% CI: 0.22–0.72), 0.51 (95% CI: 0.05–0.76), and 0.48 (95% CI: 0.23–0.74), respectively.
Conclusions: We found that high SMI increase the likelihood of high risk of CVDs, while high SMM%, SMM/BMI, and MFR lower the likelihood of high risk of CVDs. Accurate evaluation of skeletal muscle mass can help assess the cardiovascular risk in obese male workers.

Keywords: Cardiovascular diseases; Obesity; Body composition; Muscle, skeletal

BACKGROUND

In 2021, among major chronic diseases except cancer, circulatory system disorders including cardiovascular diseases (CVDs) had the highest mortality rate, with 121.5 deaths per 100,000 population. Over the past decade, the mortality rate has increased by 7.0%.[1] The socioeconomic burden of CVDs is also increasing, and the total cost due to circulatory diseases in 2020 reached approximately 19.2 trillion won, with an annual increase of 4.7%.[2]

density lipoprotein; MF-BIA: multi-frequency bioelectrical impedance analysis; MFR: muscle to body fat ratio; OR: odds ratio; SBP: systolic blood pressure; SMI: skeletal muscle index; SMM%: skeletal muscle mass percent

Competing interests
The authors declare that they have no competing interests.

Author Contributions
Conceptualization: Chong HW; Data curation: Son J, Chae C; Formal analysis: Chong HW; Investigation: Chong HW, Jae C; Methodology: Son J, Chae C; Software: Jae C; Validation: Son J, Chae C; Visualization: Chong HW; Writing - original draft: Chong HW; Writing - review & editing: Chong HW, Son J, Chae C.

There are various factors associated with CVDs, and it has been found that personal lifestyle factors and genetic factors, along with occupational factors contribute to the development of CVDs among workers.[3] It is possible to prevent the development of severe CVDs by managing chronic conditions such as hypertension, diabetes, and dyslipidemia, along with lifestyle factors. Therefore, appropriate assessment of CVD risk and post-management are necessary.

The Korea Occupational Safety and Health Agency (KOSHA) has established guidelines regarding CVDs with the recognition of the work-relatedness of CVDs and the increasing number of approved cases of industrial accident. Since the 2000s, efforts for the prevention of CVDs have been actively pursued. In 2018, the Korea Occupational Safety and Health Corporation revised the risk assessment and post-management guidelines for CVDs. In accordance with these guidelines, risk assessment, evaluation of work-fitness, and risk management related to CVDs are being conducted. This tool assesses the risk of developing CVDs based on lifestyle factors, health status factors, and other risk factors.[4]

One of the evaluation item is obesity, which is associated with various metabolic disorders such as type 2 diabetes, hypertension, and dyslipidemia, and increases the risk of cardiovascular complications.[5] Currently, sedentary work followed by telecommuting, mechanization or automation, and various work arrangements such as shift work or night work, are being introduced in the labor market, leading to problems related to obesity and physical inactivity among workers, making metabolic and CVDs more critical.

The obesity has various metabolic characteristics, and some individuals can be metabolically healthy. These individuals may have a higher insulin sensitivity, lower visceral fat, and a lower frequency of hypertension and abnormal lipid metabolism.[6] It is known that body composition is an essential factor in relation to the phenotype of obesity. Adipokines secreted from adipose tissue regulate fat metabolism and insulin sensitivity. Muscles also play an essential role in maintaining homeostasis and the occurrence of metabolic disorders by interacting with adipose tissue.[7] The concept of the "obesity paradox" has been introduced in relation to heart diseases such as CVDs and heart failure, suggesting that overweight or mild obesity is associated with better prevalence and prognosis compared to normal or underweight individuals.[8] Although the mechanisms are not clear, a protective effect of higher skeletal muscle mass has been proposed.[9] Therefore, it is necessary to evaluate the risk of CVDs in obese workers by considering skeletal muscle mass rather than standardizing them solely based on obesity.

While the World Health Organization recommends using body mass index (BMI) as an indicator for evaluating obesity, its use is limited as it is only calculated by height and weight. In addition, it is recommended to use body composition, including lean body mass and body fat mass to evaluate obesity.[10,11] Various indicators have been proposed to assess skeletal muscle mass, which is crucial for the health status of the obese workers.

Therefore, this study aims to investigate the association between skeletal muscle mass and KOSHA CVD risk among obese male workers in the manufacturing industry in Korea and to identify appropriate skeletal muscle mass indicators for predicting the risk of CVDs, which can be utilized as fundamental data for worker health management.

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METHODS

Study participants

This study used data from 14,883 workers aged 19 years or above in a manufacturing industry who received a health examination at a university hospital between January 1, 2022, and December 31, 2022. Health examination conducted on employees included not only required measurement items for national or special health examination but also additional measurement items provided by company. The study was conducted on 2,661 obese male workers with a BMI of 25 kg/m^2 or higher. Out of 2,661 participants, 2,007 were selected as the final subjects of the study after excluding those with missing measurements results.

Study variables

Height was measured up to 0.1 cm increments with the participant standing upright, looking straight forward, and their heels and occiput touching the wall. Weight was measured up to 0.1 kg increments using an automatic measuring device (GL-150; G-TECH International, Seoul, Korea) while wearing light clothing. BMI was calculated as weight (kg) divided by height squared (m^2). Blood pressure was measured twice in a seated position after a minimum of 10 minutes of rest, and the mean value was used. If there was a difference of 5 mmHg or more between the 2 measurements, additional measurements were taken until the last 2 measurements were similar, and the mean value of the last two measurements was used. Participants were instructed not to smoke for at least 30 minutes before the measurements and to limit caffeine consumption. Blood tests, including blood glucose, glycated hemoglobin and lipid levels, were performed on venous blood samples obtained after a minimum of 12 hours of fasting. Smoking history, alcohol consumption, medication use, and physical activity were assessed using a self-reported questionnaire. Participants that were smoking at the time of assessment were classified as current smokers. Those who used to smoke but currently abstaining from smoking were classified as former smoker, and those who had never smoked were classified as non-smokers. Participants who consumed 14 glasses or more of alcohol (168 g of alcohol) per week, regardless of the type of drinks, were defined as heavy drinkers. Participants who engaged in at least 2 hours and 30 minutes of moderate- to high-intensity physical activity per week (with high-intensity activity calculated as twice the time spent on moderate-intensity activity) were defined as physical activity group. Participants who engaged in strength training for 2 or more days per week were defined as strength exercise group.

Body composition analysis

Body composition was measured using a multi-frequency bioelectrical impedance analyzer (Inbody 970; InBody Co., Ltd, Seoul, Korea) to determine percent body fat, skeletal muscle mass, body fat mass, and lean body mass. Skeletal muscle index (SMI) is calculated as skeletal muscle mass (kg) divided by height squared (m^2), skeletal muscle mass percent (SMM%) is calculated as skeletal muscle mass (kg) divided by weight (kg) multiplied by 100, SMM/BMI calculated as skeletal muscle mass (kg) divided by BMI (kg/m^2). Skeletal muscle to body fat ratio (MFR), calculated as skeletal muscle mass (kg) divided by body fat mass (kg), was used to evaluate skeletal muscle mass.

KOSHA cardiovascular risk classification

According to the risk assessment and post-management guidelines for CVDs provided by the KOSHA in 2018, the classification of CVDs risk groups is as follows[4]:

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First, the subjects were classified as normal (systolic blood pressure [SBP] below 140 mmHg and diastolic blood pressure [DBP] below 90 mmHg), stage 1 hypertension (SBP between 140–159 mmHg or DBP between 90–99 mmHg) and stage 2 hypertension (SBP between 160–179 mmHg or DBP between 100–109 mmHg) based on the measured blood pressure.

Second, The number of CVD risk factors was evaluated, and the count of risk factors was determined based on the following criteria: age (45 years or older), early-onset CVD in immediate family members (male < 55 years, female < 65 years), smoking, obesity (BMI 25 kg/m^2 or higher) or abdominal obesity (waist circumference: male ≥ 90 cm), impaired fasting glucose (100–125 mg/dL) or impaired glucose tolerance (140–199 mg/dL after 2 hours of oral glucose tolerance test) or prediabetes (hemoglobin A1c [HbA1c] 5.7–6.4%), high-density lipoprotein (HDL) cholesterol < 40 mg/dL, total cholesterol ≥ 220 mg/dL or low-density lipoprotein (LDL) cholesterol ≥ 150 mg/dL or triglycerides (TG) ≥ 200 mg/dL. If the HDL cholesterol level is 60 mg/dL or higher, one risk factor is subtracted from the total count.

Finally, the risk levels of developing CVDs were classified into low-risk group, moderate-risk group, high-risk group, and highest-risk group using risk table based on the target organ damage and presence of comorbidities provided by the KOSHA.

Statistical analysis

Statistical analysis was performed using SPSS version 25.0 software (IBM Corp., Armonk, NY, USA), with the confidence interval (CI) set at 95% and the significance level at $p < 0.05$. Continuous variables were described using means and standard deviations, and categorical variables were described using frequencies. To examine the statistical differences between KOSHA CVDs risk groups, an analysis of variance was used for continuous variables, and the χ^2 test was used for categorical variables. Partial correlation analysis was performed, controlling for age, smoking status, alcohol consumption, physical activity and strength exercise to assess the correlation between skeletal muscle mass index and cardiovascular risk factors, and correlation coefficients were calculated. Each of the skeletal muscle mass indicators were categorized into quartiles. The odds ratios (ORs) and 95% CIs for the KOSHA CVD risk groups were calculated compared to the lowest quartiles of the skeletal muscle mass indicators using ordinal logistic regression analysis.

Ethics statement

The present study protocol was reviewed and approved by the Institutional Review Board of Samsung Changwon Hospital (IRB No. 2023-02-010). Informed consent was submitted by all subjects when they were enrolled.

RESULTS

General characteristics of study subjects classified by the KOSHA CVD risk groups

The total number of final subjects was 2,007, with 1,254 (62.5%) classified as low risk group, 470 (23.4%) as moderate risk group, 269 (13.4%) as high risk group, and 14 (0.7%) as highest risk group of the KOSHA CVD risk. The mean age of the low-risk group was 42.52 ± 6.81 and significantly lower compared to the mean age of the highest-risk group, which was 46.29 ± 6.13 years. The mean values of weight and BMI were higher in the higher risk group. The mean value of skeletal muscle mass was higher in higher risk group, but there were no

significant difference. The mean value of SMI was significantly higher in the higher risk group, but the mean values for SMM%, SMM/BMI, and MFR were significantly lower. The proportion of smoking status, physical activity group, and strength exercise group did not differ significantly between the risk groups (**Table 1**).

Correlations between skeletal muscle mass indicators and cardiovascular risk factors

After controlling for age, smoking status, alcohol consumption, physical activity, and strength exercise, correlations between skeletal muscle mass indicators and cardiovascular risk factors were analyzed. SMM and SMI presented positive correlations with SBP, DBP, and HbA1c, while SMM%, SMM/BMI, and MFR presented negative correlations. Conversely, SMM and SMI presented negative correlations with HDL cholesterol, while SMM%, SMM/BMI, and MFR presented positive correlations. TG presented a negative correlation with SMM%, SMM/BMI, and MFR. All of these correlations were statistically significant (**Table 2**).

Association between skeletal muscle mass indicators and the KOSHA CVD risk groups

The OR for the KOSHA CVD risk groups increased as the quartiles of SMI increased, with the OR of 1.67 (95% CI: 1.42–1.92) for the fourth quartile, indicating a higher risk with higher quartiles of the index. In contrast, the ORs of SMM%, SMM/BMI, and MFR decreased as the quartiles increased, with the ORs of 0.47 (95% CI: 0.22–0.72), 0.51 (95% CI: 0.05–0.76), and 0.48 (95% CI: 0.23–0.74) for the fourth quartiles of SMM%, SMM/BMI, and MFR, respectively. This indicates a lower risk with higher quartiles of the indicators. The ORs of SMM% and MFR were statistically significant for all quartiles (**Table 3**).

Table 1. General characteristics of study subjects classified by the KOSHA CVD risk groups

Variables	Total (n = 2,007)	Low (n = 1,254)	Moderate (n = 470)	High (n = 269)	Highest (n = 14)	*p*-value
Age (years)	43.53 ± 6.81	42.52 ± 6.72	44.67 ± 6.51	46.08 ± 6.78	46.29 ± 6.13	< 0.001
Height (cm)	173.96 ± 5.72	174.16 ± 5.71	173.68 ± 5.71	173.58 ± 5.78	172.20 ± 5.11	0.157
Weight (kg)	84.04 ± 9.84	83.08 ± 9.12	85.14 ± 10.59	86.41 ± 11.10	87.21 ± 9.01	< 0.001
BMI (kg/m^2)	27.73 ± 2.59	27.36 ± 2.34	28.17 ± 2.70	28.64 ± 3.09	29.39 ± 2.49	< 0.001
Body fat mass (kg)	22.75 ± 6.18	21.98 ± 5.66	23.75 ± 6.66	24.50 ± 7.06	24.46 ± 4.28	< 0.001
Body fat percent (%)	26.83 ± 4.82	26.28 ± 4.66	27.59 ± 4.92	28.00 ± 5.02	27.96 ± 3.55	< 0.001
Skeletal muscle mass (kg)	34.75 ± 3.76	34.64 ± 3.70	34.81 ± 3.84	35.10 ± 3.85	35.54 ± 3.94	0.243
SMI (kg/m^2)	11.46 ± 0.84	11.40 ± 0.82	11.51 ± 0.84	11.63 ± 0.89	11.97 ± 1.10	< 0.001
SMM%	41.47 ± 2.86	41.78 ± 2.79	41.04 ± 2.92	40.79 ± 2.93	40.78 ± 2.10	< 0.001
SMM/BMI	1.26 ± 0.13	1.27 ± 0.13	1.24 ± 0.13	1.23 ± 0.13	1.21 ± 0.10	< 0.001
MFR	1.62 ± 0.42	1.66 ± 0.43	1.55 ± 0.38	1.53 ± 0.39	1.49 ± 0.30	< 0.001
Smoking status						
Non-smoker	748 (37.3)	493 (39.3)	158 (33.6)	91 (33.8)	6 (42.9)	
Ex-smoker	575 (28.6)	355 (28.3)	134 (28.5)	81 (30.1)	5 (35.7)	0.199
Current-smoker	684 (34.1)	406 (32.4)	178 (37.9)	97 (36.1)	3 (21.4)	
Alcohol consumption[a]						0.016
Non-light drinker	1,503 (74.9)	962 (76.7)	327 (69.6)	205 (76.2)	9 (64.3)	
Heavy drinker[a]	504 (25.1)	292 (23.3)	143 (30.4)	64 (23.8)	5 (35.7)	
Physical activity						0.848
< 150 min/week	1,044 (52.0)	643 (51.3)	250 (53.2)	144 (53.5)	7 (50.0)	
≥ 150 min/week	963 (48.0)	611 (48.7)	220 (46.8)	125 (46.5)	7 (50.0)	
Strength exercise						0.498
< 2 /week	671 (33.4)	406 (32.4)	162 (34.5)	99 (36.8)	4 (28.6)	
≥ 2 /week	1,336 (66.6)	848 (67.6)	308 (65.5)	170 (63.2)	10 (71.4)	

Data are shown as mean ± standard deviation or number (%). *p*-value was analyzed by one-way analysis of variance or χ^2 test.
KOSHA: Korea Occupational Safety and Health Agency; CVD: cardiovascular disease; BMI: body mass index; SMI: skeletal muscle index; SMM%: percent of skeletal muscle mass; MFR: skeletal muscle to body fat ratio.
[a]Defined as an average alcohol consumption ≥ 14 cups per week (alcohol content ≥ 168 g).

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Table 2. Correlations between skeletal muscle mass indicators and cardiovascular risk factors

Variables	SMM		SMI		SMM%		SMM/BMI		MFR	
	R	P	R	P	R	P	R	P	R	P
SBP (mmHg)	0.08*	0.001	0.07*	0.002	−0.13*	< 0.001	−0.06*	0.014	−0.11*	< 0.001
DBP (mmHg)	0.05*	0.023	0.07*	0.002	−0.14*	< 0.001	−0.09*	< 0.001	−0.14*	< 0.001
Glucose (mg/dL)	0.08*	< 0.001	0.09*	< 0.001	−0.09*	< 0.001	−0.03	0.123	−0.09*	< 0.001
HbA1c (%)	0.08*	< 0.001	0.11*	< 0.001	−0.14*	< 0.001	−0.09*	< 0.001	−0.14*	< 0.001
TC (mg/dL)	−0.03	0.141	−0.06*	< 0.001	−0.00	0.924	0.01	0.815	−0.02	0.361
HDL-C (mg/dL)	−0.07*	0.002	−0.08*	< 0.001	0.13*	< 0.001	0.07*	0.002	0.14*	< 0.001
LDL-C (mg/dL)	0.00	0.979	−0.04	0.062	0.04	0.091	0.05*	0.016	0.02	0.277
TG (mg/dL)	0.01	0.771	0.03	0.162	−0.11*	< 0.001	−0.09*	< 0.001	−0.13*	< 0.001

R and P were analyzed by partial correlation analysis controlling for age, smoking status, alcohol consumption, physical activity, muscle strength exercise.
R: partial correlation coefficient; P: *p*-value; SMM: skeletal muscle mass; SMI: skeletal muscle index; SMM%: percent of skeletal muscle mass; BMI: body mass index; MFR: skeletal muscle to body fat ratio; SBP: systolic blood pressure; DBP: diastolic blood pressure; HbA1c: hemoglobin A1c; TC: total cholesterol; HDL-C: high-density lipoprotein cholesterol; LDL-C: low-density lipoprotein cholesterol; TG: triglycerides.

Table 3. The ordinal logistic regression for associations between skeletal muscle mass indicators and the KOSHA cardiovascular risk groups

Subgroup	OR (95% CI)	Estimates	*p*-value
SMI			
Q1		reference	
Q2	1.11 (0.85–1.37)	0.104	0.429
Q3	1.25 (1.00–1.50)	0.222	0.085
Q4	1.67 (1.42–1.92)	0.513	< 0.001
SMM%			
Q1		reference	
Q2	0.72 (0.48–0.96)	−0.328	0.008
Q3	0.63 (0.39–0.88)	−0.459	< 0.001
Q4	0.47 (0.22–0.72)	−0.754	< 0.001
SMM/BMI			
Q1		reference	
Q2	0.84 (0.60–1.08)	−0.176	0.153
Q3	0.62 (0.37–0.86)	−0.482	< 0.001
Q4	0.51 (0.25–0.76)	−0.68	< 0.001
MFR			
Q1		reference	
Q2	0.78 (0.54–1.02)	−0.246	0.046
Q3	0.66 (0.41–0.90)	−0.421	0.001
Q4	0.48 (0.23–0.74)	−0.727	< 0.001

Odds and *p*-value was analyzed by ordinal logistic regression analysis.
Quartiles increase as the values of skeletal muscle mass indicators increase: 1) The 25th, 50th and 75th percentiles of SMI were 10.86, 11.40 and 11.95. 2) The 25th, 50th and 75th percentiles of SMM% were 39.63, 41.67 and 43.42. 3) The 25th, 50th and 75th percentiles of SMM/BMI were 1.16, 1.25 and 1.34. 4) The 25th, 50th and 75th percentiles of MFR were 1.33, 1.58 and 1.85.
KOSHA: Korea Occupational Safety and Health Agency; OR: odds ratio; CI: confidence interval; Q1: first quartile; Q2: second quartile; Q3: third quartile; Q4: fourth quartile; SMI: skeletal muscle index; SMM%: percent of skeletal muscle mass; BMI: body mass index; MFR: skeletal muscle to body fat ratio.

DISCUSSION

This study investigated the association between skeletal muscle mass and KOSHA CVD risk in obese males working in the manufacturing industry. First, it was found that the mean values of SMM and SMI adjusted for height were higher in the higher risk groups. These results would have been shown because higher risk groups typically have higher body weight and BMI, it is expected that absolute skeletal muscle mass would also be higher in these groups. In contrast, the mean values of relative skeletal muscle mass indicators (SMM%, SMM/BMI, MFR), considering body weight and body composition, were significantly lower in the higher risk groups. This suggests that different standards should be applied when

evaluating skeletal muscle mass, considering both absolute indicators and relative indicators to body weight and body composition.

When examining the correlation between skeletal muscle mass indicators and cardiovascular risk factors, the indicators reflecting relative skeletal muscle mass (SMM%, SMM/BMI, MFR) showed negative correlations with blood pressure, HbA1c, and TG, and positive correlations with HDL cholesterol. These relative skeletal muscle mass indicators demonstrated a significant correlation with TG, indicating that using these indicators would be more appropriate for assessing cardiovascular risk by reflecting high TG levels, compared to absolute skeletal muscle mass or SMI. Generally, it presented favorable relationships of cardiovascular risk factors with lower SMM and SMI values and higher SMM%, SMM/BMI, and MFR values.

Skeletal muscle is a primary tissue responsible for insulin sensitivity and is known to impact glucose and lipid metabolism significantly. Insulin binds to insulin receptors in skeletal muscle and induces glucose uptake and glycogen synthesis through glucose transporter 4.[12,13] According to previous research, skeletal muscle mass relative to weight is associated with better insulin sensitivity and a lower risk of prediabetes.[14]

Muscle is also involved in lipid metabolism. Lipoprotein lipase in the endothelial cells of skeletal muscle catalyzes TG into chylomicrons and very low density lipoprotein particles, producing fatty acids that can be used as an energy source.[15] Also, insulin-induced translocation of long-chain fatty acid transporters in the skeletal muscle cell membrane induces the absorption of fatty acids in skeletal muscle.[16,17] Aerobic or resistance exercise activates peroxisome proliferator-activated receptor α in skeletal muscle, increasing apolipoprotein A-I production and increasing HDL cholesterol.[18]

Skeletal muscle mass is also associated with blood pressure, and a decreased skeletal muscle mass can lead to hypertension. Although the mechanism is still unknown, it is suggested that inflammation and oxidative stress caused by insulin resistance due to decreased skeletal muscle mass can increase blood pressure, and a decrease in myokines released from skeletal muscle can also lead to high blood pressure.[19]

Generally, it is known that an increase in skeletal muscle mass has a favorable effect on cardiovascular risk factors. However, in this study, various results were observed depending on the skeletal muscle mass indicators, which can be explained by the interaction between high body fat mass and skeletal muscle mass in the obese workers. Excessive fat cell accumulation increases inflammatory adipokines, activates the renin-angiotensin-aldosterone system, and decreases the fatty acid oxidation capacity of muscle mitochondria, leading to an increase in fat accumulation and active oxygen within muscles.[20,21] Despite higher skeletal muscle mass according to SMM and SMI indicators, the detrimental effects of excessive fat accumulation may offset the beneficial effects of skeletal muscle, resulting in negative effects of cardiovascular risk factors.

When analyzing the association between skeletal muscle mass indicators and KOSHA CVD risk groups, it was found that a higher SMI quartile indicates a higher likelihood of the higher risk groups, while higher quartiles of SMM%, SMM/BMI, and MFR indicate a lower likelihood of the higher risk groups. This is similar to previous research studying the association between skeletal muscle mass and cardiovascular risk.

Sarcopenia, characterized by a decrease in muscle mass, muscle strength, and muscle function, is associated with atherosclerosis and CVDs in previous research.[22] Studies investigating the association between skeletal muscle mass and coronary artery calcification found that lower skeletal muscle mass was associated with increased risk of coronary calcification and coronary artery stenosis.[23,24] Numerous studies have been conducted analyzing the prevalence and mortality of CVDs, which have shown a significant association with skeletal muscle mass. Skeletal muscle mass indices and absolute skeletal muscle mass showed inverse associations with 10-year CVD incidence, suggesting the importance of skeletal muscle mass in predicting long-term cardiovascular risk.[25,26] In another study which assessed both skeletal muscle mass and fat mass together, an association between body composition subtypes and CVD mortality has been observed.[27]

The impact of skeletal muscle mass on cardiovascular health can also be observed in the obese population. Sarcopenic obese individuals showed a higher risk of CVDs compared to the non-sarcopenic non-obese group, while the non-sarcopenic obese group did not exhibit a significant increase in cardiovascular risk.[28] This demonstrates that the risk of CVDs can vary among individuals with obesity, depending on the specific body composition.

Currently, post-management of CVDs focuses on workers diagnosed with conditions such as hypertension, dyslipidemia, and diabetes. It recommends to implement basic disease management and provide medication therapy with lifestyle improvement. Interventions for increasing muscle mass, such as resistance training, have been shown to have effects such as reduced inflammation, increased mitochondrial function, and enhanced satellite cell activity.[29] Education for workers at high risk including muscle strength exercises can improve insulin resistance and contribute to CVDs prevention.[30]

Various diagnostic techniques and indicators are currently used to evaluate skeletal muscle mass, but standardization of evaluation methods has not yet been established. Multi-frequency bioelectrical impedance analysis (MF-BIA), which has advantages in accessibility, convenience, and cost, allows for easy evaluation of body composition and skeletal muscle mass. Assessment of skeletal muscle mass using MF-BIA in obese workers is considered effective and convenient in identifying cardiovascular risk groups.

This study has several limitations. First, MF-BIA, used in this study, has lower accuracy than magnetic resonance imaging, computed tomography, or dual-energy X-ray absorptiometry. However, this study has sufficient significance considering that MF-BIA is the most commonly used method for body composition analysis in clinical practice. Second, there is a possibility of self-report bias for some variables such as smoking history, alcohol consumption, medication use, and physical activity. Since some of the self-reported data is utilized to categorize the KOSHA CVD risk groups, this can lead to inaccuracy. Third, there was a limitation in conducting the study due to the small number of obese females in the total study subjects. Due to the gender-specific differences in body composition and cardiovascular risk factors, it is necessary to conduct future research by stratifying the data based on sex. Fourth, this study has limitations in revealing the causal relationship between skeletal muscle mass indicators and the KOSHA CVD risk groups because this study is cross-sectional. A large-scale prospective study is needed in further studies.

CONCLUSIONS

In conclusion, skeletal muscle mass indicators can be utilized to predict KOSHA CVD risk groups in the obese workers. Accurate evaluation of skeletal muscle mass can help assess the metabolic status of the obese workers and stratify individuals who require systematic management. In occupational health management, instead of uniform education for obese workers, it would be beneficial implementing educational programs on exercise, dietary habits, and maintaining a healthy lifestyle specifically targeting individuals with relatively low skeletal muscle mass.

REFERENCES

1. Korean Statistical Information Service. Statistics on causes of death. https://kostat.go.kr/board.es?mid=a10301060200&bid=218&act=view&list_no=420715. Updated September 27, 2022. Accessed June 30, 2023.
2. Go DS. *The Trends of Regional Socio-Economic Disease Burden and Influencing Factors.* Sejong, Korea: Korea Institute for Health and Social Affairs; 2022.
3. Park J. Are cerebrovascular and cardiovascular diseases among employees work-related? Korean J Occup Environ Med 2005;17(4):288-96.
CROSSREF
4. Korea Occupational Safety and Health Agency. Risk assessment for the prevention of cardio-cerebrovascular disease at workplace (KOSHA code H-200-2018). http://www.kosha.or.kr/kosha/data/guidanceH.do?mode=view&articleNo=263229&article.offset=0&articleLimit=10. Updated 2018. Accessed July 14, 2023.
5. Sowers JR. Obesity as a cardiovascular risk factor. Am J Med 2003;115(8 Suppl 8A):37S-41S.
PUBMED | CROSSREF
6. Yoo HJ. Pathogenesis and clinical implications of metabolically healthy obesity (MHO) and metabolically obese normal weight (MONW) subjects. J Korean Diabetes 2014;15(1):12-6.
CROSSREF
7. Dyck DJ, Heigenhauser GJ, Bruce CR. The role of adipokines as regulators of skeletal muscle fatty acid metabolism and insulin sensitivity. Acta Physiol (Oxf) 2006;186(1):5-16.
PUBMED | CROSSREF
8. Elagizi A, Kachur S, Lavie CJ, Carbone S, Pandey A, Ortega FB, et al. An overview and update on obesity and the obesity paradox in cardiovascular diseases. Prog Cardiovasc Dis 2018;61(2):142-50.
PUBMED | CROSSREF
9. Wannamethee SG, Shaper AG, Whincup PH, Lennon L, Papacosta O, Sattar N. The obesity paradox in men with coronary heart disease and heart failure: the role of muscle mass and leptin. Int J Cardiol 2014;171(1):49-55.
PUBMED | CROSSREF
10. Romero-Corral A, Somers VK, Sierra-Johnson J, Thomas RJ, Collazo-Clavell ML, Korinek J, et al. Accuracy of body mass index in diagnosing obesity in the adult general population. Int J Obes 2008;32(6):959-66.
PUBMED | CROSSREF
11. Nuttall FQ. Body mass index: obesity, BMI, and health: a critical review. Nutr Today 2015;50(3):117-28.
PUBMED | CROSSREF
12. Zierath JR, Krook A, Wallberg-Henriksson H. Insulin action and insulin resistance in human skeletal muscle. Diabetologia 2000;43(7):821-35.
PUBMED | CROSSREF
13. Zierath JR, He L, Gumà A, Odegoard Wahlström E, Klip A, Wallberg-Henriksson H. Insulin action on glucose transport and plasma membrane GLUT4 content in skeletal muscle from patients with NIDDM. Diabetologia 1996;39(10):1180-9.
PUBMED | CROSSREF
14. Srikanthan P, Karlamangla AS. Relative muscle mass is inversely associated with insulin resistance and prediabetes. Findings from the third National Health and Nutrition Examination Survey. J Clin Endocrinol Metab 2011;96(9):2898-903.
PUBMED | CROSSREF

15. Lee B, Shao J. Adiponectin and lipid metabolism in skeletal muscle. Acta Pharm Sin B 2012;2(4):335-40.
CROSSREF

16. Wu Q, Ortegon AM, Tsang B, Doege H, Feingold KR, Stahl A. FATP1 is an insulin-sensitive fatty acid transporter involved in diet-induced obesity. Mol Cell Biol 2006;26(9):3455-67.
PUBMED | CROSSREF

17. Sylow L, Tokarz VL, Richter EA, Klip A. The many actions of insulin in skeletal muscle, the paramount tissue determining glycemia. Cell Metab 2021;33(4):758-80.
PUBMED | CROSSREF

18. Zhang B, Kawachi E, Miura S, Uehara Y, Matsunaga A, Kuroki M, et al. Therapeutic approaches to the regulation of metabolism of high-density lipoprotein. Novel HDL-directed pharmacological intervention and exercise. Circ J 2013;77(11):2651-63.
PUBMED | CROSSREF

19. Han JM, Lee MY, Lee KB, Kim H, Hyun YY. Low relative skeletal muscle mass predicts incident hypertension in Korean men: a prospective cohort study. J Hypertens 2020;38(11):2223-9.
PUBMED | CROSSREF

20. Stump CS, Henriksen EJ, Wei Y, Sowers JR. The metabolic syndrome: role of skeletal muscle metabolism. Ann Med 2006;38(6):389-402.
PUBMED | CROSSREF

21. Marcus Y, Shefer G, Stern N. Adipose tissue renin-angiotensin-aldosterone system (RAAS) and progression of insulin resistance. Mol Cell Endocrinol 2013;378(1-2):1-14.
PUBMED | CROSSREF

22. Bahat G, Ilhan B. Sarcopenia and the cardiometabolic syndrome: a narrative review. Eur Geriatr Med 2016;7(3):220-3.
CROSSREF

23. Ko BJ, Chang Y, Jung HS, Yun KE, Kim CW, Park HS, et al. Relationship between low relative muscle mass and coronary artery calcification in healthy adults. Arterioscler Thromb Vasc Biol 2016;36(5):1016-21.
PUBMED | CROSSREF

24. He W, Peng N, Chen Q, Xiang T, Wang P, Pang J. The relationships among the skeletal muscle mass index, cardiorespiratory fitness and the prevalence of coronary artery disease in the elderly population. Arch Gerontol Geriatr 2020;90:104107.
PUBMED | CROSSREF

25. Tyrovolas S, Panagiotakos D, Georgousopoulou E, Chrysohoou C, Tousoulis D, Haro JM, et al. Skeletal muscle mass in relation to 10 year cardiovascular disease incidence among middle aged and older adults: the ATTICA study. J Epidemiol Community Health 2020;74(1):26-31.
PUBMED | CROSSREF

26. Knowles R, Carter J, Jebb SA, Bennett D, Lewington S, Piernas C. Associations of skeletal muscle mass and fat mass with incident cardiovascular disease and all-cause mortality: a prospective cohort study of UK Biobank participants. J Am Heart Assoc 2021;10(9):e019337.
PUBMED | CROSSREF

27. Srikanthan P, Horwich TB, Tseng CH. Relation of muscle mass and fat mass to cardiovascular disease mortality. Am J Cardiol 2016;117(8):1355-60.
PUBMED | CROSSREF

28. Kim JH, Cho JJ, Park YS. Relationship between sarcopenic obesity and cardiovascular disease risk as estimated by the Framingham risk score. J Korean Med Sci 2015;30(3):264-71.
PUBMED | CROSSREF

29. Kim TN, Choi KM. The implications of sarcopenia and sarcopenic obesity on cardiometabolic disease. J Cell Biochem 2015;116(7):1171-8.
PUBMED | CROSSREF

30. Nishiyama Y, Minohara M, Ohe M, Hirai Y, Katoh A, Miyamoto T, et al. Effect of physical training on insulin resistance in patients with chronic heart failure. Circ J 2006;70(7):864-7.
PUBMED | CROSSREF