Observational Study

Medicine

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Correlation of muscle mass and bone mineral density in the NHANES US general population, 2017–2018

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Abstract

The appendicular skeletal muscle mass index (ASMI) is commonly used to evaluate human skeletal muscle mass. Muscle, an adjacent tissue of bone, is closely related to bone growth and development. The purpose of this study was to explore the association between the ASMI and lumbar bone mineral density (BMD) to identify potential risk factors for osteoporosis. We analyzed the data collected by the NHANES from 2017 to 2018, and finally included 948 participants aged 40 to 59 years. We evaluated the correlation between the ASMI and lumbar spine BMD using univariate and multiple linear regression models. The ASMI was calculated from height and appendicular skeletal muscle mass obtained by dual energy X-ray absorptiometry. Lumbar spine BMD was obtained by dual energy X-ray absorptiometry and used as an observation in our study. In all the models, ASMI was significantly associated with lumbar spine BMD (model 1: $\beta = 0.013$, $P < .001$; model 2: $\beta = 0.013$, $P < .001$). In the subgroup analysis stratified by sex, this positive correlation was present in both sexes (male: $\beta = 0.023$, $P < .001$, $\beta = 0.022$, < 0.001; female: $\beta = 0.030$, $P < .001$, $\beta = 0.031$, $P < .001$). This study showed that the ASMI was positively associated with lumbar BMD, and that this correlation is present in both men and women.

Abbreviations: ASM = appendicular skeletal muscle mass, ASMI = appendicular skeletal muscle mass index, BMD = bone mineral density, DXA = dual energy X-ray absorptiometry, LM = bone-mineral-free lean mass, NHANES = National Health and Nutrition Examination Survey.

Keywords: appendicular skeletal muscle mass index, ASM, bone mineral density, DXA, NHANES

1. Introduction

When an osteoporotic fracture occurs, it poses a serious health risk to elderly individuals and affects their quality of life. The risk of lung and urinary tract infections is higher in the elderly population, and this risk is increased when the fracture requires prolonged bed rest.[1] Spinal fractures are the most common fractures in older adults, and femoral neck fractures are known as the last fractures in older adults; both types of fractures are closely associated with osteoporosis. Human bone and muscle mass tend to increase during youth, and after middle age, as the aging process progresses, muscle mass and skeletal mass begin to decline. A study estimated that 10.2 million older adults in the US over age 50 in 2010 had osteoporosis and that 43.4 million older adults had reduced bone mass.[2] Therefore, early prevention and intervention for patients with low bone and muscle mass are essential.

Muscle loss and bone loss often occur together in older patients. The loss of muscle mass increases the risk of falls in older adults and can predispose them to fractures if osteoporosis is also present. Some studies have also shown that bone loss is accelerated in patients with osteoporosis who develop sarcopenia, but the mechanism is unclear.[3] During growth and development, bones and muscles are influenced by many of the same factors and can influence each other.[4] Activity can promote the growth of muscle tissue, and the stimulation of external stress on the bone can also promote the growth and development of bone tissue.[5] Moreover, both are regulated by vitamin D, which can promote protein synthesis in the muscle and enhance its activity function and can also influence calcium and phosphorus regulation in bone tissue by acting on the intestine, kidneys, and parathyroid glands.[6] Skeletal muscle, an adjacent organ of the skeleton, has a strong endocrine function in addition to being a motor organ, and its quality is closely related to bone health. Recently, myokines have been found to be able to influence and regulate bone formation through multiple pathways.[7]

Sarcopenia is a syndrome characterized by a progressive loss of skeletal muscle mass, muscle strength and function, which can lead to a reduced quality of life, interfere with daily activities, and increase the risk of death when it occurs

Written informed consent was obtained from all participants in NHANES.

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The datasets generated during and/or analyzed during the current study are publicly available.

The Ethics Review Committee of the Statistical Center approved all NHANES protocols.

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in conjunction with other diseases.[8] The appendicular skeletal muscle mass index (ASMI), an indicator of sarcopenia, is a good indicator of the body's muscle mass. As a tool for studying human composition, X-ray absorptiometry (DXA) is lower priced and more easily detected than MRI and it can be used as a health screening tool in the clinic. DXA can be performed as a whole-body scan to obtain values for fat, bone, and boneless lean tissue for each limb and the torso.[9] ASM accounts for about three-quarters of the body's total muscle mass and is a major component of active function. Therefore, we wanted to explore the correlation between muscle mass and bone mineral density (BMD) in the general population by using the ASMI as an indicator of muscle mass. Data from the study were obtained from the cross-sectional data of the National Health and Nutrition Examination Survey (NHANES), 2017 to 2018.

2. Method

2.1. Data source

NHANES is a research program designed to assess the health and nutritional status of adults and children in the United States. It consists of two major components: interviews and physical examinations. There survey data, which are used in epidemiological studies and health science research, help to shape public health policy and guide health programs and services. The data collected are open to researchers worldwide. In this study, we collected demographics, laboratory tests, general body measurement information, diabetes questionnaire responses and whole-body DXA scan information from the 2017 to 2018 data.

2.2. Study population selection criteria

The flow chart is shown in Figure 1. We selected 1732 participants aged 40 to 59 years. After excluding 730 participants without complete BMD, ASM or height records information, and 54 patients with malignancy, we analyzed the remaining 948 participants. Demographic information was obtained from DEMO_H dataset; BMI, height, and weight information was obtained from the BMX_H dataset; serum calcium, serum potassium, albumin, serum creatinine, phosphorus and alkaline phosphatase information was obtained from the BIOPRO_H dataset; ASM and total lumbar spine BMD information was obtained from the DXX_J dataset; and diabetes mellitus and malignant disease status were obtained from self-reports from the DIQ_J and MCQ_J dataset, respectively.

2.3. Appendicular skeletal muscle mass index

Whole-body scans were obtained on a Hologic Discovery A densitometer (Hologic, Inc., Bedford, MA). DXA system scans were performed with extremely low radiation doses of less than 20 μSv. All scans in the DXX_J file were analyzed using Hologic APEX version 4.0 software. DXA testing excluded participants who were pregnant or had a history of radiographic contrast (barium) use within the last 7 days or whose body dimensions exceeded the DXA table limits. Appendicular skeletal muscle mass (ASM) was measured with a whole-body scan using DXA. ASMI was then calculated from height and ASM. As a quickly obtained and convenient experimental result, the measurement of lumbar BMD has been used in the evaluation and treatment of osteoporosis. DXA was performed by trained and certified radiology technicians.

2.4. Covariates

Sex, age, and ethnicity information was obtained from demographic questionnaires administered by trained interviewers using the computer-assisted personal interview system. The total fat ratio was obtained by whole-body scanning with DXA. Respondents were recorded as having diabetes if they described in their self-report that they had been told by a physician that they had diabetes. Detailed instructions for specimen collection and handling of serum calcium levels, serum phosphorus, serum albumin, serum creatinine, alkaline phosphatase, and serum potassium are discussed in the NHANES Laboratory Procedures Manual.

2.5. Statistical methods

All data analyses were performed using IBM SPSS Statistics for Windows version 19.0 (IBM Corporation, Armonk, NY). The significance level was .05. Analysis of the sample characteristics was performed separately after grouping the samples by sex and by ASMI values referenced by sarcopenia diagnosed in previous studies.[10] Males with an ASMI less than 7.23 kg/m^2 and females with an ASMI less than 5.67 kg/m^2 were classified as low ASMI group and individuals with values higher than the cutoff for their sex were classified as the high ASMI group. Continuous variables are expressed as the means and standard deviations, and categorical variables are expressed as proportions. Categorical variables were analyzed with the chi-square test in different groups, and continuous variables were analyzed with a *t* test. Univariate and multivariate linear regression analyses were also used to examine the correlation between the ASMI and total lumbar spine BMD. Sex was used as a stratification variable, and age, race, serum calcium level, serum alkaline phosphatase, serum creatinine, serum potassium, serum albumin, diabetes status and total fat ratio were adjusted as control variables in different models.

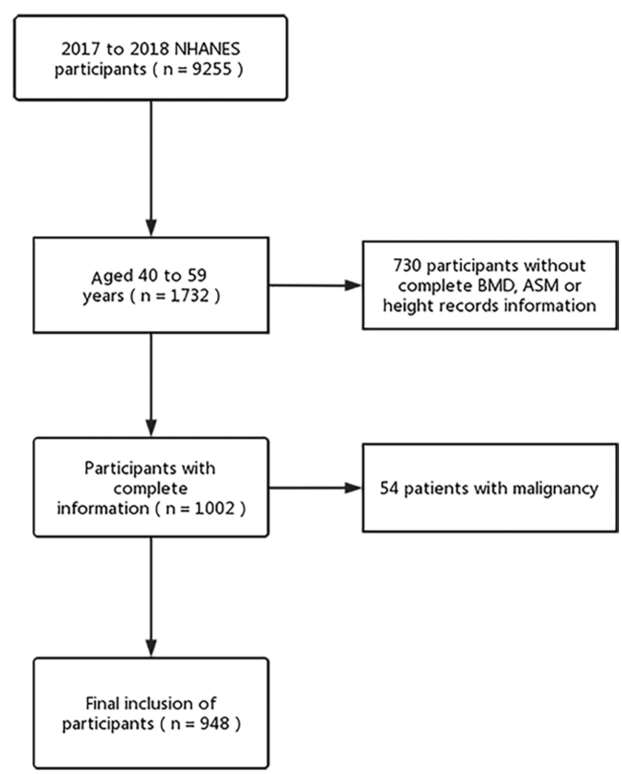

Figure 1. Flowchart of patient selection. The inclusion criteria were healthy people aged 40 to 59 years old who measured bone mineral density, appendicular skeletal muscle mass (ASM), and height. Patients were excluded if they had a malignant disease. The downward arrows indicate the process of patient selection, and the right arrows indicate the patients excluded at each step and the reasons for exclusion. BMD = bone mineral density, NHANES = National Health and Nutrition Examination Survey.

3. Result

There was a significant difference in ASMI between males and females. Men had a higher percentage of diabetes than women. In addition, there were differences between males and females in total fat ratio, albumin, serum creatinine, phosphorus, and serum potassium. However, we did not observe differences in lumbar BMD between males and females. The results are shown in Table 1.

Table 2 shows the characteristics of the subjects divided into two groups according to ASMI values. After we grouped by ASMI, it was observed that participants in the high ASMI group had higher lumbar spine BMD than those in the low ASMI group. There was no significant difference in the total fat ratio or percentage of diabetic patients between the two groups. Other variables, such as age, body mass index, weight, serum potassium, phosphorus, albumin, and creatinine were significantly different between the two groups.

In univariate analysis, there was a positive correlation between ASMI and total lumbar spine BMD. These associations remained after adjusting for influential confounders in the model. In the sex-stratified analysis, the trends were similar, with stronger associations for women than for men. The results are shown in Table 3.

Table 1

Characteristics of the included study sample.

	Male (n = 483)	Female (n = 465)	*P*
Number of subjects (%)	50.9	49.1	
Age (yr)	49.27 ± 5.74	49.78 ± 5.73	.176
Race (%)			
Mexican American	12.8	14.4	.316
Other Hispanic	9.1	12.0	
Non-Hispanic White	27.7	25.4	
Non-Hispanic Black	18.6	20.6	
Other race	31.7	27.5	
Weigh (kg)	86.30 ± 17.90	73.79 ± 19.54	<.001
Height (cm)	172.45 ± 7.00	159.61 ± 7.00	<.001
Body mass index (kg/m^2)	28.94 ± 5.21	28.90 ± 7.10	.927
ASM (kg)	26.51 ± 4.84	17.68 ± 4.20	<.001
ASMI (kg/m^2)	8.88 ± 1.32	6.91 ± 1.44	<.001
Alkaline phosphatase (IU/L)	78.88 ± 21.85	79.39 ± 26.86	.759
Serum calcium level (mmol/L)	2.31 ± 0.08	2.31 ± 0.09	.631
Serum potassium (mmol/L)	4.10 ± 0.36	3.95 ± 0.31	<.001
Phosphorus (mmol/L)	1.11 ± 0.16	1.17 ± 0.16	<.001
Lumbar BMD (g/cm^2)	1.03 ± 0.16	1.02 ± 0.17	.732
Albumin (g/L)	41.45 ± 2.96	40.06 ± 3.12	<.001
Serum creatinine (μmol/L)	87.93 ± 32.69	63.64 ± 21.05	<.001
Total fat ratio (%)	28.18 ± 5.28	39.32 ± 5.97	<.001
Diabetes (%)			
Yes	13.66	9.25	.033
No	86.34	90.75	

ASM = appendicular skeletal muscle, ASMI = appendicular skeletal muscle mass index, BMD = bone mineral density.

Table 2

Characteristics of the study sample according to low ASMI and high ASMI.

	Low-ASMI (n =134)	High-ASMI (n = 814)	*P*
Number of subjects (%)	14.14	85.86	
Sex (%)			
Male	35.82	53.43	<.001
Female	64.18	46.57	
Age (yr)	51.80 ± 5.65	49.15 ± 5.67	<.001
Body mass index (kg/m^2)	21.68 ± 2.40	30.11 ± 5.83	<.001
Serum calcium level (mmol/L)	2.32 ± 0.08	2.31 ± 0.09	.271
Phosphorus (mmol/L)	1.18 ± 0.19	1.13 ± 0.16	.046
Serum potassium (mmol/L)	4.09 ± 0.39	4.01 ± 0.34	.045
Alkaline phosphatase (IU/L)	79.76 ± 29.14	79.02 ± 23.58	.744
Albumin (g/L)	41.31 ± 2.87	40.68 ± 3.15	.035
Creatinine (μmol/L)	69.07 ± 35.71	77.13 ± 28.97	.005
Lumbar BMD (g/cm^2)	0.97 ± 0.13	1.04 ± 0.16	<.001
Total fat ratio (%)	32.49 ± 7.63	33.76 ± 7.95	.088
Diabetes			
Yes	8.96	11.92	.319
No	91.04	88.08	

ASMI = appendicular skeletal muscle mass index, BMD = bone mineral density.

4. Discussion

There is a close relationship among muscle mass, bone density, and exercise. Exercise not only increases muscle mass, but also improves bone density, and the degree and location of the effect of different types of exercise on bone density vary.[11,12] A report suggested that higher-impact training improves BMD, but it does not reduce the risk of falls and fractures in older men; Progressive resistance training is more appropriate for older adults; however, its effect is primarily on the BMD of the femoral neck rather than the lumbar spine.[13,14] It may be that the paravertebral muscles act primarily to stabilize the spine, which receives less motor stimulation during progressive resistance training. Usually, the effect of exercise on BMD is mostly localized to adjacent bones. A US ultrasound study confirmed a positive correlation between muscle thickness and local bone density.[15] However, in our study, ASMI was positively correlated with lumbar spine BMD, suggesting that there may be some other pathways by which muscles affect nonadjacent bone tissue. Some basic studies have found that the increase in muscle irisin levels during exercise can affect osteoblasts through a variety of pathways, however, whether this is through paracrine effects or the circulatory system has not been confirmed.[16,17]

Previous studies have investigated the relationship between muscle strength and BMD, but they were usually limited to grip strength or walking tests, which mainly reflect muscle strength but not exact muscle mass, while DXA obtained more accurate information and showed no significant difference compared to MRI. A previous study reported a correlation between bone-mineral-free lean mass (LM) and BMD, suggesting a positive effect of higher LM on BMD.[18,19] We obtained the same results when using the ASMI as an indicator observation, and we believe that the ASMI can better reflect a person's muscle mass. Previous studies have analyzed the relationship between muscle mass and BMD in old postmenopausal women.[20] In general, men have higher muscle mass and androgen levels than women, and in our study, men had a higher ASMI than women; and a higher ASMI in men was also strongly associated with a higher spinal BMD. In a study from China, quantitative computed tomography measurements of the back muscle

Table 3

Association between ASMI and total lumbar BMD.

ASMI (kg/m^2)	Total lumbar spine BMD (g/cm^2)								
	Total sample			Male			Female		
	β	SE	*P*	*β*	SE	*P*	*β*	SE	*P*
Univariate	0.018	0.003	<.001	0.019	0.006	.001	0.028	0.006	<.001
Model 1	0.013	0.004	<.001	0.023	0.006	<.001	0.030	0.006	<.001
Model 2	0.013	0.003	<.001	0.022	0.006	<.001	0.031	0.006	<.001

Model 1: Adjusted for age, race, serum calcium level, creatinine, albumin, total fat ratio, serum potassium, phosphorus, and diabetes status; Model 2: Adjusted for age, serum potassium, albumin, and total fat ratio.

ASMI = appendicular skeletal muscle mass index, BMD = bone mineral density, SE = standard error.

area were significantly different in older patients with fractures versus a healthy population, and lower BMD and paravertebral muscle loss were associated with an increased incidence of lumbar spine fractures.[21] Several studies have shown correlations between diabetes and sarcopenia and osteoporosis.[22,23] However, no difference in the prevalence of diabetes was observed in our comparison of high and low muscle density populations. This may be because unlike previous studies our population was selected from relatively young participants aged 40 to 59 years, and the increase in diabetes prevalence is strongly associated with age.

Our study examined this correlation in a broader population and confirmed that these correlations persisted in people aged 40 to 59 years. The NHANES database was selected for the analysis and covers a broader population. Our study has some limitations. The effect of ASMI on BMD may be different at different sites. We explored its correlation only with lumbar spine BMD.

5. Conclusion

This cross-sectional study confirmed the association between ASMI and lumbar spine BMD in a US population, and we suggest that information on BMD should be obtained along with attention to other body components for early intervention in individuals at risk for osteoporosis.

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Author contributions

Writing – original draft: Hailin Qin.
Writing – review & editing: Wenyong Jiao.

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