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Body Composition and Bone Mineral Density in Patients with Heart Failure

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Abstract

The purpose of this study was to examine associations among bone mineral density, osteopenia/osteoporosis, body mass index, and body composition in patients with heart failure. A total of 119 patients (age = 61 ± 12 yrs, 65% male) underwent dual-energy x-ray absorptiometry scans to determine bone mineral density and body composition. In multivariable linear regressions, body mass index, relative skeletal muscle index, and mineral-free lean mass were positively associated with total body bone mineral density. Mineral-free lean mass was most strongly associated with bone mineral density ($\beta = 0.398$). In multivariable logistic regressions, higher body mass index, relative skeletal muscle index, and mineral-free lean mass were associated with lower odds for osteopenia/osteoporosis. Fat mass was not associated with total body bone mineral density or osteopenia/osteoporosis. These results suggest that muscle mass may be the important component of body mass associated with bone mineral density in patients with heart failure.

Keywords

obesity; sarcopenia; bone mineral density; heart failure

Osteopenia and osteoporosis are significant problems in patients with heart failure (HF) (Abou-Raya & Abou-Raya, 2009; Shane et al., 1997) who are more likely to have lower bone mineral density than similarly-aged healthy adults (Jankowska et al., 2009; Kenny,

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Conflict of Interest

The Authors declare that there is no conflict of interest.

Boxer, Walsh, Hager, & Raisz, 2006; Terrovitis et al., 2012) increasing fracture risk. Annualized rates of incident hip fractures are twice as high in patients with HF compared to those without HF (14 vs. 6.8 per 1,000 person-years) (Carbone et al., 2010) and as many as 12% of patients with HF experience vertebral compression fractures (Lyons, Majumdar, & Ezekowitz, 2011). Patients with HF are also four times more likely to have a fracture requiring hospitalization compared to people without HF (van Diepen, Majumdar, Bakal, McAlister, & Ezekowitz, 2008). Recognizing risk and protective factors for low bone mineral density in this population could lead to testable interventions to improve bone mineral density and thereby improve patient outcomes.

Factors Influencing Bone Mineral Density in Patients with Heart Failure

Several factors increase the risk for low bone mineral density in patients with HF. Low levels of serum vitamin D have been reported (Abou-Raya & Abou-Raya, 2009; Zittermann et al., 2003) that may be worsened by limited sunlight exposure from reduced outdoor activities due to shortness of breath, fatigue, and muscle/joint soreness (Oka, Stotts, Dae, Haskell, & Gortner, 1993). These symptoms may contribute to a more sedentary lifestyle (Mezzani, Corra, Baroffio, Bosimini, & Giannuzzi, 2000) that reduces bone-preserving weight-bearing activity. Hormonal changes may also impact bone mineral density in this population. Higher parathyroid hormone levels have been associated with low bone mineral density in patients with HF (Terrovitis et al., 2012). Many men with HF have low serum androgen levels (Guder et al., 2010; Jankowska et al., 2006) increasing their risk for low bone mineral density (Keles et al., 2006). Further risk is associated with loop diuretics prescribed for management of patients with reduced ejection fraction and fluid retention (Yancy et al., 2013), which have been associated with bone loss and increased fracture risk (Lim et al., 2008; Rejnmark, Vestergaard, Heickendorff, Andreasen, & Mosekilde, 2006; Rejnmark, Vestergaard, & Mosekilde, 2006).

Body mass index (BMI) is related to bone mineral density and fracture risk. Low BMI has been associated with low bone mineral density in people without HF (Bakhireva, Barrett-Connor, Kritz-Silverstein, & Morton, 2004; Coin et al., 2008; Garriguet, 2011) and increased fracture risk (De Laet et al., 2005). There is some evidence that this is also the case in patients with HF. Anker and colleagues previously reported that non-cachectic patients with HF had bone mineral densities similar to age-matched healthy adults with similar BMIs. In contrast, cachectic patients having lower BMIs had lower bone mineral density than those who were non-cachectic (Anker, Clark, Teixeira, Hellewell, & Coats, 1999). These findings suggest that weight loss or low BMI may increase the risk of low bone mineral density in patients with HF.

It is possible that a higher BMI may lower the risk for low bone mineral density in patients with HF. However, the relationships among muscle mass, fat mass, and bone mineral density in this population have not been explored. With respect to other HF outcomes, there is some evidence that percent body fat is the strongest independent predictor of event-free survival (Lavie, Osman, Milani, & Mehra, 2003), yet other researchers suggest that lean body mass is the component associated with favorable prognostic indicators of mortality (Oreopoulos et al., 2010). Understanding relationships of the various components of body composition with

bone health could inform future research on appropriate interventions to maintain or promote bone mineral density in those with HF and therefore potentially reduce fracture risk. Associations among body composition and bone mineral density have been examined in non-HF samples with evidence that lean mass is more strongly associated with bone mineral density than fat mass (Bakker, Twisk, Van Mechelen, & Kemper, 2003; Gjesdal, Halse, Eide, Brun, & Tell, 2008; Zagarins, Ronnenberg, Gehlbach, Lin, & Bertone-Johnson, 2010). Both limb (Coin et al., 2008) and total body skeletal muscle mass (Visser et al., 1998) have been associated with greater bone mineral density among older adults. It is not known whether there are similar associations between muscle mass and bone mineral density in patients with HF.

Purpose

The purpose of this study was to examine associations among bone mineral density, osteopenia/osteoporosis, BMI, and body composition in patients with HF. The specific aims were to a) determine if BMI, relative skeletal muscle index (RSMI), mineral-free lean mass, and fat mass are associated with total body bone mineral density, and b) to determine if BMI, RSMI, mineral-free lean mass, and fat mass are associated with osteopenia/osteoporosis in patients with HF.

Methods

Design, Sample, and Setting

A sub-sample of 119 patients with HF recruited from a cardiology clinic affiliated with an academic medical center for a longitudinal, multicenter study examining nutrition and body composition in HF outcomes were included in this study. Patients were eligible to participate if they had a) documented diagnosis of HF with either preserved or reduced ejection fraction, b) been stable on cardiac medications for at least three months, c) no history of myocardial infarction or stroke within three months of enrollment, d) no terminal or inflammatory comorbidity, and e) undergone a dual-energy x-ray absorptiometry (DXA) scan. Patients who were stable on cardiac medications and had not experienced a recent myocardial infarction or stroke within three months were deemed hemodynamically stable and thus suitable to participate in the study. Institutional Review Board approval was obtained prior to recruitment.

Procedure

Eligible patients were referred by cardiologists or nurse practitioners familiar with the study to trained research assistants. Research assistants then approached patients during clinic visits to explain the study and obtain informed consent if they agreed to participate. After providing informed consent, participants were scheduled to visit the clinical research center to have body composition measured by DXA and to complete demographic and clinical questionnaires. Research assistants also completed home visits to provide digital scales with oral and written instructions for completing four-day food diaries to record the quantity of all food consumed over three weekdays and one weekend day. Food models were provided to estimate portion sizes when weighing was not possible (e.g., when dining outside the

home). Participants returned their four-day food diaries to the clinical research center where they were reviewed with a dietitian to verify accuracy and completeness.

Measurement of Variables

Demographic and Clinical Characteristics—Demographic data and clinical characteristics were obtained using questionnaires and medical record review. Data on the following variables were collected: age, sex, marital status, living status, race/ethnicity, and medication use. A trained cardiovascular research nurse determined New York Heart Association (NYHA) functional class using a structured interview.

Vitamin D and Calcium Intake—The Nutrition Data System for Research software program (Minneapolis MN) was used to analyze the diaries and provide a four-day averaged vitamin D and calcium intake.

Bone Mineral Density—Participants underwent total body DXA scans (Kanis, 2002) using GE Lunar Prodigy (software version 10.10). Trained clinical research staff performed scans with participants wearing either a hospital gown or light clothing without metal. Total body bone mineral density (g/cm^2) and t-scores were obtained for each participant. Bone mineral density t-scores were used to identify participants with osteopenia or osteoporosis based upon World Health Organization criteria. Osteopenia was defined as a bone mineral density t-score from -1 to -2.5 , and osteoporosis was defined as a t-score below -2.5 (World Health Organization, 1994).

Body Composition—Whole-body DXA scans were used to determine mineral-free lean mass, fat-free mass, absolute fat mass, and percent fat. Appendicular lean mass, which is highly correlated with total body skeletal muscle mass (J. Kim, Wang, Heymsfield, Baumgartner, & Gallagher, 2002), was estimated from the DXA scan using the mineral-free lean mass (kg) of the arms and legs. As a measure of sarcopenia, the relative skeletal muscle index (RSMI) was calculated as the sum of the mineral-free lean mass of the arms and legs in kilograms divided by height in meters squared. Cutoff values for sarcopenia are 7.26 for men and 5.45 for women (Baumgartner et al., 1998).

Body Mass Index (BMI)—Body mass index was calculated as body weight in kilograms divided by height in meters squared. All participants were weighed in a gown or light clothing to the nearest 0.01kg without shoes on a calibrated, professional-grade scale. Height was obtained by experienced nurses using a wall-fixed stadiometer and measured to the nearest 0.01cm. Body mass index groups were defined according to clinical guidelines (National Heart, Lung, and Blood Institute, 1998): underweight, $<18.5\text{kg}/\text{m}^2$; normal weight, $18.5\text{--}24.99\text{kg}/\text{m}^2$; overweight, $25\text{--}29.99\text{kg}/\text{m}^2$; class I obese, $30\text{--}34.99\text{kg}/\text{m}^2$; class II obese, $35\text{--}39.99\text{kg}/\text{m}^2$; and class III obese, $40\text{kg}/\text{m}^2$. Underweight and normal weight patients and class II and III obese patients were combined because only a few patients were underweight (2%) or class III obese (3%).

Data Analysis

Demographics, clinical characteristics, and body composition were summarized using means with standard deviations or percentages as appropriate. NYHA class was dichotomized into class I/II and III/IV due to few participants being in NYHA class I (4%) and IV (18%). To test Specific Aim 1, three separate forced-entry multivariable linear regressions were run to test whether BMI, RSMI, mineral-free lean mass, and fat mass were associated with total body bone mineral density after controlling for age, sex, NYHA class, loop diuretics, vitamin D/multivitamin supplementation, and vitamin D and calcium intake. In the first model, BMI was added without RSMI. In the second model, RSMI was added without BMI. In the third model, mineral-free lean mass, absolute fat mass, and height were included in place of BMI or RSMI. To test Specific Aim 2, three separate binary logistic regression models were run to determine if BMI, RSMI, mineral-free lean mass, and fat mass were associated with osteopenia/osteoporosis controlling for covariates. Osteopenia and osteoporosis were combined into a single category because only a few patients (3%) had osteoporosis. In the first model, BMI was added without RSMI. In the second model, RSMI was added without BMI. In the third model, mineral-free lean mass, absolute fat mass, and height were included in place of BMI or RSMI. An alpha level of 0.05 was used to determine statistical significance in all analyses. All statistical analyses were performed using SPSS version 20.

Results

Sample Characteristics

The sample was on average 61 years of age with a range from 35-90 years. The majority were male (65%) and Caucasian (85%). Fourteen percent were African American. Approximately one-third lived alone and one-fourth currently smoked. Roughly half the sample were NYHA class III/IV. Nearly 60% of the sample were prescribed loop diuretics, and 25% were taking vitamin D or multivitamins. Average dietary vitamin D intake was 7.8mcg (312 IU), and average calcium intake was 825mg. Seventy-one percent had BMIs categorized as overweight or obese. Twelve percent had bone mineral density t-scores consistent with osteopenia and 3% had values consistent with osteoporosis. Characteristics of the sample are shown in Tables 1 and 2.

Associations of Body Mass Index and Body Composition with Total Body Bone Mineral Density

Table 3 shows the linear regression models examining associations of total body bone mineral density with BMI, RSMI, mineral-free lean mass, and fat mass. In the first regression model, younger age, male sex, lower NYHA class, and higher BMI were associated with higher total body bone mineral density accounting for 32% of the variance in total body bone mineral density. In the second regression model, younger age, male sex, lower calcium intake, and higher RSMI were associated with higher total body bone mineral density accounting for 32% of the variance in total body bone mineral density. In the third regression model, younger age, lower calcium intake, and higher mineral-free lean mass were associated with higher total body bone mineral density accounting for 39% of the variance in total body bone mineral density. Mineral-free lean mass was the strongest

predictor of total body bone mineral density ($\beta = 0.398$, $p = 0.002$) among the body composition variables in the three regression models.

Associations of Body Mass Index and Body Composition with Osteopenia/Osteoporosis

Table 4 shows the logistic regression models examining associations of osteopenia/osteoporosis with BMI, RSMI, mineral-free lean mass, and fat mass. In the first regression model, higher NYHA functional class and lower BMI and were associated with higher odds for osteopenia/osteoporosis. In the second regression model, higher NYHA functional class and lower RSMI were associated with higher odds for osteopenia/osteoporosis. In the third regression model, higher NYHA functional class and lower mineral-free lean mass were associated with higher odds for osteopenia/osteoporosis.

Discussion

Patients with HF are at risk for low bone mineral density (Kenny et al., 2006) and osteopenia/osteoporosis (Abou-Raya & Abou-Raya, 2009; Shane et al., 1997). While having a higher BMI may reduce the risk for low bone mineral density, it's unclear whether this is related to muscle mass or fat mass in this population. Our study fills an important gap by providing evidence of the associations among mineral-free lean mass, fat mass, bone mineral density, and osteopenia/osteoporosis among weight-stable patients with HF. Our findings show that a higher BMI is associated with greater total body bone mineral density and lower risk for osteopenia/osteoporosis in patients with HF. Among the components of body mass that comprise BMI, mineral-free lean mass was the primary component associated with higher bone mineral density and lower risk of osteopenia/osteoporosis. Loss of muscle mass may therefore be an important risk factor for low bone mineral density in this population.

Cardiac cachexia is a complex and prevalent problem among patients with HF in which patients experience loss of muscle, fat, and bone tissue resulting in significant weight loss (Anker & Sharma, 2002). Anker and colleagues (1999) reported that cachectic patients with HF had lower total body bone mineral density compared to both noncachectic patients with HF and age-matched controls without HF. Cachectic patients with HF also had lower BMIs, total fat, and total lean mass than both groups. However, bone mineral density did not differ between noncachectic patients with HF and age-matched controls, and these groups had similar BMIs, total fat, and total lean mass. These findings suggest that weight loss or low BMI is an important risk factor for low bone mineral density in patients with HF. Our study supports this conclusion; higher BMI was associated with higher total body bone mineral density and lower odds for osteopenia/osteoporosis. Clinicians should be highly alert to patients experiencing cardiac cachexia and ensure these patients receive optimal nutritional management to prevent adverse outcomes (Lindenfeld et al., 2010).

There are several possible mechanisms whereby a higher BMI reduces the risk for low bone mineral density in patients with HF. Greater mechanical loading during exercise and daily activities lead to bone adaptation through the production of signaling molecules that exert effects on osteoblasts and osteoclasts (Klein-Nulend, Bacabac, & Bakker, 2012). Patients having a higher BMI may also have higher estrogen due to aromatase expression in adipose tissue that results in synthesis of estrogen from androgens (Nelson & Bulun, 2001). Estrogen

plays an important role in regulating bone resorption (Riggs, 2000) and has been associated with greater bone density in men and women (Khosla et al., 1998; Slemenda et al., 1997).

Although a higher BMI was associated with greater total body bone mineral density and lower risk for osteopenia/osteoporosis, associations differed when the lean tissue and fat components of body mass were examined. Greater mineral-free lean mass was associated with higher total body bone mineral density and lower risk for osteopenia/osteoporosis. However, absolute fat mass was not associated with either outcome. As an index of sarcopenia, we also found that the RSMI was positively associated with total body bone mineral density. While higher percent body fat has been associated with better survival among patients with HF (Lavie et al., 2003), our findings suggest that lower muscle mass is the primary component of body mass that is related to low bone mineral density and osteopenia/osteoporosis in this population. This finding is consistent with similar research conducted in other populations in which muscle mass was the most important component of body composition associated with bone mineral density (Bakker et al., 2003; S. M. Kim et al., 2015; Liu, Ilich, Brummel-Smith, & Ghosh, 2014). Because patients with HF are at risk for losing skeletal muscle mass (Mancini et al., 1992; Tacke et al., 2013) it is important for clinicians to consider the risk of osteoporosis and fractures in patients with HF who experience muscle loss.

There are several possible explanations why greater muscle mass, but not fat mass, was associated with higher total body bone mineral density and lower risk for osteopenia/osteoporosis in our study. Reduced skeletal muscle mass may contribute to physical activity limitations (Harrington et al., 1997) that increase the risk for reduced bone mineral density. Visser and colleagues (1998) previously reported that physical activity was positively associated with bone mineral density among a sample of older men who participated in the Framingham Heart Study. Patients with HF who have greater muscle mass may be better able to engage in weight bearing activity that would help maintain or promote favorable changes in bone mineral density. Patients with HF who are more active may also retain greater muscle mass and experience better bone health due to higher activity levels. Although the temporal nature of this association is unknown in this population, our findings provide evidence that greater muscle mass is linked to greater total body bone mineral density and reduced risk for osteopenia/osteoporosis.

Despite evidence that low bone mineral density and osteopenia/osteoporosis are significant problems in patients with HF, clinical guidelines for HF management do not address this growing area of concern (Lindenfeld et al., 2010; Yancy et al., 2013). Further, specific recommendations for strength-training exercises to prevent sarcopenia and promote muscle growth in this population are lacking. Given our findings that higher muscle mass was associated with higher bone mineral density and lower odds for osteopenia/osteoporosis, strength-training exercises may be effective non-pharmacologic interventions to improve bone mineral density and reduce fracture risk in patients with HF. Combining aerobic physical activity with strength training may be the most effective strategy to optimizing functional status while also achieving favorable effects on bone mineral density. Combined endurance-resistant training activities for patients with HF have been shown to be safe and effective in increasing sub-maximal exercise capacity and muscle strength (Beckers et al.,

2008; Maiorana et al., 2000). This approach may therefore be beneficial in preventing loss of bone mineral density and reducing fracture risk through maintaining or increasing muscle mass. Future research is needed to determine the optimal physical activity regimen that will achieve these outcomes.

Several covariates included in our analyses were associated with total body bone mineral density and osteopenia/osteoporosis independent of BMI and body composition. First, our finding that higher NYHA functional class was associated with higher odds for osteopenia/osteoporosis is consistent with others who reported that trochanteric bone mineral density is lower in patients of NYHA class III compared to NYHA class II (Chen et al., 2012). Second, the associations of increasing age and being female with lower total body bone mineral density are also consistent with previous research (Warming, Hassager, & Christiansen, 2002). Older adults and females with higher BMIs and muscle mass may need additional preventive measures to reduce the risk for low bone mineral density. However, being female was not associated with increased risk for osteopenia/osteoporosis. This may be due to having a sample that was predominantly male and the small prevalence of osteopenia/osteoporosis. Future studies are needed to provide greater insight on the risk for osteopenia/osteoporosis among female patients with HF. Higher calcium intake was also associated with lower total body bone mineral density in two regression models. This may be due to increased calcium intake among participants who are aware of their increased risk for low bone mineral density. Regardless, results suggest that calcium intake alone is not sufficient to prevent low bone mineral density in this population.

Other covariates in our analyses were not independently associated with total body bone mineral density or osteopenia/osteoporosis and may be due to our small sample size. Although loop diuretics have been associated with increased risk of fractures and bone loss in other populations (Lim et al., 2008; Rejnmark, Vestergaard, & Mosekilde, 2006; Ruths et al., 2015), we observed no associations with loop diuretics and total body bone mineral density or osteopenia/osteoporosis in our sample of patients with HF. Vitamin D/multivitamin supplementation was also not associated with total body bone mineral density or osteopenia/osteoporosis. Other possible explanations that we were unable to empirically test include a low prevalence of vitamin D deficiency, low adherence to regular supplementation, ineffective dosing, and use of low-potency vitamin D. Furthermore, findings from a meta-analysis indicate there is little evidence that vitamin D supplementation is beneficial for bone density (Reid, Bolland, & Grey, 2014).

Several limitations to our study are noted. First, this was a cross-sectional study limiting the ability to determine causal relationships among BMI, body composition, and bone mineral density. Longitudinal studies would provide additional insight regarding how changes in lean mass and BMI impact bone mineral density in patients with HF. Second, other factors impacting bone mineral density were not included in this study such as family history of osteopenia/osteoporosis, parathyroid hormone levels, and estrogen and testosterone levels. Thus it is not known how these factors might alter the relationships among BMI, lean mass, fat mass, and bone mineral density in patients with HF. Furthermore, we were unable to assess the effects of calcium supplements and osteoporosis medications due low usage in this sample (less than 10% for each). Future studies should consider these factors to better

understand the effects of muscle mass and BMI on bone mineral density in this population. Finally, although not the purpose of this study, we did not investigate the associations among BMI, lean mass, fat mass, and bone mineral density for high fracture-risk body sites such as the vertebrae and femoral neck. Future studies should examine site-specific associations among body composition variables and bone mineral density in HF samples to further expand the knowledge base in this area.

In conclusion, this was the first study to examine associations among BMI, body composition, bone mineral density, and osteopenia/osteoporosis among patients with HF controlling for covariates. Our findings suggest that a higher BMI is associated with higher total body bone mineral density and lower risk for osteopenia/osteoporosis. Our findings also suggest that a higher muscle mass, rather than fat mass, is associated with higher total body bone mineral density and lower risk for osteopenia/osteoporosis. Therefore, muscle mass may be the important component of body mass associated with higher bone mineral density and reduced risk for osteopenia/osteoporosis in this population. Because patients with HF are at risk for low bone mineral density which can contribute to greater fracture risk, clinicians should consider the potential implications of reduced muscle mass when evaluating risk for osteopenia/osteoporosis in this population.

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Table 1

Sample Characteristics (N=119)

Variable	n (%)
Female	42 (35%)
Race/Ethnicity	
Caucasian	101 (85%)
African American	17 (14%)
Other	1 (1%)
Marital Status	
Single	11 (9%)
Married	65 (54%)
Divorced/Separated	21 (18%)
Widowed	13 (11%)
Cohabitate	9 (8%)
Lives Alone	33 (28%)
NYHA Class	
I/II	57 (48%)
III/IV	62 (52%)
Currently Smokes	28 (24%)
Loop Diuretics	68 (57%)
Vitamin D or Multivitamins	30 (25%)
BMI Categories	
Under/Normal Weight	35 (29%)
Overweight	34 (29%)
Class I Obese	34 (29%)
Class II/III Obese	16 (13%)
Osteopenia	14 (12%)
Osteoporosis	4 (3%)

Table 2

Body Composition Characteristics (N=119)

Variable	Mean $\pm$ SD
BMI (kg/m ²)	28.69 $\pm$ 5.7
Height (cm)	173.73 $\pm$ 10.38
Weight (kg)	86.43 $\pm$ 17.22
Absolute fat mass (kg)	30.06 $\pm$ 11.72
Percent fat	34.58 $\pm$ 9.81
Fat-free mass (kg)	54.87 $\pm$ 10.68
Mineral-free lean mass (kg)	51.93 $\pm$ 10.21
RSMI (kg/m ²)	6.51 $\pm$ 1.12
Total Body BMD (g/cm ²)	1.22 $\pm$ 0.14

Note. BMI = Body mass index; RSMI = Relative skeletal muscle index; BMD = Bone mineral density

Table 3

Associations of Body Mass Index and Measures of Body Composition with Total Body Bone Mineral Density (N=119)

Variable	β	B (95% CI)	p-value	Adjusted R ²
<i>Model 1</i>				.322
Age	-0.207	-0.002 (-0.004, -0.001)	0.012 [*]	
Sex	-0.486	-0.137 (-0.182, -0.092)	<0.001 [*]	
NYHA class	-0.166	-0.045 (-0.088, -0.002)	0.042 [*]	
Loop diuretics	0.005	0.001 (-0.042, 0.045)	0.948	
Vitamin D or multivitamins	0.026	0.008 (-0.073, 0.089)	0.846	
Vitamin D Intake	0.099	0.002 (-0.004, 0.007)	0.506	
Calcium Intake	-0.170	0.000 (0.000, 0.000)	0.094	
BMI	0.303	0.007 (0.003, 0.011)	<0.001 [*]	
<i>Model 2</i>				.320
Age	-0.181	-0.002 (-0.004, 0.000)	0.031 [*]	
Sex	-0.300	-0.085 (-0.135, -0.034)	0.001 [*]	
NYHA class	-0.131	-0.035 (-0.078, 0.007)	0.105	
Loop diuretics	0.040	0.011 (-0.032, 0.054)	0.620	
Vitamin D or multivitamins	-0.028	-0.009 (-0.090, 0.072)	0.831	
Vitamin D Intake	0.125	0.002 (-0.003, 0.008)	0.397	
Calcium Intake	-0.207	0.000 (0.000, 0.000)	0.039 [*]	
RSMI	0.318	0.038 (0.017, 0.059)	<0.001 [*]	
<i>Model 3</i>				.388
Age	-0.197	-0.002 (-0.004, -0.001)	0.012 [*]	
Sex	-0.129	-0.036 (-0.108, 0.035)	0.316	
NYHA class	-0.143	-0.038 (-0.080, 0.003)	0.066	
Loop diuretics	-0.053	-0.014 (-0.057, 0.028)	0.503	
Vitamin D or multivitamins	0.009	0.003 (-0.074, 0.080)	0.941	
Vitamin D Intake	0.122	0.002 (-0.003, 0.008)	0.383	
Calcium Intake	-0.211	0.000 (0.000, 0.000)	0.028 [*]	
Height	0.102	0.001 (-0.001, 0.004)	0.354	
Mineral-Free Lean Mass	0.398	0.005 (0.002, 0.009)	0.002 [*]	
Absolute Fat Mass	0.140	0.002 (0.000, 0.004)	0.111	

Note. BMI = Body mass index; NYHA = New York Heart Association; RSMI = Relative skeletal muscle index

* p < .05.

Table 4

Associations of Body Mass Index and Measures of Body Composition with Osteopenia/Osteoporosis (N=119)

Variable	OR (95% CI)	p-value	Nagelkerke R ²
<i>Model 1</i>			.312
Age	1.055 (0.999, 1.113)	0.052	
Sex	2.993 (0.870, 10.300)	0.082	
NYHA class	6.973 (1.708, 28.471)	0.007 *	
Loop diuretics	0.730 (0.210, 2.534)	0.620	
Vitamin D or multivitamins	1.180 (0.105, 13.295)	0.894	
Vitamin D Intake	1.010 (0.841, 1.212)	0.917	
Calcium Intake	1.000 (0.999, 1.002)	0.556	
BMI	0.870 (0.773, 0.978)	0.019 *	
<i>Model 2</i>			.299
Age	1.055 (0.998, 1.114)	0.059	
Sex	1.191 (0.318, 4.464)	0.795	
NYHA class	5.399 (1.397, 20.863)	0.014 *	
Loop diuretics	0.861 (0.247, 2.999)	0.814	
Vitamin D or multivitamins	0.853 (0.092, 7.869)	0.888	
Vitamin D Intake	0.987 (0.834, 1.168)	0.879	
Calcium Intake	1.001 (0.999, 1.002)	0.232	
RSMI	0.495 (0.259, 0.947)	0.034 *	
<i>Model 3</i>			.386
Age	1.059 (0.998, 1.124)	0.057	
Sex	0.302 (0.029, 3.101)	0.313	
NYHA class	5.555 (1.347, 22.912)	0.018 *	
Loop diuretics	0.498 (0.124, 1.999)	0.326	
Vitamin D or multivitamins	0.808 (0.065, 10.070)	0.868	
Vitamin D Intake	0.972 (0.799, 1.184)	0.780	
Calcium Intake	1.001 (0.999, 1.003)	0.243	
Height	1.021 (0.944, 1.104)	0.605	
Mineral-Free Lean Mass	0.846 (0.744, 0.961)	0.010 *	
Absolute Fat Mass	0.997 (0.931, 1.069)	0.941	

Note. OR = odds ratio; BMI = Body mass index; NYHA = New York Heart Association; RSMI = Relative skeletal muscle index

*
p < .05