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Original Article

Relationship between muscle performance and DXA-derived bone parameters in community-dwelling older adults

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Abstract

Objectives: To examine association between muscle strength, jump test performance, muscle mass, bone mineral density (BMD), and bone strength in older adults. **Methods:** Sixty individuals (55-75 years) participated. Leg press strength and bilateral hip abduction strength were evaluated by one repetition-maximum testing. Jump power (JPow) and jump height (JHt) were assessed by jump test performance. Relative skeletal muscle mass index (RSMI), total hip BMD, femoral neck BMD, lumbar spine BMD, section modulus (Z), cross-sectional moment of inertia (CSMI), and bone strength index (BSI) were determined by DXA. **Results:** After adjusting for age and gender, leg press strength 1) positively correlated with the total hip BMD, femoral neck BMD, and Z (all $P<0.05$). Also, leg press strength predicted the total hip BMD (P=0.013) and femoral neck BMD (P=0.021), after adjusting for age, gender, and RSMI. No associations were found between jump test performance and bone density or strength. **Conclusion:** Leg press strength is positively associated with bone density and bone strength in older population. It might serve as an additional tool to identify at-risk individuals for osteoporosis.

Keywords: Jump Power, Muscle Strength, Sarcopenia, Osteoporosis, Older Population

Introduction

Osteoporosis is a disease characterized by low bone mass and abnormal bone tissue architecture[1]. It can lead to low trauma fractures[2] and is one of the major health risks reported in the older population. Ageing-associated loss of muscle mass[3] and muscle strength[4] impairs the production of maximum voluntary mechanical load on bones leading to a reduction in bone mass and bone strength[5,6]. Latest studies have shown an association between sarcopenia, poor muscle strength, and low bone mineral density (BMD) in the middle-aged and elderly populations[7,8]. Sarcopenia covers physiological processes such as denervation, mitochondrial dysfunction, inflammatory and hormonal changes, and functional outcomes such as loss in muscle strength, increased fatigue, increased metabolic disorders, and increased number of falls[9]. However, it should be noted that sarcopenia is defined in various ways[10-12].

Although muscle strength critically affects bone density[13,14] and bone strength[15] in older population, the association between muscle power and bone density or bone strength of the total hip and the proximal femur is less well-investigated in independent community-dwelling older population. Since muscle power is a function of both contractile speed of muscle fibers and muscle strength[16], it can be postulated that muscle power can act as a more discriminant variable than muscle strength for understanding aging-associated muscle-bone interaction. For example, muscle power but not muscle strength was related to the tibial bone strength in older women[17]. Furthermore, muscle power training may be a better technique than muscle strength training for the maintenance of BMD in older women[18]. Jump test has recently emerged as a safe, valid, and reliable tool to assess muscle power in older adults[19,20]. However, not much is known regarding the association between jump

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power (JPow), bone strength, and BMD at various sites such as the total hip, femoral neck, or lumbar spine in older adults. This is important because these sites are associated with fragility fractures in older population. Moreover, DXA-derived estimates of bone strength such as cross-sectional moment of inertia (CSMI) or section modulus (Z) of the proximal femur correlate highly to the same measures by high resolution quantitative computed tomography[21] and are associated with the risk of hip fracture[22]. Bone Strength Index (BSI), which is expressed as Z relative to body height, has also previously been reported as a surrogate marker of hip bone strength[23].

Evidence indicates that for every age-adjusted 1 standard deviation decrease in total hip BMD, the risk of high trauma fracture increases by ~50% in women and by ~60% in men, and the risk of low trauma fracture increases by ~50% in women and ~70% in men[24]. This demands an effective screening tool for osteopenia or osteoporosis which can be easily and safely performed in community health care center settings to aid earlier identification of at-risk individuals. Jump test performance may act as that tool. In this study we investigated the association between jump test performance and 1) BMD of the a) total hip, b) femoral neck, c) lumbar spine, and 2) bone strength of the proximal femur: a) CSMI, b) Z, and c) BSI. We also probed the correlations between 1) muscle strength, bone density, and bone strength, 2) gender and osteopenia/osteoporosis, and 3) sarcopenia and osteopenia/osteoporosis. We hypothesized that jump test performance and muscle strength will be positively related to measures of BMD and bone strength in independent community-dwelling older adults.

Materials and methods

Participants

Using a bivariate correlation analysis model with Type I error (α) at 0.05, power (1-β) at 0.8, and a correlation coefficient (r) ≥ 0.36, the total number of required participants was estimated to be 58 in this study. A total of ninety seven individuals were screened for the inclusion out of which sixty healthy and independent ambulatory individuals (men, n=27; women, n=33; 55-75 years) were recruited from the general community in the Oklahoma City metro area to participate in this study[25]. Volunteers obtained medical clearance prior to undergoing muscle strength and jump testing. Participants with: 1) thyroid disorders, 2) uncontrolled hypertension, 3) metal in body, 4) any recent surgery within the previous 6 months, 5) known prior fragility fracture within the previous 12 months, 6) any tobacco use within the prior 10 years, 7) body weight greater than 136 kg, which is the limit of the DXA, and 8) on hormone replacement therapy or corticosteroids were excluded from the study. Informed consent was obtained from the study participants. This study was conducted according to the Declaration of Helsinki and approved by the University of Oklahoma Institutional Review Board.

Study design

We utilized a cross-sectional research design. Participants were divided into two groups based on bone density: normal and osteopenia/osteoporosis. According to the World Health Organization[26], a DXA-derived T-score of the lumbar spine, total hip, or femoral neck greater than or equal to -1.0 classifies individual as normal; a T-score between -1.0 to -2.5 classifies individual as osteopenia; and a T-score of -2.5 or less classifies individual as osteoporosis. Additionally, we utilized three techniques, which are, 1) definition by Baumgartner et al.[10], 2) recommended cutoff for low muscle mass by the FNIH[12], and 3) alternative cutoff for low muscle mass by the FNIH[12], to divide our participants in two groups based on muscle mass: normal and sarcopenia. Baumgartner et al.[10] defined sarcopenia by calculating relative skeletal muscle mass index (RSMI) using the formula: RSMI = appendicular skeletal muscle mass (ASM) (kg), which is measured by dual-energy X-ray absorptiometry (DXA), relative to body height^2(m^2) where a RSMI value <7.26 kg/m^2 in men and <5.45 kg/m^2 in women is classified as sarcopenia. The Foundation for the National Institutes of Health (FNIH)[12] has recommended gender-specific thresholds for low lean mass based on the ASM relative to the body mass index (BMI), where ASM/BMI <0.789 m^2 in males and <0.512 m^2 in females is considered sarcopenia. The alternate thresholds for gender-specific low lean mass recommended by the FNIH is <19.75 kg and <15.02 kg of ASM in men and women, respectively[12]. Recently, the European Working Group on Sarcopenia in Older People recommended inclusion of handgrip strength or gait speed in conjunction with muscle mass to diagnose the severity of sarcopenia in older people[11]. Participants were required to do three visits for testing as described previously[25].

Anthropometric measurements

Height was measured to the nearest 0.1 centimeter using a wall stadiometer (Novel Products Inc., Rockton, Illinois) and body mass was measured to the nearest 0.1 kilogram by a digital body weight scale (Tanita Corporation of America, Arlington Heights, IL) while participants stood barefoot in minimal clothing with empty pockets.

Questionnaires

Participants' medical history was assessed by a health status questionnaire. Physical activity (in mets/week) was estimated by the International Physical Activity Questionnaire[27]. Additionally, Bone Specific Physical Activity questionnaire (BPAQ) was used to estimate total bone loading which refers to an effect of lifetime physical activities and sports on bones[28]. A menstrual history questionnaire was completed by female participants only to confirm they were not on any hormone replacement therapy.

Bone densitometry and body composition

DXA (GE Lunar Prodigy, enCORE™ 2010 Software, Version 13.31.016, Madison, WI) was used to estimate the lumbar

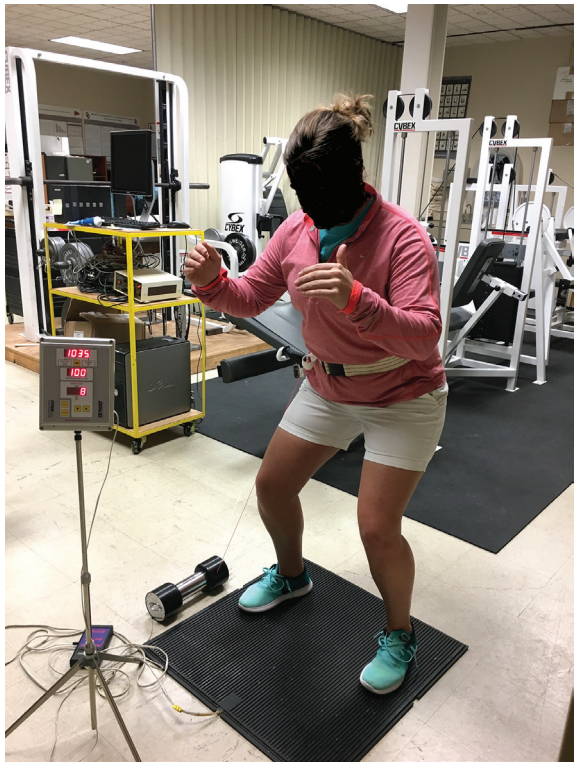

Figure 1. A velocity-sensitive cable can be seen attached near the participant's waist while participant gets ready to do countermovement jumps on the jump mat with no restriction to their arm movements.

spine BMD, total hip BMD, femoral neck BMD, proximal femur CSMI and the Z. Vertebrae affected by sclerosis at endplates and osteophytes at vertebral bodies, spinal processes, and facet joints were removed from the final analysis. BSI was calculated with the formula: Z/body height. Scan mode for the total body and lumbar spine were determined based on the participant's torso thickness at the umbilical level: thick, >25 cm; standard, 13-25 cm; and thin, <13 cm. All the hip scans were collected in the detail scan mode. All the scans were collected and analyzed by a single technician. The quality assurance feature of the DXA machine was utilized for daily calibration. The short term *in vivo* precision coefficients of variation (CV%) determined for various skeletal sites in our laboratory are: lumbar spine - 0.55%, femoral neck - 0.94%, and total hip - 0.35%. T-score at the femoral neck obtained by DXA were used to determine the diagnosis of osteopenia/osteoporosis as explained above.

Body composition (body fat %, fat mass) was assessed by a total body DXA scan performed by a single technician. ASM was quantified as the sum of the lean soft-tissues of the arms and legs[10]. RSMI was quantified as RSMI = ASM (kg) relative to body height^2 (m^2)[10]. Torso thickness at the umbilical level was used to determine scan speed for the total body composition. The short term *in vivo* precision CV% for body fat%, and fat mass are 1.24% and 1.16% in our laboratory, respectively. The diagnosis of sarcopenia was determined in three different ways[10-12] as explained above.

Jump test performance and muscle strength testing

Jump power (JPow) was assessed as previously described[25]. In short, a velocity-sensitive cable (Tendo FiTRODYNE power and speed analyzer, Tendo Sports Machine, Trenchin, Slovak Republic) was attached near the participant's waist after which participants performed 3 countermovement jumps with no restriction to their arm movements as high and as fast without bending their legs in air and landed with both feet on the jump mat (Just Jump, Probotics Inc., Huntsville, AL) as depicted in Figure 1. JPow and jump velocity (JVel) were displayed by the 'Tendo' microcomputer while jump height (JHt) was displayed by 'Just Jump' microcomputer[25]. An average of 3 jumps was used for all the calculations. In our laboratory, CV% for the JPow, JVel, and JHt in young adults are 4.0%, 3.9%, and 3.3%, respectively.

One-repetition maximum (1RM) tests were performed for leg press strength, and right, and left hip abduction strength on isotonic external resistance machines (Cybex International, Medway, MA) as described previously[25]. In short, after a warm up for 5 minutes and then performing 1 set of 10 submaximal repetitions for the respective exercise, weight was increased progressively until maximum effort to failure was reached[25]. We normalized jump power and muscle strength for body size by using the formula[45]: muscle strength or JPow/body mass$^{0.67}$ and used this value for the data analyses.

Statistical analysis

All descriptive statistics are reported as mean ± standard error (SE). Data analysis was performed using SPSS 22.0 software (SPSS Inc., Chicago, IL). We used multivariate analysis with gender as covariate to determine group differences in physical characteristics based on BMD classification. We combined individuals with osteopenia and osteoporosis together to form a single group consisting of individuals with increased risk of fracture versus normal. Since there was no difference between the left and right hip abduction strength (P=0.146) and they were strongly correlated (r=0.97, P<0.001), we decided to use only the left hip abduction strength for all the statistical calculations. Partial correlation coefficients adjusted for age and gender were used to examine associations between the variables of bone density/bone strength and 1) jump test performance, 2) muscle mass, and 3) muscle strength. Chi-square analyses were performed to determine an association between 1) gender and BMD classification, and 2) sarcopenia and BMD classification. Stepwise sequential regression analysis was used to find which independent variables significantly correlated with the outcome measures, after adjusting first for age and gender, and then for age, gender, and muscle

Table 1. Physical characteristics, muscle mass, muscle strength, and jump test performance of participants based on BMD classification[a], after adjusting for gender.

Variables	Groups		
	Normal (n=25)	Osteopenia/Osteoporosis (n=28/7)	*P**
Age, y	63.7 (1.1)	63.4 (1.0)	0.942
Height, m	1.71 (0.02)	1.67 (0.01)	0.401
Weight, kg	76.8 (3.3)	72.4 (1.8)	0.528
BMI, kg/m^2	26.2 (0.9)	26.0 (0.6)	0.990
Body fat, %	32.2 (1.4)	36.1 (1.6)	0.312
Fat mass, kg	24.9 (1.8)	27.5 (1.8)	0.444
FFM, kg	51.6 (2.3)	45.9 (1.6)	0.114
PAL, mets/week	4930 (1140)	4527 (722)	0.980
ASM, kg	21.1 (1.05)	18.4 (0.73)	0.090
RSMI, kg/m^2	7.15 (0.26)	6.51 (0.18)	0.147
LP, kg/body mass$^{0.67}$	16.6 (1.3)	14.7 (0.8)	0.626
LHAb, kg/body mass$^{0.67}$	7.1 (0.4)	6.7 (0.3)	0.814
JPow, kg/body mass$^{0.67}$	45.5 (1.8)	44.7 (1.1)	0.627
JVel, m/s	1.1 (0.04)	1.1 (0.03)	0.503
JHt, m	0.12 (0.07)	0.11 (0.05)	0.761
Men/Women	14/11	13/22	0.191

*Abbreviations: BMI, body mass index; FFM, fat free mass; PAL, physical activity level; ASM, appendicular skeletal muscle mass; RSMI, relative skeletal muscle mass index; LP, leg press strength; LHAb, left hip abduction strength; JPow, jump power; JVel, jump velocity; JHt, jump height. [a]Values are reported as means (SE). P*Significance value for group differences after adjusting for gender.*

mass, that is RSMI. For the first model, the covariates of age and sex were entered in the first block, and in the second block a stepwise selection procedure was used for all of the independent variables (RSMI, leg press strength, hip abduction strength, JPow, JVel, and JHt); for the second model, the covariates of age, sex, and RSMI were entered in the first block, and in the second block a stepwise selection procedure was used for all of the independent variables (leg press strength, hip abduction strength, JPow, JVel, and JHt) to reduce Type-I error. Level of significance for all the analyses was set at $P<0.05$.

Results

Based on the official positions of the WHO[26], osteopenia/osteoporosis was found in 58% (35/60) of the study population: 48% (13/27) of men and 67% (22/33) of women. Per the definition by Baumgarter et al.[10], sarcopenia was diagnosed in 20% (12/60) of our population: 15% (4/27) of men and 24% (8/33) of women. Per the FNIH criterion[12], low muscle mass was found in 10% (6/60) of our population: 4% (1/27) of men and 15% (5/33) of women. According to the alternative recommendation by the FNIH[12], low muscle mass was calculated to be in 23% (14/60) of our study population: 26% (7/27) in men and 21% (7/33) in women.

Table 1 shows gender-adjusted differences in physical, muscle mass, muscle strength, and jump test performance characteristics of the participants based on BMD classification. There were no group differences in physical characteristics or measures of muscle mass, muscle strength and jump test performance. Physical activity level (mets/week) was not different ($P=0.994$) between osteopenia/osteoporosis, 4527.66 (722.35) and normal groups, 4930.20 (1140.62).

Table 2 shows the age and gender adjusted partial correlations between **1)** the measures of bone density and bone strength, and **2)** variables of muscle mass, muscle strength, and jump test performance. Total hip and femoral neck BMD ($P<0.01$), and Z ($P<0.05$) were positively correlated with leg press strength. We found no relationships between measures of bone density/strength and hip abduction strength ($P>0.5$). Variables of jump test performance and muscle mass were not related to any of the bone density or bone strength variables. JHt was associated positively with JPow (r=0.72, $P<0.01$) and JVel (r=0.59, $P<0.01$). Even after adjusting for age, gender, and body height, JHt remained positively associated with JPow (r=0.55, $P<0.01$) and JVel (r=0.50, $P<0.01$).

Chi-square analyses showed no significant associations between BMD classification and sarcopenia a) as defined by Baumgartner et al.[10], ($P=0.532$; individuals with simultaneous osteopenia/osteoporosis and sarcopenia=6), 2) the FNIH recommendation for the low muscle mass[12] ($P=0.686$; individuals with simultaneous osteopenia/osteoporosis and low muscle mass=3), and c) the alternative recommendation for low muscle mass by the FNIH[12] ($P=0.357$; individuals with simultaneous osteopenia/osteoporosis and low muscle

Table 2. Age and gender adjusted correlation coefficients (r) among measures of bone density, bone strength, muscle mass, muscle strength, and jump test performance.

Variables	HBMD	FNBMD	LSBMD	CSMI	Z	BSI
RSMI	0.241	0.237	0.225	0.117	0.185	0.227
LP	0.338[b]	0.315[b]	0.101	0.196	0.257[a]	0.229
LHAb	0.118	0.196	-0.004	-0.036	0.029	-0.007
JPow	0.101	0.051	-0.007	0.074	0.093	0.114
JVel	-0.02	-0.063	0.001	-0.071	-0.044	-0.026
JHt	0.081	0.124	-0.101	0.039	0.086	0.077

Abbreviations: HBMD, total hip bone mineral density; FNBMD, femoral neck bone mineral density; LSBMD, lumbar spine bone mineral density; CSMI, cross sectional moment of inertia; Z, section modulus; BSI, bone strength index=Z/height; RSMI, relative skeletal muscle mass index; LP, leg press strength/body mass$^{0.67}$; LHAb, left hip abduction strength/body mass$^{0.67}$; JPow, jump power/body mass$^{0.67}$; JVel, jump velocity; JHt, jump height. [a]P<0.05 and [b]P≤0.01 significant relationship, after adjusting for age and gender.

Table 3. Stepwise sequential regression analyses of RSMI, LP, LHAb, JPow, JVel, and JHt versus the total hip BMD, femoral neck BMD, lumbar spine BMD, CSMI, Z, and BSI.

Dependent Variable	Model	Predictor	β-Coefficient	95% CI	P
Total Hip BMD	1	LP	0.397	0.002 - 0.017	0.01
	2	LP	0.313	0.002 - 0.016	0.013
Femoral neck BMD	1	LP	0.388	0.002 - 0.016	0.016
	2	LP	0.366	0.001 - 0.015	0.021

Abbreviations: RSMI, relative skeletal muscle mass index; LP, leg press strength/body mass$^{0.67}$; LHAb, left hip abduction strength/body mass$^{0.67}$; JPow, jump power/body mass$^{0.67}$; JVel, jump velocity; JHt, jump height; CSMI, cross sectional moment of inertia; Z, section modulus; BSI, bone strength index. Model 1: Independent variables adjusted for age and gender; Model 2: Independent variables adjusted for age, gender, and muscle mass, that is RSMI. β-Coefficients display changes in SD in dependent variable per SD change in independent variable. No independent variables (RSMI, LP, LHAb, JPow, JHt, and JVel) were found to be significantly associated with lumbar spine BMD, CSMI, Z, and BSI.

mass=10). No association was found between gender and BMD classification (*P*=0.191).

Results of stepwise sequential regression analyses of RSMI, leg press strength, hip abduction strength, JPow, JHt, and JVel versus measures of bone density and bone strength, after adjusting for age and gender are shown in Table 3. Leg press strength was a significant predictor of the total hip BMD (*P*=0.01) and femoral neck BMD (*P*=0.016). Leg press strength remained significantly correlated with the total hip BMD (P=0.013) and femoral neck BMD (P=0.021) even after adjusting for muscle mass, that is RSMI. No independent variables (RSMI, leg press strength, hip abduction strength, JPow, JHt, and JVel) correlated with lumbar spine BMD, CSMI, Z, and BSI.

Discussion

The main finding of this study was an independent association of leg press strength with the total hip and femoral neck BMD in community-dwelling older adults. This information can help in 1) identifying older individuals who may be at an increased risk of developing osteoporosis and 2) initiating musculoskeletal rehabilitation at an earlier stage before the bone density or bone strength worsens. This is important because leg press strength exercise can be carried out in community health care settings and is completely safe. Contrary to our hypothesis, we found no association between jump test performance and bone density or bone strength.

Since mechanical load stimulus has an anabolic potential on bone[29] and muscles generate the maximum voluntary mechanical load on bone, muscle strength is positively correlated with the bone density[13,14] and bone strength[15]. For example, hip abductor and quadriceps strength are positively associated with the hip and femoral neck BMD in older women[30,31]. This supports our finding of positive association between leg press strength and, bone density and bone strength. Furthermore, the association between leg press strength and the total hip BMD was maintained even after adjusting for the muscle mass indicating independent association of leg press strength with the total hip bone density. Lower quadriceps strength, in particular, has been shown to be a risk factor for osteoporotic fractures[32,33]. Also, quadriceps strength is greater than hip abduction strength[34]. Our finding of association of leg press strength, but not the

hip abduction strength with the total hip and femoral neck bone density and Z can be due to a greater mechanical strain magnitude produced by the quadriceps versus the hip abductors. This implies a critical role of quadriceps strengthening in the rehabilitation program for osteoporosis in older adults. This is further supported by our findings of leg press strength as an independent predictor of the total hip and femoral neck BMD after adjusting for age, gender, and muscle mass. A recent meta-analysis[35] indicated that muscle strength training is associated with reduction of fractures; however, studies examining the effect of strength training on fracture as a primary output are lacking[35]. Lack of any association between the measures of muscle strength and lumbar spine BMD in our study is not surprising as site-specific associations of muscular strength on bone in older adults has been reported before[31]. Future studies should prospectively examine if leg press strength can be used as a predictor for bone strength. Interestingly, in our previous work, the same participants from our current study showed lower jump power but not muscle strength[25] based on sarcopenia status. Taken together, these findings suggest that community-dwelling older adults with osteopenia/osteoporosis may not necessarily suffer from a decline in neuromuscular performance versus healthy older adults. This is supported by the fact that there was no difference in jump velocity between these groups. Also, we found no correlation between physical activity and the measures of bone density or bone strength. However, the use of IPAQ to assess physical activity is debatable[36,37] as there is a chance of over-reporting of physical activity by the participants.

Strain magnitude is a critical determinant of bone density and strength[38] as evident by athletes in high power generating sports, such as gymnastics[39] who have the greatest bone mass. Jumping induces a high magnitude strain on bone[40]. Unexpectedly, we found no differences in JPow or JHt between participants with versus without osteopenia/osteoporosis. This may have occurred due to lesser number of individuals with osteopenia/osteoporosis in our study. In addition, differences in strength and power are most profound in older decades[41] and are more prominent in men versus women[41]. Noticeably, more than 50% of our participants were females.

We found no association between jump test performance and bone density or bone strength. Our results are in line with a previous study where authors reported no relationship between BMD T-Scores of the total hip, femoral neck, and L1-L4 spine and jump power[19]. Moreover, similar to this study, their participants were also community dwelling older adults. However, our results are in contrast with previous studies where JPow positively correlated with the 1) femoral neck Z and the distal tibia BSI in postmenopausal women (mean age= 62 years)[42]; 2) total hip BMD and tibia bone strength in individuals with high bone mass[43]; and 3) tibial cortical bone strength in young and middle aged population[44]. This may be explained by 1) the use of high-resolution imaging modality such as peripheral quantitative computed tomography to assess bone strength[42-44], and 2) specific populations such as postmenopausal women with osteoarthritis but no osteoporosis[42], individuals with high bone mass[43], or young men, 25-45 years[44]. Currently, there are no longitudinal data on age-related changes with JPow. JHt is a body-size independent index of JPow[45] in young adults. Moreover, JHt was significantly correlated with JPow in our study which is comparable to a previous study[45]. It may be postulated that similar to young adults, JHt may be a body-size independent index of JPow in older age; however, more research is required to confirm this association in older population.

Data from our study suggests that sarcopenia as defined by Baumgartner et al.[10] and low muscle mass as recommended by the FNIH[12] had no association with the BMD classification. This is consistent with findings from previous studies[46,47]. However, it contrasts with some studies which reported a significant association between sarcopenia and osteoporosis[7,48,49]. Various reasons, such as a larger sample size[7,48,49], different race[49], age[48], and inclusion of clinical population[48] could be the reasons behind our findings disagreeing with those studies. For example, relationship between sarcopenia and osteoporosis has been reported in the seventh and later decades of life[48,50], especially in the elderly male population[50]. This may, in part, be explained by a preferential loss of muscle mass with aging in men[50]. This is corroborated by the fact that we did not find any association between RSMI and any measures of the bone density or bone strength in our older population, and that, more than half (55%) of our population was female.

We did not find any association between gender and BMD classification. This is consistent with a recent study which indicated that osteoporosis is not a gender specific disease[51]. There is evidence that osteopenia/osteoporosis rates are equally prevalent in men and women[51] which may be due to a reduced bioavailability of estrogen and testosterone in men and women, respectively[52]. In our study, 48% of men and 67% of women were diagnosed with osteopenia/osteoporosis which is comparable to a previous report where 44% of men and 52% of women were diagnosed with osteopenia[51]. Conversely, a higher prevalence of osteopenia/osteoporosis in females than males has also been reported[53]. Differences in body composition, such as a lower muscle mass in females is thought to contribute to weaker bone mass by compromising the production of mechanical strains on bone[54].

One of the strengths of this study was the use of homogenous population. There were no group differences in body composition. Also, we utilized a user-friendly mobile jump mat to examine the role of muscle power in identifying individuals at risk for osteopenia/osteoporosis. Furthermore, we used DXA to assess bone density which is considered the gold standard for diagnosing osteoporosis. The major limitation of this study was the small sample size. However, the percentage of individuals diagnosed with sarcopenia and osteopenia/osteoporosis is in line with what has been reported within the general population[7,8]. The limited age range was another constraint that could have been responsible for the lack of correlation between BMD status and sarcopenia. However, the focus of this study was the older population

as there is a lack of data on the association between jump test performance, osteoporosis, and sarcopenia in the older population. Furthermore, the cross-sectional design of this study did not allow for establishment of cause-effect associations. We used DXA-derived bone strength measures in this study which are limited by the resolution and are not a true representation of bone geometry. Furthermore, DXA analysis of bone strength is based on certain approximations which might not yield a true representation of the hip[55]; however, DXA-computed hip strength measures correlate well with high resolution HR-QCT measures[21,56]. Previous studies have utilized DXA-derived estimates of bone strength in clinical population[57], for examining aging-associated[58,59], gender-based[59], and longitudinal changes[60] in bone strength.

In conclusion, jump test performance was not associated with bone density or bone strength; however, leg press strength was associated with bone density of the hip and the femoral neck in older adults, and thus can help identify individuals susceptible to get fracture in later life. Whether leg press strength exercises can be incorporated into the rehabilitation for osteopenia/osteoporosis remains to be investigated. Future studies should examine the utility of jump test performance in clinical populations.

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