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Racial/ethnic differences in bone mineral density, muscle function and fat mass in young women

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Abstract

Background: Racial/ethnic differences in bone mineral density (BMD) result in increased susceptibility of some ethnic groups to fragility fractures in comparison to others. Conventionally, both lean mass and fat mass provide mechanical loading to the skeleton and increase BMD, however, increase in fat mass beyond a certain level without a concurrent increase in muscle mass/strength, is detrimental to the skeleton. The aim of this study was to determine racial/ethnic differences in BMD, muscle function and fat mass in 18-30-year-old women of Caucasian, East-Asian, South-Asian, Hispanic and African-American backgrounds. Materials and methods: Forty-six women participated in the study. The visits included signing a written informed consent and questionnaires to assess health status, menstrual history, physical activity and calcium intake. Body composition (fat mass, bone free lean body mass (BFLBM), and bone mineral content (BMC)) and total and regional BMD were measured using Dual Energy X-Ray Absorptiometry, while handgrip test, jump test, 1Repetition-Maximum leg press test, and bilateral isokinetic testing of knee flexors and extensors were used to quantify lower limb muscle strength and power. Results: African-American women had a higher BMD at the left and right trochanter (p=0.03) and higher BMC at several sites in comparison to South-Asians (p=0.02) and Hispanics (p=0.03). South-Asian women had a higher fat mass (p=0.04) and percent body fat (p=0.003), and lower BFLBM (p=0.04) and strength (p=0.003) than East-Asians and Caucasians. Conclusion: This type of research is essential to identify at-risk minorities and fundamental for creating awareness, developing ethnicity-specific diagnostic criteria, and preventative and therapeutic strategies.

Keywords: DXA; Osteoporosis; Body composition; Premenopausal; Lean mass; Muscle strength.

Resumo

Diferenças raciais/étnicas na densidade mineral óssea, função muscular e massa gorda em mulheres jovens

Introdução: Diferenças raciais e étnicas na densidade mineral óssea (DMO) resultam em uma maior susceptibilidade de alguns grupos étnicos à fragilidade de fraturas em comparação a outros grupos. Convencionalmente, ambas massa magra e massa gorda induzem estresse mecânico no esqueleto e aumentam a DMO, entretanto, aumentos na massa gorda além de um certo ponto sem concorrente aumento na força ou massa muscular são deletérios ao esqueleto. O objetivo deste estudo foi determinar diferenças raciais e étnicas na DMO, função muscular e massa gorda em mulheres caucasianas, leste-asiáticas, sul-asiáticas, hispânicas, e afro-americanas com idades entre 18 e 30 anos de idade. Materiais e métodos: Quarenta e seis mulheres participaram do estudo. As visitas consistiram em assinar o consentimento livre e esclarecido e preencher os questionários de estado de saúde, histórico menstrual, atividade física e consumo de cálcio. Composição corporal (massa gorda, massa magra livre de tecido ósseo e conteúdo mineral ósseo (CMO)) e DMO total e regional foram medidas utilizando a absortometria radiológica de dupla energia, enquanto o teste de força manual, o teste de salto, o teste de uma repetição máxima no leg press, e o teste de força isocinético bilateral para os flexores e extensores do joelho foram usados para quantificar a força e a potência dos membros inferiores. Resultados: Mulheres afro-americanas apresentaram maior DMO nos trocanteres direto e esquerdo (p=0,03) e maior CMO em diversos locais comparados com mulheres sul-africanas (p=0,02) e hispânicas (p=0,03). As mulheres sul-asiáticas apresentaram maiores massa gorda (p=0,04) e percentual de gordura (p=0,003) e menores massa magra livre de tecido ósseo (p=0,04) e níveis de força (p=0,003) do que as mulheres leste-asiáticas e caucasianas. Conclusão: Este tipo de pesquisa é essencial para identificar minorias em risco e é fundamental para a conscientização, desenvolvendo de critérios de diagnósticos específicos para determinados grupos étnicos, além de estratégias preventivas e terapêuticas.

Descritores: DXA; Osteoporose; Composição corporal; Pré-menopausa; Massa magra; Força muscular.

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Original article

Resumen

Diferencias raciales/étnicas en la densidad mineral ósea, función muscular y grasa masa en mujeres jóvenes

Introdución: Diferencias raciales/étnicas en la densidad mineral ósea (DMO) resulta a una mayor susceptibilidad de algunos grupos étnicos a las fracturas por fragilidad en comparación con otros. Convencionalmente, tanto la masa magra como la masa grasa proporcionan una carga mecánica al esqueleto y aumentan la DMO, sin embargo, el aumento de masa grasa más de un cierto nivel sin un aumento simultáneo de la masa/fuerza, es perjudicial para el esqueleto. El objetivo de este estudio fue determinar las diferencias raciales/étnicas en la DMO, la función muscular y la masa grasa en mujeres de 18 a 30 años de edad de raza Caucásica, Asiática del Este, Asiática del Sur, Hispana y Afroamericana. Materiales y métodos: Cuarenta y seis mujeres participaron en el estudio. Las visitas incluyeron la firma de un consentimiento informado por escrito y cuestionarios para evaluar el estado de salud, la historia menstrual, la actividad física y la ingesta de calcio. Composición corporal (masa grasa, masa corporal magra sin hueso (MCMSH), y contenido mineral óseo (CMO)) y la DMO regional total se midieron utilizando la Absorciometría de Rayos X de Energía Dual, mientras que la prueba de agarre de las manos, la prueba de salto, la prueba de 1 repetición máxima de presión de piernas y las pruebas de isocinética bilateral flexores y extensores de la rodilla fueron utilizadas para cuantificar la fuerza y potencia muscular de las extremidades inferiores. Resultados: Mujeres Afroamericanas tenían un DMO más alto en el trocánter (p=0,03) y un CMO más alto en varios sitios en comparación con las Asiáticas del Sur (p=0,02) y Hispanas (p=0,03). Las mujeres Asiáticas del Sur tienen una masa grasa (p=0,04) y un porcentaje de grasa corporal (p=0,003) más altas, y la MCMSH (p=0,04) y fuerza (p=0,003) más bajas que las Asiáticas del Este y las Caucásicas. Conclusión: Este tipo de estudio es esencial para identificar a las minorías en riesgo y fundamental para crear conciencia, desarrollar criterios diagnósticos específicos de etnicidad y estrategias preventivas y terapéuticas.

Palabras clave: DXA; Osteoporosis; Composición corporal; Premenopáusicas; Masa magra; Fuerza muscular.

Introduction

Osteoporosis is a debilitating disease that deteriorates bone tissue and results in approximately 1.5 million fractures in the U.S. each year.[1] These fractures are predicted to increase to more than 3 million by 2025, causing a financial burden of 25.3 billion dollars. The majority of these fractures (71%) occur in women.[2] In addition to gender, race/ethnicity is a critical factor in determining the incidence and prevalence of osteoporosis, as it is linked to genetics and is integral to other risk factors like nutrition and physical activity.[3]

It is documented that African-American women have a higher bone mineral density (BMD) than other ethnicities, including Caucasians, Asians and Hispanics, which explains the lower fracture incidence reported in this population.[1,4-7] Contrary to African-American women, Asians have a lower BMD at the axial and appendicular skeleton than Caucasians. However, Asians have lower fracture rates compared to Caucasians, contradicting the apparent link between higher BMD and lower fracture risk.[8-10] The greater resistance to fractures among Asians may be explained by the presence of thicker and denser cortical bone parameters and better microstructural properties, such as lower cortical porosity, reported in this population.[11]

Prevalence of osteoporosis and fracture incidence varies by geographical location within Asia.[12-14] However, most studies examining BMD and its determinants in Asians include East-Asians, particularly Chinese, with very few well-defined studies focusing on women of South-Asian descent.[15] Loss of BMD begins at a younger age in this population, resulting in 10-20 years earlier occurrence of osteoporotic fractures.[13,16-18] Therefore, comparative studies including South-Asians as an independent sub-group and assessing bone density using dual energy X-ray absorptiometry (DXA), the gold standard for measuring BMD, become essential to reduce the physical and economic burden of osteoporosis.

Development of the skeleton begins in the uterus and it continues to grow until peak bone density is achieved by late twenties.[19] Peak bone mass is a major predictor of BMD in late adulthood, with 20-50% of its acquisition dependent on environmental factors, such as adequate mechanical loading, and calcium and vitamin D intake.[20] Increased mechanical loading due to high lean mass and/or fat mass is conventionally linked to higher accrual of bone mass, as these loads deform or strain the bones thereby adapting them to become stronger.[21] Bone mineral density is reported to be higher in high muscle-low fat and high muscle-high fat type phenotypes.[22] However, an increase in fat mass without a concurrent increase in muscle mass results in loss of BMD and increases fracture risk, a condition termed as 'osteosarcopenic obesity'.[23] Therefore, simultaneous assessment of these three tissues is essential, particularly in young women who are still accruing bone mass, as this provides an opportunity to optimize peak bone density and reduce fracture risk later in life.

The purpose of this study was to determine differences in BMD, bone free lean body mass (BFLBM) and strength, and fat mass in 18-30 year-old young women. Our sample included women from Caucasian, East-Asian, South-Asian, Hispanic and African-American backgrounds. We hypothesized that BMD will be highest for African-American women, followed by Caucasians and Hispanics, then East-Asians, and lowest in South-Asians. We also expected to observe a low BFLBM and strength and higher fat mass in South-Asians in comparison to other ethnicities.

Materials and methods

Subject characteristics

Forty-six recreationally active females aged 18-30 years were recruited for the study. Recreationally active was defined as being physically active, but not participating in any structured exercise training program. Five participants did not return following the initial visit and were excluded from the study resulting in 41 participants completing the study. Based on an anticipated statistical power of 0.80 and an effect size of 0.6, a total sample size of 40 was required for the study (G-power 3.0.10). The participants self-identified themselves as belonging to one of the five independent racial/ethnic groups: Caucasians (n=13), South-Asians (n=9), East-Asians (n=5), Hispanics (n=9), and African-Americans (n=5). The study was conducted in accordance to the Declaration of Helsinki and approved by the University of Oklahoma Institutional Review Board (IRB #7213). The inclusion criteria were: 1) healthy, recreationally active women aged 18-30 years; 2) body weight should be less than 300 pounds (136.3 kg) and height less than six feet, which is a limit for DXA; 3) participants should belong to one of the five racial/ethnic groups. Exclusion criteria were: 1) women who are pregnant; 2) those taking medications that are known to affect bone metabolism; 3) any joint replacements or metal implants in the body; 4) uncontrolled hypertension; 5) current smoker; 6) a "Yes" answer on the Physical Activity Readiness Questionnaire.

The study utilized a cross-sectional design and consisted of two visits. During the first visit the participants signed a written informed consent and completed the questionnaires. These included the health status and physical activity readiness questionnaires, which were used as screening tools to check for exclusion criteria or any other health related issues that might impact the results or limit participation in the study; a menstrual history questionnaire was used to gather information regarding cycle characteristics and contraceptive use; daily dietary and supplemental calcium intake (mg/day) was measured using a food frequency questionnaire[24]; and International Physical Activity Questionnaire (IPAQ) was used to assess physical activity over a seven-day period by estimating the metabolic equivalent minutes per week (met/min).[25, 26] The participants also completed the Bone Specific Physical Activity Questionnaire (BPAQ), which records physical activity since 1 year of age to 12 months prior to testing (past period BPAQ, pBPAQ), and any activity reported from the past 12 months (current BPAQ, cBPAQ). This is used to estimate the total BPAQ (tBPAQ) score, which is the calculated average of pBPAQ and cBPAQ scores, using an online BPAQ calculator.[27] For the current study we only used tBPAQ scores. Following this, blood pressure was measured, and participants were familiarized with the muscular strength tests. The participants practiced at low intensity to understand the form and technique of the strength tests. The testing procedures including the total body, lumbar spine, and dual proximal femur DXA scans and muscular strength tests were performed during the second visit.

Procedures

Anthropometric measures

Resting brachial systolic and diastolic blood pressures (mm Hg) were measured with the participant in sitting position on the left arm using an automatic blood pressure monitor (OmronIntelliSense Automatic Blood Pressure Monitor with Easy Wrap Cuff, model HEM-773AC, Vernon Hills, IL, USA). Height was assessed without shoes with the participant standing in upright position to a nearest of 0.5cm using a wall mounted stadiometer (Stadi-O-Meter, Novel Products

Inc., Rockton, IL, USA). Weight was measured with the participant in light clothing and without shoes to a nearest of 0.1kg using a digital weighing scale (TANITA BWB-800, TANITA, Japan).

Pregnancy and hydration testing

Prior to the DXA scans, a urine sample was obtained and tested for pregnancy using the pregnancy test strips (SAS Pregnancy Strip, SAS Scientific, San Antonio, TX) to confirm that the participant was not pregnant and to check the hydration status. Hydration status was determined by measuring urine specific gravity using an optical refractometer (VEE GEE CLX-1, Rose Scientific Ltd., Alberta, Canada) to confirm that the participant was within the normal hydration range of 1.004 to 1.029.

Areal bone mineral density and hip structural analysis

Total body, lumbar spine (L1-L4) and dual proximal femur (total hip, trochanter, femoral neck) areal BMD was assessed using DXA ((DXA, GE Lunar, Prodigy encore software version 10.50.086, Madison, WI, USA). Bone mineral content, BFLBM, fat mass, percent body fat, and fat free mass were also determined from these scans. The DXA was calibrated daily prior to the scans and all the scans were performed by the same investigator.

For the total body measurement, participants were required to lie in supine position on the DXA table and their knees and ankles were secured with Velcro straps. For the lumbar spine measurements, a foam block was placed under the participant's feet in order to position the hip at an angle between 45-90 degrees to obtain accurate and high-quality images. The positioning laser was adjusted to approximately 5cm below the umbilicus so that part of L5 and iliac crest, and some part of T12 was visible in the image. For the proximal dual femur scans, the participant's feet were positioned in a triangular brace using Velcro straps such that both the left and right femur were internally rotated. The positioning laser was placed in the midline of the thigh and about 4cm lower than the greater trochanter or 1cm lower than the pubic symphysis. In addition, hip structural analysis (HSA) program was used to determine the structural geometry of the cross-sections traversing the proximal femur at particular locations by measuring the hip strength index, buckling ratio, cross-sectional moment of inertia (CSMI), section modulus and hip axis length. The *in vivo* precision and accuracy of the DXA RMS %CV for areal BMD is 0.7% for total body BMD, 1.4% for lumbar spine BMD, and 0.6% for total left and right hip, 0.6% for right trochanter, 0.7% for left trochanter, 0.9% for right femoral neck and 1.01% for left femoral neck BMD. The *in vivo* precision of DXA RMS %CV for body composition variables is 2.0% for percent body fat and fat mass, 1.9% for BFLBM, and 1.7% for fat free mass.

Muscular strength testing

After the DXA scans, the muscular strength tests were performed to measure upper and lower limb muscle strength and power. These included the handgrip test, vertical jump test, leg press test, and isokinetic strength testing of knee flexors and extensors.

Handgrip test

Upper body muscle strength was assessed using a hand-held dynamometer (Takei, Japan). This test was performed with the participant in sitting position, elbow flexed to 90 degrees and forearm in neutral position with wrist between 0 to 30 degrees dorsiflexion and 0 to 15 degrees ulnar deviation. Each hand was tested three times, alternating between the trials, with 60 seconds rest between trials on the same hand. The intraclass correlation (ICC) for handgrip dynamometer was 0.874.

Vertical jump test measurement

Jump test was performed to measure muscle power and velocity using a jump mat (Just Jump, Probiotic, AL) and a Tendo FiTRODYNE power and speed analyzer (Tendo Sports Machines, Trencin, Slovak Republic). The Tendo unit has two parts: 1) a velocity sensor unit; and 2) a microcomputer. The velocity sensor unit was attached to a standard barbell that was placed close to the jump mat and connected to the participant's waist by a Velcro strap enabled cable. Body weight of the participant was entered into the microcomputer. The participant performed a counter-movement vertical jump with unrestricted arm motion. A total of three successful jumps were performed with a one-minute rest period between each trial. The jump was considered unsuccessful if the participant tucked the legs or bent the knees in mid-air.

The Tendo unit determines the average velocity of mass lifted vertically while the microcomputer multiplies the weight of the lifter by acceleration from gravity to estimate the average force in Newton.

Average power is the calculated product of average force and average velocity. Air time and jump height were recorded by the jump mat and handheld computer.[28] The ICC values for jump power, time in air, jump height and velocity, range between 0.80-0.98.

Leg press test

Leg muscle strength was determined by a standard 1-Repitition Maximum (1-RM) test. The participants were in a semi-reclined position on a CYBEX two-leg press machine. The participant completed 5-6 repetitions with a load approximately 50% of the body weight. After a one-minute break, the load was increased to 75% of the body weight and the participant was asked to perform 3-4 repetitions. Then, following a 2-minute rest period, loads were increased such that a maximal voluntary effort was reached with 5 more attempts. Each attempt during this part of the test was separated by a rest period of 2-4 minutes. The ICC value for leg press was 0.997.

Isokinetic strength testing

Isokinetic strength testing of the knee flexors and extensors was performed for both the right and left legs using the biodex dynamometer at two speeds of contraction (60 and 300 degrees per second). The participants were seated on the dynamometer chair and stabilized with belts around their thorax, pelvis and thigh of the testing limb to avoid compensation of muscle strength from other regions. The shin pad was positioned approximately 2 cm above the calcaneum. The anatomical axis of rotation of the knee joint (femoral condyle) was aligned to the dynamometer axis using visual inspection and manual palpation. The testing limb was then weighed to compensate for the action of gravity, allowing more reliable data production. Three repetitions of full knee flexion and extension were completed at 60 and 300-degrees/s with a three-minute rest interval between each speed. Peak torque, torque (normalized by body weight), and average power were assessed bilaterally at both velocities. The ICC values for biodex at 60 and 300 degrees/s range between 0.516-0.704 and 0.455-0.778 respectively. These values were lower in comparison to other muscle strength tests; however, this was not unexpected, since the assessment of the reliability of muscle forces at different velocities is difficult because it relies on the participant's ability to apply the same force each time, along with other contributing factors.

Statistical Analyses

The data was analyzed using SPSS 24.0 (SPSS Inc., Chicago, IL, USA) software. All the dependent variables were tested for normality using the Shapiro-Wilk test. Descriptive statistics are reported as median accompanied by the minimum and maximum values. For variables with normal distribution, between group differences were determined using one-way ANOVA followed by Bonferroni post-hoc analyses. Partial eta-squared (η_p^2) was used to report effect sizes for normally distributed variables using ANOVA ($SS_{factor}/(SS_{factor}+SS_{error})$). The values of 0.01, 0.06, and 0.14 were interpreted as small-, medium- and large-effect size.[29] For variables with distribution other than normal, Kruskal-Wallis test was used to assess group differences, followed by Mann-Whitney U test for post-hoc analyses. Pearson correlation coefficient was used to assess relationships between measures of bone density, BFLBM and strength, fat mass, calcium intake, and physical activity scores. The level of significance for all analyses was set at $p<0.05$.

Results

Table 1 shows physical characteristics of the participants, their daily calcium intake, body composition, and physical activity scores. South-Asians had significantly higher percent fat ($\eta_{p2}=0.347$) and fat mass in comparison to Caucasians and East-Asians. Fat free mass and BFLBM was significantly higher for Caucasians and African-Americans than South-Asians. Moreover, physical activity measured in met/min using IPAQ was significantly higher for Caucasians and East-Asians compared to South-Asians ($p<0.05$).

Although no statistically significant differences were observed for total body and lumbar spine BMD, total body BMC ($\eta_p^2=0.318$) was significantly higher in African-Americans in comparison to South-Asians ($p=0.003$) and Hispanics ($p=0.02$) (Table 2). African-Americans also had a significantly higher BMC in comparison to both South-Asians and Hispanics at the left femoral neck ($p=0.02$ for South-Asians; $p=0.03$ for Hispanics; $\eta_p^2=0.263$), left trochanter ($p=0.01$ for South-Asians; $p=0.02$ for Hispanics; $\eta_p^2=0.301$) and left total hip ($p=0.01$ for South-Asians; $p=0.02$ for Hispanics; $\eta_p^2=0.292$), and a higher BMD at the left ($p=0.02$; $\eta_p^2=0.254$) and right ($p=0.03$; $\eta_p^2=0.249$) trochanter than South-Asians (Table 3). The results of the hip structural geometry analyzed using HSA showed no statistically significant differences between the racial/ethnic groups.

Table 1. Characteristics of the participants

Variable	Caucasian (n=13)	South-Asian (n=9)	East-Asian (n=5)	Hispanic (n=9)	African-American (n=5)	p
Age (yrs)¶	21.50 (19.1-30.0)	25.1 (23.8-30.0)	21.45 (19.4-21.6)	21.1 (19.1-24.1)	20.7 (18.8-27.4)	0.007*
Height (cm)	166.5 (144.5-176.5)	157.5 (152.0-169.3)	159.75 (158.0-163.0)	158.5 (151.0-166.0)	168.5 9162.5-173.5)	0.10
Weight (kg)¶	61.3 (49.4-74.9)	59.2 (49.3-98.5)	53.65 (46.4-62.2)	58.1 (56.0-102.7)	70.4 (53.6-90.1)	0.35
Calcium Intake (mg/day)	646.4 (101.4-1396.4)	716.4 (352.14-1065.0)	715.7 (412.86-1068.57)	725.0 (423.9-1263.2)	605.7 (449.29-1537.86)	0.85
Total PA Score (met/min)¶	2899.0 (1575.0-9430.5)	1256.0 (288.0-2887.5)	3672.0 (480.0-8262.0)	1866.0 (801.0-6099.0)	3220.0 (892.5-16677.0)	$0.02^{*,\#}$
tBPAQ	28.74 (6.41-132.33)	24.63 (0.78-47.09)	17.10 (4.73-20.01)	27.10 (8.80-105.67)	19.48 (2.07-47.36)	0.14
Body Fat %	28.6 (19.6-37.9)	38.4 (31.3 (51.3)	26.1 (19.5-30.8)	32.2 (26.1-49.8)	28.1 (16.3-44.8)	$0.003^{*,\#}$
Fat Mass (kg)¶	18.0 (12.75-21.87)	23.79 (15.45-49.9)	15.23 (8.99-16.05)	18.98 (14.8-49.2)	19.78 (11.43-40.34)	$0.04^{*,\#,\delta}$
BFLBM¶	39.72 (33.05-52.17)	33.72 (28.35-44.94)	37.23 (32.16-44.83)	38.84 (35.64-50.37)	46.92 (40.04-63.47)	$0.04^{*,\Phi,\Upsilon}$
Fat Free Mass (kg)¶	42.54 (34.6-55.03)	35.8 (30.0-47.43)	39.34 (34.35-47.27)	41.05 (37.88-52.97)	49.7 (42.42-66.93)	$0.04^{*,\Phi,\Upsilon}$

Data represented as median (minimum-maximum values); PA: physical activity; BFLBM: bone free lean body mass; p: p-value for one-way anova or Kruskal-Wallis test. ¶ Distribution other than normal; * Caucasians vs. South-Asians; $^{\#}$ South-Asians vs. East-Asians; $^{\delta}$ East-Asians vs. Hispanics; $^{\Phi}$ South-Asians vs. African-Americans; $^{\Upsilon}$ Hispanics vs. African-Americans.

Table 2. Total body and lumbar spine areal bone mineral density

Variable	Caucasian (n=13)	South-Asian (n=9)	East-Asian (n=5)	Hispanic (n=9)	African-American (n=5)	p
Total Body aBMD (g/cm2)	1.17 (0.99-1.28)	1.19 (1.03-1.34)	1.17 (1.14-1.28)	1.18 (1.1-1.25)	1.28 (1.16-1.48)	0.06
Total Body BMC (g)	2387.0 (1564.0-2856.0)	2076.0 (1649.0-2704.0)	2156.3 (2105.0-2438.0)	2231.0 (2040.0-2603.0)	2778.0 (2373.0-3457.0)	$0.01^{\Phi,\Upsilon}$
Total Body Z-Scores	0.90 (-1.4-2.3)	1.0 (-0.30-1.8)	1.3 (0.5-2.1)	0.70 (-0.40-1.5)	0.80 (0.3-2.3)	0.80
Spine L1-L4 aBMD (g/cm^2)	1.19 (0.95-1.52)	1.16 (0.97-1.45)	1.19 (1.08-1.32)	1.16 (1.02-1.37)	1.29 (1.05-1.51)	0.75
Spine L1-L4 BMC	65.80 (41.03-80.35)	54.43 (41.69-81.47)	63.73 (48.26-70.30)	56.02 (49.87-74.26)	63.38 (57.05-82.85)	0.48
Spine L1-L4 Z-Scores	0.1 (-1.40-2.9)	0.2 (-2.0-1.9)	0.4 (-0.80-1.20)	-0.2 (-1.70-0.70)	-0.5 (-1.40-1.6)	0.76

Data represented as median (minimum-maximum values); aBMD: areal bone mineral density; BMC: bone mineral content; p: p-value for one-way anova or Kruskal-Wallis test. $^{\Phi}$ South-Asians vs. African-Americans; $^{\Upsilon}$ Hispanics vs. African-Americans.

Table 3. Hip areal bone mineral density

Variable	Caucasian (n=13)	South-Asian (n=9)	East-Asian (n=5)	Hispanic (n=9)	African-American (n=5)	p
Right FN aBMD (g/cm^2)	1.12 (0.82-1.37)	0.97 (0.86-1.24)	1.04 (0.97-1.17)	1.04 (0.94-1.13)	1.04 (1.03-1.39)	0.28
Left FN aBMD (g/cm^2)	1.08 (0.83-1.26)	0.97 (0.82-1.26)	1.08 (0.96-1.14)	1.03 (0.93-1.71)	1.16 (1.06-1.45)	0.28
Right FN BMC	5.22 (3.47-5.96)	4.54 (3.47-5.97)	4.51 (4.3-5.08)	4.44 (4.11-5.33)	5.01 (4.65-6.87)	0.14
Left FN BMC	4.93 (3.56-5.76)	4.43 (3.55-5.87)	4.66 (4.27-5.06)	4.36 (4.13-5.18)	5.63 (4.7-7.21)	$0.02^{\phi,\Upsilon}$
Right Troch aBMD (g/cm^2)	0.88 (0.59-0.97)	0.80 (0.61-0.92)	0.89 (0.79-0.95)	0.80 (0.74-0.90)	0.86 (0.84-1.17)	0.03^{ϕ}
Left Troch aBMD (g/cm^2)	0.87 (0.63-0.95)	0.82 (0.62-0.92)	0.89 (0.75-0.94)	0.77 (0.74-0.91)	0.92 (0.84-1.11)	0.03^{ϕ}
Right Troch BMC	9.66 (5.93-12.52)	7.87 (5.14-11.2)	9.03 (6.77-10.9)	8.01 (7.53-10.84)	10.4 (9.72-13.33)	0.06
Left Troch BMC	9.61 (6.02-12.75)	7.6 (5.04-10.66)	8.71 (6.99-11.41)	7.9 (7.06-10.92)	12.05 (10.02-14.75)	$0.01^{\phi,\Upsilon}$
Right THIP aBMD (g/cm^2)	1.12 (0.79-1.22)	1.03 (0.80-1.17)	1.11 (0.98-1.17)	1.03 (0.95-1.16)	1.07 (1.06-1.39)	0.11
Left THIP aBMD (g/cm^2)	1.12 (0.79-1.19)	1.03 (0.80-1.22)	1.1 (0.96-1.16)	1.02 (0.94-1.14)	1.14 (1.06-1.35)	0.09
Right THIP BMC	31.15 (21.77-37.38)	29.0 (21.86-35.65)	30.55 (26.29-34.42)	28.19 (27.12-34.52)	33.95 (32.09-42.98)	0.03^{ϕ}
Left THIP BMC	31.85 (21.89-37.38)	28.65 (21.73-35.06)	29.64 (26.52-34.49)	27.74 (26.32-33.44)	34.91 (31.99-45.85)	$0.01^{\phi,\Upsilon}$

Data represented as median (minimum-maximum values); FN, femoral neck; aBMD, areal bone mineral density; BMC, bone mineral content; Troch, trochanter; THIP, total hip; p, p-value for one-way anova or Kruskal-Wallis test. $^{\phi}$ South-Asians vs. African-Americans; $^{\Upsilon}$ Hispanics vs. African-Americans.

For the muscular strength tests, South-Asians had significantly lower values for time in air (η_p^2=0.35) and jump height (η_p^2=0.35) in comparison to Caucasians (p=0.02 and 0.005 respectively) and East-Asians (p=0.014 and 0.012 respectively). In addition, leg muscle strength measured using 1-RM leg press was significantly lower in South-Asians than Caucasians (p=0.001), East-Asians (p=0.03), and African-Americans (p=0.01) (Table 4).

Isokinetic strength testing for knee flexors and extensors showed no statistically significant differences except for torque (normalized for body weight) (p=0.01) and average power (p=0.02) for the left leg during flexion at 60-degrees/s. These measures were significantly higher for Caucasians than South-Asians.

When analyzing the entire sample, handgrip strength was positively related to lumbar spine BMC (r=0.32, p=0.04), and 1-RM leg press to BMC at the left trochanter (r=0.35, p=0.02). A positive correlation was observed between jump power and total body (r=0.59, p=0.001), lumbar spine (r=0.33, p=0.03), left (r=0.40, p=0.009) and right (r=0.47, p=0.002) femoral neck, and left (r=0.41, p=0.008) and right (r=0.39, p=0.01) total hip BMD. Jump height (r=0.41, p=0.009) and velocity (r=0.40, p=0.01) were positively related to total body BMD Z-scores. There were positive correlations between total PA activity scores and BMC at the total body (r=0.33, p=0.03), left femoral neck (r=0.36, p=0.02), trochanter (r=0.41, p=0.009) and hip (r=0.38, p=0.02), and BMD for the left hip (r=0.34, p=0.03) and trochanter (r=0.37; p=0.02).

Table 4. Muscle performance variables

Variable	Caucasian (n=13)	South-Asian (n=9)	East-Asian (n=5)	Hispanic (n=9)	African-American (n=5)	p
Right Handgrip (kg)	27.33 (16.57-34.17)	21.67 (14.9-33.13)	24.78 (18.07-35.07)	27.77 (24.0-34.07)	24.93 (21.07-31.13)	0.27
Left Handgrip (kg)	23.53 (16.23-32.07)	23.07 (11.7-28.77)	21.72 (19.53-32.1)	26.9 (21.67-29.8)	24.0 (19.53-29.77)	0.19
Time in air (s)	0.54 (0.44-0.62)	0.46 (0.38-0.50)	0.52 (0.47-0.62)	0.51 (0.44-0.55)	0.48 (0.43-0.57)	0.003*,#
Jump Height (inches)	14.13 (9.33-18.7)	10.3 (7.77-12.17)	13.27 (10.7-19.0)	12.6 (9.4-14.6)	11.03 (9.2-15.63)	0.003*,#
Velocity (m/s)	1.21 (1.01-1.29)	1.23 (1.01-1.41)	1.20 (0.90-1.25)	1.29 (1.17-1.45)	1.21 (0.97-1.55)	0.58
Jump Power (watts)¶	727.67 (526.33-954.0)	700.67 (601.0-1268.67)	650.33 (414.0-737.0)	747.67 (681.0-1326.33)	844.33 (631.67-1386.0)	0.50
Relative Jump Power(watts/kg)	12.0 (10.1-12.87)	12.12 (9.97-14.06)	11.97 (8.92-14.9)	12.87 (11.54-14.31)	11.99 (9.5-15.38)	0.64
1 RM (kg)¶	136.08 (99.79-252.2)	95.25 (68.04-108.86)	115.67 (99.79-195.04)	122.47 (86.18-213.19)	140.61 (99.79-243.58)	0.003*,#,ɸ

Data represented as median (minimum-maximum values); RM, repetition maximum; p, p-value for one-way anova or Kruskal-Wallis test.
¶ Distribution other than normal; * Caucasians vs. South-Asians; # South-Asians vs. East-Asians; ɸ South-Asians vs. African-Americans.

Discussion

The aim of this cross-sectional study was to determine racial/ethnic differences in bone mineral density, BFLBM and strength, and fat mass in young women belonging to different racial/ethnic backgrounds. Our unique findings include that South-Asians have a higher fat mass and percent body fat, as well as lower BFLBM and strength, than East-Asians and Caucasians. In addition, physical activity is significantly lower in South-Asians in comparison to East-Asians and Caucasians.

It is well established via cross-sectional and longitudinal studies that African Americans have a higher BMD than Caucasians, Hispanics, and Asians, and a 50% lower risk of fracture at the axial and appendicular skeleton.[1,4-6,30-31] Although no statistically significant differences in BMD and BMC were observed between African-Americans and Caucasians in this study, we did observe that BMD was significantly higher for African-Americans compared to South-Asians at the left and right trochanter. Moreover, African-Americans had significantly higher BMC at the total body, left femoral neck, trochanter and hip, in comparison to South-Asians and Hispanics. The lack of significant differences in BMD between the groups in this study can be due to the relatively low age of the participants and the small sample size. Finkelstein et al., 2002,[6] reported that unadjusted BMD at the lumbar spine and femoral neck was highest in pre- and early perimenopausal African-American women, followed by Caucasians, and least in Chinese and Japanese women. Following adjustment for covariates, BMD remained highest for African-Americans, with no significant differences for the other three groups. In addition, though bone loss increases with age in both Caucasians and African-Americans, rate of bone loss is more than two times in older Caucasian women than in African-American women.[30] African-Americans also have a higher total volumetric BMD and better skeletal microarchitecture than Caucasians. Moreover, measures of bone stiffness and failure load used to predict the risk of fracture using micro-finite element analysis were significantly higher in African-Americans compared to Caucasians.[31] Thus, African-Americans have higher areal and volumetric BMD, superior bone microarchitecture, and a slower rate of bone loss, making them structurally advantageous and genetically protected against osteoporosis.

Bone free lean body mass is an important predictor of bone density and is considered as a surrogate for muscle force.[1] In this study South-Asians have significantly lower fat free mass and BFLBM than Caucasians and African-Americans, and lower values for the muscular strength test variables, such as jump height, time in air, and 1-RM leg press, in comparison to Caucasians, East-Asians and African-Americans. Similar to this study, prior studies have reported that BFLBM assessed using DXA is highest in African-American women, followed by Caucasians, Hispanics and lowest in Asians.[32] Moreover, leg muscle strength measured using 1-RM leg press test is a strong predictor of lower limb BMD and is reported to be highest in Caucasians, followed by Hispanics, and lowest in Asians (p=0.01).[33] In addition to leg press, handgrip strength measured using a handheld dynamometer is associated with reduced odds of osteoporosis, where the odds ratio was lowest for non-Hispanic Blacks and highest for non-Hispanic Asians (p<0.0001).[34] As mentioned earlier, these studies did not consider East- and South-Asians as separate groups. Though studies comparing ethnic differences in muscle strength are limited, they do support the assumption that muscle mass and strength varies with ethnicity.[35] Therefore, future studies focusing on phenotypic determination of muscle fiber type and metabolic profile along with quantification of muscle strength using handgrip strength, jump test, dynamometry, and electromyography can provide more accurate estimates of the underlying racial/ethnic differences than using BFLBM alone.

South-Asians also have significantly lower physical activity scores than Caucasians and East-Asians. Though we did not find any statistically significant differences between African-Americans, Caucasians and Hispanics, it is reported that Whites have significantly higher participation in physical activities compared to Blacks and Hispanics.[36] Load bearing or high impact activities above the threshold increase muscle strength and provide mechanical stimuli necessary for bone growth and formation.[21, 37] Moreover, physical activity scores were positively related to BMC at several sites for this study. The low physical activity levels in South-Asians, which can be due to life-style, socio-economic, cultural and religious differences, help to explain their lower BFLBM and muscle strength values.[38] These lower physical activity levels can also be potential contributors to obesity, as seen in the current South-Asian population, which has a significantly higher fat mass and percent body fat in comparison to Caucasians and East-Asians. A high fat mass is regarded as an osteogenic stimulus and positively associated with BMD due to several possible mechanisms: higher fat mass exerts higher mechanical load on the skeleton due to excess weight; association of fat mass with secretion of bone-active hormones, such as insulin, amylin, preptin, and resistin from the pancreatic beta cells; and secretion of bone-active factors, such as estrogen, leptin, and adiponectin from adipocytes.[39] However, the relationship between fat and bone is complex and not merely dependent on its mechanical loading effects as increase in fat mass beyond a certain threshold, which remains elusive, leads to deleterious effects on bone. Adipose tissue is metabolically active and produces pro-inflammatory cytokines such as prostaglandin E2, leukotriene B4, and tumor necrosis factor-alpha, which causes excessive adipogenesis and inhibition of osteoblastogenesis at the cellular level, ultimately resulting in osteosarcopenic obesity.[22, 23]

Osteosacropenic obesity is primarily a phenomenon seen in the elderly, with no clear definition proposed for young populations. Stefanaki et al., 2016,[40] reported a decreased skeletal muscle mass and bone mass in young overweight/obese participants in comparison to lean participants, presenting evidence for the existence of an early subclinical form of osteosarcopenic obesity. However, unlike the current study, these measurements were made using bio-impedance analysis, which relies on certain assumptions and predictive equations. We speculate that our South-Asian population, with high fat mass and percent body fat and low BFLBM and muscle strength, may have early subclinical osteosarcopenic obesity and that these changes will intensify with age. This helps to explain, at least in part, the 10-20 years earlier occurrence of osteoporotic fractures reported for this group. Such a phenotype was not observed for East-Asians in the current sample, which supports our decision to place East- and South-Asians in different ethnic groups based on their life-style, geographical and cultural differences. Our pilot data supports the notion for early-onset, progressive osteosarcopenic obesity and indicates that it is influenced by race/ethnicity, with South-Asians constituting the high-risk group. However, future studies with large sample size and including a wider age range are required to affirm our proposition.

Limitations

These findings must be considered in the context of several limitations. We did not find any differences in BMD at the femoral neck and lumbar spine, which are the sites designated for diagnosis of osteoporosis. This result may be due to the small sample size and the young age of our participants. Nevertheless, our interest in these preliminary findings was not to identify individuals at risk of osteoporosis, but to report that the bone-muscle-fat unit is influenced by ethnicity, and that South-Asian women may be more susceptible to the deleterious effects of any interactive dysfunction between these three tissues. Further investigations are necessary to confirm these results. In addition, the participants in this study were all volunteers and may not be representative of the general population. We did not perform any DNA genotyping and relied on self-identification of participants into one of the five racial/ethnic groups, which is typically the case for such studies. Our analysis does not take into account all the factors that can impact BMD or can differ with ethnicity, and the small sample size limited our ability to control for confounding variables. The cross-sectional design of this study does not define causality or any dynamic changes occurring in bone, muscle and fat. Moreover, we used DXA to assess bone mineral density, which does not differentiate between cortical and trabecular bone compartments or give any details of bone microarchitecture, which can vary by ethnicity. We also did not report BMD Z-scores for femoral neck, trochanter, and total hip due to technical limitations.

Conclusion

Based on the findings of this pilot data we conclude that African-Americans have a higher BMD at the left and right trochanter and higher BMC at several sites in comparison to South-Asians and Hispanics. In addition, South-Asians have significantly higher total body fat percent and fat mass, and lower BFLBM and strength than East-Asians and Caucasians. We believe that ethnicity-oriented studies are essential, since they help to identify at-risk groups and to create ethnicity-specific diagnostic and therapeutic interventions. The results of this study emphasize the need for structured exercise programs in young adults focused on increasing muscle mass/strength and decreasing fat mass to enhance their bone density, thus reducing the risk of fractures later in life.

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