Osteoporosis International (2019) 30:201–209
https://doi.org/10.1007/s00198-018-4729-9

ORIGINAL ARTICLE

Trabecular microstructure is influenced by race and sex in Black and White young adults

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Received: 22 May 2018 / Accepted: 1 October 2018 / Published online: 5 November 2018

Abstract

Summary Lower fracture rates in Black men and women compared to their White counterparts are incompletely understood. High-resolution imaging specific to trabecular bone may provide insight. Black participants have enhanced trabecular morphology. These differences may contribute to the lower fracture risk in Black versus White individuals.

Introduction Lower fracture rates in Black men and women compared to their White counterparts may be explained by favorable bone microstructure in Black individuals. Individual trabecular segmentation (ITS) analysis, which characterizes the alignment and plate- and rod-like nature of trabecular bone using high-resolution peripheral quantitative computed tomography (HR-pQCT), may provide insight into trabecular differences by race/ethnic origin.

Purpose We determined differences in trabecular bone microarchitecture, connectivity, and alignment according to race/ethnic origin and sex in young adults.

Methods We analyzed HR-pQCT scans of 184 adult (24.2 ± 3.4 years) women ($n = 51$ Black, $n = 50$ White) and men ($n = 34$ Black, $n = 49$ White). We used ANCOVA to compare bone outcomes, and adjusted for age, height, and weight.

Results Overall, the effect of race on bone outcomes did not differ by sex, and the effect of sex on bone outcomes did not differ by race. After adjusting for covariates, Black participants and men of both races had greater trabecular plate volume fraction, plate thickness, plate number density, plate surface area, and greater axial alignment of trabeculae, leading to higher trabecular bone stiffness compared to White participants and women, respectively ($p < 0.05$ for all).

Conclusion These findings demonstrate that more favorable bone microarchitecture in Black individuals compared to White individuals and in men compared to women is not unique to the cortical bone compartment. Enhanced plate-like morphology and greater trabecular axial alignment, established in young adulthood, may contribute to the improved bone strength and lower fracture risk in Black versus White individuals and in men compared to women.

Keywords Bone mineral density (BMD) · Fracture risk · Gender · High-resolution peripheral quantitative computed tomography (HR-pQCT) · Individual trabecular segmentation · Stress fracture risk

Introduction

African-American/Black men and women have lower incidence of fractures in both youth and older adulthood than Caucasian/White men and women, respectively [1–5]. The higher areal bone mineral density (aBMD) observed among Black individuals compared to Whites of all ages [6–9] does not entirely account for their lower fracture risk. [10–12] We

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previously performed a cross-sectional study using high-resolution peripheral quantitative computed tomography (HR-pQCT) to determine differences in bone morphology, microarchitecture, and micro finite element analysis (μFEA) derived bone strength of the distal tibia, according to sex and race in young Black and White adults [13]. We found that advantageous bone strength among Black men and women appears attributable to denser, less porous, and thicker cortices compared to White individuals. Similarly, among men, we found stronger estimates of bone strength attributable to larger bones with denser and thicker cortices compared to women. While these differences were notable, many trabecular bone characteristics were similar regardless of race or sex.

A more detailed analysis of trabecular bone morphology may promote further understanding of bone strength and morphology differences by sex and race. Individual trabecular segmentation (ITS) provides the ability to characterize trabecular connectivity, axial alignment, and plate- and rod-like qualities of individual trabeculae and has been shown to accurately predict elastic modulus and yield strength of trabecular bone [14]. Previous studies have shown that differences in plate and rod characteristics, as well as alignment of the trabeculae, may help explain skeletal fragility in premenopausal women with and without idiopathic osteoporosis [15], in female athletes with and without menstrual disturbances [16], in young adults with and without cystic fibrosis [17], and among various groups of different race/ethnic origin [18–20]. In particular, studies assessing trabecular morphology in Asian and White men [18] and women [19] reported more favorable trabecular structure, namely greater plate-like morphology and higher axial alignment in Asians that may contribute to their lower fracture rates despite their lower aBMD. Also, peri- and postmenopausal Black women have more plate-like trabecular morphology and higher axial alignment of trabeculae compared to White women of similar age, while White women have more rod-like trabeculae—differences that may explain the decreased fracture risk observed in Black individuals compared to White individuals that are not completely reflected by DXA and standard HR-pQCT measurements [20]. ITS has yet to be utilized to determine differences in trabecular morphology among young Black and White adults.

The primary aim of this study was to characterize differences in plate- and rod-like qualities, connectivity, and axial alignment of trabecular bone of the distal tibia according to sex and race in young Black and White adults. The secondary aim was to determine the association of ITS parameters to apparent modulus of the trabecular bone in the superior to inferior direction as estimated by μFEA. We hypothesized that Black individuals and men of both races will have more axially aligned and plate-like trabeculae compared to White individuals and women, respectively, and that this favorable trabecular morphology will be positively correlated with apparent modulus of the trabecular bone by μFEA.

Materials and methods

Participant characteristics

Participant recruitment and eligibility have been reported previously [13]. Briefly, we enrolled 184 Black and White men and women between the ages of 18–30. Exclusion criteria included underlying medical conditions or use of medications known to affect bone health, history of an eating disorder, and history of bilateral lower limb fractures. Women were excluded if they experienced fewer than 9 menses in the prior 12 months. This study was approved by the Institutional Review Board of Partners Health Care and the Human Research Protection Office at the U.S. Army Medical Research and Materiel Command. Informed written consent was obtained from each participant prior to participation in the study.

We assessed clinical history and covariates as previously described [13]. In brief, questionnaires were administered to assess health history, fracture history, and lifestyle factors. We also queried participants about their use of calcium and vitamin D supplements. Height (to the nearest millimeter) was obtained using a wall-mounted stadiometer. Body mass (to the nearest 0.1 kg) was measured on a calibrated electronic scale. Body mass index (BMI) was calculated as mass (kg) divided by height squared (m^2).

Bone microarchitecture

We measured cortical and trabecular vBMD and microarchitecture at the distal tibia using HR-pQCT (XtremeCT, Scanco Medical AG, Basserdorf, Switzerland; isotropic voxel size of 82 μm). The scan region started at 4% of tibial length (distal) and extended proximally for 110 slices (9.02 mm) as previously described. [13] We measured tibia length from the medial tibial plateau to the distal edge of the medial malleolus to the nearest mm using an anthropometric tape. The non-dominant leg was scanned unless there was a prior fracture at that region in which case the contralateral side was scanned. Quality control was maintained with daily scanning of the manufacturer's phantom. Scans were reviewed by investigators for motion artifact and were repeated if significant motion artifact was noted [21]. Scanco analysis software version 5.11 was used to obtain standard HR-pQCT outcomes.

Apparent Modulus by μFEA

Using HR-pQCT images, we determined the apparent modulus of the trabecular bone in the superior-inferior direction, as previously described [22]. The trabecular compartment analyzed had rectangular cross section, and the dimensions were varied, depending on the size of the tibia, to maximize the trabecular-bone region considered for μFEA. We assigned

each element of the μFEA model with a linear-elastic material property (a Young's modulus of 10 GPa and Poisson's ratio of 0.3).

ITS analysis

The trabecular bone compartment was extracted from each HR-pQCT image. ITS analyses were performed on each entire trabecular bone compartment as previously described [15, 23, 24]. After complete volumetric decomposition was performed using established methods [15, 24], morphological parameters obtained from the ITS algorithm included total trabecular bone volume fraction (BV/TV), plate and rod bone volume fraction (pBV/TV and rBV/TV, respectively), trabecular orientation (axial bone volume fraction; (aBV/TV, respectively)), plate and rod number density (pTbN and rTbN, respectively), plate and rod thickness (pTbTh and rTbTh, respectively), plate surface area (pTbS), rod length (rTbl), plate and rod tissue fraction (pBV/BV and rBV/BV, respectively), and plate-plate, plate-rod, and rod-rod junction density (P-PJuncD, P-RJuncD, and R-RJuncD). In addition, we calculated the plate to rod ratio (pBV/rBV).

Statistical analysis

Data are reported as mean ± one standard deviation (SD) unless otherwise noted. We performed a two-way ANOVA to assess between-group differences and assess race by sex interactions for participant demographics, covariates, and bone outcomes. Univariate regression analyses were used to determine association of age, height, and weight with bone microarchitectural parameters. Because all three variables were significantly associated with ITS parameters and differed among study groups, we next used an analysis of covariance (ANCOVA) to control for these variables while assessing differences by race and sex. In order to account for potential lifestyle factors that may influence ITS parameters by race and sex, we added physical activity and family income as independent variables to the ANCOVA and compared differences between groups using pairwise comparisons. Less than 3% of participants reported using calcium and/or vitamin D supplements; therefore, we did not adjust the models for supplement use.

To determine association between trabecular plate and rod parameters and estimated apparent modulus of the trabecular bone by μFEA, we performed Pearson's correlations followed by multiple linear regressions. To determine which variables to include in the regression model, we first looked for highly correlated variables ($r \geq 0.8$) and created clusters of these variables. To account for collinearity in the regression model, based on biomechanical relevance, we chose one variable from each cluster to enter into the regression model along with the trabecular plate and rod parameters that were not included in the clusters. Comparisons with a p value of < 0.05 are reported as statistically significant. We used Stata version 14.2 (StataCorp LP, College Station, TX) for all statistical analyses.

Results

Participant characteristics

As previously reported, [13] Black individuals were slightly younger, participated in fewer hours of recent physical activity per week, and had a history of fewer fractures, on average, than White participants. Women weighed less, were shorter, had a lower BMI, participated in fewer hours of recent weight-bearing physical activity per week, and had experienced fewer fractures than men ($p < 0.05$ for all, Table 1). There was a relatively high incidence of fractures among White individuals. Notably 85% of fractures were due to sports-related injuries, falls, and motor vehicle accidents. The remaining 15% were due to other accidents (i.e., collisions during child's play, and blunt force trauma).

ITS parameters

ITS outcomes were generally more favorable in Black than White adults and also more favorable in men than women (Table 2, Fig. 1). The effect of race/ethnic-origin was largely independent of sex. In analyses adjusted for age, height, and weight, Black men and women had greater pBV/TV, pBV/BV, pTbN, pTbS, and (pBV/BV)/(rBV/BV) compared to their White counterparts ($p < 0.01$ for all, Table 2, Fig. 2). Black men and women also had greater axial alignment within the trabecular compartment compared to White men and women, respectively. In contrast, White individuals had greater rBV/TV, rBV/BV, rTbN, R-RJuncD, and R-PJuncD compared to Black men and women ($p < 0.05$ for all, Table 2, Fig. 2).

Most morphological parameters were more favorable in men compared to women. After adjustment for age, height, and weight, men had greater total BV/TV, pBV/TV, aBV/TV, pBV/BV, (pBV/BV)/(rBV/BV), pTbTh, pTbN, rTbTh, pTbS, and P-PJuncD ($p < 0.01$ for all) compared to women. Conversely, women had greater rBV/TV, rBV/BV, rTbN, and R-RJuncD compared to men ($p < 0.05$ for all).

In an additional model adjusting for age, height, weight, physical activity, and family income, morphological results by race and sex were unchanged.

ITS predictors of trabecular bone strength by μFEA

As reported previously, μFEA-derived apparent modulus of the trabecular bone in the superior to inferior direction was similar between Black and White individuals, but higher among men

Table 1 Clinical characteristics of study participants. Values are mean (SD) or *n* (%). Bold text indicates statistical significance

	White women *n* = 50	Black women *n* = 51	White men *n* = 49	Black Men *n* = 34	*p* race/sex interaction	*p* race	*p* sex
Age (years)	25.6 (2.9)	22.6 (3.2)	25.1 (3.1)	24.3 (3.6)	**0.03**	**< 0.001**	0.2
Height (cm)	164.9(10.8)	166.1 (7.9)	179.8 (8.0)	177.8 (7.4)	0.2	0.7	**< 0.001**
Weight (kg)	63.4 (9.6)	64.4 (10.2)	78.6 (11.6)	78.2 (11.4)	0.7	0.9	**< 0.001**
BMI (kg/m$^{2)}$	23.3 (3.2)	23.3 (2.5)	24.3 (2.9)	24.9 (3.4)	0.7	0.3	**0.01**
Tibia length (mm)	367.9 (24.1)	378.3 (29.2)	408.0 (29.0)	413.4 (30.7)	0.6	0.06	**< 0.001**
Physical activity (h/week)	4.9 (4.3)	2.3 (2.8)	5.9 (5.5)	5.1 (8.6)	0.2	**0.03**	**0.02**
Age of menarche (years)	12.8 (1.6)	11.8 (1.3)			–	0.3	–
Fracture history (total)	18 (36%)	4 (8%)	24 (49%)	6 (18%)	0.7	**< 0.001**	0.05
Family income					**0.02**	**< 0.001**	0.9
< $20 K	0 (0%)	6 (11.8%)	0 (0%)	4 (11.7%)			
$20 K to $99 K	27 (54%)	27 (52.9%)	13 (26%)	22 (64.8%)			
> $100 K	23 (46%)	18 (35.3%)	36 (74%)	8 (23.5%)			
Current smoking					0.5	0.5	0.5
Daily	0 (0%)	0 (0%)	0 (0%)	1 (2.9%)			
< Daily	1 (2%)	1 (2%)	1 (2%)	0 (0%)			
None	49 (98%)	50 (98%)	48 (98%)	33 (97.1%)			
Hormonal contraceptive use					–	**< 0.001**	
Current use	37 (74%)	13 (25.5%)					
Past use	7 (14%)	9 (17.6%)					
No use	6 (12%)	29 (56.9%)					

compared to women [22]. Among the cohort as a whole, BV/TV ($r = 0.89$), pBV/TV ($r = 0.66$), aBV/TV ($r = 0.60$), P-RJuncD ($r = 0.71$), and P-PJuncD ($r = 0.87$) had moderate to strong positive correlations with the apparent modulus. In a multivariable model, pBV/TV, rBV/TV, pTbN, pTbTh, pTbS, rTbl, R-Pjunc, and P-Pjunc explained 84% of the variation in estimated apparent modulus of the trabecular bone. Independent predictors of apparent modulus in this model were pBV/TV, pTbTh, and rTbl (Table 3), which alone explained 70% of the variation in estimated apparent modulus.

Because pBV/TV and aBV/TV were highly correlated ($r = 0.98$), aBV/TV was removed from our final multivariate model. Thus, when we replaced pBV/TV with aBV/TV, as expected, the model explained 84% of the variation in apparent modulus.

Discussion

Our study revealed that young adults of Black/African-American race have advantageous plate-like trabecular bone qualities in addition to greater axial alignment compared to their White/Caucasian counterparts. Similarly, men have optimized plate-like trabecular bone qualities and greater axial alignment compared to women. Our previous analysis of bone microstructure from HR-pQCT images of the tibia suggested that morphological differences by race and sex were more notable in cortical bone compared to trabecular bone. However, the current analysis of trabecular bone via ITS indicates that trabecular bone morphology may also contribute information regarding prediction of estimated apparent modulus and, thus, bone strength.

Our previous findings using HR-pQCT scans in the same cohort revealed that advantageous bone strength among Black individuals appeared to be attributable to denser, less porous, and thicker cortices compared to White individuals. Among men, greater bone strength was due to larger bones with denser and thicker cortices compared to women [13]. While there were differences in some trabecular parameters, trabecular vBMD was similar in Black and White participants, and between men and women. In this study, ITS analysis revealed additional differences in trabecular morphology. In particular, Black men and women have greater pBV/TV, pTbTh, pTbN, and pTbS in addition to greater axial alignment of trabeculae compared to White men and women. Our findings of advantageous trabecular alignment and morphology among young Black adults compared to young White adults align with our prior study in older Black and White women, which showed that Black women have more plate-like trabecular morphology with higher axial alignment, while White women have more rod-like trabeculae [9]. That earlier study also demonstrated that whole bone failure load, estimated by μFEA, was

Table 2 Adjusted mean (SE) values for individual trabecular segmentation analyses at the distal tibia (4%) among Black and White men and women adjusted for height, weight, and age. Bold text indicates statistical significance

	White women $n = 50$	Black women $n = 51$	White men $n = 49$	Black men $n = 34$	p race/sex interaction	p race	p sex
BV/TV	0.323 (0.007)[b]	0.330 (0.007)	0.361 (0.007)	0.349 (0.007)	0.13	0.7	**0.001**
pBV/TV	0.131 (0.007)[a,b]	0.162 (0.007)[c]	0.187 (0.007)[c]	0.212 (0.008)	0.6	**< 0.001**	**< 0.001**
rBV/TV	0.192 (0.006)[a]	0.168 (0.006)[c]	0.174 (0.006)[c]	0.137 (0.007)	0.2	**< 0.001**	**0.001**
aBV/TV	0.125 (0.005)[a,b]	0.147 (0.005)[c]	0.161 (0.005)[c]	0.181 (0.006)	0.9	**< 0.001**	**< 0.001**
pBV/BV	0.403 (0.017)[a,b]	0.491 (0.016)[c]	0.513 (0.017)[c]	0.609 (0.019)	0.8	**< 0.001**	**< 0.001**
rBV/BV	0.597 (0.017)[a,b]	0.509 (0.016)[c]	0.487 (0.017)[c]	0.391 (0.020)	0.8	**< 0.001**	**< 0.001**
pBV/rBV	0.721 (0.081)[a,b]	1.043 (0.076)[c]	1.169 (0.081)[c]	1.671 (0.090)	0.2	**< 0.001**	**< 0.001**
pTbN (1/mm)	1.53 (0.02)[a,b]	1.61 (0.02)	1.63 (0.02)	1.64 (0.02)	0.3	**0.002**	**0.003**
rTbN (1/mm)	1.95 (0.02)[a,b]	1.85 (0.02)[c]	1.85 (0.02)[c]	1.70 (.03)	0.2	**< 0.001**	**< 0.001**
pTbTh (mm)	0.227 (0.003)[b]	0.229 (0.003)[c]	0.242 (0.004)	0.241 (0.004)	0.7	0.9	**0.002**
rTbTh (mm)	0.216 (0.0007)	0.217 (0.0007)[c]	0.217 (0.0007)	0.219 (0.0008)	0.4	0.1	**0.02**
pTbS (mm^2)	0.161 (0.003)[a,b]	0.169 (0.002)[c]	0.178 (0.003)[c]	0.189 (0.003)	0.5	**< 0.001**	**< 0.001**
rTbl (mm)	0.637 (0.003)[a,b]	0.645 (0.003)[c]	0.647 (0.003)[c]	0.659 (0.004)	0.6	**0.001**	**0.002**
P-P junc ($1/mm^3$)	2.68 (0.09)[a,b]	2.95 (0.09)	3.24 (0.09)	3.09 (0.1)	**0.02**	0.5	**0.003**
R-R junc ($1/mm^3$)	3.49 (0.15)[a,b]	2.77 (0.15)[c]	2.87 (0.16)[c]	1.92 (0.18)	0.5	**< 0.001**	**< 0.001**
R-P junc ($1/mm^3$)	5.25 (0.17)	5.28 (0.16)	5.68 (0.17)[c]	4.84 (0.19)	**< 0.007**	**0.01**	0.9
Apparent modulus (GPa)	2.33 (0.08)	2.48 (0.08)	2.71 (0.09)	2.61 (0.10)	0.11	0.8	**0.02**

BV/TV total trabecular bone volume fraction, *pBV/TV* plate bone volume fraction, *rBV/TV* rod bone volume fraction, aBV/TV = axial bone volume fraction, *pBV/BV* plate tissue fraction, *rBV/BV* rod tissue fraction, *pBV/rBV* plate to rod ratio, *pTbN* plate number density, *rTbN* rod number density, *pTbTh* plate thickness, *rTbTh* rod thickness, *pTbS* plate surface area, *rTbl* rod length, *P-Pjunc* plate-plate junction density, *R-Rjunc* rod-rod junction density, *R-Pjunc* rod-plate junction density. Significance was defined by a p value < 0.05 after adjusting for height, weight, and age. [a] $p < 0.05$ vs. Black women; [b] $p < 0.05$ vs. White men; [c] $p < 0.05$ vs Black men

strongly associated with plate-like trabecular morphology and axial alignment of trabecular bone qualities. Our current findings confirm and extend these observations, suggesting that differences in trabecular morphology according to race have developed by young adulthood.

Our results are consistent with a study of iliac trabecular bone histomorphometry in Black and White South African adults ages 21–83, which reported that Black men and women have thicker trabeculae than White men and women, independent of age [25]. Of note, trabecular thickness declined with age in all participants, except Black men. Similarly, trabecular number declined and trabecular separation increased with age in all participants except Black women. These findings suggest that in addition to having advantageous trabecular morphology throughout life, Black men and women have less deterioration in trabecular bone features with aging compared to their White counterparts. Together, these studies indicate that advantageous trabecular morphology observed among Black compared to White individuals is present in young adulthood and may be amplified with age—findings consistent with the lower fracture incidence among Black compared to White adults in our cohort, the lower stress fracture risk among Black versus White active adults, [1, 5] and lower fracture risk observed among Black versus White individuals throughout life [3, 4].

Prior HR-pQCT studies report principally similar trabecular bone morphology between men and women, except for consistently higher trabecular thickness among men versus women. [26–29] Consistent with these observations, we previously reported comparable trabecular microstructure between young adult men and women, with the exception of higher trabecular thickness in men. [13] However, ITS analyses revealed both greater plate-like and more axially aligned trabecular bone morphology in men compared to women, suggesting that in addition to superior cortical parameters, trabecular bone characteristics are also more favorable in men compared to women and may contribute to their lower incidence of fractures.

Our data do not allow us to determine the cause of different trabecular morphology among Black compared to White participants or among men compared to women. Prior literature suggests a combination of genetic and lifestyle factors may influence bone morphology [16, 30–37]. For example, mechanical loading has been shown to alter trabecular alignment in the proximal femur [38], patella [39], and calcaneus [40]. We attempted to account for mechanical loading by adjusting for physical activity in our statistical model. However, this adjustment did not impact our results. Moreover, despite having better trabecular bone morphology, Black individuals were significantly less active compared to White individuals. When we adjusted for family income as a proxy for socioeconomic status

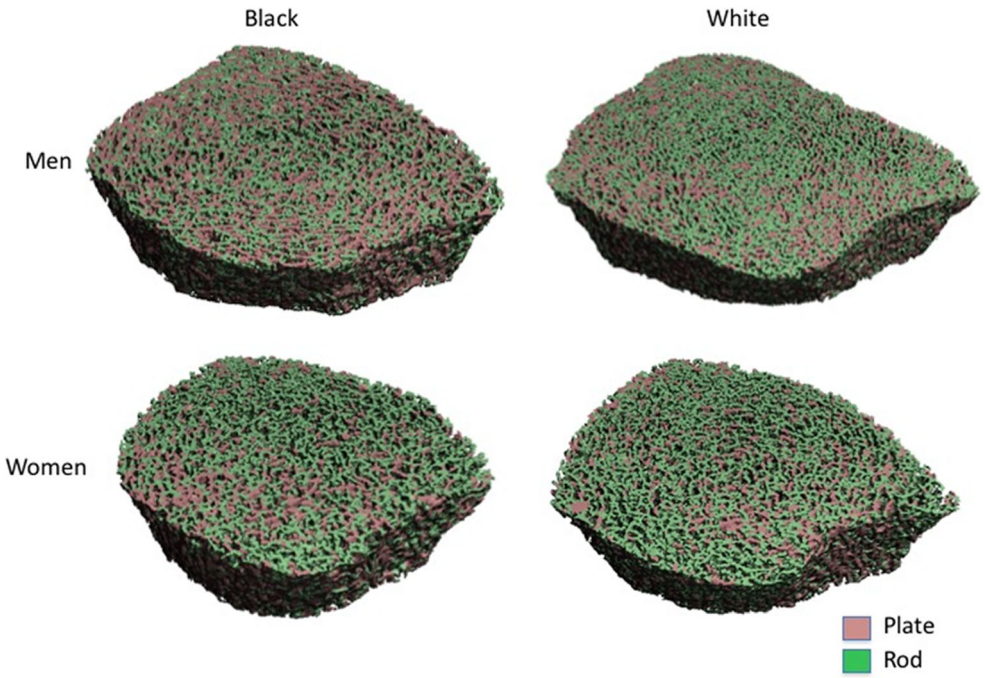

Fig. 1 Representative ITS images of the distal tibia of Black and White men and women

(SES), we also saw no difference in our results, though higher SES has previously been associated with improved BMD by DXA [41]. Thus, it is likely that other environmental and lifestyle factors that we did not assess, including factors present during the period of peak bone accrual, and their interaction with underlying differences due to genetic ancestry, contributed to the patterns of trabecular morphology seen here.

Our current analysis revealed that apparent modulus of the trabecular bone from μFEA was more strongly associated with plate-like trabecular bone characteristics and axial alignment of trabeculae than with rod-like parameters. These findings are congruent with previous in vitro studies that report trabecular alignment and proportion of plate-like trabeculae as being key contributors to the mechanical properties of trabecular bone

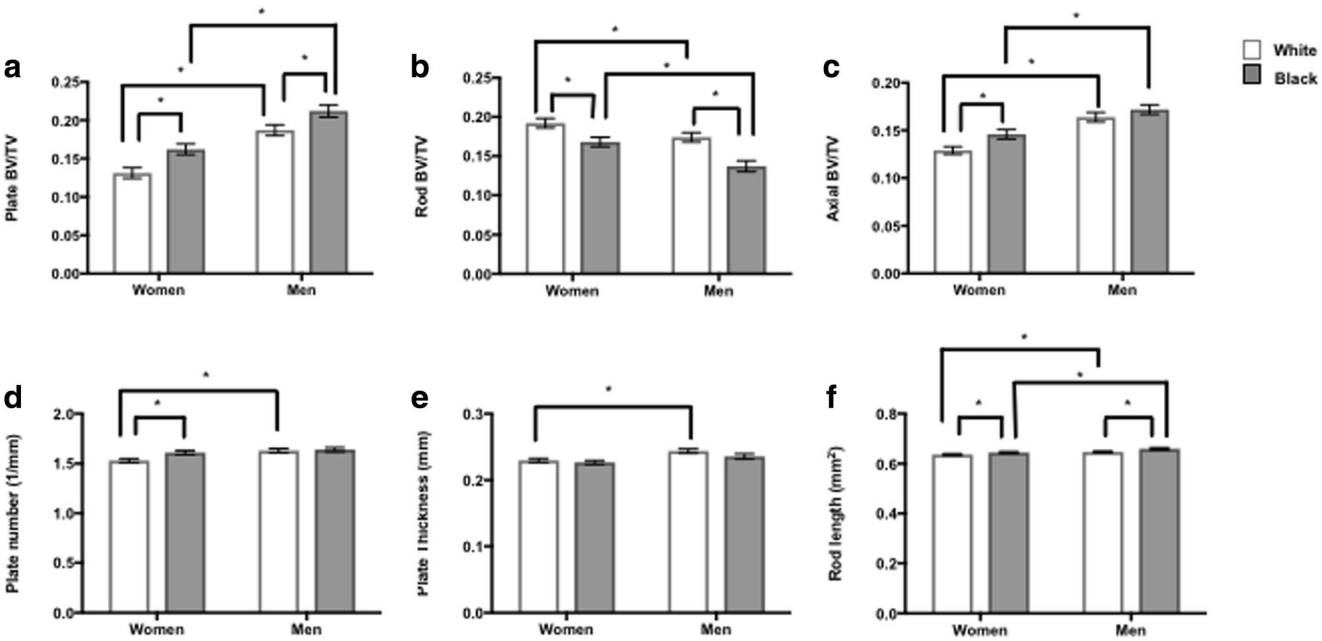

Fig. 2 Trabecular bone morphology at the distal tibia in White and Black men and women after multivariate adjustment (Mean ± SE). **a** Plate BV/TV. **b** Rod BV/TV. **c** Axial BV/TV. **d** Plate number. **e** Plate thickness. **f** Rod length for White and Black women and men. Multivariate model adjusted for height, weight, and age. *$p < 0.05$

Table 3 *P* values and standardized regression coefficients β of the predictors of μFEA-estimated trabecular apparent modulus at the distal tibia. Bold text indicates statistical significance

	Univariate correlation	Multiple regression	
	p value	β	*p* value
pBV/TV	**< 0.001**	0.57	**0.01**
rBV/TV	**0.02**	0.30	0.09
pTbN (1/mm)	**< 0.001**	0.04	0.87
pTbTh (mm)	**< 0.001**	0.29	**0.03**
pTbS (mm^2)	**< 0.001**	0.07	0.65
rTbl (mm)	**0.04**	− 0.24	**< 0.001**
P-Pjunc ($1/mm^3$)	**< 0.001**	0.09	0.74
R-Pjunc ($1/mm^3$)	**< 0.001**	0.27	0.27

pBV/TV plate bone volume fraction, *rBV/TV* rod bone volume fraction, *pTbN* plate number density, *pTbTh* plate thickness, *pTbS* plate surface area, *rTbl* rod length, *P-Pjunc* plate-plate junction density, *R-Pjunc* rod-plate junction density

[19, 23, 42, 43]. A study relating ITS-based parameters to experimentally determined trabecular bone elastic modulus found that elastic modulus is primarily determined by a positive association with plate volume fraction and a negative association with trabecular rod length [42]. Also in line with our findings, this same group previously reported that a computationally determined trabecular elastic modulus is significantly correlated to plate volume fraction, plate thickness, and rod thickness. [23]

Several studies have utilized ITS to evaluate differences in trabecular bone morphology of the tibia and/or radius in individuals with and without a history of fragility fractures [44, 45]. Postmenopausal women with a history of fragility fractures consistently show fewer trabecular plates and less axially aligned trabeculae compared to those without fractures [44, 45]. Similarly, compared to young amenorrheic athletes with no history of stress fractures, those with a history of recurrent stress fractures have lower trabecular plate volume, number, and thickness as well as less axially aligned trabecular bone at the distal radius, though no differences at the distal tibia [16]. Altogether, these data support the notion that improved plate-like trabecular morphology and more axially aligned trabeculae lead to greater bone strength and decreased fracture risk.

A strength of this study is the use of a scan location relative to limb length (4% of distal tibia) rather than a fixed location. This approach overcomes potential confounding by differences in bone length and height among groups. Limitations of this study include the cross-sectional design and reliance on self-reported racial background. Although self-report is prone to errors in classification, we asked for confirmation that at least 3 of 4 grandparents identified as the same racial background as the participant to minimize this potential error in classification. We examined only the tibia, and thus cannot say whether these results would be observed at non-weight-bearing sites. We did not have serum samples, and thus cannot assess how differences in bone metabolism may have contributed to differences in trabecular bone structure by race or sex.

Conclusion

Our results confirm and extend prior observations of more advantageous bone characteristics due to sex and race by demonstrating increased plate-like trabecular bone morphology and higher axial alignment of trabeculae in Black compared to White individuals, and in men to women. These results suggest that race- and sex-related differences are established by early adulthood. Our findings further suggest that plate-like trabecular morphology is associated with higher apparent modulus. This advantage in trabecular bone morphology likely contributes to lower fracture and stress fracture risk among Black individuals and men compared to their respective White and women counterparts.

Funding This study is supported by the U.S. Department of Defense, Defense Health Program, and Joint Program Committee (W811XWH-15-C-0024) managed by the U.S. Army Military Operational Medicine Program at the U.S. Army Medical Research and Materiel Command, Fort Detrick, MD, and the National Institutes of Health shared instrumentation grant (S10 RR023405).

Compliance with ethical standards

Conflicts of interest None.

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