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Increased bone mineral density in Aboriginal and Torres Strait Islander Australians: Impact of body composition differences

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ABSTRACT

Bone mineral density (BMD) has been reported to be both higher and lower in Indigenous women from different populations. Body composition data have been reported for Indigenous Australians, but there are few published BMD data in this population. We assessed BMD in 161 Indigenous Australians, identified as Aboriginal ($n=70$), Torres Strait Islander ($n=68$) or both ($n=23$). BMD measurements were made on Norland-XR46 ($n=107$) and Hologic ($n=90$) dual-energy X-ray absorptiometry (DXA) machines. Norland BMD and body composition measurements in these individuals, and also in 36 Caucasian Australians, were converted to equivalent Hologic BMD (BMD_H) and body composition measurements for comparison.

Femoral neck (FN) and lumbar spine *Z*-scores were high in Indigenous participants (mean FN *Z*-score: Indigenous men +0.98, $p<0.0001$ vs. mean zero; Indigenous women +0.82, $p<0.0001$ vs. mean zero). FN BMD_H was higher in Aboriginal and/or Torres Strait Islander than Caucasian participants, after adjusting for age, gender, diabetes and height and remained higher in men after addition of lean mass to the model. We conclude that FN BMD is higher in Aboriginal and/or Torres Strait Islander Australians than Caucasian Australian reference ranges and these differences still remained significant in men after adjustment for lean mass. It remains to be seen whether these BMD differences translate to differences in fracture rates.

1. Introduction

There is a paucity of published data on bone mineral density (BMD) in Indigenous Australians. A cross-sectional study of patients admitted with fractured femoral neck (FN) at Cairns Base Hospital (North Queensland, Australia) suggested a lower incidence (or occurring at a later age) of these fragility fractures in Aboriginal and Torres Strait Islander Australians [1].

It is notable that Canadian Aboriginal women have a disproportionately higher rate of fractures than Caucasian women [2]. The First Nations Bone Health Study (Manitoba, Canada) reported lower BMD, related to increased bone area, after adjustment for weight in Canadian Aboriginal than Caucasian women at the distal forearm, calcaneus and whole body [3]. However, differences in BMD were no longer significant after adjusting for body composition (total fat mass and lean mass), due to the relatively lower lean vs. fat mass in Canadian Aboriginal than Caucasian women [4].

Aboriginal Australians have also been reported to have more fat for a given body mass index (BMI) than Australians of Caucasian background [5], but there are few published data on BMD in Aboriginal Australians [6]. Findings from other studies of BMD in indigenous populations internationally have been inconsistent: South American Aboriginal women had greater BMD at the femur than Caucasians [7]; Native American women in Oklahoma had higher peak BMD than Caucasian women but the post-menopausal rate of bone loss was greater in the American Aboriginal group [8]; a multi-ethnic study of post-menopausal women in the United States reported no difference in BMD between American Aboriginal and Caucasian women after adjustment for weight [9].

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The aim of the current study was to describe BMD in Aboriginal and Torres Strait Islander Australians from the Northern Territory and Far North Queensland, recruited as part of two studies: The estimated glomerular filtration rate (eGFR) Study and Healthy Top-Enders Study. The eGFR Study aimed to improve eGFR estimates in Indigenous Australians, taking into account the heterogeneity in body build and body composition. The Healthy Top-Enders Study aimed to quantify body build and body composition of young healthy Aboriginal Australians (aged 17–25 years).

2. Materials and methods

2.1. Study setting and participants

The methods of the eGFR Study have been previously reported [10]. In brief, 600 Indigenous Australian participants (of Aboriginal and/or Torres Strait Islander background) and 100 Australians of Caucasian background aged 16 years and above were recruited across five predefined strata of health, diabetes status and kidney function from the following regions of Australia: Top End, Northern Territory, Central Australia, remote Western Australia and Far North Queensland. This detailed body composition substudy involved dual-energy X-ray absorptiometry (DXA) to validate other measures of body composition performed in remote locations (such as bioelectric impedance). The DXA substudy was performed in Darwin, capital city of the Northern Territory (September 2008 to May 2010), and Thursday Island, regional centre for the Torres Strait Islands, Far North Queensland (February 2010). Participants were recruited from local communities by word-of-mouth, local media and through local Aboriginal Medical Services and health facilities. The study is not a population representative study and all participants were volunteers. The substudy was approved by the joint Menzies School of Health Research Northern Territory Department of Health Human Research Ethics Committee (including approval by the Aboriginal subcommittee, which has absolute right of veto) and the Cairns and Hinterland Health Services District Human Research Ethics Committee. Participants with chronic kidney disease stages 3–5 (eGFR<60 ml/min/1.73 m^2, $n=22$ Indigenous and $n=13$ Caucasian participants) were excluded from this analysis of BMD.

The Healthy Top-Enders Study was conducted in Darwin, Northern Territory, from October 2009 to May 2010. Participants were healthy, nonpregnant, aged 17–25 years and self-identified as either Aboriginal (with four Aboriginal grandparents, $n=34$) or Caucasian (with four Caucasian grandparents, $n=22$). The study was designed to assess body composition and metabolic and inflammatory risk profile of young adult Aborginal adults who were matched for age, gender and body mass index with Caucasian adults. Participants were excluded if pregnant, had a chronic illness or were athletes. Health was confirmed by HbA1c<6.5%, normal urine albumin/creatinine ratio, blood pressure, and medical questionnaire. Participants provided a fasting blood sample, urine sample and underwent detailed body composition assessment including DXA and abdominal computer tomography. The study was approved by the joint Menzies School of Health Research Northern Territory Department of Health Human Research Ethics Committee

2.2. Ethnicity, anthropometry, risk factor assessment

Indigenous Australians fulfilled the definition of 'Aboriginal and/or Torres Strait Islander' according to the standard method used in National Census data collection:

"1) is of Aboriginal and/or Torres Strait Islander descent; 2) identifies as an Australian Aboriginal and/or Torres Strait Islander; and 3) is accepted as such by the community in which he or she lives or has lived." The ethnicity of Indigenous and Caucasian participants' four grandparents was also collected: 54% of Indigenous participants reported four Indigenous grandparents and 92% reported at least two Indigenous grandparents; 45% of Indigenous participants primarily spoke an Aboriginal or Torres Strait Islander language at home.

Body weight was recorded to the nearest 0.1 kg using a Seca digital portable scale (Model 767 and 841, Seca Deutschland, Hamburg, Germany). Height was measured to the nearest 0.1 cm using a wall-mounted stadiometer. Waist and hip circumferences were measured in centimeters using a 2-m nonstretch, but flexible, steel tape (Model W606PM Lufkin, Texas, USA). Interviewer-administered questionnaires determined cigarette smoking, alcohol use, diabetes diagnosis, self-reported fracture history. Nonfasting bloods were collected for analysis of HbA1c, creatinine and other measures [10]. Diabetes was defined as a previous diagnosis of diabetes or HbA1c≥6.5% [11]. Alcohol use was defined as any consumption of alcohol. Fractures were coded as hip, vertebral, other major (pelvic, distal femur, proximal tibia, multiple rib and proximal humerus) or minor (all other fractures including distal arm and leg but excluding facial fractures) [12]. Methods of Healthy Top-Enders Study were the same as those above with the exception that bloods were collected fasting. The same techniques and standard operating procedure for measuring weight, height, waist and hip measurements were employed in both the eGFR study and Healthy Top Enders Study [10]. A single investigator performed all measures in the Healthy Top-Enders study (JH). This investigator was also responsible for training and quality assurance of the four other operators in the eGFR Study. For the eGFR study, maximum interoperator differences, in circumference measurements, were as follows: waist 3.1%; hip 2.1%.

2.3. DXA measurements

BMD was measured at the lumbar spine (LS, L2-L4), femoral neck (FN) and whole body (WB) in all participants using DXA scans. Fat mass (FM), lean mass (LM; nonfat, nonbone), percent lean mass (LM divided by sum of FM, LM and BMC) and percent fat mass (FM divided by sum of FM, LM and BMC) were derived from the whole body DXA scan. The measurements performed in Darwin ($n=106$) were performed at NT Medical Imaging, Casuarina, on a Norland XR46 (Cooper Surgical Co., Trumbull, CT, USA) whole body DXA device. Scan analysis was performed using Illuminatus software (version 4.2.4a). For the scans performed on Thursday Island ($n=90$), a Hologic Delphi W (SN-70034) (Hologic, Inc., Bedford, MA) whole body DXA device (permanently installed in a vehicle) was transported to Thursday Island. The vehicle was stabilised so that the DXA device remained level for each scan, and a trained operator completed all scans and analyzed the results, using the QDR system software for Windows (XP) Hologic software APEX 3.0 (Hologic). As part of our quality control procedures, the spine phantom was scanned each morning prior to scanning. The coefficient of variation for BMD of the spine phantom was 0.352% (Hologic) and 0.59% (Norland). The DXA scanner used for participants in each group was as follows:

DXA scanner	Number of participants (%)			
	Aboriginal	Torres Strait Islander	Aboriginal and Torres Strait Islander	Caucasian
Norland	69 (100)	3 (4)	6 (26)	28 (78)
Hologic	0 (0)	65 (96)	17 (74)	8 (22)
Total	69 (100)	68 (100)	23 (100)	36 (100)

DXA was performed on the same day as anthropometry in 154 participants (78%) and within 2 weeks in all other participants.

2.4. Data analysis

To standardize results from different DXA manufacturers, Norland BMD data (FN and LS spine) were converted to Hologic BMD (BMD_H, g/cm^2) using published conversion equations for the hip subregions [13,14] and spine [15]. The Geelong reference ranges were used to

calculate T and *Z*-scores, using Geelong T and *Z*-score reference ranges for Hologic and Norland DXA machines for women [16], and by converting BMD measured on Hologic and Norland DXA machines, to equivalent Lunar BMD values for men before using the Geelong T and *Z*-score reference range [17]. The Geelong reference range without spinal abnormalities was used for LS *Z*-score in men [17]. Similarly, body composition measurements using the Norland DXA machine were converted to equivalent Hologic values, using published conversion equations [18,19].

Data analysis was performed using STATA v10.0 (Stata Corporation, TX, USA). Data are presented as mean (standard deviation). Pearson chi-square tests (categorical variables) performed to determine associations between variables; one-way analysis of variance (ANOVA) used to determine differences for normally distributed continuous variables. If differences existed on one-way analysis of variance, the groups involved were identified using an unpaired *t* test with the Bonferroni correction. (across three groups: Aboriginal, Torres Strait Islander, both Aboriginal and Torres Strait Islander). Analyses were similarly performed in the subgroup aged 20–29 years. Age-adjusted analysis in the whole group was performed using analysis of covariance (ANCOVA), with post-estimation multiple comparisons between groups using Tukey–Kramer (TK) test for pairwise comparisons. Mean *Z*-scores were compared to a mean of zero using a one-sample *t* test. Pairwise correlations were assessed using Pearson's product–moment correlation coefficient, between baseline variables and BMD_H, in the FN and LS regions. Established risk factors and variables identified in univariate analyses were then included in backward stepwise multiple regression analysis of FN and LS BMD_H. Model fit was assessed using likelihood ratio–chi square. Statistical significance accepted at $p<0.05$.

3. Results

Participants (Table 1) were stratified by gender and ethnic group. Aboriginal women were younger and had lower weight and BMI than Torres Strait Islander women, but similar waist–hip ratio. All anthropometric differences remained significant ($p<0.05$) after adjustment for age.

Table 1
Participant characteristics. Data are mean ± standard deviation or *n* (%).

	Aboriginal	Torres Strait Islander	Both Aboriginal and Torres Strait Islander
Females	$n=39$	$n=41$	$n=14$
Age (years)	36.4 ± 17.4	45.7 ± 14.4[a]	51.0 ± 11.3[a]
Height (cm)	161.7 ± 5.9	162.8 ± 6.1	161.0 ± 6.7
Weight (kg)	70.7 ± 14.2	86.5 ± 19.8[b]	86.8 ± 17.2[a]
BMI (kg/m^2)	27.0 ± 5.1	32.5 ± 6.7[b]	33.4 ± 5.6[a]
Waist (cm)	92 ± 15	101 ± 15[a]	105 ± 12[a]
Hip (cm)	104 ± 11	114 ± 14[b]	114 ± 12[a]
Waist–hip ratio	0.89 ± 0.11	0.88 ± 0.07	0.93 ± 0.06
%Diabetes	7 (18%)	16 (39%)[a]	7 (50%)[a]
%Current smokers	17 (49%)	9 (23%)[a]	6 (43%)
%Drink alcohol	16 (70%)	21 (55%)	6 (55%)
Males	$n=31$	$n=27$	$n=9$
Age (years)	29.4 ± 14.8	43.7 ± 17.2[a]	40.1 ± 17.7
Height (cm)	174.0 ± 7.6	175.2 ± 6.4	174.7 ± 10.7
Weight (kg)	82.4 ± 22.1	95.3 ± 24.8	96.9 ± 31.6
BMI (kg/m^2)	27.1 ± 6.6	31.1 ± 8.4	31.1 ± 7.7
Waist (cm)	94 ± 19	102 ± 18	99 ± 18
Hip (cm)	103 ± 13	108 ± 16	108 ± 14
Waist–hip ratio	0.91 ± 0.10	0.94 ± 0.08	0.92 ± 0.08
%Diabetes	8 (26%)	7 (26%)	2 (22%)
%Current smokers	14 (47%)	11 (42%)	3 (33%)
%Drink alcohol	21 (91%)	21 (84%)	5 (56%)[a]

Number of participants with missing data: Females: waist (5), hip (5), waist–hip ratio (5), smoking (5), alcohol (22). Males: waist (2), hip (2), waist–hip ratio (2), smoking (2), alcohol (10).
[a] $p<0.05$, compared to Aboriginal group of same gender.
[b] $p<0.005$, compared to Aboriginal group of same gender.

Of the 117 Indigenous participants with self-reported fracture data, 21% reported at least one previous fracture. For these Indigenous participants, no hip or vertebral fractures were reported. The vast majority were minor fractures (75%), usually associated with trauma such as sporting injury or assault. The remaining Indigenous participants ($n=6$, 25%) reported a major fracture that was neither hip nor vertebral.

Body composition differences were evident between Indigenous groups (Table 2). Aboriginal women had less lean mass than Torres Strait Islander women ($p<0.001$), with differences remaining after age adjustment (age-adjusted mean Aboriginal vs. Torres Strait Islander 41.6 vs. 49.5 kg, TK test 6.6, $p<0.05$). Aboriginal men had a trend towards less lean mass than Torres Strait Islander men ($p=0.055$), which was statistically significant after adjustment for age (age-adjusted mean Aboriginal vs. Torres Strait Islander 57.8 vs. 66.5 kg, TK test 4.1, $p<0.05$). There were no significant differences in FN or LS BMD_H between Indigenous groups for women or men (Table 2), including after adjustment for age.

Distribution of FN *Z*-scores was shifted to the right of zero for Indigenous Australians, in both men and women (Fig. 1). Mean FN *Z*-score in Indigenous Australians was significantly greater than a *Z*-score mean of zero (using the Geelong Australian reference range) on one-sample *t* test: Indigenous men +0.98, $p<0.0001$ vs. mean zero; Indigenous women +0.82, $p<0.0001$ vs. mean zero. LS mean *Z*-scores were also significantly higher in Indigenous Australian men and women compared to a *Z*-score mean of zero (using the Geelong Australian reference range), although the mean LS values were not as high as at the femoral neck: Indigenous men +0.54, $p=0.0025$ vs. mean zero; Indigenous women +0.48, $p=0.0006$ vs. mean zero.

For Aboriginal, Torres Strait Islander participants aged 20–29 years, results were as follows (Aboriginal, Torres Strait Islander participants, respectively): mean (SD) FN BMD_H in females ($n=10$, 9), +0.95 (0.16), +0.94 (0.08), males ($n=13$, 3), +1.04 (0.19), +1.08 (0.01) g/cm^2; femoral neck *T*-score, females, +0.94 (1.45), +0.86 (0.73), males, +0.77 (1.43), +1.09 (0.02); LS BMD_H, females, +1.06 (0.15), +1.03 (0.15), males, +1.10 (0.16), +1.05 (0.03) g/cm^2; LS *T*-score, females, −0.26 (1.20), −0.52 (1.19), males, −0.32 (1.24), −0.65 (0.23). No significant differences in participant characteristics or BMD were seen in this young age group. Chronic diseases such as diabetes were less common in this young age group: no young women had diabetes but three young Aboriginal men had diabetes.

Table 2
Bone mineral density and related results by ethnic group. Data are mean ± SD.

	Aboriginal	Torres Strait Islander	Both Aboriginal and Torres Strait Islander
Females	$n=39$	$n=41$	$n=14$
Lean $mass_H$ (kg)	40.9 ± 5.9	49.8 ± 9.3[a]	48.8 ± 6.2[a]
$Lean_H$ (%)	58.9 ± 6.9	59.5 ± 5.5	57.8 ± 5.0
Fat $mass_H$ (kg)	28.1 ± 9.8	32.7 ± 11.0	34.2 ± 11.1
Fat_H (%)	39 ± 8	38 ± 6	39 ± 6
FN BMD_H (g/cm^2)	0.87 ± 0.14	0.88 ± 0.15	0.89 ± 0.13
FN *T*-score	0.29 ± 1.25	0.35 ± 1.39	0.44 ± 1.22
FN *Z*-score	0.60 ± 1.19	0.86 ± 1.26	1.08 ± 1.07
LS BMD_H (g/cm^2)	1.07 ± 0.15	1.10 ± 0.15	1.13 ± 0.14
LS *T*-score	−0.24 ± 1.19	0.04 ± 1.24	0.31 ± 1.10
LS *Z*-score	0.49 ± 1.33	0.35 ± 1.34	0.88 ± 1.05
Males	$n=31$	$n=27$	$n=9$
Lean $mass_H$ (kg)	58.5 ± 8.9	65.9 ± 12.4	69.0 ± 16.1
$Lean_H$ (%)	74.3 + 11.2	73.5 + 4.8	74.7 + 8.8
Fat $mass_H$ (kg)	20.1 ± 14.2	21.4 ± 8.1	22.4 ± 9.3
Fat_H (%)	22 ± 12	23 ± 5	22 ± 9
FN BMD_H (g/cm^2)	1.03 ± 0.17	1.01 ± 0.13	1.08 ± 0.28
FN *T*-score	0.72 ± 1.30	0.51 ± 1.01	1.05 ± 2.07
FN *Z*-score	0.82 ± 1.19	1.01 ± 0.87	1.44 ± 1.66
LS BMD_H (g/cm^2)	1.12 ± 0.15	1.17 ± 0.15	1.18 ± 0.18
LS *T*-score	−0.12 ± 1.18	0.30 ± 1.14	0.32 ± 1.40
LS *Z*-score	0.30 ± 1.51	0.75 ± 1.32	0.76 ± 1.36

[a] $p<0.005$, compared to Aboriginal group of same gender.

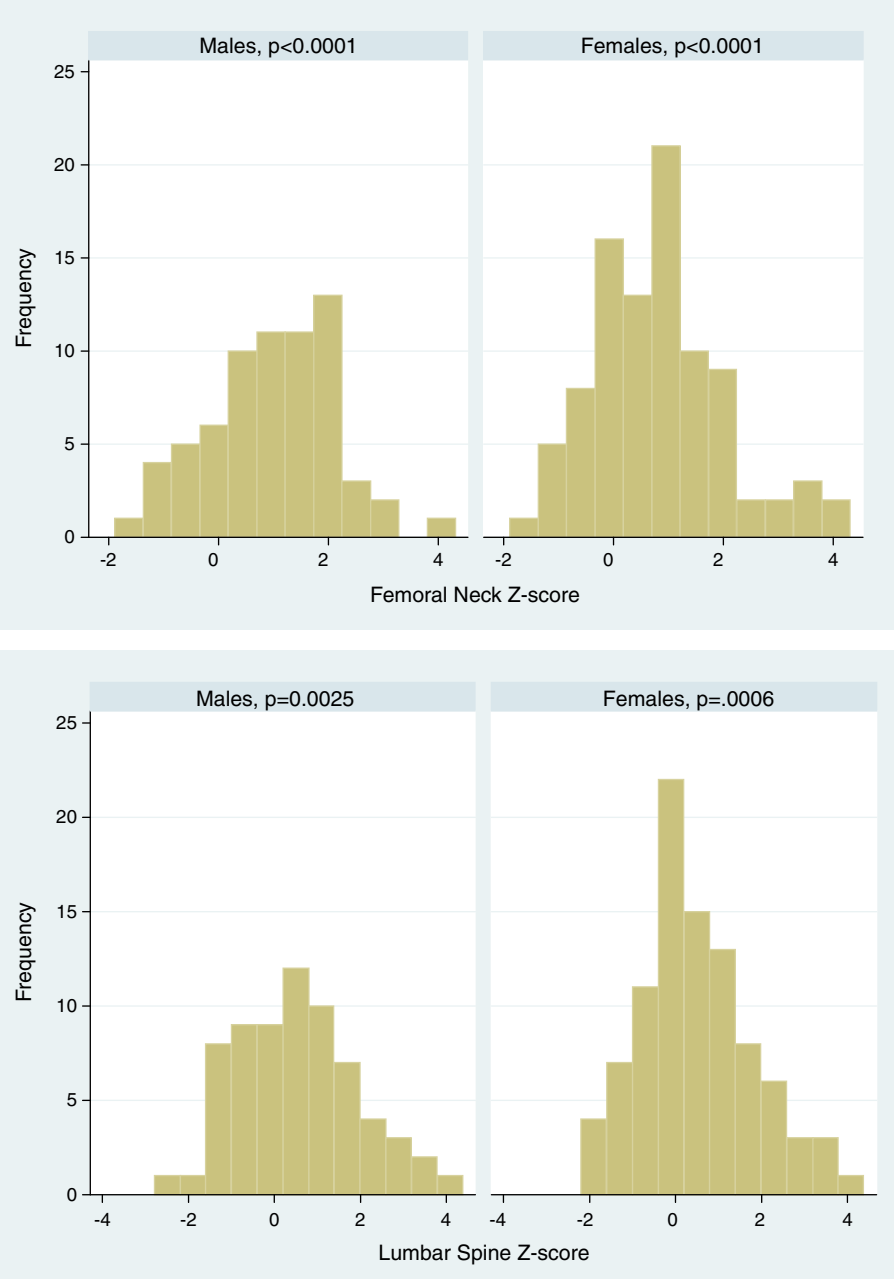

Fig. 1. Distribution of *Z*-scores (femoral neck and lumbar spine) in Indigenous Australians. *p* values refer to one-sample *t* test of mean *Z*-score compared to a mean of zero.

Aboriginal and/or Torres Strait Islander ethnicity were each independently associated with higher FN BMD_H than Caucasian ethnicity in men, after adjusting for age, gender, height and diabetes (multiple regression analysis, Table 3). Results were similar in women with the exception that the higher Fn BMD_H in Aboriginal women did not reach significance. Once lean mass was added to the model (model 3), height, gender and diabetes were no longer significant, and BMD_H in men remained higher in two of the three Indigenous groups, compared to the Caucasian group. Addition of LM_H resulted in a proportionately larger decrease in BMD_H for Torres Strait Islander than Aboriginal participants, such that the higher BMD in Torres Strait Islander men did not reach significance. With addition of lean mass to the model in women, there were no significant differences in FN BMD_H between Indigenous and Caucasian women. Characteristics of Caucasian participants ($n=36$) included in the above models were: age (mean ± standard deviation) 33 ± 18 years, 58% male, 8% diabetes, 19% current cigarette smokers, mean (SD) *Z*-score femoral neck, females +0.64 (1.04), males +0.08 (1.00), lumbar spine females +0.54 (1.12), males +0.08 (1.26).

In contrast, there were no significant differences between ethnic groups for LS BMD_H when lean mass was included in the regression model. There were no significant interactions between ethnicity and lean mass, smoking, diabetes or alcohol use. There was a significant interaction between Torres Strait Islander ethnicity and gender for LS (but not FN) BMD_H, thus regression of LS BMD_H was stratified by gender. There were differences in LS BMD_H for men between the ethnic groups, but only when lean mass was not in the model. Current cigarette smoking was inversely associated with LS BMD_H in women.

Results of the multiple regression models were similar when comparing Aboriginal and Caucasian participants assessed on the Norland (unconverted), such that Aboriginal ethnicity [beta coefficient, 95% CI, 0.063 (0.005, 0.162)] was independently associated with higher

Table 3
Multiple regression analysis of femoral neck (FN) and lumbar spine (LS) bone mineral density (BMD_H).

	Model 1	Model 2	Model 3
A. FN BMD_H, n = 197			
Males (n = 88)			
Age (years)	**−0.006** (−0.008, −0.004)	**−0.005** (−0.007, −0.003)	**−0.005** (−0.006, −0.004)
Aboriginal	0.073 (−0.014, 0.159)	**0.109** (0.025, 0.192)	**0.082** (0.005, 0.159)
Torres Strait Islander	**0.127** (0.042, 0.212)	**0.139** (0.059, 0.219)	0.079 (−0.002, 0.161)
Aboriginal and Torres Strait Islander	**0.179** (0.063, 0.295)	**0.198** (0.089, 0.307)	**0.114** (0.003, 0.224)
Diabetes	0.035 (−0.050, 0.120)	0.034 (−0.045, 0.114)	–
Height (cm)	–	**0.008** (0.003, 0.012)	–
Lean mass (kg)	–	–	**0.006** (0.003, 0.009)
Model R^2	**37.4%**	**46.0%**	**48.1%**
Females (n = 109)			
Age (years)	**−0.005** (−0.007, −0.003)	**−0.005** (−0.007, −0.003)	**−0.005** (−0.006, −0.003)
Aboriginal	0.035 (−0.041, 0.111)	0.059 (−0.017, 0.135)	0.061 (−0.007, 0.128)
Torres Strait Islander	0.067 (−0.012, 0.148)	**0.082** (0.003, 0.161)	0.027 (−0.044, 0.099)
Aboriginal and Torres Strait Islander	0.095 (−0.005, 0.194)	**0.117** (0.018, 0.216)	0.071 (−0.018, 0.160)
Diabetes	**0.079** (0.012, 0.147)	**0.091** (0.025, 0.157)	–
Height (cm)	–	**0.005** (0.001, 0.009)	–
Lean mass (kg)	–	–	**0.009** (0.006, 0.012)
Model R^2	**21.0%**	**26.1%**	**39.0%**
B. LS BMD_H, n = 192			
Males (n = 88)			
Age (years)	−0.001 (−0.002, 0.002)	0.002 (−0.001, 0.003)	0.001 (−0.001, 0.003)
Aboriginal	0.053 (−0.037, 0.142)	**0.085** (0.005, 0.165)	0.049 (−0.027, 0.126)
Torres Strait Islander	**0.106** (0.018, 0.194)	**0.105** (0.026, 0.103)	0.046 (−0.035, 0.127)
Aboriginal and Torres Strait Islander	0.103 (−0.013, 0.220)	**0.118** (0.011, 0.225)	0.028 (−0.081, 0.138)
Diabetes	0.024 (−0.065, 0.112)	–	–
Height (cm)	–	**0.008** (0.004, 0.012)	–
Current smoker	−0.059 (−0.131, 0.012)	–	–
Lean mass (kg)	–	–	**0.006** (0.003, 0.009)
Model R^2	**11.2%**	**21.8%**	**25.0%**
Females (n = 104)			
Age (years)	−0.001 (−0.004, 0.001)	−0.001 (−0.003, 0.001)	−0.001 (−0.003, 0.001)
Aboriginal	−0.044 (−0.134, 0.045)	−0.028 (−0.119, 0.062)	−0.025 (−0.113, 0.062)
Torres Strait Islander	−0.038 (−0.131, 0.054)	−0.027 (−0.120, 0.065)	−0.070 (−0.160, 0.021)
Aboriginal and Torres Strait Islander	0.003 (−0.115, 0.121)	0.019 (−0.099, 0.137)	−0.013 (−0.127, 0.100)
Diabetes	**0.099** (0.021, 0.177)	**0.106** **(0.028, 0.183)**	–
Height (cm)	–	0.004 (−0.001, 0.009)	–
Current smoker	**−0.067** (−0.129, −0.005)	**−0.061** (−0.123, 0.001)	**−0.065** (−0.125, −0.005
Lean mass (kg)	–	–	**0.007** (0.003, 0.011)
Model R^2	**13.9%**	**16.5%**	**20.3%**

femoral neck BMD compared to Caucasian ethnicity after adjusting for age, gender and lean mass. Results at the lumbar spine were also similar in this group using Norland unconverted data to those outlined in the whole group in Table 3, such that Aboriginal ethnicity [beta coefficient, 95% CI, 0.103 (0.004, 0.202)] was independently associated with higher lumbar spine BMD in males after adjusting for age, height, diabetes and current smoking status, but differences between ethnic groups were no longer significant after inclusion of lean mass in the model.

There was a positive relationship between lean mass and BMD_H (FN and LS) according to gender and ethnicity (Fig. 2) in all groups, except for non-Indigenous women, likely due to small sample size in that group.

4. Discussion

To our knowledge, this is the first detailed description of hip and spine BMD in Aboriginal and Torres Strait Islander Australians. We report differences in lean mass and BMD between Aboriginal and Torres Strait Islander people. Firstly, BMD_H was greater in Aboriginal and Torres Strait Islander Australians compared to Caucasian Australian reference values with the distribution of FN and LS *Z*-scores shifted to the right in Indigenous men and women. Secondly, greater FN BMD_H was independent of lean mass in Aboriginal and Torres Strait Islander men, but lean mass attenuated the greater BMD in Torres Strait Islander participants. Thirdly, LS BMD_H was not significantly different in Aboriginal and/or Torres Strait Islander participants as compared to Caucasians, including after adjustment for lean mass.

After adjustment for key factors such as age, gender, height and diabetes, FN BMD_H was independently greater in the Indigenous groups (Aboriginal, Torres Strait Islander, and both Aboriginal and Torres Strait Islander origin), compared to Caucasian Australians. While gender was not significant in the regression analysis of FN BMD_H, when stratified by gender, this finding was significant only for men. This may well be due to higher Z-scores in women than men in the Caucasian comparator group (the reference ethnic group in the regression analysis). FN and LS *Z*-scores were high (using the Geelong Australian reference range) for both Indigenous men and women in this study. Our finding of higher BMD in Indigenous than Caucasian Australians is consistent with: higher femoral BMD reported in premenopausal Aboriginal women from Argentina [7], and higher BMD reported in other non-White populations such as African Americans [20]. However, our finding is not consistent with the report of lower BMD in Aboriginal Canadians (compared to Caucasians), although the finding in Canadians was not at the hip and spine (weight-adjusted BMD was lower for the calcaneus and total body) and was no longer significant after adjusting for lean mass [3,4]. Thus, BMD is higher some but lower in other Indigenous populations compared to that of Caucasians.

To our knowledge, the only report of BMD in Aboriginal Australians assessed total body BMD in 16 Aboriginal and 16 Caucasian women in Sydney [6]. That study did not assess hip and spine BMD and it is likely that these Sydney-based participants would have had a greater degree

Notes to Table 3:
Ethnicity is a categorical variable (Caucasian, Aboriginal, Torres Strait Islander, Aboriginal and Torres Strait Islander, where Caucasian ethnicity coded 1 as the reference group). Data are beta coefficient (95% CI).
Coefficients in bold are significant ($p<0.05$).
Lean mass is Hologic-equivalent (LM_H).
Variables entered into each model:
Model 1: age, gender, ethnicity (categorical variable where Caucasian ethnicity was coded 1 as the reference group), diabetes, current cigarette smoker, alcohol use.
Model 2: age, gender, ethnicity, diabetes, height, current cigarette smoker, alcohol use.
Model 3: age, gender, ethnicity, diabetes, height, current cigarette smoker, alcohol use, lean mass, fat mass.

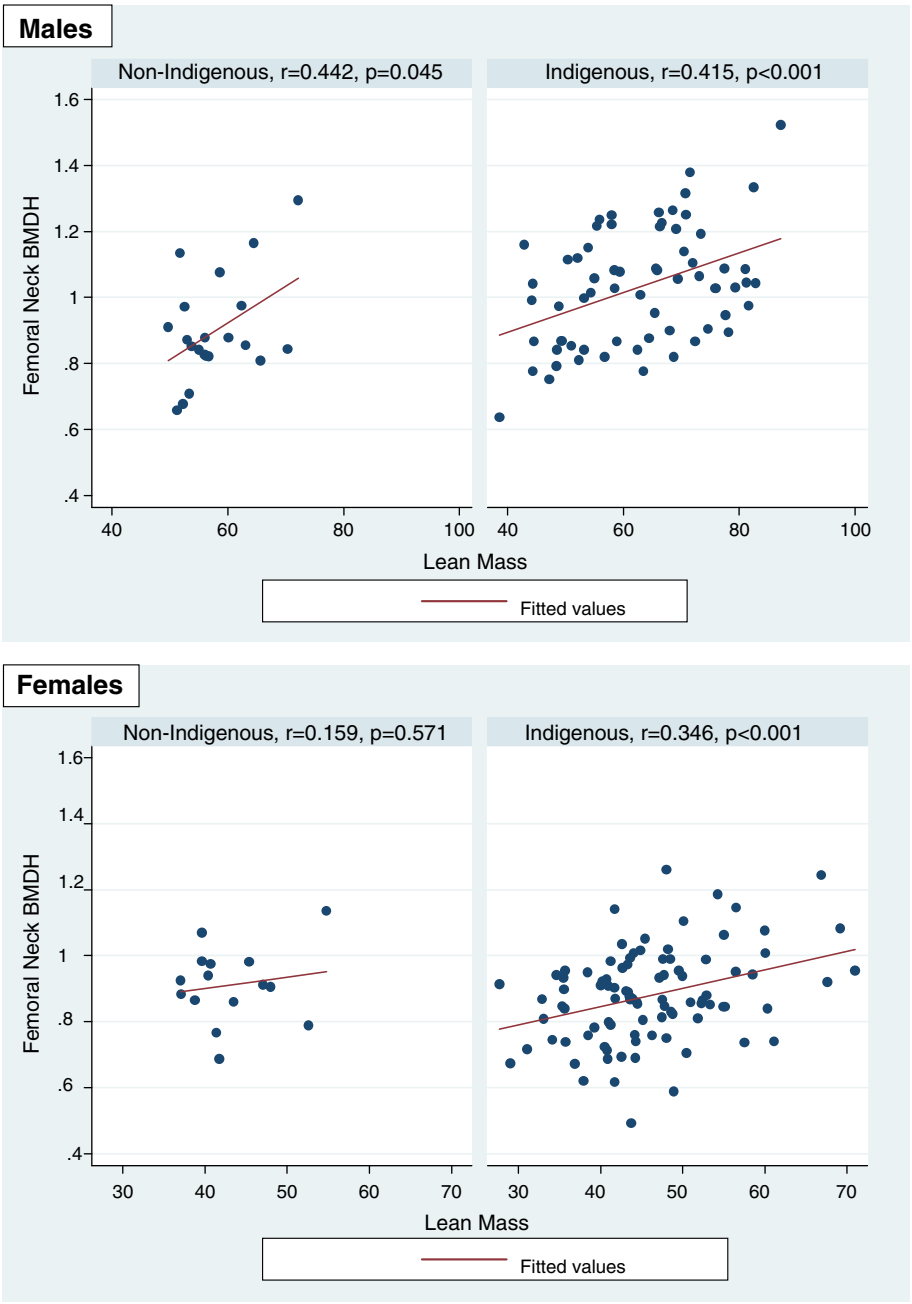

Fig. 2. Graph of relationship between lean mass and femoral neck BMD_H by ethnicity (three Indigenous ethnic groups combined) and gender.

of ethnic admixture than Indigenous participants in the current study, from Darwin or the Torres Strait (ethnic origin of grandparents was not reported in the Sydney study). Our reported greater FN BMD in Indigenous Australians is consistent with the report of reduced rates of FN fracture in Indigenous Australians compared to Caucasian Australians [1]. In that study, Aboriginal and Torres Strait Islander participants were not evaluated separately but reported as a combined Indigenous group [1].

In the current study FN BMD remained higher in the Indigenous ethnic groups compared to Caucasians, even after adjustment for lean mass. The difference in Torres Strait Islander participants was attenuated by addition of lean mass to the model and remained significant when genders were combined for analysis, but was no longer significant when analysis was performed stratified by gender. Torres Strait Islander men and women had greater lean mass than Aboriginal men and women. This impact of lean mass and body composition differences on ethnic differences in BMD in the current study is consistent with previous studies [4,9,21]. However, in contrast to previous studies, the ethnic differences in BMD that we have reported in Indigenous Australian participants remained significant after adjustment for lean mass. Of note, the differences in BMD between Aboriginal Canadian and Caucasian Canadian women were no longer significant after adjusting for body composition (total fat mass and lean mass, with only lean mass as an independently significant predictor of BMD). This appeared to be due to the lower ratio of lean to fat mass in Aboriginal than Caucasian Canadian women (and the smaller increment in bone mass from fat compared to lean mass in both ethnic groups) [4]. Reports of the major contribution of lean mass to BMD include studies across a range of ethnic groups [4,21,22] and clinical conditions such as type 2 diabetes [23].

In addition to body composition or BMD differences, differences in femur geometry and body build could contribute to fracture risk differences in Aboriginal Australians. Aboriginal Australians have been reported to have a "linear" body build: narrow across the shoulders and hips and relatively long limbs and short torso [24]. Such differences in body build could be associated with variations in geometry (such as hip axis length) at the FN in Indigenous participants, which could impact hip strength and fracture risk independent of BMD, thus possibly contributing to reduced fracture rates seen in this population [1]. Native Americans have been reported to have higher BMD, higher section modulus, lower buckling ratio and smaller bending moments acting in a fall at the hip (the latter did not reach significance in the small sample) than non-Hispanic Whites at the intertrochanteric femoral region. These biomechanical differences could contribute to ethnic differences in hip fracture rates [25].

When compared to the small Caucasian Australian group in the current study, LS BMD_H was not significantly higher in Aboriginal and/or Torres Strait Islander Australians, after adjustment for key factors. However mean LS *Z*-scores (using the Geelong Australian reference) were significantly higher than a mean of zero for both Indigenous Australian men and women. The magnitude of elevation of mean *Z*-scores in Indigenous Australians was greater at the femoral neck than at the lumbar spine. The small Caucasian Australian group could have contributed to the different comparative findings at hip and spine in the current study.

Assessment of ethnic differences in BMD has recently been the subject of some controversy [26,27]. The strengths of our study include detailed body composition assessment as well as hip and spine BMD measurement. The study also included detail of grandparents' ethnicity and self-identification to one of the three Indigenous Australian groups of Aboriginal, Torres Strait Islander or Aboriginal and Torres Strait Islander. The availability of DXA is limited in these relatively remote regions of Australia. This is an underserviced population with high background rates of chronic disease; hence, the data are unique.

Limitations of our study include no detailed assessment of socioeconomic status, lifestyle and environmental factors, all of which could contribute to differences in BMD. This cross-sectional study design had relatively small numbers in some ethnic and age groups and the groups were not matched for key variables such as age and diabetes. We did not assess menopausal status, a factor which may have contributed to our finding of higher femoral neck BMD_H in Indigenous men but not women (as Caucasian women were younger and therefore more likely to be premenopausal than Indigenous women). The DXA scans were performed on two different machines with different manufacturers; hence, the different scan technologies prevented comparison of bone area. However, we used published conversion equations to transform BMD data from Norland to Hologic in both men and women. Similarly, soft tissue data obtained with the Norland Instrument were converted to Hologic equivalent values and the appropriateness of such conversions is open to question. Notably, however, the outcomes of the multiple regression models were not significantly altered by use of converted data compared to unconverted (not shown).

5. Conclusions

Consistent with a previous report of reduced hip fracture rates in Indigenous Australians, we conclude that LS and FN BMD are higher in Aboriginal and/or Torres Strait Islander Australians than Caucasian Australian reference ranges. In part, these higher values were related to lean mass but the greater FN BMD still remained significant in men after adjustment for lean mass. Further studies of BMD, markers of bone turnover and related fracture rates in Indigenous Australians are required at a population level.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at http://dx.doi.org/10.1016/j.bone.2012.04.011.

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