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# Ethnic differences in vitamin D status, bone and body composition in South Asian indian and caucasian men

A. Altasan [a], A. Aljahdali [b,c], R. Ramadoss [d], M.M. Cheung [e], R.D. Dall [f], M. Bruneau Jr [f], J.A. Nasser [f], J. Kindler [g], A. Ramakrishnan [h], D. Sukumar [f,*]

[a] Department of Clinical Nutrition, King Saud University for Health Sciences, King Abdullah International Medical Research Center, Riyadh, Saudi Arabia
[b] Department of Clinical Nutrition, Faculty of Applied Medical Sciences, King Abdulaziz University, Jeddah, Saudi Arabia
[c] Department of Nutrition Sciences, School of Public Health, University of Michigan, Ann Arbor, MI, USA
[d] Department of Human Nutrition, Foods, and Exercise, Virginia Tech, Blacksburg, VA, USA
[e] Department of Health and Nutrition Sciences, School of Natural and Behavioural Sciences, City University of New York, Brooklyn College, Brooklyn, NY, USA
[f] Department of Health Sciences, College of Nursing and Health Professions, Drexel University, Philadelphia, PA, USA
[g] Department of Nutritional Sciences, University of Georgia, Athens, GA, USA
[h] Office of Research, College of Nursing and Health Professions, Drexel University, Philadelphia, PA, USA

A B S T R A C T

*Background:* High prevalence of metabolic abnormalities and poor bone health in ethnic minorties may stem from differences in body composition and alterations in endocrine milieu. South Asian Indians (SAIs) are at greater risk for metabolic syndrome (MetS) and poor bone health than Caucasians. Often these differences are reported later in life and/or in a resident immigrant population compared to a Caucasian population. In this study, we determined whether vitamin D status, bone, body composition differed in young SAIs and Caucasians. Notably we compared differences amongst recent SAI immigrants and Caucasians.

*Methods:* We examined differences in bone density, body composition, serum 25-hydroxy vitamin D (s25(OH)D), parathyroid hormone (sPTH), vitamin D binding protein (sDBP), osteocalcin (sOC), and dietary intakes in young healthy SAI and Caucasian men.

*Results:* Sixty men (N = 30 SAIs and N = 30 Caucasians) with a mean age of 27.8 ± 7.4 years completed the study. Compared to the Caucasians, SAIs had statistically significantly lower s25(OH)D and higher sPTH ($p < 0.05$). We also found that s25(OH)D was negatively associated with sPTH only among the SAIs (r = - 0.389, $p = 0.037$). Also, lean mass% (LM%) and fat-free mass% (FFM%) were lower in SAIs ($p < 0.05$) compared to caucasians. s25(OH)D correlated with nearly all body composition parameters, while sPTH correlated negatively with LM% and FFM%, and positively with FM% (all $p < 0.05$) in the Caucasian group. Bone mineral density at most sites were also significantly lower ($p < 0.05$) in the SAI's compared to caucasians.

*Conclusion:* Young SAIs have a poor vitamin D status and less favorable bone and body composition parameters compared to Caucasians. These findings highlight the possible complex interplay between skeletal and metabolic health in different ethnicities which may be evident early on in life. Interventions to improve bone and metabolic health should therefore target younger ethnic minorities.

## 1. Introduction

South Asian Indians are at a higher risk for developing cardiovascular disease (CVD) and diabetes mellitus compared to other ethnic groups [1]. The higher cardiometabolic risk in this population stems from differences in body composition, dietary intakes and/or alterations in the endocrine milieu [2]. SAIs have a lower lean mass and higher fat mass compared to age and weight-matched Caucasians and accumulate more visceral fat at a lower body mass index (BMI) compared to other ethnic groups [2,3]. Interestingly, dietary intakes of animal protein, fried snacks, sweets, and high-fat dairy patterns are associated with adverse metabolic risk factors in this population [4]. Intakes of minerals such as calcium, potassium and magnesium (Mg) have also been found to be below the Recommended Dietary Allowances (RDA) in the SAIs [5]. Furthermore, serum markers of cardiometabolic health such as fasting glucose, insulin, adiponectin are also altered in the SAIs [6,7]. Although these factors may contribute to a higher prevalence of cardiovascular-related mortality in the SAI's compared to other ethnicities and have been widely reported in the literature, other biomarkers may also play an important role in explaining the higher incidence of cardiometabolic alterations in the SAI population.

Recently, there has been a lot of attention on the endocrine role of bone in regulating cardiometabolic health [8,9]. Several reports in the literature suggest that bone is an organ that regulates metabolism,

* Corresponding author. Department of Health Sciences- Nutrition Division Drexel University 60 N 36 Street, Philadelphia PA, 19104, USA.
*E-mail address:* deeptha.sukumar@drexel.edu (D. Sukumar).

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energy, and glucose homeostasis [8,9]. Bone regulating hormones, in particular, 25 hydroxy vitamin D (25(OH)D), parathyroid hormone (PTH)), and other hormones such as osteocalcin (OC), are directly involved in the regulation of cardiometabolic outcomes [8,9]. Low serum concentrations of 25(OH)D, high PTH and low OC are often reported in those with metabolic syndrome (MetS) and are associated with higher cardiovascular-related events [10–12]. Interestingly, differences in calciotropic hormones are also noted in the SAI population compared to Caucasians [13,14]. Although alterations in cardiometabolic health markers and calciotropic hormones are reported in the SAI population, whether these are observed in younger men and immigrants is not known.

Migration is an important risk factor for CVD and MetS. Both environmental factors and psychological stress contribute to the increased susceptibility of migrantsto CVD risks [15–17]. Physiological contributors such as hyperlipidemia, high BMI, and other metabolic alterations are observed in immigrants compared to Caucasians or resident non-SAI migrants [15–17]. However, the impact of recent immigration on CVD risk factors in the SAI population is not well understood. The goal of the current study was to determine whether differences in bone, body composition, dietary intakes and calciotropic hormones are observed in young, immigrant SAI men compared to Caucasians. We chose to examine exclusively men in this study because several previous studies have combined male and female SAIs. Since differences in bone and body composition exist between males and females, it would be prudent to investigate this relationship in SAI men only who have the highest risk of CVD compared to SAI women and other ethnicities [18]. Furthermore, we will also determine whether dietary intakes and calciotropic hormones specifically vitamin D metabolites and sPTH are related to bone health and cardiometabolic risk factors in this population.

## 2. Study participants and methods

The study was cross-sectional in nature and participants visited the Bone Lab at Drexel University for one study visit. The study was approved by the Drexel University Institutional Review Board and was registered in clinicaltrials.gov (NCT03600675). All participants read and signed an informed consent document. The study was conducted at Drexel University, Philadelphia, PA. Adult Caucasian and South Asian men, between ages 20–60 years and BMI $<40$ kg/m$^2$ were eligible for this study. The SAIs were identified as immigrants from the Indian subcontinent who lived in the United States for at least two years but no more than 5 years at the time of enrollment in the study. Exclusion crtieria was individuals with any of the following conditions: type 2 diabetes mellitus, kidney or liver diseases or diseases and medications that may affect vitamin D, Mg, or calcium (Ca) metabolism, CVD, and bone diseases. We also excluded individuals experiencing an acute illness, consuming $>30$ g of alcohol per day, consuming tobacco, or self-supplementing with doses of Ca, vitamin D or Mg above the RDA for their age.

### 2.1. Study questionnaires and dietary Assessment

All participants completed a medical history questionnaire that contained questions regarding race, date of birth, weight history, medications, vitamin/mineral or herbal supplements, medical history, tobacco and/or alcohol use, and eating disorder history. Participants also completed a validated Mg food frequency questionnaire (Mg-FFQ) [19] and Ca-FFQ (adapted from the "calcium calculator" by the International Osteoporosis Foundation website [20] were used to quantify the Ca and Mg intake, respectively. Using a 24-h dietary recall, we employed a 5-step pass method to collect information on intakes of total energy, micronutrients, and macronutrient intakes [21,22]. Food diaries were analyzed using the FoodWorks software (Long Valley, NJ). A registered dietitian or trained research assistant completed the dietary data collection.

### 2.2. Anthropometric measurements

The height (inches) and weight (pounds [lbs]) were measured using a stadiometer with a balance beam scale (Seca 700 Physician's Balance Beam Scale, Chino, CA, USA). Body weight was documented to the nearest 0.25 lb. Height was recorded to the nearest 0.5 inches. BMI was calculated using the obtained measures of weight and height.

### 2.3. Blood sampling and analyses

After an overnight fast, blood was collected from participants via venipunture and kept at room temperature for at least 1 h and centrifuged to extract serum. Serum samples were stored at $-80$ °C until further analyses. Measurement of s25(OH)D concentrations was completed using a commercial enzyme immunoassay (EIA) (Immunodiagnostic Systems Inc., Gaithersburg, MD, coefficient of variation (CV) $<$ 11.6 %). Measurements of serum total vitamin D binding protein (sDBP), sOC, and bone turnover marker carboxy-terminal collagen crosslinks (sCTX) concentrations were completed using a commercial enzyme-linked immunosorbent assay (ELISA) (Immunodiagnostic Systems Inc., Gaithersburg, MD, CV $<$5.1 %, $<$5.1 %, and $<$10.9 % respectively). Measurement of sPTH was completed using an ELISA (ALPCO, Salem, HN, CV $<$7.0 %). Levels of triglycerides (TG) were measured using a colorimetric Assay (Cayman's Triglyceride Colorimetric Assay, Ann Arbor, MI, CV $\leq$ 3.17 %). Concentrations of serum glucose were analyzed using commercial colorimetric assay kits (Sigma-Aldrich Co. LLC, St. Louise, MO). Serum insulin concentrations and markers of inflammation, Monocyte chemoattractant protein-1 (MCP-1), Interleukin 6 (IL-6), C reactive Protein (CRP), and high molecular weight serum adiponectin concentrations were measured using ELISA (R&D Systems, Minneapolis, Minnesota; with all CVs $<$8.6 %). All samples were analyzed in duplicates.

### 2.4. Dual energy X-ray absorptiometry

To determine body composition, areal bone mineral density (BMD), and bone mineral content (BMC) at different bone sites such as the radius, total hip, femur and total body, we used the dual-energy X-ray absorptiometry (DXA; Lunar iDXA, enCORE Software Version 17, GE Healthcare, United Kingdom. The following body composition analysis variables were derived from the total body scan: lean mass% (LM%), fat mass% (FM%), fat-free mass% (FFM%), android fat mass (in lbs), the gynoid fat mass (in lbs), and visceral adipose tissue mass (VAT, in lbs). The percentages of the last three parameters were calculated out of the total fat mass.

## 3. Statistical analyses

Descriptive statistics were calculated and are presented as means $\pm$ standard deviations. Independent sample t-tests or Mann-Whitney U tests were used to assess differences among the two ethnic groups for continuous parameters that have normal and non-normal distributions, respectively. To assess the association between the bone biomarkers with body composition and dietary intake, we used Spearman bivariate correlation or Pearson's correlation tests. The SPSS statistical software program version 26.0 (IBM SPSS Statistics, New York) was used and a significance level of 0.05 was set for all statistical analyses.

## 4. Results

Sixty participants (30 Caucasians and 30 SAIs) completed the study **[Fig. 1]**. Descriptive statistics, including weight, height, BMI, age, and dietary intake are presented in Table 1. Participants did not differ significantly in their descriptive characteristics except for lower height in SAIs. Table 2 shows that dietary intakes of Ca, vitamin D and Mg were not statistically different between the two groups. The macronutrients

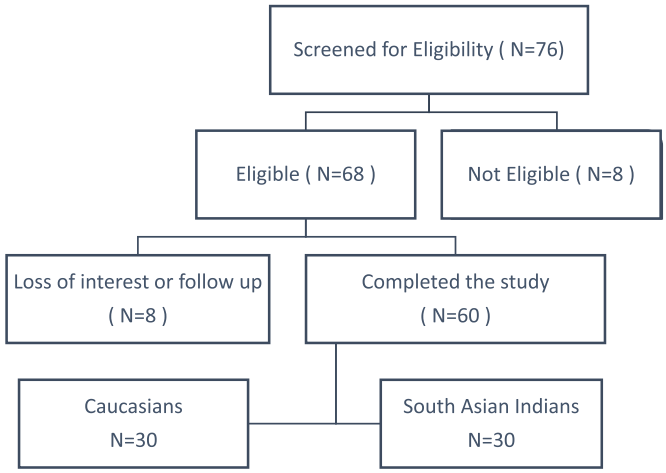


**Fig. 1.** Flowchart of the study sample.
*8 individuals did not meet eligibility criteria.

**Table 1**
Descriptive characteristics and dietary intakes of study participants.

| *Variable* | Caucasians N = 30 | SAIs N = 30 | *P* |
|---|---|---|---|
| **Age (years)** | 28 (9) | 26 (6) | 0.216[a] |
| **BMI (kg/m$^2$)** | 25.8 (5.5) | 26.5 (6.3) | 0.596[a] |
| **Weight (lbs)** | 182.0 (60.9) | 173.7 (43.6) | 0.216[b] |
| **Height (in)** | 71.5 ± 2.9 | 68.5 ± 2.8 | **<0.001**[a] |

Results displayed as mean ± standard deviation or median (interquartile range). $p \leq 0.05$. *BMI* Body Mass Index; *SAI* South Asian Indians.
[a] = Independent Samples T-Test.
[b] = Mann Whitney *U* Test.

**Table 2**
Dietary intakes of Macro and Micronutrients.

| *Variable* | Caucasians N = 30 | SAIs N = 30 | *P* |
|---|---|---|---|
| **Age (years)** | 28 (9) | 26 (6) | 0.216[a] |
| **BMI (kg/m$^2$)** | 25.8 (5.5) | 26.5 (6.3) | 0.596[a] |
| **Weight (lbs)** | 182.0 (60.9) | 173.7 (43.6) | 0.216[b] |
| **Height (in)** | 71.5 ± 2.9 | 68.5 ± 2.8 | **<0.001**[a] |
| **Energy (Kcal)** | 2194 (863) | 1787 (1205) | 0.061 |
| **Protein (g)** | 96.3 (46.7) | 84.8 (63.8) | 0.395 |
| **Carbohydrate (g)** | 276.4 (137.4) | 202.6 (170.5) | 0.067 |
| **Dietary Fiber (g)** | 23.25 (15.4) | 18.7 (19.1) | 0.24 |
| **Total Sugar (g)** | 75.1 (53.1) | 57.0 (51.6) | **0.007** |
| **Total Fat (g)** | 74 (81.5) | 76.3 (42.9) | 0.734 |
| **Vitamin D (mcg)** | 0.435 (2.9) | 1.1 (3.3) | 0.692 |
| **Vitamin K (mcg)** | 55.5 (64.8) | 42.0 (59.8) | 0.079 |
| **Vitamin C (mg)** | 46.8 (89.8) | 42.1 (44.9) | 0.225 |
| **Calcium (mg)** | 911.0 (603.9) | 593.9 (593.9) | 0.413 |
| **Magnesium (mg)** | 233.1 (233.1) | 228.1 (196.8) | 0.476 |

Results displayed as mean ± standard deviation or median (interquartile range). $p \leq 0.05$. *BMI* Body Mass Index; *SAI* South Asian Indians.
[a] = Independent Samples T-Test.
[b] = Mann Whitney *U* Test.

and micronutrients intakes were also not significantly different between the two groups except for the total sugar which was significantly higher among the Caucasian group ($p = 0.007$).

Table 3 displays the differences in the biomarkers of bone health. The 25OHD levels in the SAIs had was 22.79 ± 9.1 ng/mL and this was significantly lower compared to the Caucasians whose levels were 31.24 ± 9.1 ($p < 0.001$). (Normal range of s25OHD is > 20 ng/mL). Also, the SAIs had significantly higher sPTH (pg/mL) levels [median (IQR)] [60.04 (28.9)] compared to the Caucasians [47.6 (26.2) ] ($p = 0.045$).

**Table 3**
Biomarkers of bone health among caucasians and SAIs.

| | Caucasians (n = 30) | SAIs (n = 29) | P |
|---|---|---|---|
| **s25(OH)D (ng/mL)** | 31.2 ± 9.1 | 22.8 ± 9.1 | **<0.001**[a] |
| **sPTH (pg/mL)** | 47.6 (26.2) | 60.0 (28.9) | **0.045**[b] |
| **sDBP (ug/mL)** | 379.1 (430.4) | 116.0 (404.4) | 0.081[b] |
| **sOC (ng/mL)** | 21.1 (14.2) | 19.3 (13.7) | 0.486[b] |
| **sCTX (ng/mL)** | 0.7 (0.44) | 0.6 (0.4) | 0.077[b] |
| **sCRP (mg/dL)** | 0.1 (0.17) | 0.1 (0.2) | 0.680[b] |
| **IL-6 (pg/mL)** | 2.6 (5.8) | 2.5 (1.8) | 0.655[b] |
| **MCP-1 (pg/mL)** | 425.7 (156.7) | 404.2 (247.3) | 0.539[b] |
| **MMP-9 (ng/mL)** | 452.8 (398.1) | 328.6 (618.9) | 0.074[b] |
| **Adiponectin (mg/dL)** | 4.3 (3.8) | 1.9 (2.3) | **<0.001**[b] |
| **Insulin (uIU/mL)** | 5.4 (4.9) | 6.2 (5.4) | 0.351[b] |
| **Glucose (mg/dL)** | 84.7 (26.2) | 100.6 (54.7) | 0.444[b] |
| **TG (mg/mL)** | 45.8 (24.3) | 59.2 (55.6) | 0.128[b] |

Results displayed as mean ± standard deviation or median (interquartile range). $p \leq 0.05$. *25(OH)D* 25-hydroxyvitamin D; *PTH* parathyroid hormone; *DBP* vitamin D binding protein; *OC* Osteocalcin; *CRP* C-Reactive Protein, *IL-6* Interleukin 6, *MCP-1* Monocyte chemoattractant protein-1; *MMP-9* Matrix metallopeptidase 9; *CTX* C-terminal cross-linked telopeptide; *TG* Triglycerides. Blood draw as not obtained in 1 SAI participant.
[a] = Independent Samples T-Test.
[b] = Mann Whitney *U* Test.

The SAIs had significantly ($p < 0.001$) lower serum Adiponectin compared to the Caucasians. None of the other metabolic parameters or proinflammary cytokines differed between groups. The classic inverse relationship of s25OHD with sPTH was noted only among the SAIs ($r = -0.389$, $p = 0.037$) and not observed in the Caucasians.

The differences in body composition and bone parameters are reported in Table 4. Caucasians had higher LM% [71.4 ± 8.2 %] compared to the SAIs [67.3 ± 7.6 %] ($p = 0.048$). Similarly, FFM% was also higher among the Caucasians (75.3 ± 8.7 %) compared to the SAIs (70.9 ± 8.0 %) ($p = 0.047$). Except at the radius, SAI's also had a significantly lower BMD and BMC compared to Caucasians at all bone sites (all $p < 0.05$).

The associations between the body composition parameters and the calciotropic hormones and bone markers are presented in Table 5. Significant associations between s25(OH)D and all body composition parameters (except for gynoid fat%) were seen among Caucasians (all $p < 0.05$). Similarly, sPTH was positively correlated with FM%, and

**Table 4**
Body composition and bone mineral density in caucasians and SAIs.

| *Variable* | Caucasians n = 30 | SAIs n = 30 | *P* |
|---|---|---|---|
| **LM %** | 71.4 ± 8.2 | 67.3 ± 7.6 | **0.048**[a] |
| **FFM %** | 75.3 ± 8.7 | 70.9 ± 8.0 | **0.047**[a] |
| **FM %** | 24.9 ± 7.8 | 28.57 ± 8.0 | 0.080[a] |
| **Android fat %** | 8.1 ± 2.2 | 8.5 ± 1.7 | 0.809[a] |
| **Gynoid fat %** | 16.8 (2.0) | 16.62 (2) | 0.595[b] |
| **VAT %** | 6.52 ± 3.1 | 5.35 ± 2.8 | 0.135[a] |
| **WC (cm)** | 87.6 (18.0) | 84.7 (16.8) | 0.689[b] |
| ***BMD (g/cm$^2$)*** | | | |
| **Total BMD** | 1.35 ± 0.10 | 1.25 ± 0.10 | **0.001**[a] |
| **Spine BMD** | 1.26 ± 0.12 | 1.15 ± 0.10 | **0.001**[a] |
| **Pelvis BMD** | 1.22 ± 0.15 | 1.11 ± 0.12 | **0.003**[a] |
| **L2-L4 BMD** | 1.35 ± 0.14 | 1.25 ± 0.15 | **0.011**[a] |
| **Radius 33 % BMD** | 0.98 ± 0.08 | 0.97 ± 0.08 | 0.658[a] |
| ***BMC (g)*** | | | |
| **Total BMC** | 3393.73 ± 417.83 | 2884.53 ± 330.00 | **<0.001**[a] |
| **Spine BMC** | 244.20 ± 44.80 | 203.33 ± 36.05 | **<0.001**[a] |
| **Pelvis BMC** | 442.77 ± 78.05 | 353.03 ± 62.80 | **<0.001**[a] |
| **L2-L4 BMC** | 68.43 ± 11.84 | 55.41 ± 9.92 | **<0.001**[a] |
| **Radius 33 % BMC** | 2.73 ± 0.36 | 2.52 ± 0.32 | **0.036**[a] |

Results displayed as mean ± standard deviation or median (interquartile range). $p \leq 0.05$; *LM%* total lean mass %; *FFM%* fat free mass %; *FM%* fat mass %; *VAT* % visceral adipose tissue %; *WC* waist circumference; *BMD* bone mineral density; *L2-L4* lumbar vertebrae L2 to L4; *BMC* bone mineral concentration.
[a] = Independent Samples T-Test.
[b] = Mann Whitney *U* Test.

**Table 5**
The relationship between body composition parameters and calciotropic hormones.

| | Caucasians n = 30 | | | | SAIs n = 29 | | | |
|---|---|---|---|---|---|---|---|---|
| *Variable* | s25(OH)D (ng/mL) | sPTH (pg/mL) | sDBP (ug/mL) | sOC (ng/mL) | s25(OH)D (ng/mL) | sPTH (pg/mL) | sDBP (ug/mL) | sOC (ng/mL) |
| | *r* | *r* | *r* | *r* | *r* | *r* | *r* | *r* |
| **LM%** | 0.54[b] | −0.45[a] | 0.60 | 0.24 | −0.20 | 0.26 | 0.05 | −0.22 |
| **FM%** | −0.56[b] | 0.45[a] | 0.02 | −0.27 | 0.23 | −0.35 | −0.05 | 0.28 |
| **FFM%** | 0.54[b] | −0.45[a] | 0.01 | 0.26 | −0.16 | 0.25 | 0.18 | −0.23 |
| **Android fat%** | −0.60[b] | 0.31 | −0.06 | −0.55** | 0.21 | −0.16 | −0.08 | −0.17 |
| **Gynoid fat%** | 0.04 | 0.28 | 0.04 | 0.35 | −0.25 | −0.08 | 0.03 | 0.31 |
| **VAT%** | −0.37[a] | 0.07 | −0.11 | −0.62** | 0.35 | −0.002 | 0.18 | −0.16 |
| **WC (Inches)** | −0.60[b] | 0.36 | −0.03 | −0.31 | 0.15 | 0.02 | 0.21 | 0.17 |

Presented as bivariate Pearson's correlations or as bivariate Spearman Correlations.
*25(OH)D* 25-hydroxyvitamin D; *PTH* parathyroid hormone; *DBP* vitamin D Binding protein, *LM*% total lean mass %; *FFM%* fat free mass %; *FM%* total fat mass %; *VAT* % visceral adipose tissue%; *WC* waist circumference; *SAI* South Asian Indian. Blood draw as not obtained in 1 SAI participant.
[a] = significance <0.05.
[b] = significance <0.01.

negatively with LM% and FFM% among Caucasians (all $p < 0.05$). Furthermore, sOC was negatively correlated with android fat% and VAT % among Caucasians (all $p < 0.05$). Interestingly in the SAI group, none of the body composition parameters correlated significantly with calciotropic hormones and bone markers.

## 5. Discussion

Our cross-sectional comparative study in two populations of men found evidence for differences in calciotropic hormones particularly s25OHD and sPTH, bone, and body composition between young immigrant SAI and Caucasians. SAIs had significantly higher sPTH and lower s25(OH)D and serum adiponectin concentrations compared to Caucasians. Furthermore, the classical inverse relationship of s25(OH)D with sPTH was noted only among the SAIs. The FFM% and LM% were significantly lower among SAI, compared to Caucasians. Interestingly our study did not note any significant association between body composition parameters and calciotrophiccalciotropic hormones in the SAI's.

Our study findings showed that SAI's have alterations in calciotropic hormones and other metabolic markers compared to Caucasians. These findings are similar to the findings of Meyer et al. and Awumey et al. [13,23], who reported lower mean s25(OH)D in the South Asian populations compared to Caucasians. We also found the prevalence of vitamin D insufficiency based on the Institute of Medicine's guidelines (s25(OH)D < 20 ng/mL [24] was higher in SAIs (34.5 %) vs. Caucasians (10.0 %) among our study population, and 1 SAI participant had vitamin D deficiency (s25(OH)D < 12 ng/mL) [24]. Previous studies reported that sDBP levels vary among people from different racial backgrounds [25,26] Powe et al. found that sDBP concentrations were significantly lower in African Americans compared to Caucasians [26]. We also assessed concentrations of serum vitamin D binding protein and median sDBP level was not significantly different between Caucasians and SAIs. To our knowledge, there are no previous studies that compared the sDBP levels between SAIs and Caucasians.

SAIs in our study also had higher sPTH, which supports the fact that low vitamin D status is associated with higher sPTH levels [27–29]. Similar to our study, Meyer et al. and Awumey et al. both reported higher sPTH in South Asians compared to Caucasians [13,23]. High sPTH levels as an inflammatory biomarker can be associated with the development of chronic medical conditions such as type 2 diabetes and MetS [28,30] which may explain the SAI's higher susceptibility to MetS. Our study showed that 17 SAIs (59 %) had elevated sPTH levels while only 9 Caucasians (30 %) had elevated sPTH levels. The finding on PTH is of high importance as the ethnic differences were observed in a healthy and young SAI population with a median age of 26 years and may exacerbate the risk of the development of MetS among SAIs at a younger age compared to Caucasians. Our finding of lower adiponectin among SAIs is consistent with other studies [31,32] and could explain the existence of additional risk factors for developing MetS among young and healthy SAIs. Our findings collectively suggested that the calciotropic and metabolic biomarkers risk profile differ among young SAI and Caucasians.

The current study also documented evidence for differences in body composition and BMD. Our findings showed lower LM% and FFM% in SAIs compared to Caucasians and a tendency to have a higher FM% in SAIs. These findings are similar to those reported by Shah et al. [33] who found that SAIs had lower LM% compared to other racial groups (Caucasians, African Americans, Latinos, and Chinese Americans) living in the US [33]. Raji et al. [34] also reported that the older SAIs had significantly higher FM, greater total abdominal fat area, and greater VAT area compared to their matching Caucasian counterparts living in eastern Massachusetts (matching in age, gender, and BMI) [34]. SAIs in the study also had significantly lower BMD and BMC at different bone sites [34]. We proposed that the lower BMD among the SAIs compared to Caucasians in our study may be explained by their high sPTH, low s25 (OH)D levels and LM%, since dietary intakes of Ca and Mg were similar between the groups.

Several studies suggest a strong relationship between calciotropic hormones and body composition. However, in our study, although the SAI group had significantly lower s25(OH)D and higher sPTH levels, these biomarkers were not significantly associated with the measured body composition parameters, while few associations between body composition and calciotropic markers were detected among Caucasians. Nevertheless, Chiang et al. found that vitamin D deficiency was positively associated with total FM and abdominal VAT area among SAIs [35]. Still, these associations were seen only among women, and the study lacked a comparison group with Caucasians. Both Chiang et al. and Snijder et al. [35,36] who studied older men and women from the Netherlands, found significant or stronger correlations of s25(OH)D and sPTH with FM among women compared to men [35,36]. Also, some of these associations were observed only in individuals with vitamin D deficiency but not in a vitamin D-sufficient population, which may explain the lack of a significant association between s25(OH)D and sPTH in our study (only one participant in our study had vitamin D deficiency).

The strengths of this study include enrolling young and healthy cohorts of SAIs and Caucasians and examining exclusively men. The study excluded those with any medical conditions, which allows for controlling the possible confounding factors that may impact metabolic and bone health. Several biomarkers of bone health and metabolic health were assessed in this study. Additionally, the measurement of sDBP was unique in this study. To the best of our knowledge, this is the only study besides Chiang et al. [35]. that assessed the association between body composition parameters and biomarkers of bone health status among SAIs living in the US. However, Chiang et al. study [35] lacked a

comparison group of Caucasians and did not include the measurement of sDBP. Our study's limitations include the cross-sectional design that does not prove causation. Also the small sample size of this study, use of ELISA for determination of vitamin D status as opposed to more rigorous methodology such as HPLC or LS/MS, non determination of calcitriol-the active metabolite of vitamin D futher add to the limiations of the study [38]. Also, we did not assess the amount of physical activity or the duration of sun exposure, which can affect bone, body composition and calciotropic hormones.

In conclusion, our study showed that differences in bone, body composition and calciotropic hormones in young healthy SAI men compared to Caucasians. SAIs have an altered body composition, bone density and calciotropic hormones profiles compared to Caucasians, which might explain the higher risk for MetS among SAIs. Therefore, interventions for mitigating the risk of impaired cardiometabolic health in this population should begin at an early age.

## Ethical approval

The study was approved by the Drexel University Institutional Review Board and was registered in clinicaltrials.gov (NCT03600675). Prior to participation, all individuals read and signed an informed consent document.

## Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Author Contribution

AA, AA, RR, MMC, RDD and DS contributed to study coordination. AA, AA , RR and DS were primarily responsible for data analysis. MB contributed to statistical analysis. JAN, JK, AR, contributed to interpretation of study results. DS was primarily responsible for overseeing all aspects of study including obtaining funding, coordination, training of personnel, data analysis.

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