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ORIGINAL ARTICLE

Race/ethnic differences in the prevalence of osteoporosis, falls and fractures: a cross-sectional analysis of the Canadian Longitudinal Study on Aging

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Abstract

Summary Most of the published epidemiology on osteoporosis is derived from White populations; still many countries have increasing ethno-culturally diverse populations, leading to gaps in the development of population-specific effective fracture prevention strategies. We describe differences in prevalent fracture and bone mineral density patterns in Canadians of different racial/ethnic backgrounds.

Introduction We described prevalent fracture and bone mineral density (BMD) patterns in Canadians by their racial/ethnic backgrounds.

Methods For this cross-sectional analysis, we used the Canadian Longitudinal Study on Aging baseline data (2011–2015) of 22,091 randomly selected participants of Black, East Asian, South or Southeast Asian (SSEA) and White race/ethnic backgrounds, aged 45–85 years with available information on the presence or absence of self-reported prevalent low trauma fractures and femoral neck BMD (FNBMD) measurement. Logistic and linear regression models examined associations of race/ethnic background with fracture and FNBMD, respectively. Covariates included sex, age, height, body mass index (BMI), grip strength and physical performance score.

Results We identified 11,166 women and 10,925 men. Self-reported race/ethnic backgrounds were: 139 Black, 205 East Asian, 269 SSEA and 21,478 White. White participants were older (mean 62.5 years) than the other groups (60.5 years) and had a higher BMI (28.0 kg/m^2) than both Asian groups, but lower than the Black group. The population-weighted prevalence of falls was 10.0%, and that of low trauma fracture was 12.0% ranging from 3.3% (Black) to 12.3% (White), with Black and SSEA Canadians having lower adjusted odds ratios (aOR) of low trauma fractures than White Canadians (Black, aOR = 0.3 [95% confidence interval: 0.1–0.7]; SSEA, aOR = 0.5 [0.3–0.8]). The mean (SD) FNBMD varied between groups: Black, 0.907 g/cm^2 (0.154); East Asian, 0.748 g/cm^2 (0.119); SSEA, 0.769 g/cm^2 (0.134); and White, 0.773 g/cm^2 (0.128). Adjusted linear regressions suggested that Black and both Asian groups had higher FNBMD compared to White.

Conclusion Our results support the importance of characterizing bone health predictors in Canadians of different race/ethnic backgrounds to tailor the development of population-specific fracture prevention strategies.

Keywords Race/ethnicity · Fracture · Osteoporosis · Bone mineral density · Canadian Longitudinal Study on Aging

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Introduction

Osteoporotic fractures are a major public health issue. They result in acute care, rehabilitation and long term care costs that exceed $4.6 billion annually in Canada [1]. Although osteoporosis occurs in all populations, not all populations are at similar risk and the prevalence of fractures resulting from osteoporosis varies widely throughout the world [2]. Race/ethnicity is associated with bone mineral density (BMD) [3], with differences in risk factors for osteoporosis

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and fractures [4, 5], and with disparities in screening and treatment for osteoporosis [6].

More than one in five Canadians are foreign-born; Asia has, in recent years, been Canada's large source of immigrants [7]. Most of the published epidemiology on osteoporosis in Canada is derived from White populations [8–11] and knowledge about the determinants of this disease in other ethnic groups is lacking. This gap can lead to inaccurate identification of individuals at risk for fractures and disparities in osteoporosis outcomes and management [12]. Race/ethnicity represents complex relationships comprised of socioeconomic, geographic and environmental factors, in addition to genetic or biological factors, all of which affect health outcomes [13].

Using the Canadian Multicenter Osteoporosis Study (CaMos) cohort data, we have recently reported that self-identified Chinese and White Canadians differ on many important risk factors for osteoporosis and fractures including height, body mass index (BMI), calcium intake, tea consumption, falls and BMD [14]. However, although CaMos is a large population-based cohort, only a small minority of participants claimed race/ethnic background different than White ancestry.

The Canadian Longitudinal Study of Aging (CLSA) is a large nationwide longitudinal study that recruited and will follow 50,000 community-dwelling women and men aged 45 to 85 years old (baseline 2011–2015) for at least 20 years [15]. The CLSA collects information on biological, medical, psychological, social, lifestyle and economic aspects of people's lives to understand their impact in maintaining health and in the development of disease as people age. Using data collected at inception of the cohort, we aimed to describe BMD, the prevalence of osteoporosis and of fractures and anti-osteoporosis medication use in Canadians of different race/ethnic backgrounds and compare them to White Canadians.

Methods

Study participants

We used baseline data from the 30,097 participants of CLSA's comprehensive cohort (CLSA v4.0; sampling weights v1.2) who, in addition to providing information through telephone interviews, also participated in physical examinations, biological specimen collection at one of 11 data collection sites across Canada (https://www.clsa-elcv.ca). Participants were recruited from seven provinces (British-Columbia, Alberta, Manitoba, Ontario, Quebec, Nova-Scotia and Newfoundland) using random selections from provincial health registries and random-digit dialling sampling frames. Exclusion criteria included inability to answer in French or English, living on First Nations Reserves, being a member of the Canadian Armed Forces or having cognitive impairment. More details on the CLSA sampling frame and design are published elsewhere [15, 16]. The response rate at baseline was 10% but the distribution of key measures was similar between the CLSA and the 2011 Canadian census and other nationally representative surveys, which have higher response rates [17]. All participants were also contacted by telephone approximately 18 months after their baseline visit to complete the Maintaining Contact Questionnaire (MCQ), which included additional information. Signed informed consent was obtained from every study participant. Ethics approval for the present study was granted through the Research Institute of the McGill University Health Centre.

A total of 22,091 participants ages 45–85 years with self-reported race/ethnic background, available information on the presence or absence of self-reported prevalent low trauma fractures and with body mass index (BMI) and BMD measurements at the femoral neck and total hip were included in this study (Supplemental Fig. 1).

Race/Ethnicity and country of birth

Race/ethnic background was self-reported and derived from two questions (questions 3 and 4, module SDC) asking the participant to report on their cultural and ethnic backgrounds. We categorized self-reported race/ethnic background as: Black, East Asian (Chinese, Japanese, Korean), South or Southeast Asian (SSEA) or White, based on the CLSA nomenclature. The SSEA group combines participants of South Asian ethnic groups (India, Afghanistan, Pakistan, etc.) and those of Southeast Asian ethnic groups (Philippines, Thailand, Vietnam, Malaysia, Singapore, etc.). Participants reporting multiple racial or cultural ancestries ($n = 226$) as well as participants who self-reported race/ethnicity of groups with less than 100 participants ($n = 290$) or in whom race/ethnicity was not available were excluded from the analyses (Supplemental Fig. 1). We also considered participants' country of birth and the length of time (in years) they had been living in Canada (self-report).

Bone mineral density measurements

BMD measurements at the femoral neck and total hip were analysed. In CLSA, BMD measurements were not acquired at the lumbar spine. Each of the CLSA scanning centres used the same model of dual-energy x-ray absorptiometry (DXA) scanner: Hologic Discovery A™ DXA [18]. Our team generated femoral neck BMD T-scores using the young normal values from the NHANES III BMD of White women 20–29 years old as per the International Society of Clinical Densitometry recommendations [19]

and the Epidemiology and Quality of Life Working Group of the International Osteoporosis Foundation [20].

Standard Operating Procedures were used throughout the conduct of the CLSA study to guide quality control and system maintenance [18, 21]. DXA Quality control was performed daily using the Hologic spine phantom, weekly using a Whole Body Phantom, and yearly with the Gold Standard Traveling Phantoms. An anthropomorphic spine phantom was scanned 10 times yearly on each DXA machine and at each maintenance visits for cross-calibration of the different machines. There were no significant differences in calibration between the machines in the different centres (personal communication, National Coordinating Centre; September 2020). All spine BMD means were similar and within the 1% limit as recommended in the 2019 official positions of the International Society for Clinical Densitometry (ISCD) [22].

Osteoporosis, Falls, Fractures and Fracture risk

Osteoporosis was defined in two ways. Firstly, as a self-reported variable (question 1, module OST) "Has a doctor ever told you that you have osteoporosis, sometimes called low bone mineral density, or thin, brittle or weak bones?". Secondly, osteoporosis was defined as a T-score equal to -2.5 or less at the femoral neck, as per international recommendations [20].

We obtained information regarding falls within the previous 12 months from the Maintaining Contact Questionnaire, administered approximately 18 months after baseline. The questionnaire asked "We are interested in falls where you hurt yourself enough to limit some of your normal activities. In the past 12 months, did you have any falls?" (question 1, module FAL).

Prevalent fractures were self-reported and defined as prior fractures that occurred during adult life and resulted from a minor fall or low level of injury (ex: a simple fall from standing height). Any low trauma fracture as well as specific skeletal sites (hip, humerus, clinical spine, wrist, rib, pelvis) were reported (questions 5 and 6, module OST). We defined major osteoporotic fractures (MOF) as fractures of the hip, humerus, forearm/wrist, or clinical spine.

Using information collected at baseline, the 10-year fracture risk probabilities were generated using the Canadian FRAX® tool [23] for MOF and hip fractures with femoral neck T-score [19].

We also defined participants at high risk for fractures as those who presented one of the following criteria: a) prior low trauma fracture at any site; b) a FRAX score with BMD (Canadian tool) for hip fracture of 3% or more or a FRAX score for MOF of 20% or more; c) a femoral neck T-score of -2.5 or less.

Physical performance

Grip strength (in kg) was assessed 3 times with the dominant hand using the Tracker Freedom Wireless Grip dynamometer [24, 25]. The average of the three measures was used for the analyses. The timed up-and-go (TUG) test measured the time (seconds) it took for the participant to stand up from a chair (with arm rests) and walk a distance of 3 m, walk back and sit down again [25, 26]. For the chair rise test, measured in seconds, the participant was asked to sit as far back in a chair without arm rests, and to stand up and sit back down five times as quickly and safely as possible, with no rest in between and without using their hands to get up [25, 27]. Standing balance was also measured (in seconds). Shoeless, the participant was requested to lift the left leg and to stand on one foot as long as possible, for a maximum of 60 s, while placing their hands on their waist [25, 28]. A study of CLSA participants revealed that the relative reliability for grip strength was excellent while the TUG, balance and chair-rise tests had moderate to good reliability [25].

We divided the TUG, the chair rise and balance measures into three categories and, for each participant, counted the number of physical performance measures, in which they were classified in the worst category [29]. The TUG and Chair rise were divided in tertiles. For the balance test, since 40% of the participants had the maximum value of 60 s, we divided the participants with values less than 60 s in two (median) groups to obtain 3 categories. We then created a *physical performance score* with 3 categories: no physical performance measure in the worst category/tertile (0), having 1 or 2 physical performance measurements in the worst category/tertile (1 or 2), being in the worst category/tertile for all 3 physical performance measurements (3).

Other measurements

Demographics and lifestyle variables were obtained during the baseline interview. Age was categorized into 10-year age groups (45–54, 55–64, 65–74, 75–85). Education was categorized as holding a post high school degree or diploma, holding a high school diploma or not holding a high school diploma. Annual household income was categorized as lower than $50 K, $50 K-$100 K or $100 K or more. Participants were classified as having none, 1–3, or four or more comorbidities based on their answers to the Disease Symptoms Questionnaire regarding rheumatoid arthritis, osteoarthritis, neurological disease, dementia, stroke or ministroke, epilepsy, cardiovascular disease, hypertension, cancer, asthma or COPD, chronic kidney disease, hyper or hypothyroidism, malabsorption syndromes, diabetes and depression or anxiety. Use of any osteoporosis medication were self-reported at baseline and captured as current use of bisphosphonates (alendronate, risedronate, etidronate or zoledronic

acid), denosumab, teriparatide, raloxifene or calcitonin or ever use of hormone replacement therapy (oestrogen and progesterone) (questions 3 and 4, module OST). Use of calcium or vitamin D supplements in the previous month was also obtained from the Maintaining Contact Questionnaire.

Height (cm) and weight (kg) were measured using a stadiometer and a digital physician scale, respectively [30]. Body mass index (BMI) was obtained from dividing the weight in kg by height (m) square.

Serum total 25-hydroxy vitamin D was measured using the Liaison (Diasorin Incorporated) assay, which employs chemiluminescent immunoassay technology. The detection limits were 10 nmol/L to 375 nmol/L. The coefficient of variation varied from 7.3% at 80.5 nmol/L to 8.1% at 43.9 nmol/L. We considered the 25-hydroxy vitamin D levels in categories of < 50 nmol/L, 50 to > 75 nmol/L and ≥ 75 nmol/L.

Statistical analyses

This is a cross-sectional analysis of the baseline CLSA data. Descriptive statistics were presented as frequency (%) and mean (standard deviation [SD]). Chi-square test (for categorical variables), ANOVA (for continuous variables, normally distributed) and Kruskal–Wallis test (for continuous variables, non-normally distributed) were used to compare baseline characteristics across race/ethnicity groups. The prevalence of falls (any in the last 12 months), prior low trauma fractures (any, MOF), diagnosis of osteoporosis (self-reported and by T-score $\leq$ -2.5) and proportion of participants at high risk of fracture were reported as percentages (with 95% confidence interval) by race/ethnic groups using the CLSA inflation weights (version 1.2). Among the participants considered at high risk of fractures, we also reported the weighted proportion of participants taking anti-osteoporosis treatment by race/ethnic groups.

Logistic regressions were used to examine the associations between self-reported race/ethnicity and falls or any low trauma fractures in women and men (combined), using White participants as the reference category. Regression models stratified by sex were not possible due to the small number of falls and prevalent fractures reported in all race/ethnicity categories but White. Models were carried out in four steps. First, we created univariable models, i.e., with race/ethnicity category only. The second step adjusted the results for age groups. We additionally adjusted for height (cm) and BMI (kg/m^2) and finally, for grip strength, physical performance score and femoral neck BMD.

Linear regression models were performed to compare baseline BMD values (femoral neck, total hip) of the different race/ethnic groups to that of White participants (reference level). These regression models are presented for women and men combined since the interaction of sex with ethnicity category was found to be non-significant. The same four-step strategy as above was applied. However, in the fourth step, we further adjusted for grip strength and physical performance scores. Interaction of race/ethnic group with BMI was considered but found to be non-significant in all models.

The Bonferroni correction was used to adjust the probability values (p-values) when doing two by two comparisons for race/ethnic groups. The CLSA analytic weights (version 1.2) were applied for the regression analyses.

Since most East Asian participants were of Chinese origin, we conducted sub-analyses excluding participants of non-Chinese origin in the East Asian category (Japanese and Korean) to see the impact of these other race/ethnicity backgrounds on the prevalence and estimates obtained for the East Asian participants. The results were similar and therefore not included.

Analyses were performed using SAS Studio release 3.8 (2012–2018, SAS Institute Inc., Cary, NC, USA.)

Results

We identified 11,166 women and 10,925 men. Self-reported race/ethnic backgrounds were: 139 (0.6%) Black, 205 (0.9%) East Asian, 269 (1.2%) SSEA and 21,478 (97.2%) White. Countries of birth varied by ethnicity (Supplemental Fig. 2). Canada was the country of birth for most of the White participants (84.8%), who had lived an average of 60 years in Canada (Table 1). Half of the Black participants were born in three countries: Canada (16.5%), Haïti (18.0%) and Jamaica (15.8%); a third of East Asians were born in Canada (33.7%), while a little less than half were born either in China (26.8%) or Hong Kong (20.0%). Most of East Asian participants self-identified themselves as of Chinese race/ethnicity (82.0%), and among these, 25.6% were born in Canada. Finally, only 3.3% of the SSEA participants were born in Canada, whereas a little more than half were born either in India (38.7%) or the Philippines (14.9%). Overall, the East Asian, SSEA and Black participants had lived in Canada for a shorter duration when compared to White participants with an average of 33 (SSEA) to 43 (East Asian) years. The province of recruitment by race/ethnicity are shown in Supplemental Fig. 3. A greater proportion of Black participants were recruited in the provinces of Quebec (32.4%) and Ontario (27.3%). Almost half of East Asian participants (50.7%) and 30.5% of the SSEA participants were from British Columbia.

White participants were older (mean 62.5 years [SD = 9.9]) than the other groups (60.5 years [10.0]) and had a higher BMI (28.0 kg/m^2 [5.3]) than both Asian groups, but lower than the Black participants (Table 1). Post-secondary education also varied ranging from 78.8% in Whites to as high as 91.5% in SSEA

Table 1 Characteristics of analytical cohort participants by race/ethnic category presented as number (%) or mean (standard deviation)

			Black ($n=139$)	East Asian ($n=205$)	SSEA ($n=269$)	White ($n=21,478$)	Total ($n=22,091$)
Women			**67 (48.2%)**	**95 (46.3%)**	**107 (39.8%)**	**10 897 (50.7%)**	11 166 (50.6%)
Age group	45–54		**48 (34.5%)**	**75 (36.6%)**	**93 (34.6%)**	**5 473 (25.5%)**	5 689 (25.8%)
	55–64		**42 (30.2%)**	**74 (36.1%)**	**73 (27.1%)**	**7 327 (34.1%)**	7 516 (34.0%)
	65–74		**34 (24.5%)**	**36 (17.6%)**	**64 (23.8%)**	**5 343 (24.9%)**	5 477 (24.8%)
	75–85		**15 (10.8%)**	**20 (9.8%)**	**39 (14.5%)**	**3 335 (15.5%)**	3 409 (15.4%)
Age (years)—mean (SD)			**60.6 (9.8)**	**59.9 (9.3)**	**61.0 (10.6)**	**62.5 (9.9)**	62.5 (9.9)
Height (m)—mean (SD)			**1.68 (0.09)**	**1.64 (0.09)**	**1.64 (0.09)**	**1.69 (0.10)**	1.69 (0.10)
BMI (kg/m^2)—mean (SD)			**29.1 (5.2)**	**24.5 (3.6)**	**26.4 (4.3)**	**28.0 (5.3)**	27.9 (5.3)
Education	< Secondary school		**7 (5.0%)**	**4 (2.0%)**	**4 (1.5%)**	**1039 (4.8%)**	1054 (4.8%)
	Secondary diploma		**18 (12.9%)**	**24 (11.7%)**	**19 (7.1%)**	**3517 (16.4%)**	3578 (16.2%)
	Post-secondary diploma		**114 (82.0%)**	**177 (86.3%)**	**246 (91.5%)**	**16 890 (78.8%)**	17427 (79.0%)
Household income	< $50,000		**55 (44.7%)**	**40 (21.9%)**	**77 (29.7%)**	**5052 (25.0%)**	5224 (25.1%)
	$50,000—$100,000		**35 (28.5%)**	**61 (33.3%)**	**94 (36.3%)**	**7272 (36.0%)**	7462 (35.9%)
	≥ $100,000		**33 (26.8%)**	**82 (44.8%)**	**88 (34.0%)**	**7897 (39.0%)**	8100 (39.0%)
Smoking status	Current		**9 (6.5%)**	**5 (2.4%)**	**16 (6.0%)**	**1705 (7.9%)**	1735 (7.9%)
	Former		**29 920.9)**	**47 (22.9%)**	**61 (22.7%)**	**9501 (44.2%)**	9638 (43.6%)
	Never		**101 (72.7%)**	**153 (74.6%)**	**192 (71.4%)**	**10271 (47.8%)**	10717 (48.5%)
Alcohol intake: > 3 servings/day			**0 (0.0%)**	**1 (0.5%)**	**6 (2.2%)**	**1286 (6.0%)**	1293 (5.9%)
Number of comorbidities		None	**30 (24.6%)**	**72 (36.0%)**	**70 (27.8%)**	**4542 (22.5%)**	4714 (22.7%)
		1–3	**82 (67.2%)**	**121 (60.5%)**	**165 (65.5%)**	**13694 (67.9%)**	14062 (67.8%)
		4 +	**10 (8.2%)**	**7 (3.5%)**	**17 (6.8%)**	**1926 (9.6%)**	1960 (9.5%)
Anti-osteoporosis medication			**13 (9.6%)**	**26 (12.8%)**	**25 (9.4%)**	**3774 (18.0%)**	3838 (17.8%)
Supplement in last month	Calcium		33 (24.3%)	69 (35.2%)	78 (29.7%)	6 051 (28.5%)	6231 (28.6%)
	Vitamin D		**54 (39.7%)**	**77 (39.3%)**	**129 (48.9%)**	**10 487 (49.5%)**	10747 (49.3%)
25(OH)D (nmol/L) – mean (SD)			**74.8 (40.4)**	**76.8 (35.0)**	**68.9 (35.8)**	**90.5 (36.8)**	90.1 (36.9)
Predicted 10-year risk of fracture (FRAX with BMD)		Hip > 3%	**2 (1.4%)**	**15 (7.3%)**	**36 (13.4%)**	**2 366 (11.0%)**	2419 (11.0%)
		MOF > 20%	1 (0.7%)	4 (2.0%)	10 (3.7%)	775 (3.6%)	790 (3.6%)
Born in Canada			**23 (16.6%)**	**69 (33.7%)**	**9 (3.4%)**	**18 221 (84.8%)**	18322 (82.9%)
Time in Canada (years)—mean (SD)			**36.3 (16.7)**	**42.6 (18.0)**	**32.6 (13.7)**	**59.5 (12.3)**	58.9 (13.0)

SSEA = South or Southeast Asian; SD = standard deviation; MOF = Major Osteoporosis Fracture; FRAX = 10-year fracture risk probabilities. Number of missing values for: education = 32, household income = 1305, diagnostic of osteoporosis = 132, smoking status = 1, alcohol intake = 8, comorbidities = 1355, osteoporosis medication = 537, vit D supp. = 297, Ca supp. = 297, 25(OH)D = 1925

Bolded cells demonstrate results that are significantly different between ethnicity categories ($p < 0.05$)

Non-weighted results

and the proportion of participants with an annual household income lower than $50,000 ranged from 21.9% in East Asian to 44.7% in Black participants. We also noted a difference in the number of comorbidities reported with a higher proportion of the Black and White participants reporting four or more comorbidities. We saw a difference in the pattern of comorbidities reported with hypertension being more prominent in Black participants, diabetes in SSEA, and cancers in White participants. Use of anti-osteoporosis medication differed across groups, with the highest proportion of users in White participants. Vitamin D supplement, but not calcium supplement, use varied across groups; while almost half of the participants reported taking vitamin D supplement in the previous month. Overall, 23.6% of the participants used both calcium and vitamin D supplements in the past month, 25.7% only vitamin D supplement, 5.0% only calcium supplement, and finally, 45.7% reported taking none. The mean 25-hydroxy vitamin D serum level ranged from 68.9 nmol/L (SSEA) to 90.5 nmol/L (White). This resulted into statistically different proportions of participants with sufficient 25-hydroxy vitamin D levels (higher than 50 nmol/L) by race/ethnicity category: 69.2% in Black, 75.1% in East Asian, 66.7% in SSEA and 88.5% in White.

Physical performance

Differences between race/ethnicity categories were noted in all physical performance measures (Table 2). The median grip strength varied from 29.1 kg (interquartile range [IQR]: 22.5–37.1] in SSEA to 31.8 kg (IQR: 25.0–42.3) in White, the median TUG from 9.0 s (IQR: 8.1–10.0) in East Asian (best score) to 10.0 s (IQR: 8.6–11.3) in Black, and the median chair rise time from 12.6 s (10.5–14.8) in East Asian to 13.2 s (IQR: 11.2–16.4) in Black. For balance, the lowest median value was 38.8 s (IQR: 8.0–60.0) in SSEA, while the highest median value was seen in East Asian participants with 60.0 s (IQR: 14.0–60.0) which is the highest and best score a participant can achieve. These differences between race/ethnicity categories in physical performance assessments were most notably seen when summarized into the physical performance score. East Asian participants had the highest proportion of participants with the best physical performance score (47.3%), although this was not statistically different from the White participants (43.2%).

Falls and prevalent fractures

The number of participants who reported a fall in the prior 12 months was low in non-White groups: 11 (8.1%) Black, 14 (7.1%) East Asian, 19 (7.2%) SSEA, compared to 2196 (10.4%) in White participants. Applying the CLSA inflation weights, we obtained that the population-weighted Canadian prevalence of falls in the past 12 months varied by race/ethnicity groups from 4.2% (1.0; 8.2) in East Asian to 10.2% (9.4; 11.0) in White participants (Table 3). Fully adjusted regression models failed to show significant between-group difference, but analysis was limited by wide confidence intervals which included differences of clinical interest (Table 4).

The number of participants reporting a low trauma fracture was also small: 6 (4.3%) in Black, 12 (5.9%) in East Asian, 19 (7.1%) in SSEA, and 3230 (15.0%) in White participants. Overall, the population-weighted Canadian prevalence of any low trauma fracture was 12.0% (11.3; 12.8), ranging from as low as 3.3% (0.0; 8.1) in Black participants to as high as 12.3% (11.5; 13.1) in White participants (Table 3). Compared to White participants, SSEA and Black participants had lower adjusted odds of low trauma fracture (aOR 0.5 [95% CI: 0.3; 0.8] and aOR 0.3 [95% CI: 0.1; 0.7], respectively), while the results for East Asian (aOR 0.6 [95% CI: 0.3; 1.6]) were not significant (Table 4). Adjusting for femoral neck BMD did not change these estimates.

Bone mineral density

The mean (SD) femoral neck and total hip BMD are shown in Fig. 1 stratified by sex as well as for combined women and men. Black participants had higher unadjusted femoral neck and total hip BMD compared to White participants and these differences remained significant after multivariable adjustments. East Asian participants had significantly lower unadjusted total hip BMD values than White participants; however once adjusted for BMI, East Asians were found to have significantly higher femoral neck than White participants (Table 4). Finally, the difference between SSEA and White participants became significant after adjusting for BMI for femoral neck. Multiple

Table 2 Physical performance measures by race/ethnicity category

Median (interquartile range) unless otherwise indicated		Black	East Asian	SSEA	White	Total
Grip strength (kg)		**30.9 (25.9–42.4)**	**30.7 (24.2–40.1)**	**29.1 (22.5–37.1)**	**31.8 (25.0–42.3)**	31.8 (25.0; 42.2)
Physical performance	Timed up & go (s)	**10.0 (8.6–11.3)**	**9.0 (8.1–10.0)**	**9.7 (8.8–11.0)**	**9.1 (8.1–10.3)**	9.1 (8.1; 10.3)
	Chair rise (s)	**13.2 (11.2–16.4)**	**12.6 (10.5–14.8)**	**13.1 (11.1–15.6)**	**12.8 (10.8–15.2)**	12.8 (10.8; 15.2)
	Balance (max 60 s)	**47.5 (12.2–60.0)**	**60.0 (14.0–60.0)**	**38.8 (8.0–60)**	**41.9 (9.7–60.0)**	42.1 (9.7; 60.0)
Physical performance score- n (%)	0 (best)	**44 (32.6%)**	**96 (47.3%)**	**89 (34.6%)**	**8 928 (43.2%)**	9 157 (43.0%)
	1–2	**77 (57.0%)**	**98 (48.3%)**	**139 (54.1%)**	**9 936 (48.0%)**	10 250 (48.2%)
	3 (worst)	**14 (10.4%)**	**9 (4.4%)**	**29 (11.3%)**	**1 821 (8.8%)**	1 873 (8.8%)

SSEA = South or Southeast Asian. Number of missing values for: grip strength = 1450, timed up and go = 73, chair rise = 540, balance = 683, physical performance score = 811

Non-weighted results

Bolded cells demonstrate results that are significantly different between race/ethnicity categories ($p < 0.05$)

Table 3 Prevalence (95% confidence interval) of falls, low trauma fractures, diagnosis of osteoporosis and high risk for fracture

Percentage (95% C.I.)		Black	East Asian	SSEA	White	Total
Falls (any in the past 12 months)		**4.7% (1.2; 8.2)**	**4.6% (1.0; 8.2)**	**4.7% (1.4; 8.0)**	**10.2% (9.4; 11.0)**	10.0% (9.2; 10.8)
Low trauma fractures (any site in adult life)		**3.3% (0.0; 8.1)**	**9.6% (1.0; 18.2)**	**3.8% (1.4; 6.1)**	**12.3% (11.5; 13.1)**	12.0% (11.3; 12.8)
Diagnosis of osteoporosis	Self-reported	6.0% (0.0; 12.7)	4.9% (1.1; 8.6)	4.5% (1.6; 7.4)	7.3% (6.6; 8.0)	7.2% (6.6; 7.9)
	Femoral neck BMD T-score ≤ -2.5	NA	1.4% (0.0; 2.9)	2.9% (0.7; 5.0)	2.4% (2.0; 2.8)	2.3% (2.0; 2.7)
High Risk for fracture: Prior low trauma fracture or T-score ≤ -2.5 or High FRAX risk*		**3.8% (0.0; 8.7)**	**11.9% (3.3; 20.6)**	**10.0% (5.7; 14.3)**	**17.9% (17.0; 18.9)**	17.6% (16.7; 18.5)

SSEA = South or Southeast Asian

Number of missing values for: falls = 273, diagnosis of osteoporosis by self-report = 132, high risk for fracture = 22

Weighted results, v1.2

FRAX = Predicted 10-year risk of fracture

* High FRAX risk: FRAX score (with BMD) for hip fracture of 3% or more or a FRAX score (with BMD) for MOF of 20% or more

Bolded cells demonstrate results that are significantly different between race/ethnicity categories ($p < 0.05$)

NA = Not-applicable since there were no participants with a T-score ≤ -2.5

two by two comparisons revealed that Black participants also had higher adjusted femoral neck and total hip BMD than East Asian and SSEA participants. Sex-stratified analyses revealed similar results and are shown in Supplemental Table 1.

Prevalence of osteoporosis and anti-osteoporosis treatment use in participants at high risk for fractures

The population-weighted prevalence of self-reported osteoporosis in combined women and men was 7.2% (95% CI: 6.6; 7.9), but lower (2.3% [95% CI: 2.0; 2.7]) when based on BMD T-score at the femoral neck (Table 3). No differences were found in weighted prevalence between race/ethnic groups, regardless of method of assessment, although confidence intervals around the estimates were wide.

The number of participants considered at high risk for fracture, i.e., with a prior low trauma fracture or a femoral neck BMD T-score ≤ -2.5 or a FRAX score (with BMD) exceeding the thresholds of 3% for hip fracture or 20% for MOF, was low in the study population: 8 in Black (5.8%), 24 in East Asian (11.7%), 54 in SSEA (20.1%) and 4903 in White (22.8%). The overall population-weighted prevalence of Canadians at risk for fracture, as defined above, was 17.6% (95% CI: 16.7; 18.5) and varied by race/ethnicity with Black (3.8% [0.0; 8.7]), East Asian (11.9% [3.3; 20.6]) and SSEA (10.0% [5.7; 14.3]) participants having lower prevalence than White participants (17.9% (17.0; 18.9)], and Black participants having lower prevalence than East Asian and SSEA participants (Table 3). Among the participants at high risk for fracture, the weighted proportion (95% CI) of participants taking anti-osteoporosis medication varied from 12.5% (0.0; 26.7) in East Asian participants to 30.4% (27.7; 33.1) in White participants (Supplemental Fig. 4), but comparisons between race/ethnic groups were non-significant due to the small number of participants considered at high risk for fractures in non-White groups. Bisphosphonate use among high-risk participants was notably low (below 10%) across groups despite the high risk for fractures.

Discussion

Using cross-sectional data from the large Canadian Longitudinal Study on Aging, we have documented differences in the prevalence of falls and low trauma fractures, as well as in femoral neck and total hip BMD in participants from different race/ethnicity categories. Although the prevalence of falls and prevalent fractures was low in all groups, we have shown that SSEA and Black participants have higher adjusted femoral neck and total hip BMD values and lower odds prevalent low trauma fractures compared to White participants. The overall self-reported population-weighted prevalence of osteoporosis was 7.2%, which is slightly lower than recently published by the Public Health Agency of Canada based on the Canadian Community Health Survey-Osteoporosis Rapid Response Component (10.1%) [31] and the Canadian Chronic Disease Surveillance System: Osteoporosis and related Fracture in Canada, in adults 40 years and older (11.9%) [32]. This could be in part explained by the greater proportion of CLSA participants with higher education levels compared to the Canadian population [17].

There is evidence that BMD and fracture risk vary across racial and ethnic groups, in keeping with our results

Table 4 Associations between race/ethnicity category and falls, prevalent low trauma fracture, femoral neck and total hip BMD, in women and men combined

FALLS (any in the past 12 months)	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
	Model 1 (n = 21,818)	Model 2 (n = 21,818)	Model 3 (n = 21,818)	Model 4 (n = 19,707)
Black	0.9 (0.4; 1.8)	0.9 (0.4; 1.8)	0.9 (0.4; 1.8)	0.9 (0.4; 2.0)
East Asian	0.5 (0.2; 1.2)	0.5 (0.2; 1.3)	0.6 (0.2; 1.4)	0.6 (0.2; 1.4)
SSEA	**0.5 (0.3; 0.9)**	**0.5 (0.3; 0.9)**	**0.5 (0.3; 1.0)**	0.6 (0.3; 1.1)
White	Reference level			
LOW TRAUMA FRACTURE (any site in adult life)	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**	**OR (95% CI)**
	Model 1 (n = 22,091)	Model 2 (n = 22,091)	Model 3 (n = 22,091)	Model 4 (n = 19,957)
Black	**0.2 (0.1; 0.5)**	**0.2 (0.1; 0.5)**	**0.2 (0.1; 0.5)**	**0.3 (0.1; 0.7)**
East Asian	0.5 (0.2; 1.2)	0.6 (0.2; 1.3)	0.6 (0.3; 1.4)	0.6 (0.3; 1.6)
SSEA	**0.3 (0.2; 0.6)**	**0.4 (0.2; 0.7)**	**0.4 (0.2; 0.7)**	**0.5 (0.3; 0.8)**
White	Reference level			
BMD (g/cm^2)	**Estimate (95% CI)**	**Estimate (95% CI)**	**Estimate (95% CI)**	**Estimate (95% CI)**
Femoral neck BMD	Model 1 (n = 22,091)	Model 2 (n = 22,091)	Model 3 (n = 22,091)	Model 4 (n = 19,957)
Black	**0.138 (0.106; 0.170)**	**0.134 (0.104; 0.164)**	**0.130 (0.103; 0.156)**	**0.130 (0.133; 0.157)**
East Asian	-0.020 (-0.041; 0.001)	**-0.031 (-0.052; -0.009)**	0.019 (-0.003; 0.041)	**0.022 (0.000; 0.045)**
SSEA	0.004 (-0.019; 0.027)	-0.011 (-0.034; 0.012)	**0.027 (0.006; 0.047)**	**0.033 (0.014; 0.052)**
White	Reference level			
Total hip BMD	Model 1 (n = 22,091)	Model 2 (n = 22,091)	Model 3 (n = 22,091)	Model 4 (n = 19,957)
Black	**0.108 (0.080; 0.136)**	**0.106 (0.076; 0.135)**	**0.098 (0.073; 0.122)**	**0.098 (0.074; 0.122)**
East Asian	**-0.028 (-0.047; -0.009)**	**-0.039 (-0.058; -0.020)**	0.012 (-0.006; 0.031)	0.016 (-0.002; 0.035)
SSEA	0.001 (-0.025; 0.028)	-0.016 (-0.041; 0.010)	0.019 (-0.003; 0.042)	**0.027 (0.005; 0.050)**
White	Reference level			

SSEA = South or Southeast Asian; OR = Odds Ratio; 95% CI = 95% Confidence Intervals

Weighted results, v1.2

Model 1: unadjusted

Model 2: adjusted for sex and age group

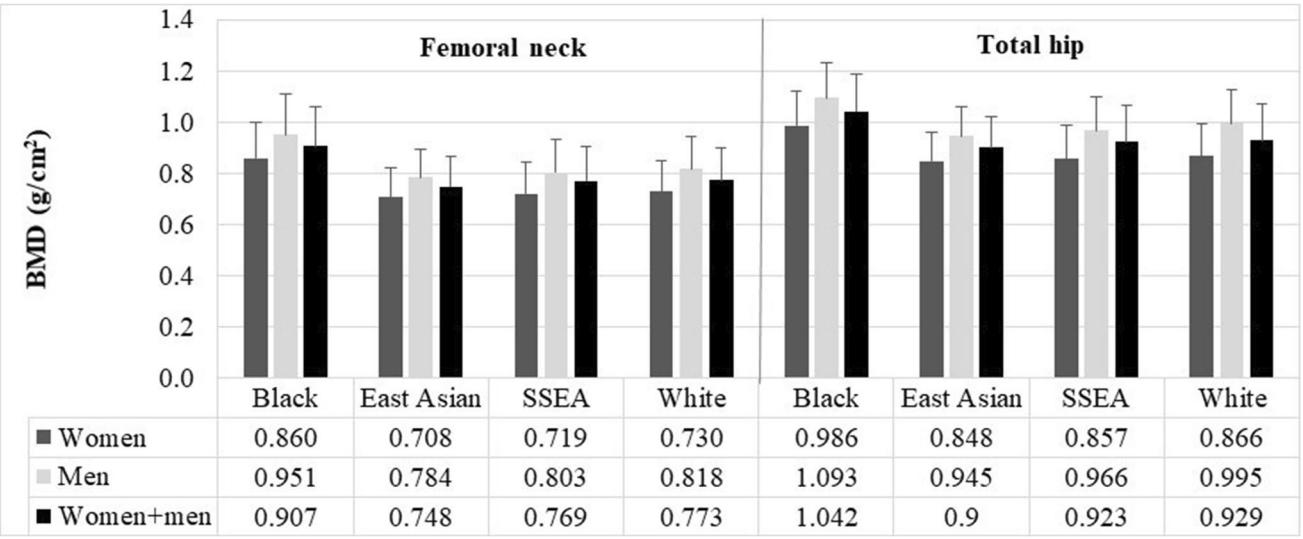
Model 3: adjusted for sex, age group, height and BMI

Model 4: adjusted for sex, age group, height and BMI, grip strength, physical performance score

Falls and low trauma fractures are further adjusted for femoral neck BMD

Bolded cells demonstrate results that are significantly different from the White ethnicity category ($p < 0.05$)

[6]. The multiethnic Study of Women's Health Across the Nation (SWAN) examined White, Black, Japanese, and Chinese women living in the United States. Black women had the highest, whereas Japanese and Chinese women had the lowest unadjusted BMD; following adjustment for anthropometric measures, there were no differences in adjusted lumbar spine and femoral neck BMD between Chinese, Japanese and Caucasian women [33], supporting the importance of body weight/bone size in ethnic differences in BMD. Similarly, we noted a change in the estimate for BMD at the femoral neck and total hip once we adjusted for BMI. Nam and colleagues compared hip and spine BMD in men of seven race/ethnic groups and five countries; in age-adjusted analysis Afro-Caribbean and Afro-American men had higher level of total hip BMD compared to American White men [34]. Similarly, using data from the US National Health and Nutrition Examination Survey (2005–2008), Looker and colleagues estimated that the age-adjusted prevalence of osteoporosis in non-Hispanic Black men was lower than the prevalence in non-Hispanic White men [35]. The National Osteoporosis Risk Assessment Cohort (NORA) reported that Black women had a lower risk for T-score in the osteoporotic range, whereas Hispanic and Native American women had risks that were not appreciably different from White women. Asian women had the highest prevalence of osteoporosis (by T-score) but the multivariate-adjusted risk was similar to White women [7]. This was attributed to the adjustment for body weight. In contrast, we did not find any differences in the prevalence of osteoporosis defined by T-scores between ethnicities, but our results included women and men combined. We derived T-scores using reference data



	Femoral neck				Total hip			
	Black	East Asian	SSEA	White	Black	East Asian	SSEA	White
Women	0.860	0.708	0.719	0.730	0.986	0.848	0.857	0.866
Men	0.951	0.784	0.803	0.818	1.093	0.945	0.966	0.995
Women+men	0.907	0.748	0.769	0.773	1.042	0.9	0.923	0.929

Fig. 1 Mean (SD) femoral neck and total hip BMD (g/cm^2) by race/ethnicity for combined women and men as well as stratified by sex. SSEA = South or Southeast Asian. Non-weighted results

for White young women in NHANES as recommended by multiple organizations and as required by FRAX [19, 20, 36]. This approach avoids possible confounding from the use of ethnicity-specific reference data. Whether there is a role for ethnicity-specific reference data in clinical practice is controversial and cannot be directly addressed from this study.

Fracture rates have been documented to be lower in US non-Hispanic Black and Asian men and women compared to their non-Hispanic White counterparts [37]. Similarly, the Women's Health Initiative (WHI) has shown that Black women had lower hip fracture rate than White women [38]. The WHI further showed that this association was consistent with the differences seen in the geometry of the proximal femur. In the NORA study, Black and Asian women had significantly lower fracture rates than non-Hispanic White and Hispanic women [7]. Despite lower BMD, several studies indicate lower rates of hip and wrist fractures in women of Chinese origins compared to those of European ancestry [39–42]. Similarly, hip fractures rates are 50% lower in Chinese men compared to age-matched White men [43].

In our study population, most East Asian participants self-identified as of Chinese race/ethnicity (82.0%); when we repeated the analyses in those who reported Chinese race/ethnicity only, we found no difference in the prevalence of fractures or of osteoporosis in this group compared to White participants, while adjusted BMD values were higher in Chinese compared to White Canadians. In contrast, we have previously shown that Chinese participants in the Canadian Multicentre Osteoporosis Study had a lower prevalence of fracture and a similar adjusted femoral neck or total hip BMD values compared to White Canadians [14]. These differences might reflect period of enrolment (CaMos 1995–97 and CLSA 2012–15), and the fact that CaMos also recruited participants who could communicate in Mandarin or Cantonese only, therefore including a greater proportion of first immigrants. Indeed, in the CaMos study only 6.4% of Chinese participants were born in Canada and had lived a median of 13 years in Canada, whereas in the present study a quarter of the Chinese participants were born in Canada and had lived a mean of 40 years in Canada. A degree of acculturation is expected overtime among populations who have adopted a new country which could gradually affect health outcomes [44, 45].

Physical performance measures are associated with falls and fractures and did vary across race/ethnicity categories in our study population [46]. CLSA participants of East Asian and White backgrounds demonstrated better performance in the physical performance composite score compared to the other groups. In older women from the Study of Women's Health Across the Nation (SWAN), physical performance differed by ethnicity, with White women demonstrating higher scores than African American, Hispanic and Chinese women [47]. Some of these differences were thought to be mediated by education, pain, obesity and financial strain and might explain some of the discrepancy between cohorts' results.

Osteoporosis screening and management has been suboptimal across all populations [48]; however, certain race/ethnic groups are less likely to receive screening and treatment [6]. We documented that East Asians participants used vitamin D supplements in lower proportion than White participants and they comprised the lowest proportion of anti-osteoporosis medication users in those at high risk for fractures. There is evidence that service barriers, such as language and cultural differences, have a negative impact on the health status and

perceived self-rated health in older Chinese Canadians [49, 50]. This may lead to differential access to care, medication use and clinical outcomes in this population compared to others [51]. Confidence in healthcare is also lower among Chinese than Canadians of European descent [52].

Limitations and strength

Our study has strengths and limitations. The CLSA is a large population-based cohort which collected information on many socio-demographic and lifestyle variables in a rigorous fashion and thus far provides the first national estimates of bone health parameters in Canadians of different race/ethnic backgrounds. It is worth noting that Canadians other than of White descent were less likely to participate in CLSA, since ability to communicate in English or French was required as an inclusion criterion, this is reflected by the lower percentage of participants of different race/ethnic background. Furthermore, the response rate was low in the CLSA. Both limitations would affect the generalizability of our results, and as in other cohort studies, could lead to recruitment of healthier participants. However key measures such as sex, age, non-smokers, marital and working status had similar frequencies in the CLSA compared to those of the 2011 Canadian census or other national survey. Even though our analysis was cross-sectional in nature, we are reassured by the fact that our findings are supported by those in previous publications. We were able to describe patterns of BMD by race/ethnicity categories and contrast them to White Canadians, as well as stratify those results by sex; however, the low prevalence of reported osteoporosis, falls and fractures at entry into the cohort, reflecting the selection of relatively healthy participants, prevented us from stratifying these analyses by sex. CLSA has documented vertebral fractures at baseline via DXA vertebral fracture assessment; these results are still currently unavailable to researchers but will be of great value in the future since vertebral fractures are the commonest osteoporosis-related fractures.

Conclusion

Bone mineral density and prevalent fractures rates differ by race/ethnicity in the Canadian population, consistent with disparities previously reported in other countries. These results support the importance of better characterization of bone health predictors in Canadians of different race/ethnic backgrounds to tailor the development of population-specific fracture prevention strategies that must be informed by respective social and cultural determinants of health and access to care.

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Authors' contributions SNM conceived the study and secured funding for this study. SNM and CB conducted the data analysis and drafted the initial manuscript. AP, AMC, ER, WDL and DG helped with results interpretation and gave critical feedback on the manuscript. All authors approved the final manuscript.

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Data are available from the Canadian Longitudinal Study on Aging (www.clsa-elcv.ca) for researchers who meet the criteria for access to de-identified CLSA data.

Declarations

Conflict of interest SN Morin, C Berger, E Rahme, WD Leslie and D Goltzman declare they have no conflict of interests. A Papaioannou has received grants and honoraria from Amgen. AM Cheung has received honoraria from Amgen and Paladin.

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