Journal of Bone and Mineral Research, 2026, **00(00)**, 1–7
https://doi.org/10.1093/jbmr/zjag020
Advance access publication: January 28, 2026
Research Article

Fracture probability is predictive of fall-associated hospitalization: the Manitoba BMD Registry

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Abstract

The current version of FRAX does not consider prior falls as a primary input variable. Limited data suggest that greater FRAX-derived fracture probability is associated with incident falls at least in elderly men. Our aim was to examine the association of FRAX-derived fracture probability with the risk for subsequent fall-associated hospitalizations. We identified individuals aged 40 yr or older at the time of baseline DXA with FRAX-derived major osteoporotic fracture (MOF) probability assessed through the Manitoba BMD Program. We used linkage with population-based data to identify subsequent hospitalization that included a fall diagnosis code. Sensitivity analyses examined fall-associated hospitalizations unrelated to a concurrent fracture (diagnosed within 30 d). Cox regression was used to estimate HR for time to fall-associated hospitalization according to MOF probability without and with BMD (per SD increase and also for individual variables in the FRAX tool). The study comprised 88 684 individuals, mean age 64.6 yr, 89.5% female. During mean 8.6 yr observation (total 759 963 person-years), 9715 (11.0%) individuals experienced a fall-associated hospitalization; of these, 3363 (3.8%) were unrelated to concurrent fracture. Every SD increase in MOF fracture probability was strongly associated with fall-associated hospitalization (without BMD HR, 2.47; 95% CI, 2.41-2.52; with BMD HR, 2.48; 95% CI, 2.43-2.53). No significant interaction was seen between fracture probability and follow-up time ($p = .516$). Findings were similar when restricted to individuals with falls unrelated to concurrent fracture, when adjusted for previous fall-associated hospitalization (last 3 yr) or self-reported fall (last 12 mo), when restricted to individuals without previous falls, and for FRAX-derived hip fracture probability. All FRAX variables except for parental hip fracture showed a positive relationship with fall-associated hospitalization. In conclusion, FRAX-derived fracture probability is strongly associated with risk for future fall-associated hospitalization, including falls unrelated to concurrent fracture.

Keywords fracture risk assessment, falls, osteoporosis, bone mineral density, prediction algorithms

Lay Summary

FRAX, a widely used fracture prediction tool, does not currently consider prior falls. Limited data suggest that FRAX may predict future falls. In 88 684 individuals, we showed that FRAX-derived fracture probability is strongly associated with fall-associated hospitalization.

Introduction

Falls are an important cause of disability and mortality among people above age 65 yr.[1] Around 10%-20% of individuals who fall sustain injuries, including fractures or traumatic brain injuries.[2] These injuries are frequently associated with pain, reduced mobility, and loss of independence, resulting in significant health care costs.[2] An international meta-analysis of 46 prospective

Received: 19 October 2025. **Revised:** 4 January 2026. **Accepted:** 21 January 2026

cohorts (total 9 102 207 person-years) showed that self-reported prior falls were associated with increased risk of any clinical fracture in both women and men (HR, 1.42 and 1.53, respectively).[3] In 2015, total Medicare expenses related to falls in the United States amounted to more than US $31 billion.[4] It is therefore important to identify people at high risk of falls to allow for early intervention to reduce fall risk and potentially decrease health care costs. It has been estimated that implementing only one of several evidence-based strategies to reduce fall risk could prevent between 9563 and 45 164 medically-treated falls and save $94-$442 million annually in direct medical costs.[5]

The FRAX tool was released in 2008 to assess 10-yr probability of major osteoporotic fracture (MOF) and hip fracture. This tool includes age, sex, and 7 clinical risk factors (previous fracture, parent hip fracture, current smoking, glucocorticoids, rheumatoid arthritis, secondary osteoporosis, and high alcohol intake) with FN bone density as an optional input. Previous falls was not included when the FRAX algorithm was developed as there was a lack of uniform falls data from the contributing cohorts, and uncertainty whether the fracture risk attributable to falls was amenable to intervention. Currently, the FRAX algorithm is being updated and falls is a candidate variable for inclusion given high-quality evidence from multiple cohorts to estimate the independent effect of falls on fracture and death adjusted for other risk factors.[3,6]

Falls are typically considered an exposure that increase the probability of fracture. However, the reverse possibility, namely that high fracture probability predicts falls risk, has also been proposed though data are limited. One study of 735 men and 602 women in Australia showed that FRAX hip fracture probability (with BMD) was associated with greater scores on the Elderly Falls Screening Test, but this relationship was negated by adjustment for age and sex.[7] This same study showed an increased risk for incident falls with increasing hip fracture probability, but not after adjustment for age and sex. In 1836 men from the MrOS Sweden cohort, incident fall risk increased with greater FRAX probability (HR per SD 1.16, 95% CI, 1.06-1.26).[8] High FRAX-MOF probability (>15% vs <15%) was strongly predictive of increased falls risk (HR, 1.64; 95% CI, 1.36-1.97). Moreover, while the risk associated with past falls decreased with longer follow-up time, the risk associated with FRAX was stable during follow-up.

Although these previous data suggest that FRAX may be marker of falls risk, they are based upon relatively small research cohorts. The primary aim of the current study was to determine whether FRAX-derived fracture probability for MOF and its individual components predict the risk of fall in a large population representative of routine clinical practice.

Materials and methods

Study population

The Manitoba Bone Mineral Density Program maintains a registry of all clinical DXA performed in the Province of Manitoba, Canada. The current study used population-based data from the Manitoba Bone Density Registry and included all Manitoba patients age 40 yr and older undergoing baseline DXA between February 1999 and March 2018. In Manitoba, health services included DXA are provided to virtually all residents through a single public health care system. Criteria for DXA testing have been published, and include age 65 yr or older for all women, and for men and younger women in the presence of additional risk factors.[9] Using an anonymous personal identifier, DXA results in the Registry can be linked with other population-based health databases. The database has been previously characterized with accuracy and completeness in excess of 99%.[10] The study was approved by the University of Manitoba Human Research Ethics Board.

BMD measurements and fracture probability

DXA scans were performed and analyzed in accordance with manufacturer recommendations. Femoral neck T-scores (number of SDs above or below young adult mean BMD) were calculated from NHANES III White female reference values for all subjects. The cross-calibrated instruments used for this study (Prodigy and iDXA, GE/Lunar Healthcare) showed minimal between-scanner femur neck differences (<0.1 T-score) and exhibited stable long-term performance (coefficient of variation <0.5%). All reporting physicians and supervising technologists are required to maintain DXA certification with the International Society for Clinical Densitometry. The 10-yr probability for MOF (FRAX-MOF) and hip fracture (FRAX-HIP) were calculated for each individual using the Canadian FRAX tool (FRAX Desktop Multi-Patient Entry, version 3.7). At the time of DXA, height and weight were measured and BMI was calculated. A questionnaire was completed by each patient to capture FRAX risk factors. FRAX input variables were derived from the questionnaire data and supplemented through linkage to a population-based research registry, which includes hospital discharge abstracts, physician billing claims, and medications dispensed through retail pharmacies, as previously described.[11] Those variables include age, sex, BMI, previous fracture, parental history of hip fracture, current smoking, rheumatoid arthritis, high alcohol use (3 or more units a day or diagnosed alcohol use disorder), glucocorticoid use (oral glucocorticoids for more than 3 mo in the preceding year), secondary osteoporosis (hyperthyroidism, ankylosing spondylitis, celiac disease, chronic liver disease, inflammatory bowel disease, cerebrovascular disease, multiple sclerosis, muscular dystrophy, pancreatitis, Parkinson's disease, solid organ or marrow transplantation, aromatase inhibitor use, or androgen deprivation therapy).

Fall-associated hospitalization

The primary outcome was fall-associated hospitalization after DXA (index date) until March 31, 2018. Prior falls were identified as any fall-associated hospitalization in the last 3 yr or (since September 1, 2012) and any self-reported fall during the last 12 mo prior to the index date. Hospital discharge abstract codes (International Classification of Diseases, Clinical Modification [ICD-9-CM] prior to 2004 and International Classification of Diseases, 10th Revision, Canadian Enhancements [ICD-10-CA] from 2004 onwards) were used to identify accidental falls (ICD-9-CM codes E880-886, 888; ICD-10-CA codes W00-W19). Importantly, these are secondary diagnosis codes and may not be the primary reason for hospitalization.

Statistical analysis

Baseline characteristics of the study population were summarized as mean ± SD for continuous variables and number

(%) for categorical variables. The relationship between FRAX-MOF probability category (low <10%, moderate 10%-19%, high >20%) and incident fall-associated hospitalization was assessed using Kaplan–Meier survival analysis. The log-rank test was used to identify between-group differences. Multivariable Cox proportional hazards models were used to examine the relationship of fall-associated hospitalization with individual FRAX input variables and of fall-associated hospitalization per SD increase in FRAX-MOF probability (computed without and with BMD). FRAX-MOF probability scores were log-transformed due to a skewed distribution. We also tested for an interaction between FRAX probability and follow-up time. Three subsequent models were created: Model 1 which adjusted for prior fall-associated hospitalization; Model 2 which excluded those with prior fall-associated hospitalization; and Model 3 which excluded those with prior self-reported fall (limited to those with index date since September 1, 2012). To rank the relative importance of each predictor variable, we examined the change in log-likelihood chi-square from removing each variable individually from the full multivariable model. The greater the increase in log-likelihood chi-square with removal of the variable from the final model, the more important that variable is for prediction of the outcome. A sensitivity analysis was conducted in which we further excluded any fall-associated hospitalization that was concurrent (within 30 d) with any fracture diagnosis as recorded in hospitalization or physician claims data. Stratified subgroup analyses were conducted by sex and by age group (<65 vs ≥65 yr) with testing for a corresponding two-way interaction. As a secondary analysis, we also examined 10-yr fracture probability for hip fracture (FRAX-HIP). Statistical analyses were performed with IBM SPSS for Windows (Version 29).

Results

Baseline characteristics

Baseline cohort characteristics are summarized in Table 1. The study comprised 88 684 individuals, mean age 64.6 ± 11.0 yr with 89.5% being female. During the 3 prior years, 11% had experienced a hospitalization-associated fall. The median (interquartile range, IQR) FRAX probability computed without BMD was 8.5% (5.3-14.3), while the median FRAX with BMD was 8.0% (5.3-12.8).

Fall-associated hospitalization with individual risk factors

Over a mean follow-up period of 8.6 yr, 9715 (11.0%) of the cohort experienced a fall-associated hospitalization. Female sex was associated with slightly lower risk for fall-associated hospitalization (primary analysis HR, 0.79; 95% CI, 0.74-0.85), while parental hip fracture was not associated with fall-associated hospitalization (Table 2). All other FRAX risk factors were associated with increased risk for fall-associated hospitalization, greatest for high alcohol use (HR, 3.37; 95% CI, 2.81-4.04) followed by age (HR, 1.95 per decade; 95% CI, 1.91-2.00). Similar results were seen after adjustment for prior fall-associated hospitalization, after excluding those with prior fall-associated hospitalization, and after excluding those with prior self-reported fall. Similar results were also seen for fall-associated hospitalizations without concurrent fracture (Table S1).

Table 1 Baseline characteristics of the study population.

Characteristic	
Age, years	64.6 ± 11.0
BMI, kg/m^2	27.4 ± 8.0
Sex, female	79 407 (89.5)
Previous fracture	1784 (29.1)
Parental hip fracture	6729 (7.6)
Smoking	8953 (10.1)
Glucocorticoid use	4828 (5.4)
Rheumatoid arthritis	2787 (3.1)
Secondary osteoporosis	13 198 (14.9)
High alcohol use	529 (0.6)
Femoral neck T-score	−1.37 ± 1.00
Prior hospitalization-associated fall	3611 (4.1)
FRAX-MOF probability without BMD (%)	8.5 (5.3-14.3)
FRAX-MOF probability with BMD (%)	8.0 (5.3-12.8)

Data presented as Mean ± SD or *N* (percent) or median (IQR). BMI, body mass index.

Variable importance for fall-associated hospitalization based upon the full multivariable Cox model is summarized in Table 3. The most influential variables (largest change in log-likelihood chi-square, χ^2) were age (χ^2 = 3881.89), FN T-score (χ^2 = 1143.51), and prior fracture (χ^2 = 407.73). Those remained the most influential in the analysis of variable importance for fall-associated hospitalization without concurrent fracture (Table S2). Age, prior fracture and secondary osteoporosis were the most influential variables in the model without BMD (Table S3).

Fall-associated hospitalization with FRAX-MOF probability

Kaplan–Meier survival curves showed increasing risk for fall-associated hospitalization with higher risk category from FRAX-MOF probability computed with BMD (high > moderate > low) (Figure 1). All between-group differences were statistically significant (log-rank $p < .001$). Similar results were seen for fall-associated hospitalizations without concurrent fracture (Figure S1).

Every SD increase in FRAX-MOF probability on the continuous scale (log-transformed) was strongly associated with fall-associated hospitalization (FRAX-MOF without BMD HR, 2.47; 95% CI, 2.41-2.52; FRAX-MOF with BMD HR, 2.48; 95% CI, 2.43-2.53) (Table 4). No significant interaction was seen between FRAX-MOF computed with BMD and follow-up time ($p = .516$). Results were similar after adjustment for prior fall-associated hospitalization, after excluding those with prior fall-associated hospitalization, after excluding those with prior self-reported fall, and for fall-associated hospitalizations without concurrent fracture. Stratified analyses showed significant effects in men and women and for age <65 yr and >65 yr (Table S4). Effects were slightly greater in females (FRAX-MOF without BMD HR, 2.58; 95% CI, 2.52-2.64; FRAX-MOF with BMD HR, 2.57; 95% CI, 2.52-2.63) vs males (HR,

Table 2 Hazard ratios (HR, 95% CI) for fall-associated hospitalization according to FRAX input variables.

Clinical risk factor	Primary analysis	Adjusted for prior hospitalization-associated fall	Excluding prior hospitalization-associated fall	Excluding prior self-reported fall
Age per 10 yr increase	**1.95 (1.91-2.00)**	**1.95 (1.91-1.99)**	**1.97 (1.93-2.02)**	**1.81 (1.62-2.03)**
Female sex	**0.79 (0.74-0.85)**	**0.80 (0.75-0.86)**	**0.82 (0.76-0.88)**	0.88 (0.65-1.18)
BMI per 5 kg/m^2 increase	**1.01 (1.01-1.02)**	**1.01 (1.00-1.02)**	**1.01 (1.01-1.02)**	0.95 (0.86-1.05)
Prior fracture	**1.59 (1.52-1.66)**	**1.51 (1.44-1.58)**	**1.53 (1.46-1.60)**	**1.75 (1.39-2.20)**
Parental hip fracture	0.98 (0.90-1.07)	0.98 (0.89-1.07)	0.99 (0.90-1.09)	0.87 (0.62-1.24)
Smoking	**1.52 (1.41-1.62)**	**1.51 (1.41-1.62)**	**1.49 (1.38-1.60)**	**1.39 (1.03-1.88)**
High alcohol use	**3.37 (2.81-4.04)**	**3.02 (2.51-3.63)**	**3.23 (2.56-4.09)**	**2.71 (0.86-8.52)**
Glucocorticoid use	**1.37 (1.26-1.49)**	**1.38 (1.27-1.51)**	**1.40 (1.28-1.52)**	1.39 (0.90-2.15)
Rheumatoid arthritis	**1.64 (1.48-1.82)**	**1.63 (1.47-1.81)**	**1.63 (1.46-1.82)**	**1.84 (1.16-2.93)**
Secondary osteoporosis	**1.45 (1.38-1.54)**	**1.45 (1.37-1.53)**	**1.43 (1.35-1.51)**	**1.32 (1.03-1.70)**
Femoral neck T-score per SD decrease	**1.52 (1.48-1.55)**	**1.51 (1.47-1.55)**	**1.51 (1.47-1.55)**	**1.53 (1.34-1.74)**

Significant effects ($p < 0.05$) in boldface.

Table 3 Variable importance for prediction of fall-associated hospitalization.

	Fall associated hospitalization	
	Variable importance	***p*-value**
Age	3881.89	**<.001**
Femoral neck T-score	1143.51	**<.001**
Prior fracture	407.73	**<.001**
Secondary osteoporosis	162.33	**<.001**
Smoking	127.47	**<.001**
High alcohol use	123.08	**<.001**
Rheumatoid arthritis	76.87	**<.001**
Glucocorticoid use	49.30	**<.001**
Sex	39.51	**<.001**
BMI	5.77	**.016**
Parental hip fracture	0.18	.669

Variable Importance for each predictor estimated from the loss in log-likelihood Chi-squared value when that predictor is removed from the full multivariable Cox model. Significant effects ($p < 0.05$) in boldface.

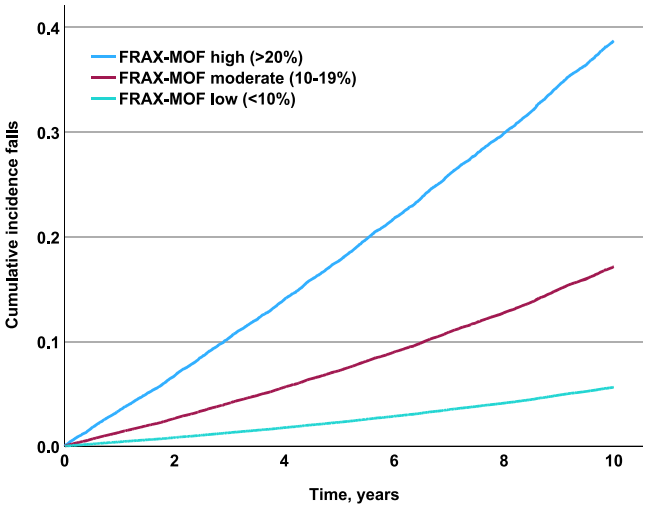

Figure 1 Cumulative incidence in fall-associated hospitalization according to baseline FRAX-MOF probability computed with BMD categorized as low (<10%), moderate (10%-19%), and high (>20%).

2.28; 95% CI, 2.11-2.47; *p*-interaction = .039; HR, 2.22; 95% CI, 2.06-2.39; *p*-interaction = .004, respectively). Effects were much greater among individuals aged 65 yr and older (FRAX-MOF without BMD HR, 2.43; 95% CI, 2.35-2.52; FRAX-MOF with BMD HR, 2.31; 95% CI, 2.24-2.39) vs individuals aged less than 65 yr (HR, 1.78, 95% CI, 1.70-1.88, *p*-interaction < .001; HR, 1.92; 95% CI, 1.84-2.01; *p*-interaction < .001, respectively).

Similar results were seen for FRAX-HIP probability (log-transformed), which showed strong correlations with FRAX-MOF when computed without BMD ($r = 0.960$) and with BMD ($r = 0.891$). Every SD increase in FRAX-HIP probability was associated with fall-associated hospitalization (FRAX-HIP without BMD HR, 2.58; 95% CI, 2.52-2.64; FRAX-HIP with BMD HR, 2.81; 95% CI, 2.74-2.88) (Table S5).

Discussion

We found that FRAX probability and most risk factors for fracture were associated with increased risk for fall-associated hospitalization, after adjusting for prior falls and after excluding falls with concurrent fractures. Each SD increase in FRAX-MOF probability more than doubled the risk of fall-associated hospitalization. This was also seen in secondary analysis that examined females only, males only, individuals aged 65 yr and older, and FRAX-HIP probability. A significant but weaker effect was seen in individuals less than age 65 yr (*p*-interaction < .001). Age, FN T-score and prior fracture were the most influential variables. High alcohol use showed the greatest risk (more than threefold) but was overall less important than these other variables due to low prevalence. Our current findings have implications for clinical practice and suggest that individuals identified as having a high risk of fracture are also more likely to experience fall-associated hospitalization.

Table 4 Hazard ratios (HR, 95% CI) for fall-associated hospitalization per SD increase in FRAX-MOF probability.

Fall-associated hospitalization	Primary analysis	Adjusted for prior hospitalization-associated fall	Excluding prior hospitalization-associated fall	Excluding prior self-reported fall
FRAX-MOF probability without BMD	**2.47 (2.41-2.52)**	**2.42 (2.36-2.47)**	**2.45 (2.39-2.50)**	**2.24 (1.99-2.52)**
FRAX-MOF probability with BMD	**2.48 (2.43-2.53)**	**2.43 (2.38-2.49)**	**2.47 (2.42-2.53)**	**2.19 (1.96-2.45)**
Fall-associated hospitalization without concurrent fracture	Primary analysis	Adjusted for prior hospitalization-associated fall	Excluding prior hospitalization-associated fall	Excluding prior self-reported fall
FRAX-MOF probability without BMD	**2.50 (2.41-2.60)**	**2.45 (2.35-2.54)**	**2.48 (2.39-2.58)**	**2.14 (1.77-2.59)**
FRAX-MOF probability with BMD	**2.37 (2.29-2.46)**	**2.32 (2.23-2.41)**	**2.35 (2.27-2.45)**	**1.92 (1.60-2.30)**

Significant effects ($p < 0.05$) in boldface.

The current FRAX calculator does not include falls history as an input variable.[11] This was related to the lack of a uniform definition and assessment in the initial cohorts to derive FRAX.[6,12] Over time, more data have become available highlighting falls as an important risk factor for fracture and a candidate for inclusion in future iterations of FRAX.[6] However, the overall impact may be limited, as other clinical risk factors already capture some of the predictive value from a prior fall. While the components of FRAX align to some extent with traditional risk factors for falling, there is limited discussion in the literature regarding the association between FRAX scores and the occurrence of subsequent falls.[13,14] In an observational study of 209 post-menopausal women referred to a fracture liaison service at a university hospital in Istanbul, FRAX scores were higher in patients with impaired balance tests that predicts fall.[15] The authors suggested that poor static, dynamic posture, and hyperkyphosis in some patients with high FRAX may predispose to falls.[15–18] However, this can only partially explain the association between FRAX scores and fall as history of falls remains an important FRAX-independent risk factor for fracture.[19] A study of 24 943 women and men aged 40 yr or older reported that self-reported fall in the last year was associated with increased risk of fall independent of baseline fracture risk and BMD.[20]

Few previous studies have directly investigated the effect of FRAX on predicting subsequent falls. One study of 735 men and 602 women (age 40-90 yr) showed a weak positive correlation between FRAX probability and fall risk. On cross-sectional analysis, this study showed no correlation between FRAX score and fall risk score (Elderly Fall Screening Test EFST).[7] In the same study, a prospective relationship between baseline FRAX and self-reported fall at 1 yr was observed but became non-significant after adjustment for age and sex. In our much larger study, we found that risk factors included in FRAX predict fall-associated hospitalization even after adjustment for age and sex.[7] Analysis of 1836 men from the prospective MrOS Sweden cohort of elderly men reported that the risk of incident self-reported falls increased with increasing FRAX at baseline (HR per SD, 1.16; 95% CI, 1.06-1.26), and this remain significant after adjustment for prior fall and age, similar to our study.[8] In this study, they were unable to find a clinical risk factor that predominated the association between FRAX and fall. Another study found that age was the only component of FRAX predictive of fall risk.[21] In contrast, we found that age and most FRAX components including FN T-score were significant independent predictors. Our study was significantly larger and the falls outcome was objectively assessed from hospitalization records than self-report.

To the best of our knowledge, this is the largest study to show an association between greater FRAX probability and a fall-related outcome. This may be particularly important in the geriatric population where a simple FRAX calculation may help predict the risk of fall associated hospitalization in addition to its ability to assess fracture risk. Our study has multiple strengths including the large number of patients, objective diagnosis of fall from hospital records, similar findings after considering prior falls, and the ability to show gradient of risk between higher FRAX probability and future fall-associated hospitalization on both continuous and categorical scales. Limitations of this study include the predominantly female White population, limiting the generalizability of our findings to men or other ethnicities. Although the cohort was largely female, the study included more than 9000 males, and sex-stratified analyses demonstrated similar associations, supporting the robustness of the findings. We were also unable to adjust for physical performance, muscle strength, kyphosis, and posture. Another limitation is the inability to assess the severity and mechanism of fall. Most importantly, it is impossible to establish whether falls were the primary reason for hospitalization or were secondary to another condition. Another limitation is that no data were available on the nature of the hospitalization. However, of the 9715 fall associated hospitalizations only a minority, 2670 (27%), were concurrent with a hip fracture. Finally, our outcome of fall-associated hospitalization captures only a minority of the overall falls burden, most of which are not associated with hospitalization, but is likely weighted towards more severe falls.

In conclusion, fracture probability assessed with the FRAX tool is strongly associated with risk for future fall-associated hospitalization, including falls unrelated to concurrent fracture. This may help to identify individuals at high risk for falls and apply measures to decrease this risk.

Acknowledgments

The authors acknowledge the Manitoba Centre for Health Policy for use of data contained in the Population Health Research Data Repository (HIPC 2016/2017-29). The results and conclusions are those of the authors and no official endorsement by the Manitoba Centre for Health Policy, Manitoba Health, Seniors and Active Living, or other data providers is intended or should be inferred. This article has been reviewed and approved by the members of the Manitoba Bone Density Program Committee.

Author contributions

Fatima Zarzour (Conceptualization, Data curation, Methodology, Project administration, Resources, Validation, Visualization, Writing—original draft, Writing—review & editing), Eugene V. McCloskey (Conceptualization, Methodology, Resources, Supervision, Validation, Writing—review & editing), Helena Johansson (Conceptualization, Methodology, Project administration, Supervision, Validation, Writing—review & editing), Nicholas C. Harvey (Conceptualization, Data curation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing—review & editing), John A. Kanis (Conceptualization, Formal analysis, Investigation, Methodology, Project administration, Supervision, Validation, Writing—review & editing), and William D. Leslie (Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing—review & editing)

Supplementary material

Supplementary material is available at *Journal of Bone and Mineral Research* online.

Funding

No funding support was received for this research.

Conflicts of interest

F.Z., H.J., and W.D.L. report no competing interests. E.V.M. has received consultancy/lecture fees/grant funding/honoraria from AgNovos, Amgen, AstraZeneca, Consilient Healthcare, Fresenius Kabi, Gilead, GSK, Hologic, Internis, Lilly, Merck, Novartis, Pfizer, Radius Health, Redx Oncology, Roche, Sanofi Aventis, UCB, ViiV, Warner Chilcott, and I3 Innovus. N.C.H. has received consultancy/lecture fees/honoraria/grant funding from Alliance for Better Bone Health, Amgen, MSD, Eli Lilly, Radius Health, Servier, Shire, UCB, Consilient Healthcare, Kyowa Kirin, Theramex, and Internis Pharma. J.A.K. led the team that developed FRAX as director of the WHO Collaborating Centre for Metabolic Bone Diseases; he is a director of Osteoporosis Research Ltd that maintains FRAX.

Data availability

Data sharing is not permitted under the Researcher Agreement with Manitoba Health and Seniors Care (MHASC). However, researchers may apply for data access through the Health Research Ethics Board for the University of Manitoba and the Health Information and Privacy Committee of MHASC.

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Journal of Bone and Mineral Research, 2026, 1–7
https://doi.org/10.1093/jbmr/zjag020
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