BMJ Open

The Fracture Risk Scale (FRS) Predicts Fracture Over a 1 Year Time Period in Institutionalized Frail Older People: An Electronic Record-Linked Longitudinal Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-016477
Article Type:	Research
Date Submitted by the Author:	17-Feb-2017
Complete List of Authors:	Ioannidis, George; McMaster University, Medicine; Geriatric Education and Research in Aging Sciences Centre, Jantzi, Micaela ; University of Waterloo, Health Studies and Gerontology Bucek, Jenn; University of Waterloo, Health Studies and Gerontology Adachi, Jonathan; McMaster University, Medicine Giangregorio, Lora; University of Waterloo, Kinesiology Hirdes, John; University of Waterloo, Health Studies and Gerontology Pickard, Laura; Geriatric Education and Research in Aging Sciences Centre Papaioannou, Alexandra; McMaster University, Medicine; Geriatric Education and Research in Aging Sciences Centre
Primary Subject Heading:	Geriatric medicine
Secondary Subject Heading:	Health informatics
Keywords:	fracture, long term care, prediction model, resident assessment instrument minimum data set version 2.0, frail older adults

The Fracture Risk Scale (FRS) Predicts Fracture Over a 1 Year Time Period in Institutionalized Frail Older People: An Electronic Record-Linked Longitudinal Cohort Study

George Ioannidis[1, 2], Micaela Jantzi[3], Jenn Bucek[3], Jonathan D. Adachi[1, 2], Lora Giangregorio[2, 3], John Hirdes[3], Laura Pickard[1, 2], Alexandra Papaioannou[1, 2]

Author affiliations:

[1]McMaster University, Hamilton, Ontario, Canada;

[2]GERAS centre, Hamilton, Ontario, Canada;

[3]University of Waterloo, Waterloo, Ontario, Canada

Corresponding to Dr. George Ioannidis; g.ioannidis@sympatico.ca

Abstract

Objectives: To develop and validate our Fracture Risk Scale (FRS) over a 1 year time period, using the long-term care Resident Assessment Instrument Minimum Data Set Version 2.0 (RAI-MDS).

Design: A retrospective cohort study.

Setting: Long-term care (LTC) homes in Ontario, Canada.

Participants: Older adults who were admitted to LTC and received a RAI-MDS admission assessment between 2006 and 2010.

Results: A total of 29,848 LTC residents were enrolled in the study. Of these 22,386 were included in the derivation dataset and 7,462 individual were included in the validation dataset. Approximately 2/3 of the entire sample were women, and 45% were 85 years of age or older. A total of 1553 fractures were reported over the one year time period. Of these, 959 (61.8%) were hip fractures. Following a hip fracture, 6.3% of individuals died in the emergency department or as an inpatient admission and did not return to their LTC home. Using decision tree analysis, our final outcome scale had 8 risk levels of differentiation. The percentage of individuals with a hip fracture ranged from 0.6 (lowest risk level) to 12.6 % (highest risk level). The area under the curve of the outcome scale was similar for the derivation (0.67) and validation (0.69) samples, and the scale exhibited a good level of consistency.

Conclusions: Our FRS predicts hip fracture over a 1 year time period and should be used as an aid to support clinical decisions in the care-planning of LTC residents. Future research should focus on the transformation of our scale to a Clinical Assessment Protocol and to assess the FRS in other health care settings.

Strengths and Limitations of this study

- The Fracture Risk Scale (FRS) will be a standardized instrument that predicts hip fracture over a 1 year time period, and will automatically generate fracture risk assessments for residents as part of the RAI-MDS 2.0 data collection process.
- The FRS will minimize the duplication of work that is often required to support non-integrated scales in long term care.
- The scale's properties are beneficial for the potential transformation of the FRS to a Clinical Assessment Protocol.
- It is not clear if the FRS outcomes are unique to LTC residents and further validation studies will be needed in different populations.

Introduction

Older adults usually enter long term care (LTC) homes because of difficulties in functional status triggered by physical decline, cognitive impairment, or the onset of an acute illness. These individuals are at higher risk for hip fracture, due to increased age related bone loss [1]; increased propensity to fall [2]; and altered mechanics of the fall, where older individuals are more likely to fall backwards or sideways [3 4]. Compared with similarly aged seniors residing in the community, the rate of hip fractures are 1.6 and 2.2 times greater in women and men living in LTC, respectively [5]. Hip fractures are the most common fracture type in LTC, accounting for 49 % of all fractures [5]. Furthermore, hip fracture is one of the leading causes of hospitalization for LTC residents [6] and is associated with increased mortality, reduced mobility and worsening health related quality of life [7]. Approximately 50% of LTC residents who have some independence in locomotion prior to hip fracture either die or develop total dependence within 6 months of their fracture [8].

Unfortunately, it is difficult to identify LTC residents at high risk for fracture, as the current fracture risk assessment tools in Canada, including the Canadian Fracture Risk Assessment Tool (FRAX) and the Canadian Association of Radiologists and Osteoporosis Canada tool (CAROC) [9-12], are not valid for or generalizable to LTC. For instance, the instruments provide a 10 year fracture risk assessment timeframe, which is too long, given that 20% of residents die within one year of LTC admission [13]. In addition, both instruments use bone mineral density as a major factor that predicts future fracture risk. However bone density is challenging to obtain in LTC, and previous work has identified that the use of the FRAX model without bone mineral density identified 98% of residents as candidates for treatment [14]. Finally, the instruments do not include LTC specific risk factors for hip fracture which are different than

in the community specific risk factors [15]. Thus, fracture prediction outputs of FRAX-Canada and CAROC may not be suitable for decision making and care planning among LTC residents who have multiple comorbidities [16 17].

The Resident Assessment Instrument Minimum Data Set Version 2.0 (RAI-MDS 2.0) is a comprehensive, standardized tool that has been implemented in LTC homes in many Canadian provinces.[18-20]. The RAI-MDS 2.0 is used during routine clinical practice and data from the instrument provides an opportunity for health care providers to evaluate the health care needs and risks of all residents. The instrument is completed within 14 days of a resident entering a home and quarterly thereafter. The RAI-MDS 2.0 includes individual data elements and outcome scores that may provide the necessary information to determine residents at high risk for hip fracture. The purpose of our study was to develop and validate our Fracture Risk Scale (FRS) that predicts hip fracture over a 1 year time period, using RAI-MDS 2.0 data. The ability to screen and identify frail residents at risk for hip fracture is clinically useful for the development of fracture prevention care planning strategies.

Methods

Study design

All admission assessments completed in Ontario LTC homes from April 1st, 2006 to March 31st 2010 (n=47,556) were selected. Those with multiple admissions were excluded (n=4,041). Among the unique admissions (n=43,515) those reported on the RAI-MDS 2.0 to have End Stage Disease (n=511), were comatose (n=12), received hospice (n=16) or respite care (n=785), expected a short stay (n=4,016) or admission assessment completed more than 14 days after the date of admission (n=4,105) were excluded. Those who had no reassessments during the 1 year follow up (n=4,222) were also excluded. The final sample size was 29,848 residents. These residents were divided between a derivation (n=22,386) and validation sample (n=7,462) for the development and testing of our scale (Figure 1). Over the course of a 1 year follow-up period, residents were classified as to the presence or absence of an incident fracture using nationally collected data.

This project continues from previous work done through the Innovations in Data, Evidence and Applications for Persons with Neurological Conditions (ideasPNC) research project [21], and has ethics approval obtained from the University of Waterloo Office of Research Ethics (ORE # 17045).

Incident Fractures

RAI 2.0 data were linked with the Canadian Discharge Abstract Database (DAD) that captures information regarding each in-patient hospital stay and the National Ambulatory Care Reporting System (NACRS) that captures each Emergency Department visit [22 23]. Linked DAD

and NACRS records were available for 2 years prior to the MDS 2.0 assessment, and at least 1 year after the assessment.

Incident fractures were captured using International Classification of Disease (ICD)-10 codes. The codes were selected using the Revised Framework for National Surveillance on Osteoporosis and Osteoporosis-related Fractures of the Public Health Agency of Canada [24]. A resident with at least one of these codes within 1 year after the admission assessment was coded as having a fracture (hip (S72.0, S72.1, S72.2), spine (S22.0, S22.1, S32.0, S32.7, S32.8), humerus (S42.2), forearm (S52.x, S62.x) and pelvis (S32.1, S32.3, S32.4, S32.5, S32.7, S32.8)).

Statistical analyses

Population characteristics are expressed in count and percent for categorical variables using SAS 9.4 (SAS Institute, Cary, NC).

A decision tree [25] was created using the 75% derivation sample to predict incident hip fractures within 1 year of admission to a LTC home. The unadjusted odds ratios of over 150 individual items and outcome scales from the RAI-MDS were calculated. A clinical expert panel evaluated the relevance of the items, and those that had both face validity and were significantly associated with incident fractures based on the odds ratios were retained. A recursive partitioning method called Chi-squared Automatic Interaction Detection (CHAID) was employed [25] using SAS Enterprise Miner 13.1 (SAS Institute, Cary, NC). The final decision tree was validated in an in-person meeting with clinical experts.

Once the decision tree was completed, the individual nodes were collapsed into 8 categories and logistic regression was performed to calculate the odds of having a hip fracture

within the first year of admission to an LTC home. C-statistics were calculated to compare the discriminative properties of the full, derivation, and validation samples.

Results

Table 1 displays the population characteristics of residents for the combined, derivation, and validation dataset. For the combined sample, approximately 45% of LTC residents were 85 years and older, 2/3 were women, 1/3 had a prior fall within the past 180 days, and 3% had a prior hip fracture within the past 180 days. A total of 1553 new fractures (including hip, spine humerus, forearm, and pelvis) were reported over the one year time period. Of these, 959 (61.8%) were hip fractures. The fracture proportion was similar for individuals in the derivation and validation samples (data not shown). Only 15 (0.07%) older adults had multiple hip fractures over the one year time period.

Decision tree model

The final decision tree model contains 17 leaves. Each leaf represented a distinct proportion of residents with an incident hip fracture during the one year assessment period (Figure 2). By combining leaves with similar risk, the 17 leaves were collapsed into the FRS, which included 8 risk levels of differentiation (Figure 3). Our scale's one year absolute hip fracture risk levels ranged from 0.6 to 12.6 % (Table 2). The odds ratios shows a clear stepped progression of risk, achieving a 23 fold increase in the odds of developing a hip fracture for residents between the lowest to highest risk level (Table 3). Furthermore, the distribution of residents within each risk level decreased as the risk level for hip fracture increased (Table 4).

Within our FRS, the ability of an individual to walk in a corridor on the unit (root node) showed the highest discriminatory power, as well as the best ability to organize the tree branches relative to other risk factors. Body mass index and fall status in the past 30 days were risk factors that also had high discriminatory powers. Other variables included in the tool included

wandering events, transfer ability (how resident moves between surfaces-to and from; bed, chair, wheelchair, standing position), fall status in the past 180 days, prior fracture in past 180 days, cognitive performance, and age greater than 85 years (Figure 3, Appendix 1).

Discrimination and predictive accuracy

The overall discriminative properties of the FRS were similar between the combined (c-statistic= 0.673) derivation (c-statistic= 0.669) and validation (c-statistic= 0.687) datasets. In addition, the absolute hip fracture rate for the individual risk levels (Table 2), the odds ratios comparisons (Table 3), and the predictive accuracy (Figure 2) of the scale were similar between the derivation and validation datasets. Overall, the FRS exhibited a good level of consistency between the datasets.

Death rates

Following a hip fracture, 6.27% in individuals died in the emergency department or as an inpatient admission and did not return to their LTC facility. The mean length of stay (standard deviation) for those who died during an in-patient admission was 8.9 days (7.3).

Discussion

While a large proportion of residents in LTC are at risk of suffering a hip fracture, a fracture care planning gap has been well documented [26-30]. Potential causes for this planning care gap include inadequate access to bone mineral density testing; a lack of knowledge of clinicians regarding fracture risk assessment and treatment; and the complex nature of providing care to residents in LTC that requires clinical competence [31]. Therefore, standardized methods must be used to identify residents at risk for hip fracture to reduce the care gap and to improve the efficient allocation and delivery of limited LTC health resources.

Our results show that the FRS is capable of both discriminating and predicting residents at risk for hip fracture over a one year time period. Our findings indicate that in addition to community risk factors for hip fracture that are used in the FRAX and CAROC instruments, there are several LTC specific risk factors that are important in predicting hip fracture risk including walking ability, wandering, falling, cognitive impairment, and transfer status. Our scale identifies 8 risk levels for hip fracture in LTC and provides the clinical information that is needed to develop person-centered care plans. Of note, the distribution property of the scale allocates over 50% of the assessed residents into the lowest three risk levels with progressively fewer residents spread across each of the higher risk levels. The scale's properties are beneficial for the potential transformation of the FRS to a Clinical Assessment Protocol (CAP).

Our intention is to further develop the FRS into a CAP algorithm, to assist LTC health professionals to systematically interpret fracture risk levels that are generated by the instrument and to inform clinical decision making as part of the care planning process. The CAP may combine our scale's 8 risk levels into three risk categories for hip fracture (i.e. very high risk, high risk, and lower risk for hip fracture). The very high risk category may be defined as risk

levels 7 and 8; high risk as risk levels 4, 5 and 6; and lower risk as risk levels 1, 2 and 3. The proposed three level triggering CAP is similar to CAPs used in other interRAI instruments [32-34]. The CAP may be triggered for the very high risk and the high risk categories, which represents 8.5%, and 35.7% of the resident population in LTC, respectively. The non-triggered lower risk category represents 55.8% of the population. This large population of low risk persons within the potential CAP is important because the triggering of too many high risk individuals may quickly overwhelm LTC resources that are needed for clinical management and may fail to differentiate individuals at the point of care. Person-centered care planning recommendations for those that trigger the CAP may be based on effective interventions recommended by LTC guidelines from Canada and around the world, and include vitamin D and calcium supplementation, hip protectors, exercise, multifactorial interventions to prevent falls, and pharmacologic therapies [35-37]. The CAP outputs will assist in resident care planning and the process should reduce the risk of hip fracture, increase life expectancy, preserve or improve quality of life, and reduce health care costs.

Our findings should be interpreted based on the strengths and limitations of our study design. Strengths that may prevent bias include the large number of residents that were used to develop and validate our outcome scale. A comprehensive set of independent variables were included in the analyses. Our outcome scale did not use bone mineral density as a predictor of hip fracture, which is difficult to measure in LTC. We used a "gold standard" method (DAD/NACRS databases) to assess incident hip fracture status. Decision tree analysis was used to develop our outcome scale, which provides an empirically sound, visual representation of the contributing factors for hip fracture among residents living in LTC; and by clinical feedback to improve the instrument's face validity. Using decision tree analysis may have higher utility in

identifying high risk individuals relative to traditional algorithm developed in LTC using regression analyses [38 39] because of the no parametric assumptions of the technique, the methods distinctive clustering of risk factors, and the tree's ability to better account for independent and dependent variable outliers. Furthermore, the FRS will be a standardized tool that uses existing items from the RAI-MDS 2.0, will automatically generate fracture risk assessments for residents as part of the RAI-MDS 2.0 quarterly data collection process, and will rely on existing assessor training skills and resources that are currently present in LTC homes. As such, the use of our scale will minimize the duplication of work that is often required to support non-integrated tools. Our instrument has a logical flow, and is easily interpretable by LTC healthcare professionals. As a product of the process by which the scale was created, we believe that our scale's approval and use in LTC will be enhanced. Finally, our FRS utilizes similar items that are collected using the next version of the instrument (interRAI Long-Term Care Facilities) that is used internationally and in some Canadian provinces [20], and by the MDS-Home Care instrument [40] and thus, our tool may potentially be useful globally and in home care settings.

Our study limitations include the exclusion of individuals that we believed would not survive the one year assessment period. Therefore, our findings may not be generalizable to these residents. The study was limited to the independent variables available in the RAI-MDS 2.0 and may not have captured all relevant risk factors for hip fractures among LTC residents. Finally, it is not clear if our results are unique to LTC residents and further validation studies will be needed in different populations (i.e. home care).

In conclusion, the findings of our study provide support for the discriminatory and predictive properties of the FRS. The instrument may have significant implications for health strategy, service delivery and care planning that may impact policy choices for vulnerable

residents living in LTC. Our scale that predicts hip fracture over a 1 year time period should be used as an aid to support clinical decisions in the care-planning process and should be incorporated as part of a comprehensive clinical assessment where the preference of the resident should be considered. Future research should focus on CAP development and how the outcome scale performs in home care.

Author affiliations:

[1]McMaster University, Hamilton, Ontario, Canada;

[2]GERAS centre, Hamilton, Ontario, Canada;

[3]University of Waterloo, Waterloo, Ontario, Canada

Corresponding to Dr. George Ioannidis; g.ioannidis@sympatico.ca

Contributions: GI, was responsible for study design, data analysis interpretation, and drafting of manuscript, MJ was responsible for study design, data analysis and interpretation, and drafting of manuscript. JB, JDA, LG, JH LP, AP were responsible for study design, data interpretation, critical review of the manuscript. All authors read and approved the final manuscript.

Funding: The Ministry of Health and Long-Term care through the Ontario Osteoporosis Strategy for Long-Term Care

Disclaimer: The funding sources had no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; or preparation, review or approval of the manuscript.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work (GI, MJ, JB, JH). Dr. Giangregorio reports personal fees from ICON. Dr. Papaioannou and Ms. Pickard reports grants from Ontario Ministry of Health and Long Term Care Ontario Osteoporosis Strategy. Dr. Adachi reports grants and personal fees from Amgen , grants and personal fees from Eli Lilly, personal fees from AgNovos, during the conduct of the study; non-financial support from Osteoporosis Canada, non-financial support from International Osteoporosis Foundation, outside the submitted work.

Ethics approval: Obtained from the University of Waterloo Office of Research Ethics (ORE # 17045).

Provenance and peer review: Not commissioned; externally peer reviewed.

Data sharing statement: No additional data are available.

Figure 1: Study Sample Flow Diagram

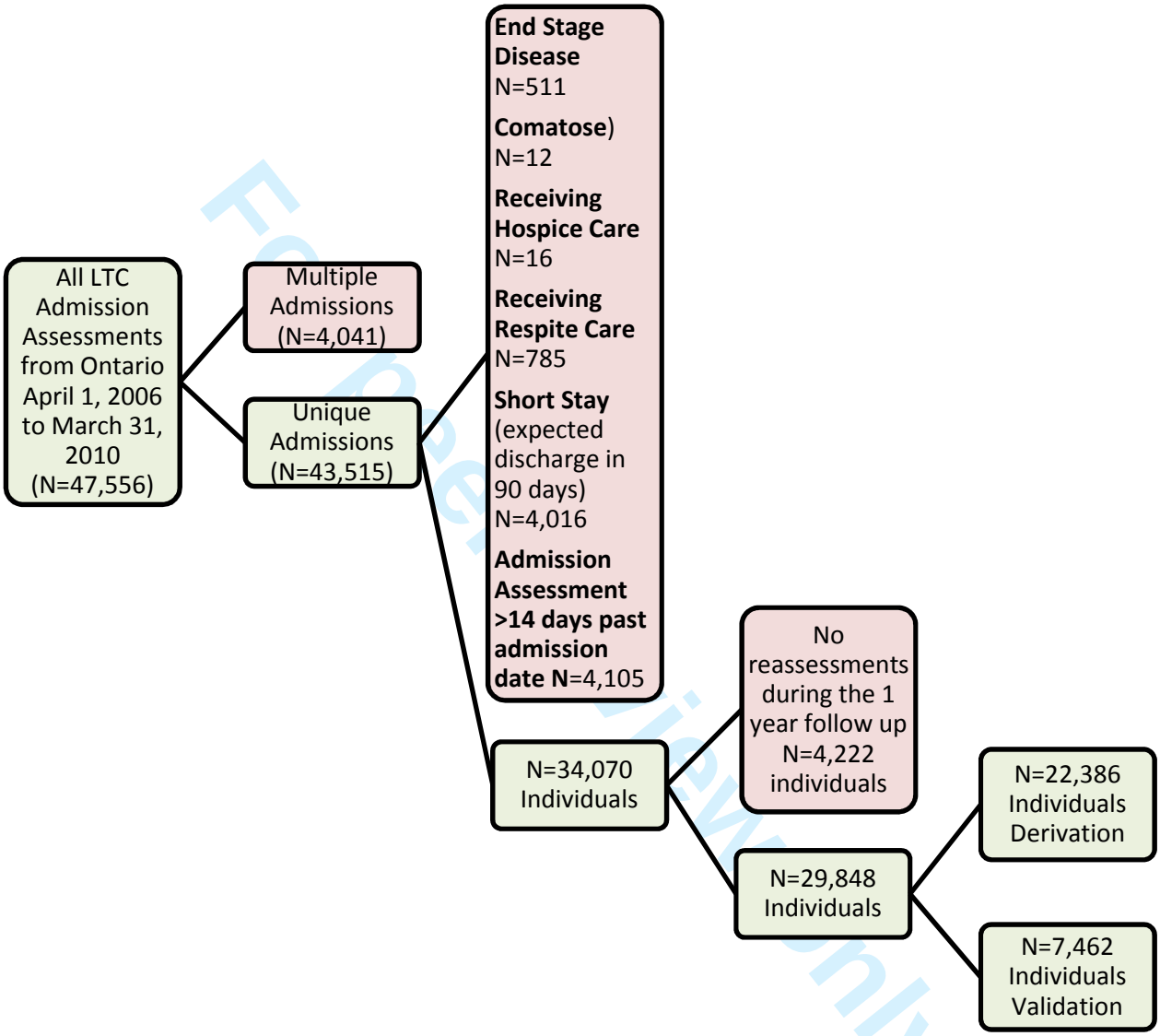


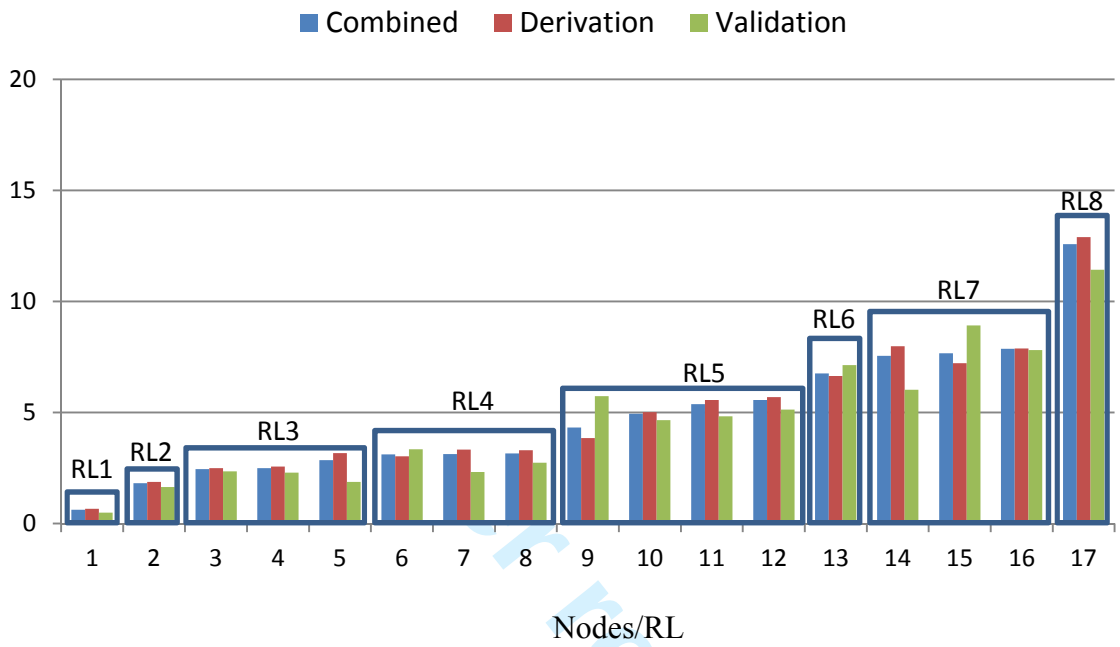
Table 1. Resident Characteristics for the Combined, Derivation and Validation Datasets.

Characteristics: n (%)	Combined Sample (N=29,848)	Derivation Sample (N=22,386)	Validation Sample (N=7,462)
Demographics and anthropometrics			
Age group			
18 to 64	1700 (5.7)	1268 (5.7)	432 (5.8)
65 to 74	3128 (10.5)	2308 (10.3)	820 (11.0)
75 to 84	11300 (37.9)	8466 (37.8)	2834 (38.0)
85+	13708 (45.9)	10335 (46.2)	3373 (45.2)
Women	19706 (66.0)	14831 (66.3)	4875 (65.3)
Weight loss (5% or more last 30 days)	1567 (5.3)	1204 (5.4)	363 (4.9)
Body Mass Index			
<18	2396 (8.0)	1828 (8.2)	568 (7.6)
18-29	22252 (74.6)	16646 (74.4)	5606 (75.1)
30+	4753 (15.9)	3586 (16.0)	1167 (15.6)
Married	8978 (30.1)	6695 (29.9)	2283 (30.6)
Education			
Grade 8 or less	6495 (21.8)	4939 (22.1)	1556 (20.9)
High School	8428 (28.2)	6323 (28.3)	2105 (28.2)
Post-Secondary	5010 (16.8)	3742 (16.7)	1268 (17.0)
Unknown	9915 (33.2)	7382 (33.0)	2533 (34.0)
Diseases			
Alzheimer's disease and related dementias	16778 (56.2)	12553 (56.1)	4225 (56.6)
Epilepsy	1118 (3.8)	839 (3.8)	279 (3.7)
Traumatic Brain Injury	237 (0.8)	179 (0.8)	58 (0.8)
Parkinson's disease	2004 (6.7)	1487 (6.6)	517 (6.9)
Multiple sclerosis	283 (1.0)	207 (0.9)	76 (1.0)
Diabetes	7239 (24.3)	5444 (24.3)	1795 (24.1)
Osteoporosis	7247 (24.3)	5464 (24.4)	1783 (23.9)
Depression	6462 (21.7)	4834 (21.6)	1628 (21.8)
General Health			
Wandering Frequency			
Not in last 7 days	22825 (76.5)	17120 (76.5)	5705 (76.5)

1 to 3 days (in past 7 days)	1925 (6.5)	1440 (6.4)	485 (6.5)
4 to 6 days (in past 7 days)	1614 (5.4)	1213 (5.4)	401 (5.4)
Daily (in past 7 days)	3484 (11.7)	2613 (11.7)	871 (11.7)
Walking in corridor			
Independent	10530 (35.3)	7916 (35.4)	2614 (35.0)
Supervision	4477 (15.0)	3378 (15.1)	1099 (14.7)
Limited assistance	2789 (9.3)	2076 (9.3)	713 (9.6)
Extensive assistance	2086 (7.0)	1593 (7.1)	493 (6.6)
Total dependence	381 (1.3)	288 (1.3)	93 (1.3)
Activity did not occur	9585 (32.1)	7135 (31.9)	2450 (32.8)
Transfer status			
Independent	9569 (32.1)	7207 (32.2)	2362 (31.7)
Supervision	3576 (12.0)	2685 (12.0)	891 (11.9)
Limited assistance	4662 (15.6)	3473 (15.5)	1189 (15.9)
Extensive assistance	7140 (23.9)	5364 (24.0)	1776 (23.8)
Total dependence	4806 (16.1)	3589 (16.0)	1217 (16.3)
Activity did not occur	95 (0.3)	68 (0.3)	27 (0.4)
Cognitive performance scale			
Intact	5159 (17.3)	3871 (17.3)	1288 (17.3)
Borderline Intact	4517 (15.1)	3420 (15.3)	1097 (14.7)
Mild	6270 (21.0)	4710 (21.0)	1560 (20.9)
Moderate to very severe	8697 (29.1)	6535 (29.2)	2162 (29.0)
Moderate Severe	1650 (5.5)	1234 (5.5)	416 (5.6)
Severe	2538 (8.5)	1877 (8.4)	661 (8.9)
Very Severe	1017 (3.4)	739 (3.3)	278 (3.7)
Medications (taken last 7 days)			
Antipsychotic	8313 (27.9)	6167 (27.6)	2146 (28.8)
Antianxiety	4832 (16.2)	3646 (16.3)	1186 (15.9)
Antidepressant	12034 (40.3)	9007 (40.2)	3027 (40.6)
Hypnotic	2152 (7.2)	1655 (7.4)	497 (6.7)
Medical history			
Previous fall in past 30 days	5228 (17.5)	3931 (17.6)	1297 (17.4)
Previous fall in past 180 days	10097 (33.8)	7568 (33.8)	2529 (33.9)
Previous fracture in past 180 days[1]	1736 (5.8)	1291 (5.8)	455 (6.0)
Prior hip fracture in past 180 days	938 (3.1)	692 (3.1)	249 (3.3)
Very Severe	1017 (3.4)	739 (3.3)	278 (3.7)

[1] Any hip or other fracture in the past 180 days

Figure 2. Incident Hip Fracture Rates Classified by Individual Decision Nodes and the 8 Hip Risk levels for the Combined, Derivation and Validation Datasets. *



*RL=risk level derived from decision tree analysis.

Table 2. Incident Hip Fracture Rates by Hip Fracture Risk Levels for the Combined, Derivation and Validation Datasets.

Hip Fracture Risk Levels Categories	Combined Sample Percent with Hip Fracture	Derivation Sample Percent with Hip Fracture	Validation Sample Percent with Hip Fracture
Hip fracture risk level 1	0.6	0.67	0.5
Hip fracture risk level 2	1.8	1.88	1.64
Hip fracture risk level 3	2.5	2.64	2.24
Hip fracture risk level 4	3.1	3.2	2.96
Hip fracture risk level 5	5.0	4.9	5.1
Hip fracture risk level 6	6.8	6.64	7.14
Hip fracture risk level 7	7.8	7.8	7.68
Hip fracture risk level 8	12.6	12.9	11.43

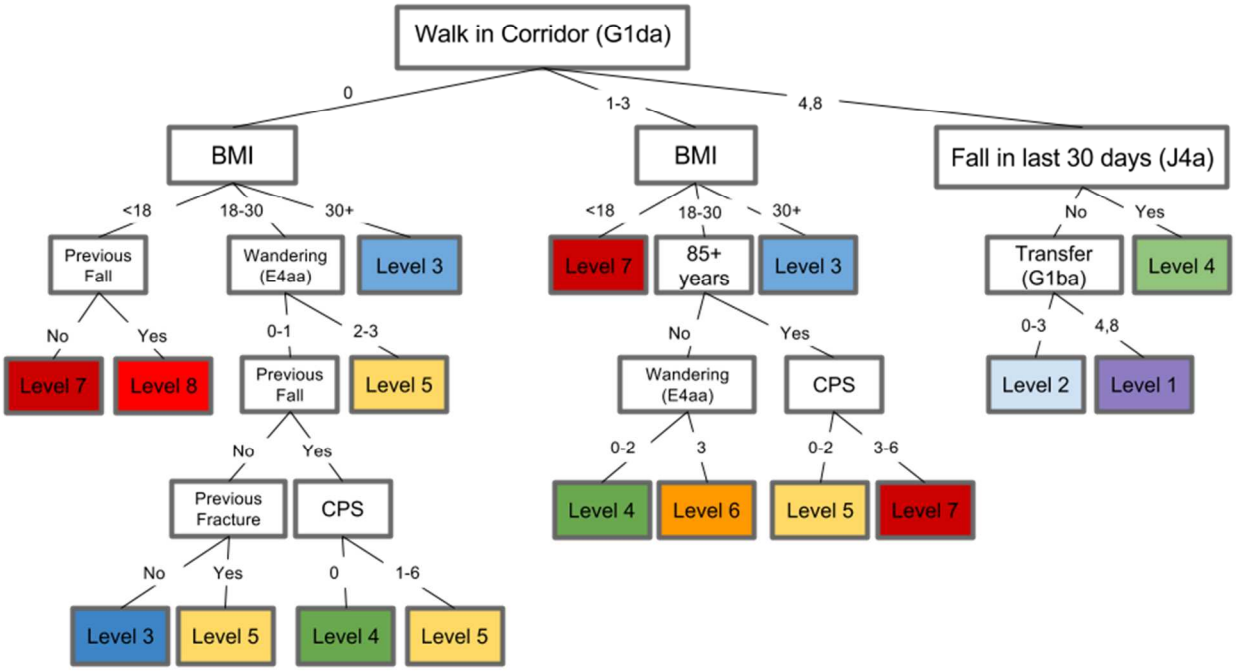
Table 3. Odds Ratios Comparisons for the 8 Hip Fracture Risk Levels for Full, Derivation and Validation Dataset.

Hip Fracture Risk Level Categories	Combined Sample Odd Ratios (95% CI)	Derivation Sample Odds Ratios (95% CI)	Validation Sample Odds Ratios (95% CI)
Hip fracture risk level 2 vs 1	3.0 (1.9-4.6)	2.9 (1.7-4.7)	3.3 (1.3-8.9)
Hip fracture risk level 3 vs 1	4.2 (2.7-6.3)	4.1 (2.5-6.5)	4.6 (1.8-11.7)
Hip fracture risk level 4 vs 1	5.2 (3.4-7.9)	4.9 (3.1-7.9)	6.1 (2.4-15.6)
Hip fracture risk level 5 vs 1	8.3 (5.5-12.6)	7.7 (4.8-12.2)	10.8 (4.3-26.9)
Hip fracture risk level 6 vs 1	11.6 (7.0-19.1)	10.6 (6.0-18.7)	15.4 (5.3-45)
Hip fracture risk level 7 vs 1	13.4 (8.8-20.5)	12.6 (7.9-20.2)	16.7 (6.6-42.2)
Hip fracture risk level 8 vs 1	23.0 (12.5-42.3)	22.1 (11.2-43.9)	25.9 (6.6-101)

Table 4. Distribution of Residents by Hip Fracture Risk Level for Combined, Derivation and Validation Datasets.

Hip Fracture Risk Level categories	Combined Sample: % (n) in each level	Derivation Sample: % (n) in each level	Validation Sample: % (n) in each level
Hip fracture risk level 1	13.5 (4,014)	13.4 (3,007)	13.5 (1,007)
Hip fracture risk level 2	18.3 (5,446)	18.3 (4,104)	18 (1,342)
Hip fracture risk level 3	24.1 (7,198)	24 (5,371)	24.5 (1,827)
Hip fracture risk level 4	17.0 (5,065)	16.9 (3,783)	17.2 (1,282)
Hip fracture risk level 5	16.6 (4,948)	16.7 (3,732)	16.3 (1,216)
Hip fracture risk level 6	2.1 (636)	2.2 (482)	2.1 (154)
Hip fracture risk level 7	8.0 (2,382)	8.0 (1,783)	8.0 (599)
Hip fracture risk level 8	0.5 (159)	0.6 (124)	0.5 (35)

Figure 3: FRS*



*Fracture Risk Scale

References

1. Choi YJ. Dual-Energy X-Ray Absorptiometry: Beyond Bone Mineral Density Determination. *Endocrinol Metab (Seoul)* 2016;31(1):25-30. doi: 10.3803/EnM.2016.31.1.25
2. Morris JN, Howard EP, Steel K, et al. Strategies to reduce the risk of falling: Cohort study analysis with 1-year follow-up in community dwelling older adults. *BMC Geriatr* 2016;16:92. doi: 10.1186/s12877-016-0267-5
3. Nevitt MC, Cummings SR. Type of fall and risk of hip and wrist fractures: the study of osteoporotic fractures. The Study of Osteoporotic Fractures Research Group. *J Am Geriatr Soc* 1993;41(11):1226-34.
4. Talbot LA, Musiol RJ, Witham EK, et al. Falls in young, middle-aged and older community dwelling adults: perceived cause, environmental factors and injury. *BMC Public Health* 2005;5:86. doi: 10.1186/1471-2458-5-86
5. Papaioannou A, Kennedy CC, Ioannidis G, et al. Comparative trends in incident fracture rates for all long-term care and community-dwelling seniors in Ontario, Canada, 2002-2012. *Osteoporos Int* 2016;27(3):887-97. doi: 10.1007/s00198-015-3477-3
6. Ronald LA, McGregor MJ, McGrail KM, et al. Hospitalization rates of nursing home residents and community-dwelling seniors in British Columbia. *Can J Aging* 2008;27(1):109-15. doi: 10.3138/cja.27.1.109
7. Dyer SM, Crotty M, Fairhall N, et al. A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatr* 2016;16:158. doi: 10.1186/s12877-016-0332-0
8. Neuman MD, Silber JH, Magaziner JS, et al. Survival and functional outcomes after hip fracture among nursing home residents. *JAMA Intern Med* 2014;174(8):1273-80. doi: 10.1001/jamainternmed.2014.2362
9. Siminoski K, Leslie WD, Frame H, et al. Recommendations for bone mineral density reporting in Canada: a shift to absolute fracture risk assessment. *J Clin Densitom* 2007;10(2):120-3. doi: 10.1016/j.jocd.2007.01.001
10. Siminoski K, Leslie WD, Frame H, et al. Recommendations for bone mineral density reporting in Canada. *Can Assoc Radiol J* 2005;56(3):178-88.
11. Kanis JA, Johnell O, De Laet C, et al. A meta-analysis of previous fracture and subsequent fracture risk. *Bone* 2004;35(2):375-82. doi: 10.1016/j.bone.2004.03.024
12. Leslie WD, Lix LM, Langsetmo L, et al. Construction of a FRAX(R) model for the assessment of fracture probability in Canada and implications for treatment. *Osteoporos Int* 2011;22(3):817-27. doi: 10.1007/s00198-010-1464-2
13. Bravo G, Dubois MF, De Wals P, et al. Relationship between regulatory status, quality of care, and three-year mortality in Canadian residential care facilities: a longitudinal study. *Health Serv Res* 2002;37(5):1181-96.
14. Greenspan SL, Perera S, Nace D, et al. FRAX or fiction: determining optimal screening strategies for treatment of osteoporosis in residents in long-term care facilities. *J Am Geriatr Soc* 2012;60(4):684-90. doi: 10.1111/j.1532-5415.2011.03884.x
15. Khatib R, Santesso N, Pickard L, et al. Fracture risk in long term care: a systematic review and meta-analysis of prospective observational studies. *BMC Geriatr* 2014;14:130. doi: 10.1186/1471-2318-14-130
16. Cox L, Kloseck M, Crilly R, et al. Underrepresentation of individuals 80 years of age and older in chronic disease clinical practice guidelines. *Can Fam Physician* 2011;57(7):e263-9.
17. Mutasingwa DR, Ge H, Upshur RE. How applicable are clinical practice guidelines to elderly patients with comorbidities? *Can Fam Physician* 2011;57(7):e253-62.

18. Morris JN, Nonemaker S, Murphy K, et al. A commitment to change: revision of HCFA's RAI. *J Am Geriatr Soc* 1997;45(8):1011-6.
19. Hawes C, Morris JN, Phillips CD, et al. Development of the nursing home Resident Assessment Instrument in the USA. *Age Ageing* 1997;26 Suppl 2:19-25.
20. Hirdes JP, Ljunggren G, Morris JN, et al. Reliability of the interRAI suite of assessment instruments: a 12-country study of an integrated health information system. *BMC Health Serv Res* 2008;8:277. doi: 10.1186/1472-6963-8-277
21. Jantzi M, Maher AC, Ioannidis G, et al. Individuals with neurological diseases are at increased risk of fractures within 180 days of admission to long-term care in Ontario. *Age Ageing* 2015;44(2):252-7. doi: 10.1093/ageing/afu156
22. Canadian Institute for Health Information. Data Quality Documentation, Discharge Abstract Database – Multi-Year Information. 2012 ed. Ottawa, ON https://www.cihi.ca/sites/default/files/document/nacrs_multi-year_info_en.pdf . accessed Dec 20th, 2016.: CIHI, 2012.
23. Canadian Institute for Health Information. Data Quality Documentation National Ambulatory Care Reporting System – Multi-Year Information. Ottawa: CIHI, 2012.
24. O'Donnell S, Canadian Chronic Disease Surveillance System Osteoporosis Working G. Use of administrative data for national surveillance of osteoporosis and related fractures in Canada: results from a feasibility study. *Arch Osteoporos* 2013;8:143. doi: 10.1007/s11657-013-0143-2
25. Kass G. An Exploratory Technique for Investigating Large Quantities of Categorical Data. *Applied Statistics* 1980;29(2):8.
26. Kennedy CC, Ioannidis G, Thabane L, et al. Osteoporosis prescribing in long-term care: impact of a provincial knowledge translation strategy. *Can J Aging* 2015;34(2):137-48. doi: 10.1017/S0714980815000057
27. Jachna CM, Shireman TI, Whittle J, et al. Differing patterns of antiresorptive pharmacotherapy in nursing facility residents and community dwellers. *J Am Geriatr Soc* 2005;53(8):1275-81. doi: 10.1111/j.1532-5415.2005.53401.x
28. Kennedy CC, Ioannidis G, Thabane L, et al. Successful knowledge translation intervention in long-term care: final results from the vitamin D and osteoporosis study (ViDOS) pilot cluster randomized controlled trial. *Trials* 2015;16:214. doi: 10.1186/s13063-015-0720-3
29. Colon-Emeric CS, Lyles KW, House P, et al. Randomized trial to improve fracture prevention in nursing home residents. *Am J Med* 2007;120(10):886-92. doi: 10.1016/j.amjmed.2007.04.020
30. Giangregorio LM, Jantzi M, Papaioannou A, et al. Osteoporosis management among residents living in long-term care. *Osteoporos Int* 2009;20(9):1471-8. doi: 10.1007/s00198-009-0837-x
31. Wall M, Lohfeld L, Giangregorio L, et al. Fracture risk assessment in long-term care: a survey of long-term care physicians. *BMC Geriatr* 2013;13:109. doi: 10.1186/1471-2318-13-109
32. Perlman CM, Hirdes JP, Vigod S. Psychiatric Rehospitalization: Development of a Person-Level Indicator for Care Planning and Quality Assurance. *Prim Care Companion CNS Disord* 2015;17(4) doi: 10.4088/PCC.15m01784
33. Neufeld E, Perlman CM, Hirdes JP. Predicting inpatient aggression using the InterRAI risk of harm to others clinical assessment protocol: a tool for risk assessment and care planning. *J Behav Health Serv Res* 2012;39(4):472-80. doi: 10.1007/s11414-011-9271-x
34. Mathias K, Hirdes JP, Pittman D. A care planning strategy for traumatic life events in community mental health and inpatient psychiatry based on the InterRAI assessment instruments. *Community Ment Health J* 2010;46(6):621-7. doi: 10.1007/s10597-010-9308-2
35. Papaioannou A, Santesso N, Morin SN, et al. Recommendations for preventing fracture in long-term care. *CMAJ* 2015;187(15):1135-44, E450-61. doi: 10.1503/cmaj.141331

36. Duque G, Close JJ, de Jager JP, et al. Treatment for osteoporosis in Australian residential aged care facilities: consensus recommendations for fracture prevention. *Med J Aust* 2010;193(3):173-9.
37. Duque G, Lord SR, Mak J, et al. Treatment of Osteoporosis in Australian Residential Aged Care Facilities: Update on Consensus Recommendations for Fracture Prevention. *J Am Med Dir Assoc* 2016;17(9):852-9. doi: 10.1016/j.jamda.2016.05.011
38. Colon-Emeric CS, Biggs DP, Schenck AP, et al. Risk factors for hip fracture in skilled nursing facilities: who should be evaluated? *Osteoporos Int* 2003;14(6):484-9. doi: 10.1007/s00198-003-1384-5
39. Chen JS, Sambrook PN, Simpson JM, et al. A selection strategy was developed for fracture reduction programs in frail older people. *J Clin Epidemiol* 2010;63(6):679-85. doi: 10.1016/j.jclinepi.2009.08.018
40. Morris JN, Fries BE, Steel K, et al. Comprehensive clinical assessment in community setting: applicability of the MDS-HC. *J Am Geriatr Soc* 1997;45(8):1017-24.

Appendix 1: Decision Tree Schematic Legend

Decision Tree Schematic Legend - All variables are derived from the MDS assessment		
Variable	**Response values**	**Response meaning**
Walk in corridor (G1da)	0 1 to 3 4, 8	Independent Supervision to extensive assistance Total assistance, or walking did not occur
Fall in last 30 days (J4a)	No/Yes	Any fall in the past 30 days
Previous fall	No/Yes	Any fall in the past 180 days
Wandering	0,1 2 3	No wandering to infrequent wandering Less than daily wandering Daily wandering
Transfer (G1ba)	0 to 3 4, 8	Independent to extensive assistance Total assistance, or transfer did not occur
CPS (Cognitive Performance Scale)	0 1 to 2 3 to 6	Intact cognition Borderline intact or mild impairment Moderate to Very Severe impairment
Previous fracture	No/Yes	Any hip or other fracture in the past 180 days

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	12
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	16
		(b) Give reasons for non-participation at each stage	16
		(c) Consider use of a flow diagram	16
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	17-18
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(*b*) Report category boundaries when continuous variables were categorized	17-18
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-13
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

The Development and Validation of the Fracture Risk Scale (FRS) that Predicts Fracture Over a 1 Year Time Period in Institutionalized Frail Older People living in Canada: An Electronic Record-Linked Longitudinal Cohort Study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2017-016477.R1
Article Type:	Research
Date Submitted by the Author:	16-Jun-2017
Complete List of Authors:	Ioannidis, George; McMaster University, Medicine; Geriatric Education and Research in Aging Sciences Centre, Jantzi, Micaela ; University of Waterloo, Health Studies and Gerontology Bucek, Jenn; University of Waterloo, Health Studies and Gerontology Adachi, Jonathan; McMaster University, Medicine Giangregorio, Lora; University of Waterloo, Kinesiology Hirdes, John; University of Waterloo, Health Studies and Gerontology Pickard, Laura; Geriatric Education and Research in Aging Sciences Centre Papaioannou, Alexandra; McMaster University, Medicine; Geriatric Education and Research in Aging Sciences Centre
Primary Subject Heading:	Geriatric medicine
Secondary Subject Heading:	Health informatics
Keywords:	fracture, long term care, prediction model, resident assessment instrument minimum data set version 2.0, frail older adults

The Development and Validation of the Fracture Risk Scale (FRS) that Predicts Fracture Over a 1 Year Time Period in Institutionalized Frail Older People living in Canada: An Electronic Record-Linked Longitudinal Cohort Study

George Ioannidis[1, 2], Micaela Jantzi[3], Jenn Bucek[3], Jonathan D. Adachi[1, 2], Lora Giangregorio[2, 3], John Hirdes[3], Laura Pickard[1, 2], Alexandra Papaioannou[1, 2]

Author affiliations:

[1]McMaster University, Hamilton, Ontario, Canada;

[2]GERAS centre, Hamilton, Ontario, Canada;

[3]University of Waterloo, Waterloo, Ontario, Canada

Corresponding to Dr. George Ioannidis; g.ioannidis@sympatico.ca

Abstract

Objectives: To develop and validate our Fracture Risk Scale (FRS) over a 1 year time period, using the long-term care Resident Assessment Instrument Minimum Data Set Version 2.0 (RAI-MDS).

Design: A retrospective cohort study.

Setting: Long-term care (LTC) homes in Ontario, Canada.

Participants: Older adults who were admitted to LTC and received a RAI-MDS admission assessment between 2006 and 2010.

Results: A total of 29,848 LTC residents were enrolled in the study. Of these 22,386 were included in the derivation dataset and 7,462 individual were included in the validation dataset. Approximately 2/3 of the entire sample were women, and 45% were 85 years of age or older. A total of 1553 (5.2%) fractures were reported over the one year time period. Of these, 959 (61.8%) were hip fractures. Following a hip fracture, 6.3% of individuals died in the emergency department or as an inpatient admission and did not return to their LTC home. Using decision tree analysis, our final outcome scale had 8 risk levels of differentiation. The percentage of individuals with a hip fracture ranged from 0.6 (lowest risk level) to 12.6 % (highest risk level). The area under the curve of the outcome scale was similar for the derivation (0.67) and validation (0.69) samples, and the scale exhibited a good level of consistency.

Conclusions: Our FRS predicts hip fracture over a 1 year time period and should be used as an aid to support clinical decisions in the care-planning of LTC residents. Future research should focus on the transformation of our scale to a Clinical Assessment Protocol and to assess the FRS in other health care settings.

Strengths and Limitations of this study

- The Fracture Risk Scale (FRS) was developed and validated using a large number of residents living in LTC homes and thus the results may be generalizable to all LTC residents living in Canada.
- The FRS did not use bone mineral density as a predictor of hip fracture, which is difficult to measure in LTC, but used a comprehensive set of community and LTC specific risk factors to predict new fractures.
- Decision tree analysis was used to develop our outcome scale, which provides an empirically sound, visual representation of the contributing factors for hip fracture among residents living in LTC; and by clinical feedback to improve the instrument's face validity.
- Our study excluded individuals that we believed would not survive the one year assessment period. Therefore, our findings may not be generalizable to these residents.

Introduction

Older adults usually enter long term care (LTC) homes because of difficulties in functional status triggered by physical decline, cognitive impairment, or the onset of an acute illness. These individuals are at higher risk for hip fracture, due to increased age related bone loss [1]; increased propensity to fall [2]; and altered mechanics of the fall, where older individuals are more likely to fall backwards or sideways [3 4]. Compared with similarly aged seniors residing in the community, the rate of hip fractures are 1.6 and 2.2 times greater in women and men living in LTC, respectively [5]. Hip fractures are the most common fracture type in LTC, accounting for 49 % of all fractures [5]. Furthermore, hip fracture is one of the leading causes of hospitalization for LTC residents [6] and is associated with increased mortality, reduced mobility and worsening health related quality of life [7]. Approximately 50% of LTC residents who have some independence in locomotion prior to hip fracture either die or develop total dependence within 6 months of their fracture [8].

Unfortunately, it is difficult to identify LTC residents at high risk for fracture, as the current fracture risk assessment tools in Canada, including the Canadian Fracture Risk Assessment Tool (FRAX) and the Canadian Association of Radiologists and Osteoporosis Canada tool (CAROC) [9-12], are not valid for or generalizable to LTC. For instance, the instruments provide a 10 year fracture risk assessment timeframe, which is too long, given that 20% of residents die within one year of LTC admission [13]. In addition, both instruments use bone mineral density as a major factor that predicts future fracture risk. However bone density is challenging to obtain in LTC, and previous work has identified that the use of the FRAX model without bone mineral density identified 98% of residents as candidates for treatment [14]. Finally,

the instruments do not include potential LTC specific risk factors (i.e. wandering, cognitive impairment and transfer status) for hip fracture which are different than in the community specific risk factors (i.e. age, sex, and prior fracture status) [15]. Thus, fracture prediction outputs of FRAX-Canada and CAROC may not be suitable for decision making and care planning among LTC residents who have multiple comorbidities [16 17].

The Resident Assessment Instrument Minimum Data Set Version 2.0 (RAI-MDS 2.0) is a comprehensive, standardized tool that has been implemented in LTC homes in many Canadian provinces[18-20]. The RAI-MDS 2.0 is used during routine clinical practice and data from the instrument provides an opportunity for health care providers to evaluate the health care needs and risks of all residents. The instrument is completed within 14 days of a resident entering a home and quarterly thereafter. The RAI-MDS 2.0 includes individual data elements and outcome scores that may provide the necessary information to determine residents at high risk for hip fracture. The purpose of our study was to develop and validate our Fracture Risk Scale (FRS) that predicts hip fracture over a 1 year time period, using RAI-MDS 2.0 data. The ability to screen and identify frail residents at risk for hip fracture is clinically useful for the development of fracture prevention care planning strategies.

Methods

Study design

All admission assessments completed in Ontario LTC homes from April 1st, 2006 to March 31st 2010 (n=47,556) were selected. Those with multiple admissions were excluded (n=4,041). Among the unique admissions (n=43,515) those reported on the RAI-MDS 2.0 to have End Stage Disease (n=511), were comatose (n=12), received hospice (n=16) or respite care (n=785), expected a short stay (n=4,016) or admission assessment completed more than 14 days after the date of admission (n=4,105) were excluded. Those who had no reassessments during the 1 year follow up (n=4,222) were also excluded. The final sample size was 29,848 residents. These residents were randomly divided between a derivation (n=22,386) and validation sample (n=7,462) for the development and testing of our scale (Figure 1). Over the course of a 1 year follow-up period, residents were classified as to the presence or absence of an incident fracture using nationally collected data.

This project continues from previous work done through the Innovations in Data, Evidence and Applications for Persons with Neurological Conditions (ideasPNC) research project [21], and has ethics approval obtained from the University of Waterloo Office of Research Ethics (ORE # 17045).

Incident Fractures

RAI 2.0 data were linked with the Canadian Discharge Abstract Database (DAD) that captures information regarding each in-patient hospital stay and the National Ambulatory Care Reporting System (NACRS) that captures each Emergency Department visit [22 23]. Linked DAD

and NACRS records were available for 2 years prior to the MDS 2.0 assessment, and at least 1 year after the assessment.

Incident fractures were captured using International Classification of Disease (ICD)-10 codes. The codes were selected using the Revised Framework for National Surveillance on Osteoporosis and Osteoporosis-related Fractures of the Public Health Agency of Canada [24]. A resident with at least one of these codes within 1 year after the admission assessment was coded as having a fracture (hip (S72.0, S72.1, S72.2), spine (S22.0, S22.1, S32.0, S32.7, S32.8), humerus (S42.2), forearm (S52.x, S62.x) and pelvis (S32.1, S32.3, S32.4, S32.5, S32.7, S32.8)).

Statistical analyses

Population characteristics are expressed in count and percent for categorical variables using SAS 9.4 (SAS Institute, Cary, NC).

A decision tree [25] was created using the 75% derivation sample to predict incident hip fractures within 1 year of admission to a LTC home. The unadjusted odds ratios of over 150 individual items and outcome scales from the RAI-MDS were calculated. A clinical expert panel evaluated the relevance of the items, and those that had both face validity and were significantly associated with incident fractures based on the odds ratios were retained. A recursive partitioning method called Chi-squared Automatic Interaction Detection (CHAID) was employed [25] using SAS Enterprise Miner 13.1 (SAS Institute, Cary, NC). The final decision tree was validated in an in-person meeting with clinical experts.

Once the decision tree was completed, the individual nodes were collapsed into 8 categories and logistic regression was performed to calculate the odds of having a hip fracture

within the first year of admission to an LTC home. C-statistics were calculated to compare the discriminative properties of the full, derivation, and validation samples.

Results

Table 1 displays the population characteristics of residents for the combined, derivation, and validation dataset. For the combined sample, approximately 45% of LTC residents were 85 years and older, 2/3 were women, 1/3 had a prior fall within the past 180 days, and 3% had a prior hip fracture within the past 180 days. A total of 1553 (5.2%) new fractures (including hip, spine humerus, forearm, and pelvis) were reported over the one year time period. Of these, 959 (61.8%) were hip fractures. The fracture proportion was similar for individuals in the derivation and validation samples (data not shown). Only 15 (0.07%) older adults had multiple hip fractures over the one year time period.

Decision tree model

The final decision tree model contains 17 leaves. Each leaf represented a distinct proportion of residents with an incident hip fracture during the one year assessment period (Figure 2). By combining leaves with similar risk, the 17 leaves were collapsed into the FRS, which included 8 risk levels of differentiation (Figure 3). Our scale's one year absolute hip fracture risk levels ranged from 0.6 to 12.6 % (Table 2). The odds ratios shows a clear stepped progression of risk, achieving a 23 fold increase in the odds of developing a hip fracture for residents between the lowest to highest risk level (Table 3). Furthermore, the distribution of residents within each risk level decreased as the risk level for hip fracture increased (Table 4).

Within our FRS, the ability of an individual to walk in a corridor on the unit (root node) showed the highest discriminatory power, as well as the best ability to organize the tree branches relative to other risk factors. Body mass index and fall status in the past 30 days were risk factors that also had high discriminatory powers. Other variables included in the tool included

wandering events, transfer ability (how resident moves between surfaces-to and from; bed, chair, wheelchair, standing position), fall status in the past 180 days, prior fracture in past 180 days, cognitive performance, and age greater than 85 years (Figure 3, Appendix 1).

Discrimination and predictive accuracy

The overall discriminative properties of the FRS were similar between the combined (c-statistic= 0.673) derivation (c-statistic= 0.669) and validation (c-statistic= 0.687) datasets. In addition, the absolute hip fracture rate for the individual risk levels (Table 2), the odds ratios comparisons (Table 3), and the predictive accuracy (Figure 2) of the scale were similar between the derivation and validation datasets. Overall, the FRS exhibited a good level of consistency between the datasets.

Death rates

Following a hip fracture, 6.27% in individuals died in the emergency department or as an inpatient admission and did not return to their LTC facility. The mean length of stay (standard deviation) for those who died during an in-patient admission was 8.9 days (7.3).

Discussion

While a large proportion of residents in LTC are at risk of suffering a hip fracture, a fracture care planning gap has been well documented [26-30]. Potential causes for this planning care gap include inadequate access to bone mineral density testing; a lack of knowledge of clinicians regarding fracture risk assessment and treatment; and the complex nature of providing care to residents in LTC that requires clinical competence [31]. Therefore, standardized methods must be used to identify residents at risk for hip fracture to reduce the care gap and to improve the efficient allocation and delivery of limited LTC health resources.

Our results show that the FRS is capable of both discriminating and predicting residents at risk for hip fracture over a one year time period. Our findings indicate that in addition to community risk factors for hip fracture that are used in the FRAX and CAROC instruments, there are several LTC specific risk factors that are important in predicting hip fracture risk including walking ability, wandering, falling, cognitive impairment, and transfer status. Our scale identifies 8 risk levels for hip fracture in LTC and provides the clinical information that is needed to develop person-centered care plans. Of note, the distribution property of the scale allocates over 50% of the assessed residents into the lowest three risk levels with progressively fewer residents spread across each of the higher risk levels. The scale's properties are beneficial for the potential transformation of the FRS to a Clinical Assessment Protocol (CAP).

Our intention is to further develop the FRS into a CAP algorithm, to assist LTC health professionals to systematically interpret fracture risk levels that are generated by the instrument and to inform clinical decision making as part of the care planning process. The CAP may combine our scale's 8 risk levels into three risk categories for hip fracture (i.e. very high risk, high risk, and lower risk for hip fracture). The very high risk category may be defined as risk

levels 7 and 8; high risk as risk levels 4, 5 and 6; and lower risk as risk levels 1, 2 and 3. The proposed three level triggering CAP is similar to CAPs used in other interRAI instruments [32-34]. The CAP may be triggered for the very high risk and the high risk categories, which represents 8.5%, and 35.7% of the resident population in LTC, respectively. The non-triggered lower risk category represents 55.8% of the population. This large population of low risk persons within the potential CAP is important because the triggering of too many high risk individuals may quickly overwhelm LTC resources that are needed for clinical management and may fail to differentiate individuals at the point of care. Person-centered care planning recommendations for those that trigger the CAP may be based on effective interventions recommended by LTC guidelines from Canada and around the world, and include vitamin D and calcium supplementation, hip protectors, exercise, multifactorial interventions to prevent falls, and pharmacologic therapies [35-37]. The CAP outputs will assist in resident care planning and the process should reduce the risk of hip fracture, increase life expectancy, preserve or improve quality of life, and reduce health care costs.

Our findings should be interpreted based on the strengths and limitations of our study design. Strengths that may prevent bias include the large number of residents that were used to develop and validate our outcome scale. A comprehensive set of independent variables were included in the analyses. Our outcome scale did not use bone mineral density as a predictor of hip fracture, which is difficult to measure in LTC. We used a "gold standard" method (DAD/NACRS databases) to assess incident hip fracture status. Decision tree analysis was used to develop our outcome scale, which provides an empirically sound, visual representation of the contributing factors for hip fracture among residents living in LTC; and by clinical feedback to improve the instrument's face validity. Using decision tree analysis may have higher utility in

identifying high risk individuals relative to traditional algorithm developed in LTC using regression analyses [38 39] because of the no parametric assumptions of the technique, the methods distinctive clustering of risk factors, and the tree's ability to better account for independent and dependent variable outliers. Furthermore, the FRS will be a standardized tool that uses existing items from the RAI-MDS 2.0, will automatically generate fracture risk assessments for residents as part of the RAI-MDS 2.0 quarterly data collection process, and will rely on existing assessor training skills and resources that are currently present in LTC homes. The use of our scale will minimize the duplication of work that is often required to support non-integrated tools, such as FRAX, CAROC or QFracture [9-12 40]. Our instrument has a logical flow, and is easily interpretable by LTC healthcare professionals. As a product of the process by which the scale was created, we believe that our scale's approval and use in LTC will be enhanced. Finally, our FRS utilizes similar items that are collected using the next version of the instrument (interRAI Long-Term Care Facilities) that is used internationally and in some Canadian provinces [20], and by the MDS-Home Care instrument [41] and thus, our tool may potentially be useful globally and in home care settings.

Our study limitations include the exclusion of individuals that we believed would not survive the one year assessment period. Therefore, our findings may not be generalizable to these residents. The study was limited to the independent variables available in the RAI-MDS 2.0 and may not have captured all relevant risk factors for hip fractures among LTC residents. Finally, it is not clear if our results are unique to LTC residents and further validation studies will be needed in different populations (i.e. home care).

In conclusion, the findings of our study provide support for the discriminatory and predictive properties of the FRS. The instrument may have implications for health strategy,

service delivery and care planning that may impact policy choices for vulnerable residents living in LTC. Our scale that predicts hip fracture over a 1 year time period may be used as an aid to support clinical decisions in the care-planning process and may be incorporated as part of a comprehensive clinical assessment where the preference of the resident should be considered. Future research should focus on comparing the FRS to other fracture prediction instruments, developing a CAP for the scale and evaluating the performance of the FRS in home care.

Author affiliations:

[1]McMaster University, Hamilton, Ontario, Canada;

[2]GERAS centre, Hamilton, Ontario, Canada;

[3]University of Waterloo, Waterloo, Ontario, Canada

Corresponding to Dr. George Ioannidis; g.ioannidis@sympatico.ca

Contributions: GI, was responsible for study design, data analysis interpretation, and drafting of manuscript, MJ was responsible for study design, data analysis and interpretation, and drafting of manuscript. JB, JDA, LG, JH LP, AP were responsible for study design, data interpretation, critical review of the manuscript. All authors read and approved the final manuscript.

Funding: The Ministry of Health and Long-Term care through the Ontario Osteoporosis Strategy for Long-Term Care

Disclaimer: The funding sources had no role in the design and conduct of the study; collection, management, analysis and interpretation of the data; or preparation, review or approval of the manuscript.

Competing interests: All authors have completed the ICMJE uniform disclosure form at www.icmje.org/coi_disclosure.pdf and declare: no support from any organisation for the submitted work; no financial relationships with any organisations that might have an interest in the submitted work in the previous three years; no other relationships or activities that could appear to have influenced the submitted work (GI, MJ, JB, JH). Dr. Giangregorio reports personal fees from ICON. Dr. Papaioannou and Ms. Pickard reports grants from Ontario Ministry of Health and Long Term Care Ontario Osteoporosis Strategy. Dr. Adachi reports grants and personal fees from Amgen , grants and personal fees from Eli Lilly, personal fees from AgNovos, during the conduct of the study; non-financial support from Osteoporosis Canada, non-financial support from International Osteoporosis Foundation, outside the submitted work.

Ethics approval: Obtained from the University of Waterloo Office of Research Ethics (ORE # 17045).

Provenance and peer review: Not commissioned; externally peer reviewed.

Data sharing statement: No additional data are available.

Table 1. Resident Characteristics for the Combined, Derivation and Validation Datasets.

Characteristics: n (%)	**Combined Sample (N=29,848)**	**Derivation Sample (N=22,386)**	**Validation Sample (N=7,462)**
Demographics and anthropometrics			
Age group			
18 to 64	1700 (5.7)	1268 (5.7)	432 (5.8)
65 to 74	3128 (10.5)	2308 (10.3)	820 (11.0)
75 to 84	11300 (37.9)	8466 (37.8)	2834 (38.0)
85+	13708 (45.9)	10335 (46.2)	3373 (45.2)
Women	19706 (66.0)	14831 (66.3)	4875 (65.3)
Weight loss (5% or more last 30 days)	1567 (5.3)	1204 (5.4)	363 (4.9)
Body Mass Index			
<18	2396 (8.0)	1828 (8.2)	568 (7.6)
18-29	22252 (74.6)	16646 (74.4)	5606 (75.1)
30+	4753 (15.9)	3586 (16.0)	1167 (15.6)
Married	8978 (30.1)	6695 (29.9)	2283 (30.6)
Education			
Grade 8 or less	6495 (21.8)	4939 (22.1)	1556 (20.9)
High School	8428 (28.2)	6323 (28.3)	2105 (28.2)
Post-Secondary	5010 (16.8)	3742 (16.7)	1268 (17.0)
Unknown	9915 (33.2)	7382 (33.0)	2533 (34.0)
Diseases			
Alzheimer's disease and related dementias	16778 (56.2)	12553 (56.1)	4225 (56.6)
Epilepsy	1118 (3.8)	839 (3.8)	279 (3.7)
Traumatic Brain Injury	237 (0.8)	179 (0.8)	58 (0.8)
Parkinson's disease	2004 (6.7)	1487 (6.6)	517 (6.9)
Multiple sclerosis	283 (1.0)	207 (0.9)	76 (1.0)
Diabetes	7239 (24.3)	5444 (24.3)	1795 (24.1)
Osteoporosis	7247 (24.3)	5464 (24.4)	1783 (23.9)
Depression	6462 (21.7)	4834 (21.6)	1628 (21.8)

Characteristics: n (%)	Combined Sample (N=29,848)	Derivation Sample (N=22,386)	Validation Sample (N=7,462)
General Health			
Wandering Frequency			
Not in last 7 days	22825 (76.5)	17120 (76.5)	5705 (76.5)
1 to 3 days (in past 7 days)	1925 (6.5)	1440 (6.4)	485 (6.5)
4 to 6 days (in past 7 days)	1614 (5.4)	1213 (5.4)	401 (5.4)
Daily (in past 7 days)	3484 (11.7)	2613 (11.7)	871 (11.7)
Walking in corridor			
Independent	10530 (35.3)	7916 (35.4)	2614 (35.0)
Supervision	4477 (15.0)	3378 (15.1)	1099 (14.7)
Limited assistance	2789 (9.3)	2076 (9.3)	713 (9.6)
Extensive assistance	2086 (7.0)	1593 (7.1)	493 (6.6)
Total dependence	381 (1.3)	288 (1.3)	93 (1.3)
Activity did not occur	9585 (32.1)	7135 (31.9)	2450 (32.8)
Transfer status			
Independent	9569 (32.1)	7207 (32.2)	2362 (31.7)
Supervision	3576 (12.0)	2685 (12.0)	891 (11.9)
Limited assistance	4662 (15.6)	3473 (15.5)	1189 (15.9)
Extensive assistance	7140 (23.9)	5364 (24.0)	1776 (23.8)
Total dependence	4806 (16.1)	3589 (16.0)	1217 (16.3)
Activity did not occur	95 (0.3)	68 (0.3)	27 (0.4)
Cognitive performance scale			
Intact	5159 (17.3)	3871 (17.3)	1288 (17.3)
Borderline Intact	4517 (15.1)	3420 (15.3)	1097 (14.7)
Mild	6270 (21.0)	4710 (21.0)	1560 (20.9)
Moderate to very severe	8697 (29.1)	6535 (29.2)	2162 (29.0)
Moderate Severe	1650 (5.5)	1234 (5.5)	416 (5.6)
Severe	2538 (8.5)	1877 (8.4)	661 (8.9)
Very Severe	1017 (3.4)	739 (3.3)	278 (3.7)
Medications (taken last 7 days)			
Antipsychotic	8313 (27.9)	6167 (27.6)	2146 (28.8)
Antianxiety	4832 (16.2)	3646 (16.3)	1186 (15.9)
Antidepressant	12034 (40.3)	9007 (40.2)	3027 (40.6)
Hypnotic	2152 (7.2)	1655 (7.4)	497 (6.7)
Medical history			
Previous fall in past 30 days	5228 (17.5)	3931 (17.6)	1297 (17.4)
Previous fall in past 180 days	10097 (33.8)	7568 (33.8)	2529 (33.9)

Previous fracture in past 180 days[1]	1736 (5.8)	1291 (5.8)	455 (6.0)
Prior hip fracture in past 180 days	938 (3.1)	692 (3.1)	249 (3.3)

[1] Any hip or other fracture in the past 180 days

Table 2. Incident Hip Fracture Rates by Hip Fracture Risk Levels for the Combined, Derivation and Validation Datasets.

Hip Fracture Risk Levels Categories	Combined Sample Percent with Hip Fracture	Derivation Sample Percent with Hip Fracture	Validation Sample Percent with Hip Fracture
Hip fracture risk level 1	0.6	0.67	0.5
Hip fracture risk level 2	1.8	1.88	1.64
Hip fracture risk level 3	2.5	2.64	2.24
Hip fracture risk level 4	3.1	3.2	2.96
Hip fracture risk level 5	5.0	4.9	5.1
Hip fracture risk level 6	6.8	6.64	7.14
Hip fracture risk level 7	7.8	7.8	7.68
Hip fracture risk level 8	12.6	12.9	11.43

Table 3. Odds Ratios Comparisons for the 8 Hip Fracture Risk Levels for Full, Derivation and Validation Dataset.

Hip Fracture Risk Level Categories	Combined Sample Odd Ratios (95% CI)	Derivation Sample Odds Ratios (95% CI)	Validation Sample Odds Ratios (95% CI)
Hip fracture risk level 2 vs 1	3.0 (1.9-4.6)	2.9 (1.7-4.7)	3.3 (1.3-8.9)
Hip fracture risk level 3 vs 1	4.2 (2.7-6.3)	4.1 (2.5-6.5)	4.6 (1.8-11.7)
Hip fracture risk level 4 vs 1	5.2 (3.4-7.9)	4.9 (3.1-7.9)	6.1 (2.4-15.6)
Hip fracture risk level 5 vs 1	8.3 (5.5-12.6)	7.7 (4.8-12.2)	10.8 (4.3-26.9)
Hip fracture risk level 6 vs 1	11.6 (7.0-19.1)	10.6 (6.0-18.7)	15.4 (5.3-45)
Hip fracture risk level 7 vs 1	13.4 (8.8-20.5)	12.6 (7.9-20.2)	16.7 (6.6-42.2)
Hip fracture risk level 8 vs 1	23.0 (12.5-42.3)	22.1 (11.2-43.9)	25.9 (6.6-101)

Table 4. Distribution of Residents by Hip Fracture Risk Level for Combined, Derivation and Validation Datasets.

Hip Fracture Risk Level categories	Combined Sample: % (n) in each level	Derivation Sample: % (n) in each level	Validation Sample: % (n) in each level
Hip fracture risk level 1	13.5 (4,014)	13.4 (3,007)	13.5 (1,007)
Hip fracture risk level 2	18.3 (5,446)	18.3 (4,104)	18 (1,342)
Hip fracture risk level 3	24.1 (7,198)	24 (5,371)	24.5 (1,827)
Hip fracture risk level 4	17.0 (5,065)	16.9 (3,783)	17.2 (1,282)
Hip fracture risk level 5	16.6 (4,948)	16.7 (3,732)	16.3 (1,216)
Hip fracture risk level 6	2.1 (636)	2.2 (482)	2.1 (154)
Hip fracture risk level 7	8.0 (2,382)	8.0 (1,783)	8.0 (599)
Hip fracture risk level 8	0.5 (159)	0.6 (124)	0.5 (35)

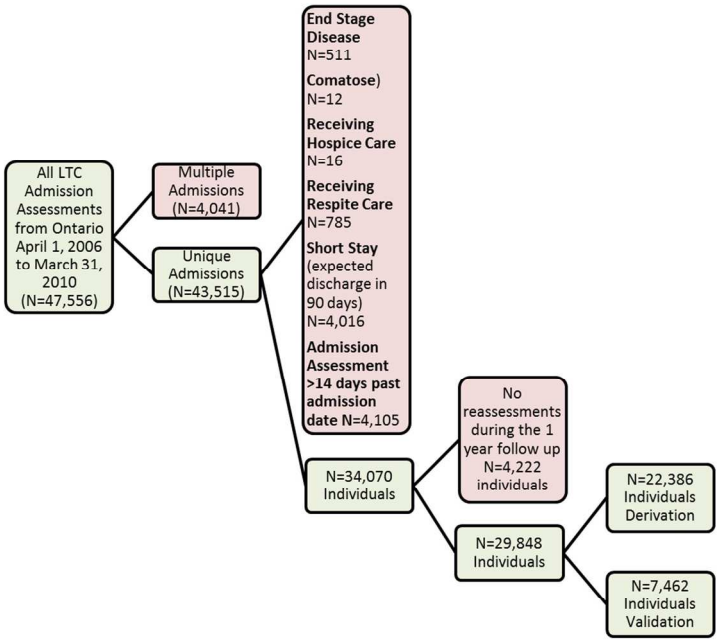
References

1. Choi YJ. Dual-Energy X-Ray Absorptiometry: Beyond Bone Mineral Density Determination. *Endocrinol Metab (Seoul)* 2016;31(1):25-30. doi: 10.3803/EnM.2016.31.1.25
2. Morris JN, Howard EP, Steel K, et al. Strategies to reduce the risk of falling: Cohort study analysis with 1-year follow-up in community dwelling older adults. *BMC Geriatr* 2016;16:92. doi: 10.1186/s12877-016-0267-5
3. Nevitt MC, Cummings SR. Type of fall and risk of hip and wrist fractures: the study of osteoporotic fractures. The Study of Osteoporotic Fractures Research Group. *J Am Geriatr Soc* 1993;41(11):1226-34.
4. Talbot LA, Musiol RJ, Witham EK, et al. Falls in young, middle-aged and older community dwelling adults: perceived cause, environmental factors and injury. *BMC Public Health* 2005;5:86. doi: 10.1186/1471-2458-5-86
5. Papaioannou A, Kennedy CC, Ioannidis G, et al. Comparative trends in incident fracture rates for all long-term care and community-dwelling seniors in Ontario, Canada, 2002-2012. *Osteoporos Int* 2016;27(3):887-97. doi: 10.1007/s00198-015-3477-3
6. Ronald LA, McGregor MJ, McGrail KM, et al. Hospitalization rates of nursing home residents and community-dwelling seniors in British Columbia. *Can J Aging* 2008;27(1):109-15. doi: 10.3138/cja.27.1.109
7. Dyer SM, Crotty M, Fairhall N, et al. A critical review of the long-term disability outcomes following hip fracture. *BMC Geriatr* 2016;16:158. doi: 10.1186/s12877-016-0332-0
8. Neuman MD, Silber JH, Magaziner JS, et al. Survival and functional outcomes after hip fracture among nursing home residents. *JAMA Intern Med* 2014;174(8):1273-80. doi: 10.1001/jamainternmed.2014.2362
9. Siminoski K, Leslie WD, Frame H, et al. Recommendations for bone mineral density reporting in Canada: a shift to absolute fracture risk assessment. *J Clin Densitom* 2007;10(2):120-3. doi: 10.1016/j.jocd.2007.01.001
10. Siminoski K, Leslie WD, Frame H, et al. Recommendations for bone mineral density reporting in Canada. *Can Assoc Radiol J* 2005;56(3):178-88.
11. Kanis JA, Johnell O, De Laet C, et al. A meta-analysis of previous fracture and subsequent fracture risk. *Bone* 2004;35(2):375-82. doi: 10.1016/j.bone.2004.03.024
12. Leslie WD, Lix LM, Langsetmo L, et al. Construction of a FRAX(R) model for the assessment of fracture probability in Canada and implications for treatment. *Osteoporos Int* 2011;22(3):817-27. doi: 10.1007/s00198-010-1464-2
13. Bravo G, Dubois MF, De Wals P, et al. Relationship between regulatory status, quality of care, and three-year mortality in Canadian residential care facilities: a longitudinal study. *Health Serv Res* 2002;37(5):1181-96.
14. Greenspan SL, Perera S, Nace D, et al. FRAX or fiction: determining optimal screening strategies for treatment of osteoporosis in residents in long-term care facilities. *J Am Geriatr Soc* 2012;60(4):684-90. doi: 10.1111/j.1532-5415.2011.03884.x
15. Khatib R, Santesso N, Pickard L, et al. Fracture risk in long term care: a systematic review and meta-analysis of prospective observational studies. *BMC Geriatr* 2014;14:130. doi: 10.1186/1471-2318-14-130
16. Cox L, Kloseck M, Crilly R, et al. Underrepresentation of individuals 80 years of age and older in chronic disease clinical practice guidelines. *Can Fam Physician* 2011;57(7):e263-9.
17. Mutasingwa DR, Ge H, Upshur RE. How applicable are clinical practice guidelines to elderly patients with comorbidities? *Can Fam Physician* 2011;57(7):e253-62.

18. Morris JN, Nonemaker S, Murphy K, et al. A commitment to change: revision of HCFA's RAI. *J Am Geriatr Soc* 1997;45(8):1011-6.
19. Hawes C, Morris JN, Phillips CD, et al. Development of the nursing home Resident Assessment Instrument in the USA. *Age Ageing* 1997;26 Suppl 2:19-25.
20. Hirdes JP, Ljunggren G, Morris JN, et al. Reliability of the interRAI suite of assessment instruments: a 12-country study of an integrated health information system. *BMC Health Serv Res* 2008;8:277. doi: 10.1186/1472-6963-8-277
21. Jantzi M, Maher AC, Ioannidis G, et al. Individuals with neurological diseases are at increased risk of fractures within 180 days of admission to long-term care in Ontario. *Age Ageing* 2015;44(2):252-7. doi: 10.1093/ageing/afu156
22. Canadian Institute for Health Information. Data Quality Documentation, Discharge Abstract Database – Multi-Year Information. 2012 ed. Ottawa, ON https://www.cihi.ca/sites/default/files/document/nacrs_multi-year_info_en.pdf . accessed Dec 20th, 2016.: CIHI, 2012.
23. Canadian Institute for Health Information. Data Quality Documentation National Ambulatory Care Reporting System – Multi-Year Information. Ottawa: CIHI, 2012.
24. O'Donnell S, Canadian Chronic Disease Surveillance System Osteoporosis Working G. Use of administrative data for national surveillance of osteoporosis and related fractures in Canada: results from a feasibility study. *Arch Osteoporos* 2013;8:143. doi: 10.1007/s11657-013-0143-2
25. Kass G. An Exploratory Technique for Investigating Large Quantities of Categorical Data. *Applied Statistics* 1980;29(2):8.
26. Kennedy CC, Ioannidis G, Thabane L, et al. Osteoporosis prescribing in long-term care: impact of a provincial knowledge translation strategy. *Can J Aging* 2015;34(2):137-48. doi: 10.1017/S0714980815000057
27. Jachna CM, Shireman TI, Whittle J, et al. Differing patterns of antiresorptive pharmacotherapy in nursing facility residents and community dwellers. *J Am Geriatr Soc* 2005;53(8):1275-81. doi: 10.1111/j.1532-5415.2005.53401.x
28. Kennedy CC, Ioannidis G, Thabane L, et al. Successful knowledge translation intervention in long-term care: final results from the vitamin D and osteoporosis study (ViDOS) pilot cluster randomized controlled trial. *Trials* 2015;16:214. doi: 10.1186/s13063-015-0720-3
29. Colon-Emeric CS, Lyles KW, House P, et al. Randomized trial to improve fracture prevention in nursing home residents. *Am J Med* 2007;120(10):886-92. doi: 10.1016/j.amjmed.2007.04.020
30. Giangregorio LM, Jantzi M, Papaioannou A, et al. Osteoporosis management among residents living in long-term care. *Osteoporos Int* 2009;20(9):1471-8. doi: 10.1007/s00198-009-0837-x
31. Wall M, Lohfeld L, Giangregorio L, et al. Fracture risk assessment in long-term care: a survey of long-term care physicians. *BMC Geriatr* 2013;13:109. doi: 10.1186/1471-2318-13-109
32. Perlman CM, Hirdes JP, Vigod S. Psychiatric Rehospitalization: Development of a Person-Level Indicator for Care Planning and Quality Assurance. *Prim Care Companion CNS Disord* 2015;17(4) doi: 10.4088/PCC.15m01784
33. Neufeld E, Perlman CM, Hirdes JP. Predicting inpatient aggression using the InterRAI risk of harm to others clinical assessment protocol: a tool for risk assessment and care planning. *J Behav Health Serv Res* 2012;39(4):472-80. doi: 10.1007/s11414-011-9271-x
34. Mathias K, Hirdes JP, Pittman D. A care planning strategy for traumatic life events in community mental health and inpatient psychiatry based on the InterRAI assessment instruments. *Community Ment Health J* 2010;46(6):621-7. doi: 10.1007/s10597-010-9308-2
35. Papaioannou A, Santesso N, Morin SN, et al. Recommendations for preventing fracture in long-term care. *CMAJ* 2015;187(15):1135-44, E450-61. doi: 10.1503/cmaj.141331

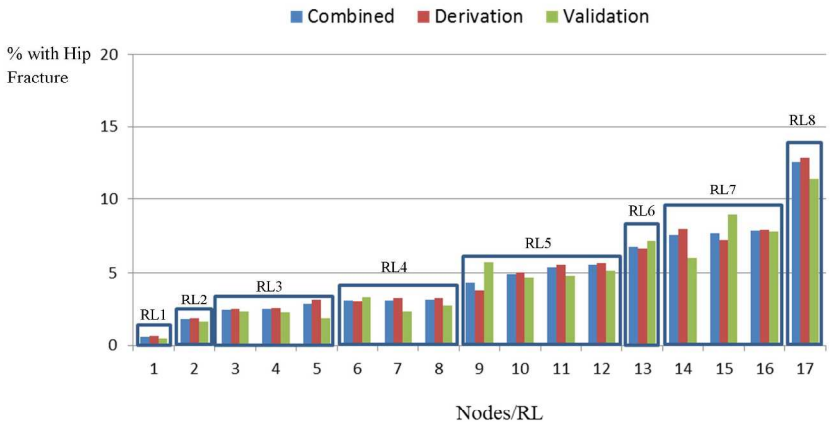
36. Duque G, Close JJ, de Jager JP, et al. Treatment for osteoporosis in Australian residential aged care facilities: consensus recommendations for fracture prevention. *Med J Aust* 2010;193(3):173-9.
37. Duque G, Lord SR, Mak J, et al. Treatment of Osteoporosis in Australian Residential Aged Care Facilities: Update on Consensus Recommendations for Fracture Prevention. *J Am Med Dir Assoc* 2016;17(9):852-9. doi: 10.1016/j.jamda.2016.05.011
38. Colon-Emeric CS, Biggs DP, Schenck AP, et al. Risk factors for hip fracture in skilled nursing facilities: who should be evaluated? *Osteoporos Int* 2003;14(6):484-9. doi: 10.1007/s00198-003-1384-5
39. Chen JS, Sambrook PN, Simpson JM, et al. A selection strategy was developed for fracture reduction programs in frail older people. *J Clin Epidemiol* 2010;63(6):679-85. doi: 10.1016/j.jclinepi.2009.08.018
40. Hippisley-Cox J, Coupland C. Predicting risk of osteoporotic fracture in men and women in England and Wales: prospective derivation and validation of QFractureScores. *BMJ* 2009;339:b4229. doi: 10.1136/bmj.b4229
41. Morris JN, Fries BE, Steel K, et al. Comprehensive clinical assessment in community setting: applicability of the MDS-HC. *J Am Geriatr Soc* 1997;45(8):1017-24.

Figure 1: Study Sample Flow Diagram



215x279mm (300 x 300 DPI)

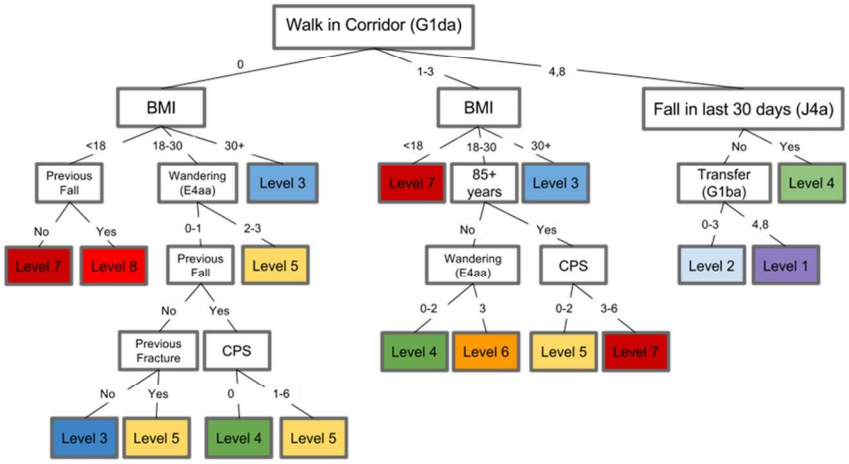
Figure 2. Incident Hip Fracture Rates Classified by Individual Decision Nodes and the 8 Hip Risk levels for the Combined, Derivation and Validation Datasets. *



*RL=Risk level derived from decision tree analysis.

215x279mm (300 x 300 DPI)

Figure 3: Fracture Risk Scale (FRS)*



*Previous Fall= Any fall in the past 180 days.

Previous Fracture= Any hip or other fracture in the past 180 days.

215x279mm (300 x 300 DPI)

Appendix 1: Decision Tree Schematic Legend

Decision Tree Schematic Legend - All variables are derived from the MDS assessment		
Variable	**Response values**	**Response meaning**
Walk in corridor (G1da)	0 1 to 3 4, 8	Independent Supervision to extensive assistance Total assistance, or walking did not occur
Fall in last 30 days (J4a)	No/Yes	Any fall in the past 30 days
Previous fall	No/Yes	Any fall in the past 180 days
Wandering	0,1 2 3	No wandering to infrequent wandering Less than daily wandering Daily wandering
Transfer (G1ba)	0 to 3 4, 8	Independent to extensive assistance Total assistance, or transfer did not occur
CPS (Cognitive Performance Scale)	0 1 to 2 3 to 6	Intact cognition Borderline intact or mild impairment Moderate to Very Severe impairment
Previous fracture	No/Yes	Any hip or other fracture in the past 180 days

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cohort studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up	6
		(*b*) For matched studies, give matching criteria and number of exposed and unexposed	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6-7
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*6-7*
Bias	9	Describe any efforts to address potential sources of bias	12
Study size	10	Explain how the study size was arrived at	6
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-8
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7-8
		(*b*) Describe any methods used to examine subgroups and interactions	NA
		(*c*) Explain how missing data were addressed	6
		(*d*) If applicable, explain how loss to follow-up was addressed	NA
		(*e*) Describe any sensitivity analyses	NA
Results			

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	16
		(b) Give reasons for non-participation at each stage	16
		(c) Consider use of a flow diagram	16
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	17-18
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) Summarise follow-up time (eg, average and total amount)	NA
Outcome data	15*	Report numbers of outcome events or summary measures over time	9
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	NA
		(*b*) Report category boundaries when continuous variables were categorized	17-18
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	NA
Discussion			
Key results	18	Summarise key results with reference to study objectives	11-13
Limitations			
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	12-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	13-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	15

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.