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..	not available for a specific reference period
...	not applicable
0	true zero or a value rounded to zero
0^s	value rounded to 0 (zero) where there is a meaningful distinction between true zero and the value that was rounded
^{p}	preliminary
^{r}	revised
x	suppressed to meet the confidentiality requirements of the *Statistics Act*
^{E}	use with caution
F	too unreliable to be published
*	significantly different from reference category ($p < 0.05$)

Validation of an index to estimate the prevalence of frailty among community-dwelling seniors

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Abstract

Background
This study validates cut-points for a frailty index (FI) to identify seniors at risk of a hospital-related event and estimates the number of frail seniors living in the community. The FI developed by Rockwood and Mitnitski defines levels of frailty based on scores of 0 to 1.0.

Data and methods
The cut-point validation was conducted using Stratum-Specific Likelihood Ratios applied to combined 2003 and 2005 Canadian Community Health Survey (CCHS) data, linked to hospital records from the Discharge Abstract Database (2002 to 2007). Based on the validated cut-points, frailty prevalence was estimated using 2009/2010 CCHS data.

Results
Seniors scoring more than 0.21 on the FI were considered to be at elevated risk of hospital-related events. Four additional frailty levels were identified: non-frail (0 to ≤0.1), pre-frail (>0.1 to ≤0.21), more frail (>0.30 to ≤0.35) (women only), and most frail (frail-group subset) (0.45 or more). The number of community-dwelling seniors considered to be frail was estimated at about 1 million (24%) in 2009/2010; another 1.4 million (32%) could be considered pre-frail. Frailty prevalence rose with age; was higher among women than among men; and varied by geographic location.

Interpretation
A cut-point of more than 0.21 can be used to identify frail seniors living in the community.

Keywords
Activities of daily living, health status indicators, hospital records, probabilistic linkage, validation studies

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Frailty is an age-related physiological state of increased vulnerability. Frail individuals are less likely to adapt and/or recover to a normal health state after acute illnesses or injuries.[1] Frailty manifests as an accumulation of health problems, including chronic conditions and physical disability.[1,2] Independent of age, frailty has been found to be predictive of death, hospitalization, institutionalization, falls, and worsening health status.[3-5] Information about the prevalence of frailty among Canada's community-dwelling seniors is important for policy development and health resource planning, including home care and residential care.[3,6,7]

Various measures of frailty have been developed at both the clinical and population level. In clinical settings, frailty is commonly assessed by unintentional weight loss, weak grip strength, poor energy/endurance, slow walking speed, and low physical activity.[8] At the population level, frailty indices (FI) have been applied to data from large-scale health surveys in Canada,[9,10] the United States,[11,12] Britain,[13] and Hong Kong.[4] Like their clinical counterparts, FIs consider the cumulative effect of multiple factors indicating physical and cognitive decline.[5] The FI methodology can be applied to health survey data to make valid assessments of frailty at the individual or population level.[3,14,15] Frailty scores from 0 to 1 are often assigned based on the number of health deficits present among the health indicators considered, with higher values denoting greater frailty.[3] Health deficits include chronic conditions and physical/cognitive limitations.

While FI scores provide information about frailty at the individual level, cut-points are required to estimate the prevalence of frailty at the population level. Currently, no cut-points are universally accepted; previous research has used cut-points of 0.21, 0.25 and 0.35 for community-dwelling seniors.[9,10,16,17] Ranges have also been used to define categories of frailty (for example, mild, moderate, severe).[9,16-18]

The primary objective of this study is to apply an FI to a representative sample of community-dwelling seniors in Canada and validate a cut-point at which individuals can be considered frail. Combined data from the 2003 (cycle 2.1) and 2005 (cycle 3.1) Canadian Community Health Survey (CCHS) were linked prospectively to hospital administrative data to determine ranges of frailty scores associated with higher versus lower risks of hospital-related events.

The second objective is to apply the validated cut-points to 2009/2010 CCHS data to estimate frailty prevalence and present a profile of community-dwelling Canadian seniors who are considered frail.

Methods

Data sources

Canadian Community Health Survey (CCHS) cycles 2.1 (2003) and 3.1 (2005) data linked to Discharge Abstract Database (DAD) (2002/2003 to 2007/2008) were used to validate the frailty cut-points. The CCHS is a cross-sectional survey providing information about the health, health determinants and health care use of the non-institutionalized household population aged 12 or older in all provinces and territories. The survey excludes full-time members of the Canadian Forces and residents of First Nations reserves and some remote areas. A detailed description of the survey and methodology is available elsewhere.[19,20] CCHS 2.1 was conducted from January through December 2003; CCHS 3.1, from January through December 2005. The overall response rates were 80.7% and 78.9%, respectively, for a combined sample of 268,520.[19,20]

The DAD contains information on inpatient discharges and deaths from most acute-care and some psychiatric, chronic and rehabilitation hospitals across Canada.[21] Each DAD record has basic demographic (for example, postal code, dates of birth), non-medical administrative (such as de-identified health card numbers, dates of admission and discharge), and clinical information (diagnoses and procedures, for example). Only acute-care inpatient hospitalizations were used for this validation.

The CCHS data were deterministically and probabilistically linked to the DAD using Generalized Record Linkage Software (GRLS) and G-LINK.[22] CCHS records pertaining to respondents living outside Quebec and who agreed to link and share their information were eligible for linkage (2003 n = 90,450; 2005 n = 88,144). (Insufficient information was available in the hospital data for Quebec residents' records to be linked.) The coverage of this type of CCHS-hospital data linkage has been determined to range from 76% to 99%, depending on the age group.[23] Data linkage details are available on request.[24,25]

The validation sample consisted of CCHS respondents aged 65 or older who provided responses to the Health Utility Index (HUI), an integral part of the FI score (n = 13,472). In the 2003 and 2005 CCHS, questions pertaining to the HUI were administered to a representative subsample of respondents. For each cycle, some provinces opted to administer the questions to their full provincial samples: Prince Edward Island, Nova Scotia, New Brunswick, and Newfoundland and Labrador in 2003, and British Columbia in 2005. The other variables on which the remaining deficits were based also had to have been asked of the 2003 and 2005 CCHS samples (validation cohort), as well as of the 2009/2010 samples.

Data from the 2009/2010 CCHS were used to obtain recent estimates of the prevalence of frailty among community-dwelling seniors. The overall response rate was 71.5%.[26] Details about the survey design and sampling techniques are available elsewhere.[26] The sample used in this analysis consisted of all community-dwelling seniors with valid frailty scores (n = 30,289).

Frailty score

This study builds on the FI framework developed by Rockwood and Mitnitski.[5,10] That FI, expressed as a 0 (lowest) to 1 (highest level of frailty) score, relates the number of deficits an individual has to the total number considered.[3,5] Ideally, FIs should contain at least 30 items and cover a range of health indicators, including chronic conditions, physical/cognitive limitations, and general health.[3] Each deficit should be health-related and increase with age, but not saturate too early; for example, the need for reading glasses is not a good deficit candidate because most people require reading glasses by mid-life.[3] Deficits are treated as independent; that is, the value on one is not taken into account when scoring another.

For this study, the FI contained 30 deficits (Text table 1). Of these, 18 pertained to chronic conditions and the need for assistance with activities of daily living (ADL), and were dichotomized (1=presence of condition or attribute; 0=absence of condition or attribute). The presence of chronic conditions was established by asking respondents if a health professional had diagnosed them as having conditions that had lasted, or were expected to last, at least six months. Only conditions primarily related to age, such as arthritis and heart disease, were included in the FI. Physical limitations (for example, needing help from another person to complete ADLs, such as meal preparation and housework, because of a physical or mental condition) were also coded as dichotomous variables. The other dichotomous variables were fall-related injuries in the past 12 months and not walking for exercise in the past 3 months.

The remaining 12 deficits were assigned three to six levels to reflect differences in severity and ensure that their frequency increased with age.[3] Preliminary analyses were conducted for each deficit to determine appropriate response category groupings. For example, participation and activity limitations were based on the frequency with which respondents limited their activities/participation because of health problems, and were coded 0 for "never," 0.5 for "sometimes," and 1.0 for "often." Self-perceived health, change in health status and self-reported body mass index corrected for reporting error[27] were also

Text table 1
Deficits included in Canadian Community Health Survey-based frailty index (FI)

Concept/Variable	Description	FI value
Self-perceived health	Excellent/Very good	0.00
	Good	0.50
	Fair/Poor	1.00
Change in health status (past year)	Much better/Somewhat better/About the same	0.00
	Somewhat worse	0.50
	Much worse	1.00
Body mass index	Normal/Overweight	0.00
	Obese	0.50
	Underweight	1.00
Participation and activity limitations	Never	0.00
	Sometimes	0.50
	Often	1.00
Speech	Understood by everyone or only those who know them	0.00
	Partially understood by everyone	0.50
	Not understood by anyone or partially understood by those who know them	1.00
Emotional health	Happy and interested in life	0.00
	Somewhat happy	0.25
	Somewhat unhappy	0.50
	Very unhappy	0.75
	So unhappy that life is not worthwhile	1.00
Pain	None	0.00
	Pain does not prevent activity	0.25
	Pain prevents a few activities	0.50
	Pain prevents some activities	0.75
	Pain prevents most activities	1.00
Vision	Sees with/without glasses	0.00
	Reads newsprint with/without glasses; cannot see person across street with glasses	0.25
	Sees person across street with/without glasses; cannot read newsprint with glasses	0.50
	Cannot read newsprint or see person across street with glasses	0.75
	Cannot see	1.00
Hearing	Hears in group without hearing aid (HA)	0.00
	Hears one-on-one without HA; needs HA for group	0.20
	Can hear with HA	0.40
	Hears one-on-one without HA; cannot hear with HA in group	0.60
	Hears one-on-one with HA; cannot hear with HA in group	0.80
	Cannot hear	1.00
Mobility	Walks without difficulty and without aids	0.00
	Walks outside with difficulty; no help/aids needed	0.20
	Walks outside with aids; no help of another person	0.40
	Walks short distances unaided; needs wheelchair for longer distances	0.60
	Walks short distances with help; needs wheelchair for longer distances	0.80
	Cannot walk	1.00
Cognition	Can remember most things, think clearly, solve problems	0.00
	Remembers most things; some difficulty to think, solve problems	0.20
	Somewhat forgetful, but thinks, solves problems	0.40
	Somewhat forgetful; some difficulty to think, solve problems	0.60
	Very forgetful; great difficulty to think, solve problems	0.80
	Unable to remember anything, think, solve problems	1.00
Dexterity	Full use of two hands and 10 fingers	0.00
	Limited use of hands, no help needed	0.20
	Limited use of hands, uses special tools	0.40
	Limited use of hands, needs help for some tasks	0.60
	Limited use of hands, needs help for most tasks	0.80
	Limited use of hands, needs help for all tasks	1.00
Chronic conditions	Absence of a condition	0.00
	Arthritis or rheumatism; back problems other than arthritis; high blood pressure; chronic bronchitis or emphysema; heart disease; diabetes; cancer; effects of stroke; urinary incontinence; Alzheimer's disease/dementia	1.00
Limited in activities of daily living	Able to perform activities of daily living	0.00
	Preparing meals; getting to appointments and running errands; doing everyday housework; personal care such as washing, dressing; moving inside the house; looking after personal finances	1.00
Other	No fall-related injuries (past 12 months); walked for exercise (past 3 months)	0.00
	Fall-related injury (past 12 months); no walking for exercise (past 3 months)	1.00

assigned one of three levels. Overweight and normal weight were combined and coded 0, based on evidence that some excess weight can be protective.[28,29] Underweight was coded 1.0, consistent with previous FI studies[3] and the tendency for low-weight seniors to be at higher risk of illness and death[28]; obese was coded 0.5.[29]

Deficits related to functional health were derived from the Health Utility Index Mark III (HUI3).[30] HUI3 measures eight attributes of individual functional health: vision, hearing, speech, ambulation, dexterity, emotion, cognition and pain. Each attribute is measured using five or six levels ranging from normal to severely limited function. To generate a frailty score, HUI3-related deficits were rescaled to three (speech), five (emotional health, pain and vision), or six levels (hearing, mobility, cognition and dexterity). Categories of some variables with smaller cell counts were combined to ensure that each deficit increased with age.[3] For the vision component, two response categories—seeing with and without corrective lens—were combined. For speech, the first two (understood by everyone and understood only by those who know them) were combined, as were the last two response categories (not understood by anyone and understood partially only by those who know them).

When information about a deficit was missing, the denominator was adjusted by the number of missing deficits, up to a maximum of five per record.[12] For example, the FI score of a respondent reporting two full deficits and one missing value would be calculated as 2/29, yielding an FI value of 0.06. With no missing values, the FI score would be calculated out of 30. A large majority (81%) of validation cohort records had complete data for all deficits comprising the FI score; 13% had one missing value; and the remaining 6% had two to five missing values.

Hospital-related events

To validate cut-points for the FI scores, a number of hospital-related events that were correlated with frailty and that were available in the DAD were selected. The

main outcome was having at least one hospitalization in the 18-month period after the CCHS interview (n = 2,964). Secondary outcomes were: hospitalized more than once (n = 1,019); emergency hospitalization (n = 2,112); discharged to a long-term care (LTC) facility from hospital (n = 235); and in-hospital death (n = 325). A composite variable was also created by combining respondents who had at least one of the secondary outcomes (n = 2,285).

Analytical techniques

Stratum-Specific Likelihood Ratios (SSLRs) were calculated using the 2003/2005 CCHS-DAD linked cohort to: 1) identify the cut-point distinguishing frail versus non-frail seniors; specifically, to assess the validity of using scores of greater than 0.21,[16] 0.25,[9,10] or more than 0.35,[17] and 2) identify "natural" ranges of frailty associated with differential risks of experiencing a hospital-related event.

SSLRs have been used previously to validate categories for other instruments.[14,31] SSLRs are generalizable and independent of actual probabilities in the population. They are less prone to spectrum bias, because misclassification is minimized by using multiple categories (strata), thereby ensuring that the lower and higher scores are correctly assigned.[32]

SSLRs represented the likelihood that respondents in a given frailty category (stratum) will experience a hospital-related event (for example, at least one admission) relative to their likelihood of not experiencing such an event, using the following formula:

$$SSLR = (x_{1g}/n_1)/(x_{0g}/n_0)$$

where x_{1g} represents the total number of respondents experiencing a hospital event (at least one admission) in the gth stratum; n_1 is the total number of respondents in the sample who experienced the event; x_{0g} is the total number of respondents who did not experience the event in the gth stratum; and n_0 is the total number of respondents in the sample not hospitalized.

SSLRs of 1.0 indicate that the likelihood of experiencing the event is as likely as not experiencing it. Scores greater than 1.0 indicate a higher likelihood of experiencing the event; scores below 1.0 indicate a lower likelihood. SSLR statistics were expected to rise with FI scores. T-tests at the $p < 0.05$ were used to determine if strata were significantly different from the preceding stratum.

A 10-level SSLR analysis was conducted with strata defined using frailty cut-points suggested in previous studies (≤0.03, >0.03 to ≤0.1, >0.1 to ≤0.21, >0.21 to <0.45 and 0.45+).[16] Strata between 0.21 and 0.45 (>0.21 to ≤0.23… >0.35 to <0.45) were included to assess the validity of the 0.25 and 0.35 cut-points, and to identify additional frailty subgroups. To ensure adequate cell counts, the upper stratum consisted of all FI scores greater than 0.45.

The primary aim was to identify strata that were significantly different from the preceding stratum and that had SSLRs exceeding 1.0, thereby indicating a higher risk of experiencing the particular hospital-related event. Strata determined not to be statistically different from the preceding stratum could be combined. Separate SSLR analyses were conducted for each hospital-related event. Sex-specific SSLRs were also estimated.

Prevalence of frailty

Prevalence rates of frailty were derived by applying the validated cut-point to the 2009/2010 CCHS. Age was divided into three categories: 65 to 74, 75 to 84, and 85 or older. Estimates were calculated for each province and for the three territories combined. Standard errors and coefficients of variation were estimated using the bootstrap technique.[33,34] Results at the $p < 0.05$ were considered to be statistically significant. Geographic differences were determined by comparing each province/territory with the rest of Canada.

Results

The majority (59%) of the validation cohort were women. The average age of the cohort was 75. More than half (53%) the cohort were aged 65 to 74; 37% were aged 75 to 84; and 10% were aged 85 or older. The mean and median frailty scores among the validation cohort were 0.16 and 0.13, respectively, with values ranging from 0 to 0.70.

Stratum-Specific Likelihood Ratios

In analyses of both sexes combined, SSLRs were greater than 1.0 for each stratum with FI scores above 0.21 for all hospital-related events except transferred to LTC facility (Table 1). Strata with FI scores of 0.21 or lower had SSLRs less than 1.0 for all outcomes except having been hospitalized. Statistically significant differences were found between the >0.21 to ≤0.23 stratum and the previous stratum for all hospital-related events except transferred to LTC. Generally, the >0.23 to ≤0.25 stratum did not differ significantly from the 0.21 to ≤0.23 stratum. Nor was the >.25 to <.27 stratum significantly different from the >0.23 to ≤0.25 stratum. SSLRs calculated separately for men and women showed similar patterns. These findings support the use of >0.21 as a cut-point to distinguish frail versus non-frail individuals.

Results of the SSLR analyses suggest four frailty categories: non-frail (0 to 0.1), pre-frail (>0.1 to ≤0.21), more-frail (>0.30 to ≤0.35) (women only), and most-frail (0.45+). SSLRs approached 1.0 and were significant across all hospital-related events for the >0.1 to ≤0.21 stratum, indicating the presence of a pre-frail group. The strata between >0.21 and <0.45 were not consistently significantly different from the preceding stratum for both sexes combined or for men. Sex-specific analyses suggested the existence of an additional "more-frail" category at the >0.30 to ≤0.35 stratum for women.

Regardless of sex, the 0.45+ stratum ("most frail") had the highest SSLRs for the selected hospital-related events, ranging from 3.4 to 7.7 for both sexes combined, and from 3.3 to 8.2 in the sex-specific analyses. With just two exceptions ("transferred to LTC facility" for men and "died in hospital" for women), the 0.45+ stratum differed significantly from the >0.35 to <0.45 stratum.

Prevalence of frailty

The greater-than-0.21 cut-point was applied to the results of the 2009/2010 CCHS to estimate the prevalence of frailty. Based on this cut-point, an estimated 24% (about 1 million) community-dwelling seniors were frail. Of these, 108,000 (women only) were considered to be "more frail" (data not shown), and 132,000 were "most frail" (Figure 1). Another 32% of seniors living in the community (1.4 million) were considered pre-frail.

As expected, the percentage of frail seniors rose with age, from 16% at ages 65 to 74 to 52% at age 85 or older (Table 2). Men were less likely than women to be frail (19% versus 27%). The percentages were significantly high in Nova Scotia, New Brunswick, Ontario, Saskatchewan and the territories, compared with the rest of Canada. The percentages were significantly lower in British Columbia and Quebec.

Discussion

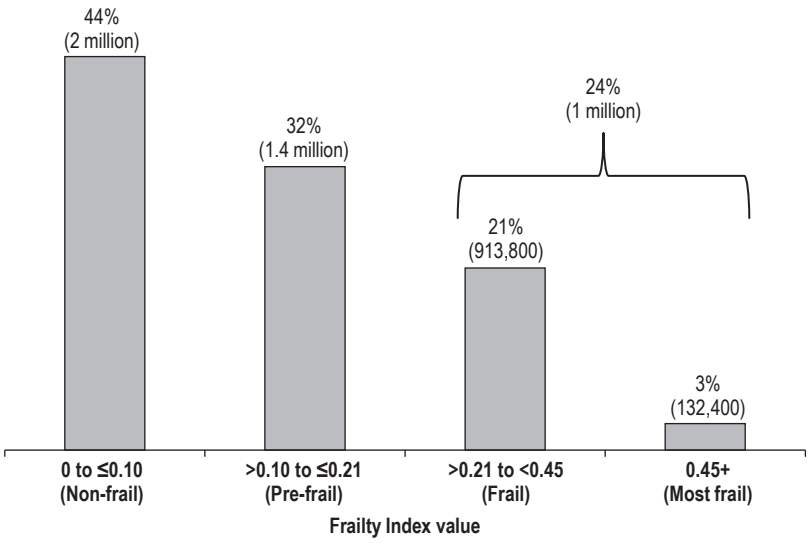
The prevalence of frailty among Canada's community-dwelling seniors is useful information for health and social program planning. Frailty is associated with a higher risk of adverse outcomes and an increased need for health care services.[3,6,7] While FI scores had previously been applied to large-scale population health survey data, their utility had been limited by the lack of an agreed-upon cut-point to identify the frail among community-dwelling seniors. Cut-points and categories pro-

Table 1
Stratum-specific likelihood ratios (SSLR) for selected hospital-related outcomes, by Frailty Index (FI) stratum, household population aged 65 or older, Canada excluding Quebec, 2002/2003 to 2007/2008

	Hospitalized			Multiple hospitalizations			Died in hospital			Transferred to long-term care facility			Emergency hospitalization			Any outcome (excluding hospitalized)		
		95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval			95% confidence interval	
FI stratum	SSLR	from	to	SSLR	from	to	SSLR	from	to	SSLR	from	to	SSLR	from	to	SSLR	from	to
Total																		
≤0.03	0.3	0.3	0.4	0.3	0.2	0.5	0.2	0.1	0.5	0.2	0.1	0.5	0.3	0.2	0.4	0.3	0.2	0.4
>0.03 to ≤0.10	0.6*	0.5	0.6	0.5*	0.4	0.6	0.3	0.2	0.4	0.2	0.1	0.3	0.5*	0.5	0.6	0.5*	0.5	0.6
>0.10 to ≤0.21	1.0*	0.9	1.0	0.9*	0.8	1.0	0.8*	0.6	0.9	0.7*	0.5	0.9	0.9*	0.8	1.0	0.9*	0.8	1.0
>0.21 to ≤0.23	1.4*	1.2	1.7	1.4*	1.1	1.9	1.4*	0.9	2.2	0.9	0.5	1.6	1.3*	1.1	1.6	1.4*	1.2	1.7
>0.23 to ≤0.25	1.6	1.3	1.9	1.3	1.0	1.8	1.3	0.8	2.1	2.4*	1.5	3.6	1.5	1.2	1.9	1.6	1.3	1.9
>0.25 to ≤0.27	1.5	1.2	1.8	1.7	1.3	2.3	0.7	0.4	1.5	1.0*	0.5	2.0	1.6	1.2	2.0	1.6	1.3	2.0
>0.27 to ≤0.30	1.6	1.3	1.8	1.5	1.2	2.0	2.1*	1.5	3.0	1.3	0.8	2.2	1.4	1.1	1.7	1.4	1.2	1.7
>0.30 to ≤0.35	2.2*	1.9	2.6	2.0	1.6	2.5	2.0	1.4	2.7	1.8	1.2	2.7	2.4*	2.1	2.8	2.4*	2.0	2.8
>0.35 to <0.45	2.4	2.1	2.7	2.3	1.9	2.8	3.3*	2.6	4.3	3.6*	2.7	4.7	2.5	2.2	2.9	2.5	2.2	2.9
0.45+	3.4*	2.8	4.2	3.7*	3.0	4.6	5.4*	4.1	7.1	7.7*	5.8	10.0	4.0*	3.3	4.8	3.9*	3.3	4.8
Men																		
≤0.03	0.4	0.3	0.5	0.4	0.2	0.6	0.3	0.1	0.8	0.1	0.0	0.7	0.4	0.3	0.6	0.4	0.3	0.5
>0.03 to ≤0.10	0.6*	0.5	0.7	0.6	0.5	0.7	0.3	0.2	0.4	0.2	0.1	0.4	0.6	0.5	0.6	0.6*	0.5	0.7
>0.10 to ≤0.21	1.0*	0.9	1.1	0.9*	0.8	1.1	0.7*	0.5	0.9	0.8*	0.6	1.1	1.0*	0.9	1.1	1.0*	0.9	1.1
>0.21 to ≤0.23	1.7*	1.3	2.2	1.4*	1.0	2.1	1.8*	1.0	3.2	2.1*	1.1	4.3	1.6*	1.2	2.2	1.7*	1.3	2.2
>0.23 to ≤0.25	1.6	1.2	2.1	1.6	1.0	2.4	1.3	0.6	2.7	1.8	0.8	4.0	1.7	1.3	2.4	1.7	1.3	2.3
>0.25 to ≤0.27	1.9	1.4	2.7	1.6	1.0	2.6	1.1	0.4	2.7	1.0	0.3	3.5	1.9	1.3	2.8	1.9	1.3	2.7
>0.27 to ≤0.30	2.0	1.5	2.7	2.3	1.6	3.3	4.1*	2.6	6.2	1.8	0.8	4.1	1.7	1.3	2.4	2.0	1.5	2.7
>0.30 to ≤0.35	2.0	1.6	2.7	1.8	1.3	2.6	1.7*	0.9	3.0	2.9	1.6	5.3	2.3	1.7	3.0	2.2	1.6	2.9
>0.35 to <0.45	2.3	1.8	3.0	2.4	1.7	3.3	4.1*	2.7	6.1	4.2	2.5	7.0	2.6	2.0	3.5	2.5	1.9	3.3
0.45+	3.6*	2.6	5.0	3.9*	2.7	5.7	8.2*	5.5	12.1	6.4	3.8	11.1	4.1*	2.9	5.7	4.3*	3.1	6.0
Women																		
≤0.03	0.2	0.2	0.3	0.2	0.1	0.5	0.1	0.0	0.5	0.2	0.1	0.7	0.2	0.2	0.4	0.2	0.1	0.4
>0.03 to ≤0.10	0.5*	0.5	0.6	0.4	0.3	0.5	0.3	0.2	0.5	0.2	0.1	0.4	0.5*	0.4	0.5	0.5*	0.4	0.5
>0.10 to ≤0.21	0.9*	0.8	1.0	0.8*	0.7	0.9	0.8*	0.6	1.1	0.6*	0.5	0.8	0.8*	0.8	0.9	0.9*	0.8	0.9
>0.21 to ≤0.23	1.3*	1.0	1.6	1.5*	1.0	2.0	1.2	0.6	2.2	0.3	0.1	1.0	1.2*	0.9	1.6	1.3*	1.0	1.6
>0.23 to ≤0.25	1.5	1.2	2.0	1.2	0.8	1.8	1.2	0.6	2.4	2.6*	1.6	4.2	1.4	1.1	1.8	1.5	1.1	1.9
>0.25 to ≤0.27	1.3	1.0	1.7	1.9	1.3	2.6	0.5	0.2	1.5	1.0*	0.4	2.2	1.4	1.1	1.9	1.4	1.1	1.9
>0.27 to ≤0.30	1.3	1.0	1.6	1.2	0.9	1.7	1.1	0.6	2.0	1.0	0.5	2.0	1.2	0.9	1.5	1.2	0.9	1.5
>0.30 to ≤0.35	2.4*	2.0	2.9	2.2*	1.7	2.8	2.2	1.5	3.3	1.4	0.8	2.4	2.5*	2.1	3.0	2.5*	2.1	3.1
>0.35 to <0.45	2.3	2.0	2.8	2.4	1.9	3.0	3.2	2.3	4.3	3.2*	2.3	4.4	2.5	2.1	2.9	2.5	2.1	3.0
0.45+	3.3*	2.6	4.1	3.6*	2.8	4.8	4.0	2.6	6.0	8.0*	5.9	10.9	4.0*	3.2	5.1	3.8*	3.0	4.8

* significantly different from previous stratum ($p < 0.05$)
Source: 2003 and 2005 Canadian Community Health Survey; 2002/2003 to 2007/2008 Discharge Abstract Database.

Figure 1
Percentage distribution and estimated numbers, by frailty category, household population aged 65 or older, Canada, 2009/2010



Source: 2009/2010 Canadian Community Health Survey.

Table 2
Percentage distribution of frail seniors, based on Frailty Index (FI) cut-point of >0.21, by age group, sex and province/territory, household population, Canada, 2009/2010

	Estimated population '000	%	95% confidence interval	
			from	to
Total	1,046	23.5	22.8	24.3
Age group				
65 to 74†	407	16.0	15.2	16.8
75 to 84	430	28.6*	27.1	30.1
85 or older	209	52.1*	49.2	55.0
Sex				
Male†	387	19.3*	18.3	20.3
Female	659	27.1	25.9	28.2
Province/Territory				
Newfoundland and Labrador	18	24.4	20.7	28.0
Prince Edward Island	4	21.2	16.7	25.8
Nova Scotia	45	32.3*	28.4	36.1
New Brunswick	30	27.5*	24.2	30.8
Quebec	218	19.7*	18.0	21.4
Ontario	442	25.9*	24.7	27.2
Manitoba	39	25.6	22.3	28.9
Saskatchewan	37	26.6*	23.8	29.4
Alberta	82	22.7	20.1	25.3
British Columbia	128	20.4*	18.6	22.3
Yukon, Northwest Territories, Nunavut‡	2	33.2*	26.0	40.5

* significantly different from reference category (p <0.05)
† reference category; for province/territory, reference category is rest of Canada
‡ 10 largest communities in Nunavut (Iqaluit, Cambridge Bay, Baker Lake, Arviat, Rankin Inlet, Kugluktuk, Pond Inlet, Cape Dorset, Pangnirtung, Igloolik)
Source: 2009/2010 Canadian Community Health Survey.

posed in earlier research[9,10,16-18,35] had good face and construct validity and were highly correlated with other clinically based measures.[18,35] However, these categories had not been validated using SSLRs on a nationally representative sample of Canadian seniors. The results of this study confirmed the validity of the greater-than-0.21 cut-point, which had been used in other research.[16]

As well, the SSLR analyses identified several categories of frailty: non-frail, pre-frail, more-frail (women only) and most-frail. The non-frail group, comprising 45% of community-dwelling seniors in 2009/2010, was determined to be at low risk of hospitalization. The pre-frail are at higher risk of various adverse health outcomes, compared with the non-frail.[9,16] Because of their numbers (about one-third of seniors living in the community), the pre-frail may be important for health care services planning. The most-frail (a subset of the frail), who represented about 3% of community-dwelling seniors, and the more-frail, comprised only of women, representing another 4% of those living in the community, had higher numbers of health deficits (10 to 24) and were determined to be at much higher risk of hospital-related events. These groups may be of particular interest because of their potentially imminent needs for hospital and convalescent care.

Based on the greater-than-0.21 cut-point, the prevalence of frailty among community-dwelling seniors was 24% in 2009/2010. This was close to an estimate of 22% for the provinces only.[16]

Frailty has consistently been found to be more common among women than men,[9,35,36] and its prevalence has been shown to increase with advancing age.[9,36] Results of the present study exhibit the same patterns.

It is not known what accounts for geographic variations in the prevalence of frailty. They may reflect the health and age profiles of seniors in different provinces and territories. They may also be attributable to differential access to home care support, which enables frail seniors to live at home longer,[37] and/or to limited

What is already known on this subject?

- Frailty is an age-related physiological state of increased vulnerability.
- After acute illness or injury, frail individuals are less likely to adapt and/or recover to a normal health state.
- Frailty index (FI) scores provide information at the individual and population levels, but to estimate the prevalence of frailty at the population level, cut-points are needed.
- In previous research, various cut-points have been used to distinguish frail from non-frail community-dwelling seniors, but no cut-point is universally accepted.

What does this study add?

- Based on data from the Canadian Community Health Survey, an FI was applied to a nationally representative sample of community-dwelling seniors.
- Data analysis supported the use of a cut-point of greater than 0.21 to identify frail seniors.
- In 2009/2010, almost a quarter (24%) of community-dwelling people aged 65 or older were estimated to be frail and at risk of a hospital-related event; another 32% could be considered pre-frail.

access to residential care, which may mean that frail seniors continue to live in the community.

Limitations

The CCHS data were collected by self- or proxy-report and are subject to reporting error. No independent clinical source was available to verify the accuracy of responses.

The CCHS-DAD linked file allows events to be situated in time; for example, frailty scores were estimated before individuals were hospitalized. However, because CCHS data were collected for only one time-point, changes in frailty over the follow-up period[3] could not be detected.

Probabilistic linkage was used to match hospitalization and survey records; the possibility of some false links or missed links exists.[24]

Outcomes used in the validation were derived only from inpatient hospitalization data. Information about out-of-hospital deaths and institutionalization directly from the community, two relevant outcomes of frailty, were not available. Inclusion of data about these outcomes might have yielded different cut-points. However, the cut-points confirmed in this study are consistent with research using mortality and institutionalization.[9,16] Furthermore, mortality and institutionalization are associated with higher levels of frailty; hence, potential differences in cut-points may have affected only the definition of the more-frail and the most-frail.

SSLRs are sensitive to sample size. Efforts were made to construct strata with sufficient numbers of records and hospitalizations, yet at the same time, create meaningful categories. Preliminary analyses using a single CCHS cycle produced fewer statistically significant results, which demonstrated the need to combine two cycles to ensure adequate cell sizes. Sample sizes may have been influential in at least two of the less common outcomes: discharged to LTC and in-hospital death, for which the results and suggested cut-points were not always consistent with others. Much of this apparent inconsistency is likely attributable to the small sample counts. In fact, additional analyses confirmed that when smaller-count strata were collapsed, the ratios became statistically significant (data not shown). Sample size may also have affected the sex-specific analysis.

Of course, frailty estimates based on data for seniors living in the community will be lower than estimates that include the institutionalized.

Many of the variables included in the FI had multiple levels and lack published cut-points. Additional analyses were performed to determine those that were the least arbitrary, including adherence to the FI principle that the frequency of each deficit should increase with age. FI scoring has been shown to be remarkably resilient to differences in methodology and deficit inclusions/exclusions.[3]

Conclusion

The results of this analysis confirm that community-dwelling seniors with frailty scores greater than 0.21 are at an elevated risk of a hospital-related event. In addition, distinct frailty categories were identified. Understanding of the degree and prevalence of frailty among Canada's senior population is important in anticipating future need for community-living assistance and residential care facilities and hospital beds. Additional research is required to develop profiles of risk and protective factors and estimate frailty prevalence at the health region level. Repeated measurement of frailty over time may provide information about the interplay between morbidity and life expectancy among the elderly. ■

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