ORIGINAL RESEARCH

Prevalence and Outcomes of Frailty in Older Men—the Manitoba Follow-Up Study

Philip D. St John, MD[1,2], Robert B. Tate, PhD[2,3]

[1]Section of Geriatric Medicine, Max Rady College of Medicine, University of Manitoba, Winnipeg; [2]Centre on Aging, University of Manitoba, Winnipeg; [3]College of Community and Global Health, Max Rady College of Medicine, University of Manitoba, Winnipeg, MB

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ABSTRACT

Background

The Frailty Index (FI) is a measure of frailty with recent guidance on its calculation. Objectives were: 1) To determine the prevalence of frailty and its component domains at different ages in older men; and 2) To determine if the FI, and/or its component scores predict death or long-term care (LTC) admission. Design: A cohort study. Setting: Most of the participants lived in Canada. Subjects: 3,983 men who qualified for air crew training during the Second World War. We included 1,711 men (mean age 76) free of dementia, living in the community, who had data to construct a FI in 1996.

Methods

Medical conditions have been measured from 1948. Functional status, health status, and social well-being have been measured by survey since 1996. We constructed a FI from these data and calculated the prevalence of frailty from the age of 75+. We considered three domains of frailty: medical, functional, and psychosocial. We calculated the mortality risk and the risk of LTC care admission using proportional hazards models.

Results

Frailty, dementia, and LTC use are all strongly related to age. The FI is associated with mortality and LTC admission at all ages. This effect was a spectrum of risk. The effect of functional domains was seen at all ages, while the effect of medical conditions on these outcomes declined with advancing age. Psychosocial domains were less strongly correlated with these outcomes.

Conclusions

The FI is associated with adverse outcomes, and should be considered in clinical and policy decisions.

Key words: frailty, frailty index, men, cohort study, prevalence

INTRODUCTION

Frailty in a condition characterized by decreased reserve resulting in a state of vulnerability to acute and chronic stressors, brought about by the complex interaction of multiple factors over time.[1] Frailty is common in older adults[2] and has been associated with death,[3,4] worsening functional status,[5] depressive symptoms,[6] and a lower life satisfaction.[7] There are many theoretical models of frailty. The two most common are the "Frailty Phenotype" which postulates that frailty is a distinct syndrome caused by dysregulation of multiple interconnected physiological and biological systems;[8] and the "Accumulation of Deficits" theory which views frailty as the end result of a piling up of deficits in different domains over time.[9] One common measure is the Frailty Index (FI) which is based upon the "Accumulation of Deficits" model.[9] A "Standard Operating Procedure" was described to calculate a FI[10]: age-related deficits in several domains are enumerated and the number of deficits an individual has are summed and divided by the number measured, resulting in a summary proportion from 0 to 1.[10] Recently, this process has been refined and expanded.[11] The FI derived from this more standardized approach has not been replicated to the same extent as previous frailty measures. Moreover, the course of the FI over a long period of time has not received adequate attention. Finally, the different domains of the FI (i.e., medical, functional, and psychosocial) have not been thoroughly studied.

The Manitoba Follow-Up Study (MFUS) allows inquiry into some of these questions. MFUS is a prospective cohort study of men whose health has been closely followed for many decades.[12] With these data, it is possible to construct a FI, and follow the FI over a long time horizon.

The specific objectives are:

1. To construct a FI for use in MFUS, following the recent guidance;
2. To determine the prevalence of frailty at different ages;
3. To determine the mean score of medical frailty, functional frailty, and psychosocial frailty subscales at different ages; and

4. To determine if the FI, and/or its component scores, predict death or long-term care (LTC) admission.

METHODS

MFUS is a prospective closed cohort study which was sealed on July 1, 1948, when 3,983 men who qualified for air crew training in the Royal Canadian Air Force (RCAF) were enrolled in MFUS.[13] As of July 1, 2024, there were 3,960 men who died, eight who were lost to follow up, and 15 who were still alive and under observation. To qualify for air crew training, men had to be fit for service and free of known heart disease.[14] From 1948 to 1996, the cohort was assessed regularly by their primary care provider. As well, throughout the study, health-care contacts including health records and death records are obtained. These records include primary care notes, consultant letters, hospital records, and LTC records. These records are reviewed and coded by study physicians using the same diagnostic coding procedure throughout the study. Beginning in 1996, a Successful Aging Questionnaire (SAQ) was added. This was sent to the members again in 2000, 2002, and annually since 2004. The SAQ was not sent to those in long-term care, nor to those who request the SAQ not be sent (most of whom decline to participate for reasons related to declining cognition). These members continue to provide medical and vital statistics data. The SAQ measures self-rated health, Activities of Daily Living (ADL), and instrumental ADLs (IADLs), the Short Form–36 (SF-36), life satisfaction, and other items related to health and general well-being.

For these analyses, we included the members of the cohort who were alive, residing in the community, and had not been diagnosed with dementia on July 1, 1996. We considered the period to July 1, 2024. The status of the participants for the study is shown in *Table S1 in the Supplementary Material*. Note that this is the flow by survey wave, where other results are presented by age. We used both sources of data—the medical file and data from the SAQ—to construct a FI. The data from the medical file are a continuous record of diagnosed medical events and conditions, and are coded such that they are present after initial diagnosis to death; that is—they are not resolved once present. They are thus unidirectional in nature. We consider a medical condition to be prevalent if it was present at any time prior to the age of the study member on July 1. We also used self-reported data from the SAQ from the survey wave at the most proximate time prior at the age of the participant on July 1, and a deficit was considered to be present if the participant reported it on the survey immediately prior to their age on July 1 of that year. Unlike the chronic conditions, it is possible for functional deficits from the SAQ to resolve on the next survey wave; in these cases, the condition is considered resolved and scored as not present. For all analyses, we use age rather than calendar year. MFUS receives annual approval from the Health Research Ethics Board (Bannatyne Campus) of the University of Manitoba and adheres to the Declaration of Helsinki.

We constructed a FI according to the method of Theou *et al*.[11] We also constructed three subscales: a Medical FI, a Functional FI, and a Psychosocial FI. To summarize briefly, we considered candidate chronic conditions from the medical file for the Medical FI. We considered items from the SAQ which reflect activities of daily living (ADL), instrumental ADL (IADL), and physical functioning for the Functional FI, and psychological and social well-being for the Psychosocial FI. We considered candidate items which were related to age, which had less than 5% missing on all survey waves, which were neither too rare nor too common, which measured an issue associated with an adverse outcome, which were measured the same way over time. We then summed the deficits present for a participant and divided by the number we considered. We collapsed some items (i.e., abdominal aortic aneurysm was considered together with thoracic aneurysm) to ensure an adequate prevalence. This resulted in a FI with 83 items—29 medial items, 34 functional items, and 20 psychosocial items. The full process we followed is outlined in the data file *Appendix S1 in the Supplementary Material*. The items we included are shown in *Table S2 in the Supplementary Material*. We considered the mutually exclusive categories of: FI of 0-0.1; 0.1-0.2; 0.2-0.3; 0.3-0.4; >0.4; Dementia; LTC; and FI not calculated. We constructed these latter three categories to account for the inability to construct a FI. Many of the participants with a clinical diagnosis of dementia were not sent an SAQ because they or family requested that they should no longer receive the SAQ. The SAQ is not sent to men residing in LTC. There also were some men for whom a FI could not be calculated, as they had missing data on one or more items at that age. At age 75, 62 of 753 men did not have a FI calculated; at age 80, this was 90 of 1,384 men; at age 85 this was 47 of 1,202 men; at age 90, this was 13 of 696 men; and at age 95, this was 2 of 218 men. Once we constructed the FI in MFUS data, we graphed the frailty categories according to age on July 1. For these analyses, we did not include those with no FI calculated. We then graphed the mean score of each subscale and the total FI according to age.

We calculated the risk of mortality and LTC admission for the FI. For mortality, we used the entire sample; for the outcome of LTC admission, we considered only study members living in the community. We created Kaplan Meier survival plots and tested for differences using log-rank tests, and we constructed Cox proportional hazards models. We considered the overall FI index in categories. We adjusted for calendar year, since there were period effects in death risk and (more pronounced) LTC risk over the time frame of several decades. We then constructed Cox proportional hazards models for each subscale. Here, we considered the score as a continuous variable, and considered the mortality risk per 0.1 increment on the FI. We checked the proportional hazards models to ensure that the assumptions of the model were met.

RESULTS

Frailty, dementia, and LTC use all increased with age (Figure 1). At the age of 75, fewer than 10% of the study members

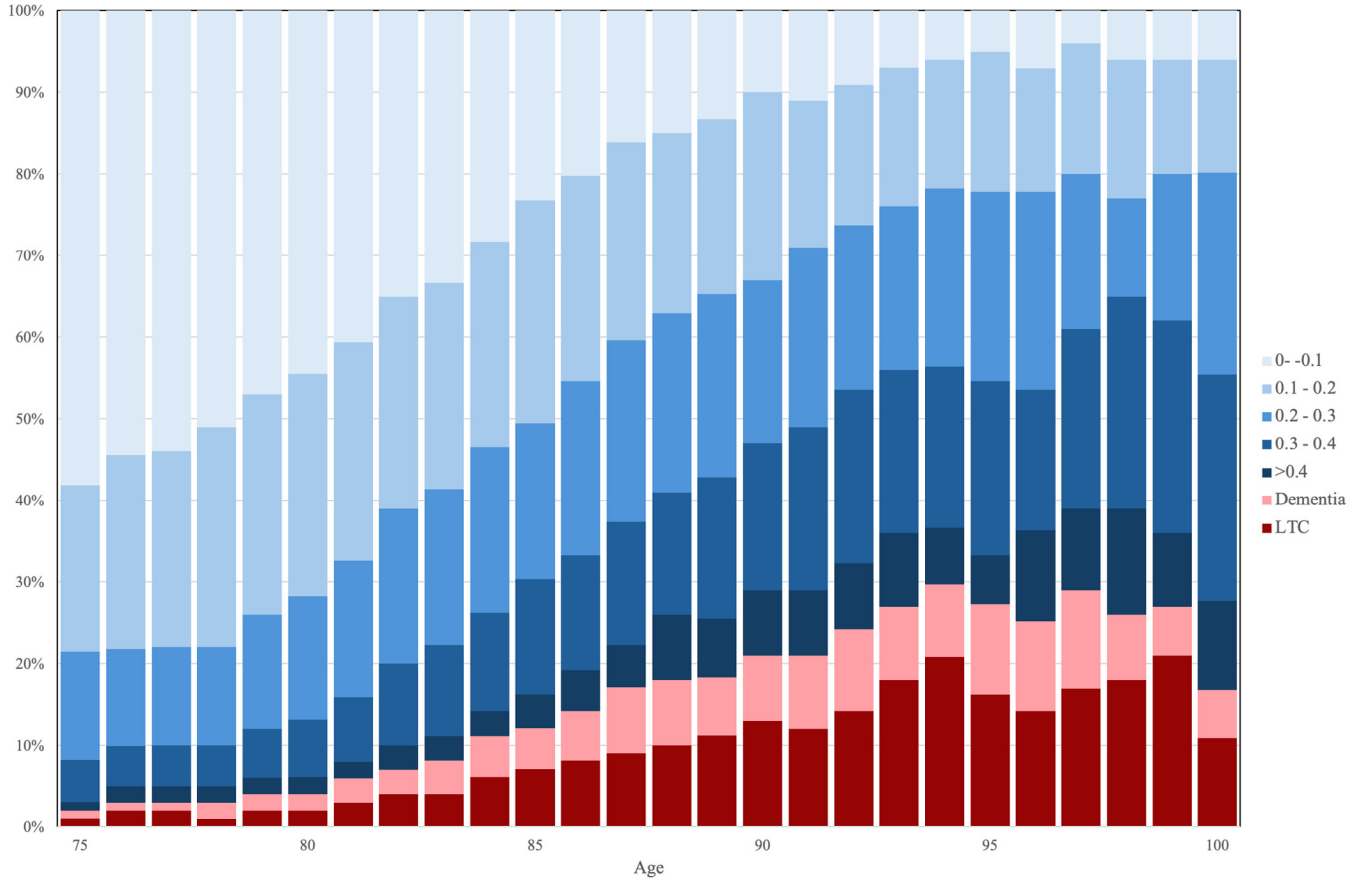

FIGURE 1. Prevalence of frailty, dementia, and long-term care use by age

were living with frailty (more than 0.4 on the FI), dementia, or in LTC. However, this proportion increased steadily from age 75 to 95, at which age more than one-third were living with frailty, dementia, or in LTC. Note that these numbers represent the point prevalence at a specific age and not the trajectory of frailty for an individual. When we considered different aspects of frailty, we found a similar association with age—medical conditions, functional impairment, and psychosocial deficits all increased with age (*see Figure S2 in the Supplementary Material*). At all ages, the medical component had the lowest score, while the functional component had the highest.

When we considered the mortality risk associated with the FI, we found a very strong and consistent graded association: those with a higher FI had a markedly higher risk of mortality. Those living in LTC consistently had the highest mortality risk, and those living with dementia also had a high mortality risk. The Kaplan Meier plots at various ages are shown in *Figures S2 to S6 in the Supplementary Material*. They show the time to event for death by frailty category at different ages. The mortality risk with frailty was seen across all ages, even at very advanced ages. Similarly, there was an association between frailty and the time to LTC, even at advanced ages. This association was noted as a gradient across frailty categories. Note as well that both living with dementia and living in LTC were strongly associated with death. Table 1 shows the results of the Cox proportional hazards models for mortality at various ages. At all ages, the FI index predicted survival time, even after considering period effects. This association with mortality appeared to be a gradient effect across the FI, as has been previously postulated.[15] The FI was also strongly associated with LTC utilization across all ages. Similar to previous reports, persons living with dementia were also at a high risk of LTC admission.[16] The supplementary figures show the Kaplan Meier plots for LTC admission. The Cox proportional hazards models for LTC admission are shown in Table 2, which also show a strong and graded effect of frailty on the risk of LTC utilization.

When we consider the domains of our FI, we found that different aspects of frailty were associated with mortality differently (Table 3). Functional impairment was a strong predictor of death at all ages throughout the study. However, the effect of medical conditions declined with advancing age. Psychosocial factors were generally less strongly associated with death than the other domains. Similarly, functional impairment predicted LTC admission at nearly all ages, except very old age; whereas the effect of medical conditions was increasing less apparent with advancing age (Table 4).

DISCUSSION

We have created a FI in a closed prospective cohort study of aging men, following a recently published framework.[11] We found that frailty, dementia, and LTC use increased steadily

TABLE 1.
Results of Cox proportional hazards for mortality at different ages; the Hazard Ratio and 95% CI are presented

From Age (in years)	*75*	*80*	*85*	*90*	*95*
Number of Deaths/ Total Number of Men	*739 / 753*	*1366 / 1384*	*1186 / 1202*	*682 / 696*	*205 / 218*
FI 0–0.1	ref	ref	ref	ref	ref
FI 0.1–0.2	1.19 (0.98, 1.45)	1.37 (1.20, 1.57)	1.15 (0.97, 1.36)	1.22 (0.92, 1.62)	1.33 (0.64, 2.76)
FI 0.2–0.3	1.65 (1.30, 2.08)	1.72 (1.46, 2.04)	1.75 (1.45, 2.10)	1.49 (1.11, 2.00)	2.12 (1.05, 4.27)
FI > 0.30	2.23 (1.63, 3.03)	2.41 (1.98, 2.95)	2.41 (1.99, 2.92)	2.43 (1.82, 3.25)	2.56 (1.28, 5.12)
Has Dementia	1.72 (0.71, 4.17)	2.99 (2.09, 4.28)	2.47 (1.86, 3.28)	2.58 (1.80, 3.71)	3.87 (1.80, 8.28)
In LTC	9.96 (3.66, 27.1)	3.62 (2.53, 5.17)	4.64 (3.59, 6.01)	5.38 (3.86, 7.50)	5.19 (2.50, 10.76)
No FI Calculated	1.93 (1.47, 2.54)	2.47 (1.97, 3.10)	2.03 (1.48, 2.78)	1.64 (0.90, 2.98)	1.92 (0.42, 8.84)
Year	1.00 (0.95, 1.05)	0.98 (0.96, 1.00)	0.99 (0.98, 1.01)	0.99 (0.98, 1.01)	1.00 (0.96, 1.04)

FI = Frailty Index; LTC = long-term care.

TABLE 2.
Results of Cox proportional hazards for long-term care admission at different ages; the Hazard Ratio and 95% CI are presented

From Age (in years)	*75*	*80*	*85*	*90*	*95*
Number of LTC Admissions/ Total Number of Men	*217 / 749*	*423 / 1352*	*378 / 1122*	*190 / 606*	*47 / 183*
FI 0–0.1	ref	ref	ref	ref	ref
FI 0.1–0.2	1.23 (0.85, 1.78)	1.63 (1.28, 2.06)	1.29 (0.96, 1.72)	0.93 (0.56, 1.54)	0.51 (0.15, 1.71)
FI 0.2–0.3	2.27 (1.53, 3.37)	1.76 (1.29, 2.38)	1.69 (1.21, 2.35)	1.24 (0.75, 2.08)	1.64 (0.60, 4.49)
FI > 0.30	2.79 (1.60, 4.84)	2.82 (1.99, 3.98)	2.87 (2.07, 3.99)	2.15 (1.30, 3.56)	1.44 (0.52, 4.03)
Has Dementia	10.7 (3.9, 29.3)	6.98 (4.09, 11.91)	5.92 (3.96, 8.85)	4.80 (2.74, 8.41)	3.74 (1.15, 12.22)
No Frailty Index Calculated	1.80 (1.06, 3.05)	2.41 (1.59, 3.67)	2.02 (1.16, 3.53)	1.60 (0.61, 4.24)	1.66 (0.20, 14.1)
Year	0.91 (0.82, 1.00)	0.96 (0.92, 1.00)	0.98 (0.95, 1.01)	0.98 (0.94, 1.01)	0.93 (0.87, 1.00)

FI = Frailty Index; LTC = long-term care.

with age, and that each domain of frailty increased steadily with age. Griffith *et al*.[17] have recently noted that psychological frailty did not increase with advancing age among older men in the Canadian Longitudinal Study on Aging. However, the sample age overall was considerably lower than the age of men in the CLSA. They also considered items which were not age-related. The association between age and the FI is not at all surprising, since items included on a FI must be age-related.[11] However, we found that the point prevalence of all items in our data set increased with age, although this association was not universally linear. While obvious, this is important. Unless there are major period effects in the risk of frailty, the case fatality ratio of frailty, or competing risk from new acute causes of death, we can expect a large increase in the number of older adults living with frailty as populations age. Health and social systems must adapt to this. The recent WHO report on an ageing society[18] lays out necessary changes: aligning health-care systems to an ageing population; developing resilient and accessible LTC systems; creating age-friendly societies; and establishing better data systems to measure, track, and monitor all aspects of health, including functional capacity.[18] Clinicians should also be aware of the strong association between age and frailty, and adapt care to the expected health changes in very old individuals.

A second important finding is the strong association between frailty and adverse outcomes. Efforts to delay the onset of frailty are important. It is also important for clinicians to adapt care to older adults living with frailty, and to consider frailty in clinical decisions. The treatment burden of aggressively treating each condition must be considered[19]; treatment of one condition could worsen another. The risk of LTC in those with frailty is also important—as frailty progresses, adequate attention to chronic disease and functional decline, as well as home-care services, may delay LTC—but LTC planning should be considered for those with high levels of frailty.

We also found a gradient effect of frailty on adverse outcomes with a consistent increase in the risk of death and LTC admission across the frailty spectrum. This was apparent at

TABLE 3.
Results of Cox proportional hazards for mortality at different ages; the Hazard Ratio[a] and 95% CI are presented

From Age (in years)	*75*	*80*	*85*	*90*	*95*
Number of Deaths/ Total Number of Men	*669 / 682*	*1213 / 1230*	*998 / 1014*	*523 / 537*	*144 / 157*
Medical	1.34 (1.17, 1.54)	1.10 (1.01, 1.21)	1.06 (0.97, 1.16)	1.06 (0.96, 1.18)	1.08 (0.89, 1.32)
Functional	1.11 (1.04, 1.19)	1.18 (1.12, 1.24)	1.18 (1.13, 1.24)	1.17 (1.10, 1.24)	1.16 (1.01, 1.32)
Psychosocial	1.05 (0.98, 1.11)	1.04 (0.99, 1.08)	1.04 (1.00, 1.10)	1.10 (1.03, 1.16)	1.08 (0.95, 1.23)
Year	0.99 (0.94, 1.04)	0.98 (0.96, 1.00)	0.99 (0.97, 1.01)	0.99 (0.96, 1.01)	0.99 (0.95, 1.04)

[a]Each hazard ratio is based on a 10-unit difference in the medical, functional or psychosocial frailty component.

TABLE 4.
Results of Cox proportional hazards for LTC at different ages; the Hazard Ratio[a] and 95% CI are presented

From Age (in years)	*75*	*80*	*85*	*90*	*95*
Number of LTC Admissions/ Total Number of Men	*197 / 682*	*382 / 1230*	*326 / 1014*	*156 / 537*	*39 / 157*
Medical	1.29 (1.00, 1.67)	1.15 (0.98, 1.35)	1.10 (0.95, 1.28)	0.99 (0.82, 1.20)	1.24 (0.85, 1.82)
Functional	1.16 (1.02, 1.33)	1.21 (1.11, 1.33)	1.26 (1.16, 1.36)	1.20 (1.07, 1.36)	1.12 (0.84, 1.48)
Psychosocial	1.07 (0.95, 1.19)	1.04 (0.96, 1.13)	0.99 (0.92, 1.07)	1.10 (0.98, 1.22)	0.93 (0.70, 1.23)
Year	0.91 (0.83, 1.00)	0.96 (0.93, 1.00)	0.98 (0.95, 1.01)	0.96 (0.93, 1.00)	0.94 (0.87, 1.02)

[a]Each hazard ratio is based on a 10-unit difference in the medical, functional or psychosocial frailty component.

all ages in the study, except for the risk of LTC admission in those over the age of 95. Even here, this may reflect the small numbers of individuals and, thus, a low power to detect a gradient in risk. We also noted a limit to frailty at approximately 0.6. This is consistent with the notion that there is a limit to frailty beyond which survival in the community is highly improbable. This has been referred to as a "limit to frailty" in the Accumulation of Deficits model,[20] and a "point of no return"[21] in the Frailty Phenotype model.

We considered the effect of dementia and living in LTC to methodologically account for the effect of missing or inaccurate data. Nevertheless, our findings underscore the importance of these factors. Both are increasingly common in late life, and both are strongly associated with mortality. Dementia is also a very strong predictor of LTC utilization. In Canada—where most of the study participants lived—LTC is closely associated with dementia and functional impairment[22]; so these results should not be surprising. Yet they are very important, and these factors should also be considered in clinical and policy decisions.

Finally, we found a differential effect of different domains on adverse outcomes. At all ages, the presence of functional impairment and dementia predicted mortality and LTC use, while the effect of chronic conditions was attenuated in very advanced ages. This is consistent with previous analyses of this data set.[23] Thus, in the younger age groups (i.e., age 75 to 85), attending to chronic illness is important, but shifting attention to functional impairment may become more relevant in very late life.

There are some strengths to our approach. The sample size is large and there is a long follow-up time with an extremely low loss to follow-up. Thus, our findings are less susceptible to selection bias due to attrition. There is very little censoring, and a low risk of interval censoring of items since the surveys waves are frequent. Finally, there are no items with more than 5% missing data. There are, however, participants to whom a survey is not sent. To account for this, we categorized the FI and considered LTC and dementia as categories. The very low loss to follow-up for medical and vital status of the participants allows us to consider the non-response to the SAQ as a category. Most cohort studies would consider these participants as "lost to follow-up", while we can consider them as a category for analysis.

There are also limitations. This is a study of men with unique life experiences, most of whom lived most of their lives in Canada. Our findings should not be overly generalized, notably to women or to those outside Canada. We rely on clinical reports from clinical contacts of the study members and there may be some mismeasurement or underreporting of some chronic conditions. There may also be subclinical disease which we cannot measure. We also do not measure the severity of an illness, or the resolution of a chronic condition. Since the FI is an aggregate measure of many factors, considering the effect of confounding factors is difficult. Nevertheless, there may be some potentially important factors which we did not consider: diseases which we did not measure, health behaviors, and biomarkers could all potentially confound the association between the FI and adverse outcomes.

Our analyses also raise further research questions. We considered point estimates of frailty and not a trajectory of frailty over time. The trajectory of frailty—and its components—merits further attention.[24] The clustering of diseases, impairments, and symptoms of disease also need further investigation. There has been some study into the cross-sectional clustering of chronic conditions (but this should be extended to other domains of frailty), as well as the clustering of items longitudinally over time.[25] Chronic conditions are only rarely cured and, in our data set, do not resolve. Conversely, functional impairment and psychosocial measures can improve over time. This methodological issue should be furthered studied, as it is not unique to MFUS.

Finally, there are other measurement issues to consider. The choice of items on a FI will affect the prevalence estimates of frailty, and perhaps the association between the FI and mortality. This may affect the calibration and perhaps the discrimination of the FI. A better understanding of the effect of the choice of items with differing prevalence and associations with mortality is needed. As the FI becomes more commonly used, further study into its characteristics should be undertaken.

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CONFLICT OF INTEREST DISCLOSURES

We have read and understood the *Canadian Geriatrics Journal*'s policy on conflicts of interest disclosure and declare the following interests: Dr. St John is employed by the University of Manitoba, the Winnipeg Regional Health Authority, and Shared Health. Dr. Tate is a Senior Scholar at the University of Manitoba. Dr. St John has received management consulting fees from the University Health Network (University of Toronto), and has received speaking fees from the Manitoba Association of Gerontological Nursing. No family member has a conflict of interest.

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SUPPLEMENTARY MATERIALS

Supplemental material linked to the online version of the paper (https://doi.org/10.5770/cgj.29.907):

- **Appendix S1:** The process used to construct a FI.
- **Table S1:** The status of the participants for the study.
- **Table S2:** Items included in constructing a FI.
- **Figure S1:** Domains of frailty by age.
- **Figures S2–S6:** Kaplan Meier Plots for mortality of Frailty Index at various ages.

Correspondence to: Philip St John, MD, Section of Geriatric Medicine, Max Rady College of Medicine, GE 547 Health Sciences Centre, 820 Sherbrook St., Winnipeg MB R2A 1R9
E-mail: pstjohn@hsc.mb.ca