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Original Research

Changes in frailty predict social vulnerability among home care clients living in the community followed for ten years

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ABSTRACT

Background: Among community dwelling older adults, social vulnerability increases with age. Advanced age alone does not fully explain how or why older adults become more socially vulnerable; frailty may offer a better explanation.
Objective: We aimed to understand how change in frailty relates to change in social vulnerability over time.
Design: Retrospective cohort study.
Setting and Participants: We analyzed older adults aged 65 years and older from the province of Nova Scotia who accessed publicly funded home care in 2005 and 2008 followed for up to ten years.
Measurements: We measured social vulnerability and frailty using indices. Controlling for time constant covariates, multi-level growth modelling was used to evaluate whether within-person changes in frailty were associated with within person changes in social vulnerability, after accounting for between-person differences.
Results: There were 2,791 older adults in the 2005 cohort and 2,741 older adults in the 2008 cohort. Mean age, frailty index and social vulnerability index were 80.6 years (SD 7.5), 0.23 (SD 0.10), 0.22 (SD 0.07) and 80.4 (SD 7.6), 0.23 (SD 0.10), and 0.23 (SD 0.07) for each cohort respectively. After accounting for age, sex and baseline frailty, a 0.1 point increase in change of FI from baseline was associated with a 0.017 (CI 0.016 – 0.019, $p < 0.001$) increase in SVI in the 2005 cohort and a 0.014 (CI 0.013 – 0.016, $p < 0.001$) increase in SVI in the 2008 cohort.
Conclusions: Although social vulnerability tends to remain constant in the absence of increases in frailty, changes in frailty are closely associated with changes in social vulnerability. Incorporating within-person changes in health into quantitative models of late-life social vulnerability may further improve our understanding of how and why some individuals are able to stay in the community despite their vulnerabilities.

1. Background

Social vulnerability is the degree to which overall social circumstances leave people susceptible to, or unable to recover from, adverse health events. It helps explain, for example, how two older adults with the same medical conditions experience different outcomes whereby one lives in the community with supports and the other requires institutionalization. Meaningful associations have been found between social vulnerability and cognition [1], mortality [2–4], disability [5], and long-term care home placement [6].

In community dwelling older adults, social vulnerability increases with age [3–5,7]. However, advanced age alone does not fully explain how or why older adults become more socially vulnerable. Factors beyond age contribute to social vulnerability including loss of friends and family, loss of purpose, economic insecurity and increasing frailty. Frailty, describing cumulative burden of accumulating health deficits which brings vulnerability to adverse health outcomes, is a compelling reason to account for the greater social vulnerability observed in geriatric populations. Individuals with higher frailty have physical or cognitive barriers making it difficult to maintain social connections, perform daily activities, maintain independence or participate in social activities. Frail individuals may also be marginalized within societal circles through social exclusion and age- or disability-based discrimination.

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The association between social vulnerability and frailty is less established. Social vulnerability was weakly to moderately correlated (r = 0.13–0.47) among Canadian older adults [3] and strongly correlated (r = 0.81) among rural Tanzanian older adults [8]. Individuals with higher social vulnerability also experiencing higher frailty have been reported in several other studies and summarized in two recent systematic reviews [9–12]. These studies were primarily descriptive, cross-sectional, or only utilized baseline vulnerability, thus the dynamic nature of social vulnerability and frailty is under researched. Social vulnerability, like frailty [13], is expected to change over time because it reflects accumulation of social deficits. Furthermore, there may be a bidirectional relationship between social vulnerability and frailty, and the temporal association between change in frailty in relation to social vulnerability has yet to be explored.

Using multilevel growth models, we aimed to answer the research question: how does change in frailty relate to change in social vulnerability among older adults living in the community? In doing so, we aim to further the understanding of the relationship between social vulnerability and age, exploring whether the positive correlation may not simply reflect increasing age, but increasing health deficits. Examining the complex and evolving nature of frailty in relation to social vulnerability may lead to development of more effective strategies for supporting healthier aging in older adults who experience the problems of old age simultaneously rather than one at a time [14].

2. Methods

2.1. Study design and population

We conducted a retrospective cohort study of older adults aged 65 years and older from the province of Nova Scotia (NS), Canada who accessed publicly funded long-term care services in the community. Long-term care in the community is called home care (or Continuing Care) in NS. NS is estimated to have the highest proportion of households accessing home care [15] and the province has one of the largest proportions of older adults nationally, ranging from 21.2 to 23.6 % in 2021 [16]. Since most home care clients are older, NS's status as a 'superaged' province provides a robust home care sample size and provides insights into future trends for other regions with younger demographics.

All Nova Scotians can be assessed for eligibility to receive publicly funded home care comprised of home supports and home health care. Home care service fees are mostly income adjusted (approximately three quarters of clients with homes supports pay zero fees) although some services (e.g., hospital bed loan or nursing services) have no fees [17]. Public funding combined with a central intake process means that all long-term care clients receive an initial intake and structured assessment of health and functional capacity using the Resident Assessment Instrument-Home Care (RAI-HC), resulting in an abundance of routinely collected administrative data [18]. We examined two cohorts of older adults who received a full RAI-HC assessment in the calendar years 2005 and 2008 with follow up for a period of 10 years. In NS, full RAI-HC reassessments occur annually, or are triggered by a major health incident (e.g., hospitalization) or social change (e.g., change in caregiver status or living situation). Reasons for no follow up assessments are varied: no longer eligible for supports, clients no longer desired supports, relocation, entered long-term care homes, death, other reasons not specified, etc. Ethics approval came from the Nova Scotia Health Research Ethics Board (REB #1025990).

2.2. Outcome measure

The social vulnerability index (SVI) is an accepted tool for measuring social vulnerability [19]. The SVI provides a quantitative summary integrating multiple sources of information from several social domains (e.g., socioeconomic status, support networks, built environment) and social levels (e.g., individual, household, neighbourhood). Within the RAI-HC, a SVI was calculated following a standard methodology [20,21]. In short, each social item was analyzed to examine distribution, missingness and determine relevant cut points to define a deficit. Then, each item was coded into a score of 0 to 1; 0 represents the absence of a deficit and 1 represents presence of the deficit (e.g., lives with family = 0 and lives alone = 1). Intermediate values were assigned in the case of categorical variables. A raw score was calculated as the sum of all deficits. The final SVI score divided the raw score by the total number of social items generating an index value between 0 and 1. Items included from the RAI-HC in all indices are shown in Table 1.

2.3. Frailty index (FI)

The FI is calculated using a similar standard procedure as used for the SVI [22,23]. The feasibility and validity of using FIs within RAI-HC assessments were previously reported [24,25]; items and coding guidance, representing health deficits, is drawn from this literature.

2.4. Covariates

Age and sex were chosen a priori as covariates due to their known association with social vulnerability and frailty. Age was grand mean centered, representing an individual's age relative to the cohorts' mean age at baseline assessment (in years).

2.5. Statistical analysis

The objectives of the analysis were: [1] assess the extent to which social vulnerability trajectories are patterned by between-person differences in frailty; and [2] assess whether within-person changes in frailty are associated with within person changes in social vulnerability. All analyzes were conducted in R using the nlme package [26,27] for modelling multi-level growth model. FI scores were multiplied by 10 such that the model represents a 0.1 increase in FI score.

We chose multi-level modeling because this approach is recommended for longitudinal data collected at irregular time points [28]. Model 1 (null model) was used to calculate the Interclass Correlation Coefficient (ICC) to determine the degree of variation in SVI scores attributable to inter-individual differences. ICC is calculated as variance of the random intercept (between-person variance) divided by the variance of the random intercept plus the residual variance (within-person variance). We included time (in years since initial assessment) to examine the trajectories of SVI scores in Model 2. Model 3 included both a random intercept and a random slope for time for each person, allowing for different baseline SVIs and different rates of change over time. Model 3 included time constant covariates of sex, age and baseline frailty. Model 4 included frailty change from baseline as a time-varying covariate to test whether within-person changes in frailty were associated with within-person changes in social vulnerability, after accounting for between-person differences. We used deviance (calculated as −2Log Like-2 Log Likelihood (−2LL)), Akaike Information Criterion (AIC), and Bayesian Information Criterion (BIC) to assess model fit. Deviance differences were used to compare models with anovas. We checked assumptions that residuals and random effects were centered at zero, normally distributed, and independent using Q-Q plots and scatterplots.

We repeated these analyses in three subgroups as sensitivity analyses to account for survivorship bias. We looked at members of each cohort who died within three years of their follow up period (2005: n = 1046; 2008: n = 1048). We also looked at members of the cohort who received three or fewer assessments (2005: n = 1728; 2008: n = 1877) and members of the cohort who received four or more assessments (2005: n = 1063; 2008: n = 864) over the follow up period.

3. Results

Characteristics: There were 2791 older adults who received a baseline RAI-HC assessment in 2005. Mean age was 80.6 (SD7.5), baseline

Table 1
Items and coding for the social vulnerability index (SVI) and frailty index (FI).

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
1	BB4	Marital status	Married = 0 Never married = 1 Widowed = 1 Separated = 1 Divorced = 1 Other = 1	B1a	Short term memory okay	Memory okay = 0 Memory problem demonstrated = 1
2	BB5a	Primary language	English = 0 Any other = 1	B1b	Procedural memory okay	Memory okay = 0 Memory problem demonstrated = 1
3	BB5b	Interpreter required	Does not require interpreter = 0 Interpreter required = 1	B3b	In the last 90 days, client became agitated or disoriented (delirium)	No = 0 Yes = 1
4	BB6	Education	Less than high school = 1 High school = 0.67 Technical or trade school or some college/university = 0.33 College diploma or bachelor's degree or above = 0	C1	Hearing	Hears adequately = 0 Minimal difficulty = 0.33 Hears in special situations only = 0.66 Highly impaired = 1
5	BB7a	Legal guardian/ Substitute decision maker	Yes = 0 No = 1	D1	Vision	Adequate = 0 Impaired, Moderately impaired, Highly impaired, Severely impaired = 1
6	BB7b	Advanced medical directives	Yes = 0 No = 1	E1a	A feeling of sadness or being depressed	Indicator not exhibited in last three days = 0 Exhibited 1–3 symptoms in last 3 days = 1
7	CC5	Where lived at time of referral	Private home with no home care services = 0 Private home with home care services = 0 Board and care/assisted living/group home = 1 Residential care facility = 1 Other = 1	E1e	Repetitive anxious complaints / concerns (non health related)	Indicator not exhibited in last three days = 0 Exhibited 1–3 symptoms in last 3 days = 1
8	CC6	Who lived with at referral	Lived with spouse only = 0 Lived with spouse and others = 0 Lived with child = 0 Lived with others (not spouse or children) = 0 Resident in group setting with non-relatives = 0 Lived alone = 1	H2a	Mobility in bed	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
9	CC7	Prior residential care facility placement	No = 0 Yes = 1	H2b	Transfer	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
10	F1b	Openly expresses conflict with friends/ family	Yes = 1 No = 0	H2c	Locomotion in home	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
11	F2	Change in social activities in last 90 days	No decline = 0 Decline, not distressed = 0.5 Decline, distressed = 1	H2d	Locomotion outside home	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
12	F3a	Length of time client is alone during the day (morning and afternoon)	Never or hardly ever = 0 About one hour = 0.33 Long periods of time = 0.67 All the time = 1	H2e	Dressing upper body	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1

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Table 1 (*continued*)

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
13	F3b	Client says or indicates he/she feels lonely	No = 0 Yes = 1	H2f	Dressing lower body	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
14	G1ea	Informal helpers lives with client	Yes, informal helper lives with client = 0 No, informal helper does not live with client = 0.5 No helper = 1	H2g	Eating	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
15	G1fa	Informal helper relationship to client	Child or child in law = 0 Spouse = 0 Other relative = 0.5 Friend / neighbor = 0.5 No helper from G1e = 1	H2h	Toilet use	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
16	G1la	Informal helper willing to increase help for ADLs	More than 2 h per day = 0 1–2 h per day = 0.33 No = 0.66 No helper from G1e = 1	H2i	Personal hygiene	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
17	G2a	Caregiver status – unable to continue in caring activities	No = 0 Yes = 1	H2j	Bathing	Independent = 0 Set up help only = 0.5 Supervision = 1 Limited assistance = 1 Extensive assistance = 1 Maximal assistance = 1 Total dependence = 1
18	G2b	Primary caregiver is not satisfied with current supports	No = 0 Yes = 1	H1aa	Meal preparation	Independent = 0 Some help = 0.5 Full help or by others = 1
19	G2c	Primary caregiver expresses feelings of distress	No = 0 Yes = 1	H1ba	Ordinary housework	Independent = 0 Some help = 0.5 Full help or by others = 1
20	G3a	Number of hours and minutes informal helpers spent assisting client in IADLs over last 7 days	Number of hours / Max number of hours (120)	H1ca	Managing finances	Independent = 0 Some help = 0.5 Full help or by others = 1
21	G3b	Number of hours and minutes informal helpers spent assisting client in ADLs over last 7 days	Number of hours / Max number of hours (48)	H1da	Managing meds	Independent = 0 Some help = 0.5 Full help or by others = 1
22	H1e	Phone use	Independent = 0 Did not occur = 0 Some Help = 0.5 Full help = 1 Dependent on others = 1	H1fa	Shopping	Independent = 0 Some help = 0.5 Full help or by others = 1
23	K9a & O1f	Personal safety (includes fearful of a family member of caregiver, fear of violence in or out of the home, safety problem going out or visiting neighbors)	No = 0 Yes = 1	H1ga	Transportation	Independent = 0 Some help = 0.5 Full help or by others = 1
24	O1b	Home environment flooring and carpeting hazards	No = 0 Yes = 1	H4a	Primary mode of locomotion indoors	No assistive device = 0 Cane = 0.5 Walker/crutch = 1 Scooter = 1 Wheelchair = 1 Activity did not occur (cannot go outdoors) = 1

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Table 1 (*continued*)

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
25	O1c & O1d	Bathroom and toilet room hazards & kitchen hazards	No = 0 Yes = 1	H4b	Primary mode of locomotion outdoors	No assistive device = 0 Cane = 0.5 Walker/crutch = 1 Scooter = 1 Wheelchair = 1 Activity did not occur (cannot go outdoors) = 1
26	O1g	Access to home	Yes = 1 No = 0	I1a	Bladder continence	Continent = 0 Continent with catheter = 0 Usually continent = 0.5 Occasionally incontinent = 1 Frequently incontinent = 1 Incontinent = 1 Did not occur (dialysis) = 1
27	O2b	Client or primary caregiver feels the client would be better off in another living environment	No = 0 Client only = 0.5 Caregiver only = 0.5 Client and caregiver = 1	J1a	Cerebrovascular accident (stroke)	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
28	P7	Trade offs during the last month (because of limited funds, client made trade offs)	No = 0 Yes = 1	J1b	Congestive heart failure	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
29				J1c	Coronary artery disease	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
30				J1d	Hypertension	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
31				J1e	Irregularly irregular pulse	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
32				J1f	Peripheral vascular disease	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
33				J1g	Alzheimer's disease	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
34				J1h	Dementia other than Alzheimer's disease	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1

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Table 1 (*continued*)

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
35				J1i	Head trauma	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
36				J1j	Hemiplegia/hemiparesis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
37				J1k	Multiple sclerosis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
38				J1l	Parkinsonism	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
39				J1m	Arthritis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
40				J1n	Hip fracture	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
41				J1o	Other fracture	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
42				J1p	Osteoporosis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
43				J1q	Cataract	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1
44				J1r	Glaucoma	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional = 1

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Table 1 (*continued*)

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
45				J1s	Any psychiatric diagnosis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
46				J1u	Pneumonia	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
47				J1v	Tuberculosis	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
48				J1w	Urinary tract infection	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
49				J1x	Cancer	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
50				J1y	Diabetes	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
51				J1z	Emphysema/Chronic obstructive pulmonary disease/Asthma	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
52				J1aa	Renal failure	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
53				J1ab	Thyroid disease	Disease absent = 0 Disease present not subject to focused treatment or monitoring by healthcare professional = 1 Disease present and being monitored or treated by health care professional =
54				K4b	Intensity of pain	No pain = 0 Mild = 1 Moderate = 1 Severe = 1 Times when pain is horrible or excruciating = 1
55				K4c	From client's point of view, pain intensely disrupts usual activities	No = 0 Yes = 1

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Table 1 (*continued*)

	SVI			FI		
	RAI-HC Item	Item Description	Coding	RAI-HC Item	Item Description	Coding
56				K5	Falls frequency (number of times client fell in last 90 days)	Number of falls / Max number of falls [9]
57				K6a	Unsteady gait	No = 0 Yes = 1
58				K7b	Alcoholic drink first thing in the morning	No = 0 Yes = 1
59				K7c	Smoked or chewed tobacco daily	No = 0 Yes = 1
60				L1a	Unintended weight loss of more than 5 % In last 30 days	No = 0 Yes = 1
61				L1b	Severe malnutrition	No = 0 Yes = 1
62				L1c	Morbid obesity	No = 0 Yes = 1
63				L3	Swallowing	Normal = 0 Required diet modification to swallow solid foods = 1 Required diet modification to swallow foods and liquids = 1 Combined oral and tube feeding = 1 No oral intake = 1
64				P2a	Oxygen	Scheduled, full adherence, partial adherence or not received = 1 No = 0
65				P2c	All other respiratory therapy treatments	No = 0 Yes = 1
66				Q1	Number of medications	0–2 = 0 3–8 = 0.5 >8 = 1
67				Q4	Compliance with medicationss	Always compliant = 0 Compliant 80 % of the time = 0.5 Compliant less than 80 % of the time = 1

ADLs = Activities of daily living; IADLs = Instrumental activities of daily living; NA = not applicable; RAI-HC - Resident Assessment Instrument - Home Care.

FI was 0.23 (SD0.10), baseline SVI was 0.22 (SD0.07) and 68.4 % were female. There were 9136 total RAI-HC assessments in the 2005 cohort. Among the 2741 older adults who received a baseline assessment in 2008, mean age was 80.4 (SD7.6), baseline FI was 0.23 (SD0.10), baseline SVI was 0.23 (SD0.07) and 64.8 % were female. There were 8159 total RAI-HC assessments in the 2008 cohort. The mean time from baseline until the second assessment was similar in both cohorts: 1.68 years (SD1.66) in the 2005 cohort and 1.69 (SD1.55). in the 2008 cohort. Over ten years of follow up, at each subsequent assessment, the average FI of the remaining cohorts was greatersuch that by the 10th assessment, the mean FI is 0.37 (SD0.10), although the mean SVI did not change much (0.24 [SD0.08]) for the 2005 cohort (similar in the 2008 cohort). Descriptive summaries across follow up assessments are shown in Table 2.

3.1. Model 1: Null model

In the 2005 cohort, the ICC was 0.61, indicating that 61 % of the variation in SVI scores occurred between individuals and 39 % of variation between SVI scores could be due to within-person changes, warranting the use of multilevel modeling analytic approaches. In the 2008 cohort, the ICC was similar, at 0.65. All models are shown in Table 3.

3.2. Model 2: Determining average trajectory

Average baseline SVI score was 0.22 (Confidence Interval(CI) 0.22 – 0.23). A time estimate of 0.005 (CI 0.004 – 0.005, $p < 0.001$) indicated participants in the 2005 cohort experienced an average increase in SVI score of 0.005 per year. The estimated coefficient for time in the 2008 cohort was 0.004 (CI 0.003 – 0.005, $p < 0.001$).

3.3. Model 3: Adding time invariant predictors

Baseline FI, standardized age at baseline, and sex were added into model 3 as time constant fixed effects. Interactions of these co-variates with time were added to evaluate impact on the slope of SVI change. The intercept represents the SVI for a female at baseline mean age with a FI of 0. For both cohorts, baseline older age was associated with higher SVI scores (2005: $B = 0.001$, CI 0.000 – 0.001, $p < 0.001$; 2008: $B = 0.001$, CI 0.001 – 0.001, $p < 0.001$). On average male SVI scores were lower than females (2005: $B = -0.015$, CI −0.021 – −0.010, $p < 0.001$; 2008: $B = -0.017$, CI-0.023 – −0.012, $p < 0.001$). Baseline frailty was not associated with greater SVI.

3.4. Model 4: Adding frailty as time varying predictor

Frailty (change from baseline) was added as a time varying covariate. On average, accounting for age, sex and baseline frailty, a 0.1 point increase in change of FI was associated with a 0.017 (CI 0.016 – 0.019, $p < 0.001$) increase in SVI in the 2005 cohort and a 0.014 (CI 0.013 – 0.016, $p < 0.001$) increase in SVI in the 2008 cohort. In model 4, baseline age and sex remained significantly correlated with SVI. The previously significant associations whereby SVI increased with time (Model 3) disappeared for both cohorts when change of frailty was added in the model.

We illustrate the expected changes in SVI of three hypothetical individuals based on model 4 in Fig. 1.

Table 2
Cohort characteristics across each subsequent follow up assessment.

	Baseline	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11
2005											
n	2791	1939	1487	1063	709	486	307	186	101	46	21
Mean years since baseline (SD)	0	1.68 (1.66)	2.76 (1.90)	3.74 (1.88)	4.76 (1.80)	5.79 (1.83)	6.86 (1.75)	7.72 (1.52)	8.35 (1.44)	8.91 (1.31)	8.99 (1.47)
Mean age (SD)	80.6 (7.46)	82.3 (7.4)	83.2 (7.2)	83.9 (7.03)	84.2 (7.01)	84.7 (6.9)	85.3 (6.8)	85.3 (6.4)	86.2 (5.8)	87.2 (6.2)	88.0
Age range	65–103	65–104	66–103	67–103	69–104	70–100	70–101	71–102	72–101	75–102	75–103
%Female	68.4	71.8	73.8	76.7	78.4	78.2	79.2	79.0	78.2	80.4	81.0
Mean FI (SD)	0.23 (0.10)	0.26 (0.11)	0.28 (0.11)	0.30 (0.11)	0.31 (0.11)	0.32 (0.11)	0.32 (0.11)	0.33 (0.11)	0.35 (0.11)	0.34 (0.12)	0.37 (0.10)
FI range	0.00–0.56	0.01-0.57	0.04-0.65	0.04-0.58	0.05-0.59	0.07-0.59	0.07 – 0.55	0.04-0.57	0.04-0.56	0.06-0.54	0.15-0.52
Mean SVI (SD)	0.22 (0.07)	0.23 (0.07)	0.24 (0.07)	0.24 (0.07)	0.24 (0.07)	0.25 (0.07)	0.25 (0.08)	0.25 (0.07)	0.25 (0.07)	0.26 (0.07)	0.24 (0.08)
SVI range	0.04-0.56	0.03-0.48	0.03 - 0.49	0.02-0.49	0.03-0.48	0.05-0.47	0.05-0.58	0.06-0.46	0.11-0.42	0.11-0.45	0.11-0.46
2008											
n	2741	1876	1318	864	541	355	222	124	73	33	12
Mean years since baseline (SD)	0	1.69 (1.55)	2.8 (1.76)	3.98 (1.86)	5.17 (1.86)	6.31 (1.79)	7.2 (1.66)	7.97 (1.57)	8.58 (1.44)	9.32 (1.34)	9.48 (1.07)
Mean age (SD)	80.4 (7.62)	82.0 (7.41)	82.9 (7.24)	83.6 (7.04)	84.2 (6.89)	85.0 (6.78)	85.2 (6.68)	85.4 (6.92)	85.1 (6.69)	86.8 (6.51)	88.2 (6.26)
Age range	65 –103	65–104	66–102	68–102	68–101	69–100	69–102	71–103	71–101	75–99	79 –99
%Female	64.8	68.2	71.2	73.5	76.5	77.7	78.8	78.2	75.3	75.8	66.7
Mean FI (SD)	0.23 (0.098)	0.27 (0.11)	0.29 (0.11)	0.31 (0.11)	0.31 (0.11)	0.31 (0.11)	0.31 (0.11)	0.30 (0.11)	0.31 (0.12)	0.29 (0.12)	0.34 (0.13)
FI range	0.015-0.57	0.022 –0.59	0.036–0.57	0.022–0.62	0.037–0.59	0.037–0.61	0.060–0.60	0.077–0.53	0.082–0.55	0.082–0.51	0.13-0.56
Mean SVI (SD)	0.23 (0.07)	0.23 (0.07)	0.24 (0.07)	0.24 (0.07)	0.24 (0.07)	0.24 (0.07)	0.25 (0.07)	0.25 (0.07)	0.25 (0.08)	0.27 (0.08)	0.28 (0.08)
SVI range	0.04-0.50	0.05-0.54	0.06-0.52	0.06-0.46	0.04-0.52	0.05-0.42	0.05-0.41	0.05-0.44	0.05-0.44	0.05-0.44	0.13-0.40

A# = Assessment number; FI = Frailty index; SD = Standard deviation; SVI = Social vulnerability index.

Table 3
Parameter estimates and confidence intervals.

	2005 Cohort				2008 Cohort			
Fixed Models								
	Null Model	Model 2	Model 3	Model 4	Null Model	Model 2	Model 3	Model 4
Intercept	0.233*** [0.230, 0.235]	0.225*** [0.222, 0.227]	0.234*** [0.227, 0.240]	0.231*** [0.224, 0.237]	0.234*** [0.231, 0.236]	0.228*** [0.225, 0.230]	0.234*** [0.227, 0.241]	0.231*** [0.224, 0.238]
Time		0.005*** [0.004, 0.005]	0.008*** [0.006, 0.009]	0.001 [−0.001, 0.002]		0.004*** [0.003, 0.005]	0.007*** [0.006, 0.009]	0.002 [0.000, 0.003]
Age			0.001*** [0.000, 0.001]	0.001*** [0.000, 0.001]			0.001*** [0.001, 0.001]	0.001*** [0.001, 0.001]
Sex = Male			−0.015*** [−0.021, −0.010]	−0.016*** [−0.021, −0.010]			−0.017*** [−0.023, −0.012]	−0.017*** [−0.023, −0.012]
Baseline FI			−0.002 [−0.004, 0.001]	−0.001 [−0.003, 0.002]			0.000 [−0.003, 0.003]	0.001 [−0.002, 0.003]
Time * Age			0.000 [0.000, 0.000]	0.000** [0.000, 0.000]			0.000 [0.000, 0.000]	0.000 [0.000, 0.000]
Time * Sex			0.000 [−0.001, 0.002]	0.000 [−0.002, 0.001]			0.000 [−0.001, 0.002]	0.000 [−0.002, 0.001]
Time × Baseline FI			−0.002*** [−0.002, −0.001]	0.000 [−0.001, 0.000]			−0.002*** [−0.002, −0.001]	−0.001 [−0.001, 0.000]
Change in FI				0.017*** [0.016, 0.019]				0.014*** [0.013, 0.016]
Covariance Parameters								
SD (Intercept)	0.055	0.059	0.059	0.059	0.057	0.061	0.060	0.061
SD (time)		0.008	0.008	0.008		0.008	0.008	0.008
Intercept x time		−0.396	−0.414	−0.432		−0.389	−0.409	−0.408
Residual	0.044	0.038	0.038	0.037	0.042	0.037	0.037	0.036
Model Fit								
AIC	−26,518.4	−27,294.2	−27,294.6	−27,801.9	−23,868.3	−24,445.0	−24,474.0	−24,762.3
BIC	−26,497.0	−27,251.5	−27,209.2	−27,709.4	−23,847.2	−24,403.0	−24,390.0	−24,671.2
ICC	0.61	0.71	0.71	0.72	0.65	0.73	0.72	0.74
RMSE	0.04	0.03	0.03	0.03	0.04	0.03	0.03	0.03
Deviance	−26,536.03	−27,332.12	−27,426.90	−27,948.92	−23,885.83	−24,482.74	−24,605.79	−24,908.43

* $p < 0.05$,.
** $p < 0.01$,.
*** $p < 0.001$AIC = Akaike information criterion; BIC = Bayesian information criterion; FI = Frailty index; ICC = Intraclass correlation coefficient; SD = Standard deviation.

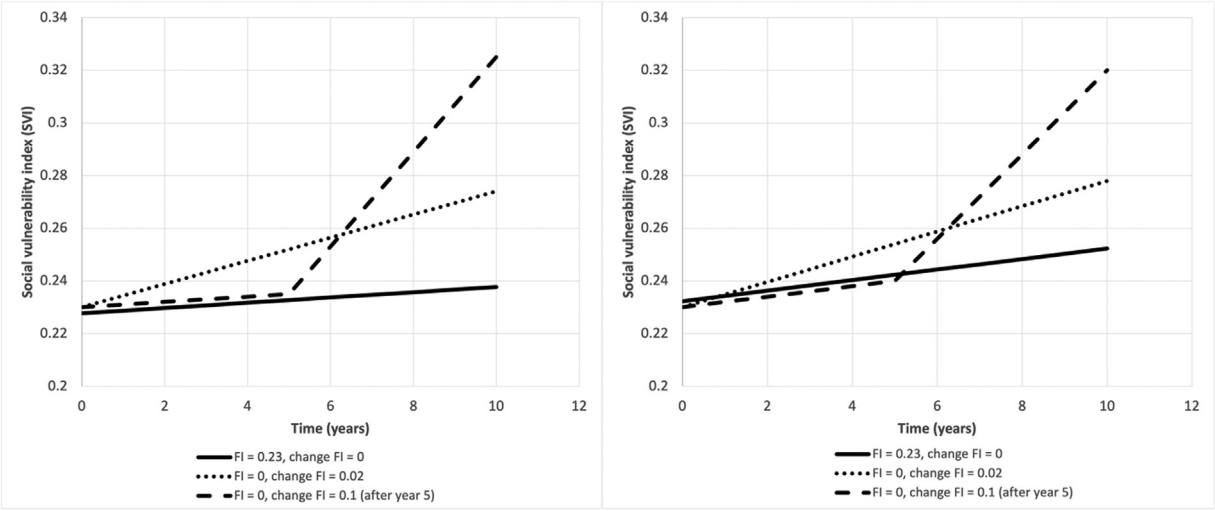

Fig. 1. Model 4 predicted change in SVI for 2005 cohort (left) and 2008 cohort (right) for three hypothesized female individuals with baseline frailty index of 0.23 (cohort means), 0, and 0, and change in frailty of 0, 0.02, and 0.1 (after year 5), respectively.

3.5. Model fit

Model 4 provided the best fit with the data and accounted for more variance in SVI change than prior models with a significant change in deviance between each subsequent model ($p < 0.001$).

3.6. Covariance parameters

In model 4 of the 2005 and 2008 cohorts, the correlation between the random effects is estimated to be −0.43 and −0.41, indicating that groups with higher intercepts tended to have slower rates of change over time. The remaining covariance parameters are also in Table 3.

3.7. Sensitivity analyses

Repeat analyses among individuals who died within three years of cohort intake, who had three or fewer assessments and four or more assessments yields results that are consistent (in direction and magnitude) demonstrating change in frailty is associated with greater social vulnerability (Supplementary Material).

4. Discussion

In a cohort of older adults assessed for public home care and residing in the community, we demonstrated a significant correlation between changes in frailty status over a 10-year period and change in social vulnerability. Notably, time alone and baseline frailty were not associated with greater social vulnerability in our final model. Individuals in the cohort may be frail, but if they stay the same level of frailty, their SVI will be stable. It is an individual's change in frailty that is more significantly associated with a rise in social vulnerability (the dashed lines in Fig. 1). Our findings also confirm several properties of social vulnerability indices in keeping with previous literature. No one has zero social vulnerability (minimum 0.02 in our data) [3,29]. Females have higher social vulnerability than males [7,30].

The finding that within person changes in frailty better predict social vulnerability adds to emerging literature on the value of within-person frailty fluctuations [31,32]. It is known frailty becomes more common as people age, yet there is significant variation in how it progresses. Individuals start their later years in widely different states of health and follow diverse frailty paths, which can include both slow and sharp rises in frailty, as well as periods of steadiness or even improvement [13]. Using the Survey of Health, Ageing and Retirement in Europe, Stolz et al. demonstrated within-person frailty fluctuations, representing loss of individual homeostasis, was associated with long-term frailty trajectories and mortality. Similar to our findings, the process of how rapidly or variably health deficit accumulated also has prognostication value, with the implications that frailty measurements in older adults should be measured more frequently to capture accurate trajectories [13].

Since it can be difficult to obtain appropriate data, our study is one of few studies examining frailty and social vulnerability dynamically over time. Our dataset, featuring repeated measurements over time, enabled us to use mixed effects models to analyze changes that would typically be reflected in observation level residuals, which are often viewed as measurement error or statistical noise [33]. Our findings are similar to previous literature showing between-person social vulnerability increases with age – in a cohort of American retirees, SVI was found to be u-shaped in relation to age decreasing until age 61 then increasing such that SVI was one standard deviation larger at age 90 than 60 [7]. While we found that baseline age at intake was associated with higher SVI, increasing age thereafter (time in our models) was not associated with higher social vulnerability.

Establishing that aging alone may not lead to increased social vulnerability is important. The attractiveness of defining social vulnerability and frailty, in comparison to age, is the shift from viewing age merely as an unchangeable risk factor to a broader reflection of life course changes that may be modifiable. Our findings suggest accumulating health deficits (frailty) may have a greater risk on social vulnerability among older adults. This allows us to postulate several possible mechanisms linking increasing frailty to social vulnerability. One research team described how biological mechanisms arise from immune and physiological responses that restructure the body's priorities for recuperation following an infection, perhaps manifesting as reduced participation in normal social activities [34]. Frailty has been shown to be linked to loneliness, social exclusion, and stigma and may be influencing social vulnerability through by subjective (e.g., loneliness) or objective (e.g., exclusion) separation of older adults from social networks [35–37]. Using a political economy of health lens, scholars have commented on the relationships between chronic illness and the broader determinants of health, which not only increase risk of frailty, but also cause social marginalization by exclusion from the labor market reducing social and capital resources; the loss of which are associated with social vulnerability [38]. Nonetheless, while we looked at frailty to explain social vulnerability, it is more likely that the relationship between the two is reciprocal. For example, each standard deviation increase from baseline social vulnerability has been found to correlate with a 20 %

increase in frailty at any age [7]. The interplay and interaction between both likely contributes to increased mortality and decline in quality of life [39].

5. Limitations

Our findings of associations between frailty and social vulnerability must be interpreted cautiously. The cohort from NS receiving long-term care may not represent broader populations or different regions. Home care practices, varying due to regional rules and regulations in Canada and internationally, make comparisons challenging. Consequently, our cohort might exhibit different social vulnerability compared to others receiving home care assessments, despite similar SVI means (ranging from 0.25 to 0.38) found in other studies [2,3,5,11]. Additionally, in this NS population, those remaining in our sample over time are individuals who have not died, not entered long-term care homes or recovered such that home care is no longer required. Unfortunately, a limitation of this data is the inability to track the characteristics of individuals who are lost to follow up (or their reasons are lost to follow up). This attrition bias (that people who stayed in the cohort are different than those who left the cohort) should be considered carefully. People likely exit this cohort when they accumulate enough frailty and/or social vulnerability (e.g., no one able to advocate for their needs) that they are not able to manage living at home, so the faster progressors will likely have disappeared. We hypothesize most people left the cohort due to illness or death as our mortality rates are high, similar to Jacobsen et al.'s longitudinal study of older adults living in the community in America, where one-third of the attrition was due to death and another 20 % was due to being too ill [40,41]. Nonetheless, in subgroup analyses, even among those who died within 3 years of home care intake or had fewer assessments, our results remained consistent.

6. Practice / policy relevance

Although our data have limitations, these insights still provide valuable understanding into how some frail individuals successfully live in the community over a decade. The findings are intriguing: while the mean frailty in the cohort increases over time, mean social vulnerability does not rise much (Table 2). This could highlight the critical role of a narrow social vulnerability index (SVI) range in maintaining community living. It also suggests that home care in NS may better respond to frailty but cannot respond to worsening social vulnerability and these clients exit the home care system. A key predictor of increasing social vulnerability could be the rate at which frailty changes, as illustrated in Model 4 and a hypothetical clinical scenario (Fig. 1) where frailty jumps significantly after 5 years. In such cases, a client's rapidly increasing frailty might link to high social vulnerability soon to exceed the capacity of home care services. This has implications on the scope of home care: Critics have suggested that home care no longer provides basic help such as cooking, driving, visiting, and maintaining a home – the functional social elements that could keep people at home [42]. It has been suggested home care services are overmedicalized largely focusing on responding to short term health problems [42]. Further exploration of FI and SVI in this population could lead to different decisions related to publicly funded health care programs within and around home care – for example, perhaps home care case management consideration of measures such as the FI and SVI could lead to additions of services and supports to stretch the maximum threshold of frailty and social vulnerability supported in the community.

7. Conclusion

By examining changes in social vulnerability and frailty in older adults in the community assessed for home care services, we highlight the importance of longitudinal analyses accounting for within-person changes in frailty in relation to social vulnerability. The results suggest that although social vulnerability tends to remain constant in the absence of increases in frailty, changes in frailty are closely associated with changes in social vulnerability, even after accounting for baseline frailty, age, sex and interactions with time. Incorporating within-person changes in health into quantitative models of late-life social vulnerability may further improve our understanding of how and why some individuals are able to stay in the community despite their vulnerabilities. The study highlights the importance of monitoring frailty and social vulnerability in older adults with implications for predicting the trajectories of home care clients.

Consent for publication

Not applicable

Ethics approval and consent to participate

Not applicable

Declaration of generative AI and AI-assisted technologies in the writing process

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Declaration of competing interest

JCM is an Geriatric Medicine resident with Nova Scotia Health and receives scholarships supporting her PhD research from the Department of Medicine at Dalhousie University, Dalhousie Medical Research Foundation, Dr. Patrick Madore Foundation and the Pierre Elliott Trudeau Foundation. MKA reports grants from Sanofi, grants from GSK, grants from Pfizer, grants from Canadian Frailty Network, grants from Merck, grants from Public Health Agency of Canada, grants from Canadian Institutes of Health Research, outside the submitted work. KR is President of Ardea Outcomes, which in the last five years has contracts with pharma and device manufacturers on individualized outcome measurement. In 2019 he attended an advisory board meeting with Nutricia. Otherwise any personal fees are for invited guest lectures and academic symposia, received directly from event organizers, chiefly for presentations on frailty. Until December 2023, he was Associate Director of the Canadian Consortium on Neurodegeneration in Aging, which is funded by the Canadian Institutes of Health Research, and with additional funding from the Alzheimer Society of Canada and several other charities. He receives career support from the Dalhousie Medical Research Foundation as the Clinical Research Professor of Frailty & Aging, Research Nova Scotia, and research support from the Canadian Institutes of Health Research, the QEII Health Science Centre Foundation, the Capital Health Research Fund and the Fountain Family Innovation Fund of the QEII Health Science Centre Foundation. KR has asserted copyright of the Clinical Frailty Scale through Dalhousie University. Use is free for research, education or not-for-profit care (users are asked not to change it or charge for its use). The remaining authors have no conflicts of interest.

CRediT authorship contribution statement

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.tjfa.2025.100031.

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