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A frailty-intrinsic capacity index to predict disability in community-dwelling older Japanese adults

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ABSTRACT

Purpose: We constructed and validated a frailty-intrinsic capacity (FR-IC) index for predicting disability in community-dwelling older Japanese adults.
Methods: This longitudinal cohort study included 1179 participants aged ≥60 years (mean age: 71.3 ± 7.4 years, 51 % men). A multidisciplinary geriatric team constructed a 35-item FR-IC index (score range: 0: robust to 1: severe frailty, accumulation model) comprising 15 domains incorporating the intrinsic capacity concept (IC-Vision, IC-Hearing, IC-Locomotor capacity, IC-Cognition, IC-Vitality, and IC-Psychological capacity) based on questionnaires widely used in Japan. To test predictive validity, age- and sex-adjusted Cox proportional hazard models estimated hazard ratios (HRs) for incident disability (care need levels ≥1) by FR-IC index quartiles using the cohort study's existing data.
Results: The mean FR-IC index score (32 items, three missing) was 0.08±0.05 (range: 0.00–0.31). During a mean follow-up of 9.0 ± 2.8 years, 284 (24 %) adults developed a disability. Compared with the lowest quartile, the adjusted HRs for developing an incident disability in the second to fourth quartiles were 2.32 (95 % confidence interval: 1.15–5.33), 3.18 (1.64–7.15), and 4.15 (2.14–9.32), respectively. The area under the curve of the FR-IC index for incident disability was 0.86. Among healthy participants, defined as robust by the baseline phenotypic physical frailty assessment ($n = 437$), sex- and age-adjusted HRs for incident support care through the second to third tertiles were 1.72 (0.79–4.30) and 2.51(1.17–6.22), respectively (trend $P = 0.028$).
Conclusions: The novel FR-IC index can predict future disability among community-dwelling older Japanese adults. Integrating IC into frailty assessments provides a more comprehensive measure of aging.

Introduction

Frailty, also known as "frailty syndrome," is commonly seen in older adults and characterized by a decline in physical and physiological reserves, which increases vulnerability to stressors [1].

The following two primary approaches explain frailty: 1) the "accumulated deficit model," which evaluates frailty by assessing the accumulation of impairments, functional disabilities, and age-related diseases and can evaluate every individual; and 2) the "phenotype model," which captures symptoms resulting from age-related physiological function decline as a pre-disability syndrome [2]. Most phenotypic models, including that in the Cardiovascular Health Study [1], comprise five classifications (e.g., unintentional weight loss, exhaustion, weakness, slow walking speed, and low physical activity) and are

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insufficient for determining individual health differences in healthy older adults because of the simplicity of the assessment. Cumulative deficit models tally various health deficits, e.g., those related to cognition, mood, and social support. Given their comprehensive nature, cumulative models are more sensitive to underlying health changes than are phenotypic models and may be more effective in evaluating health improvements following interventions targeting frailty-related outcomes [3]. However, it requires several items to quantitatively and chronologically assess age-related diseases and functional disorders, and these items are not sufficiently standardized [3]. The aging period in aging societies is increasing, and a preventive approach to frailty progression from early to advanced stages that leverages individual abilities is desirable. Thus, a highly versatile evaluation index that can be easily used by healthcare professionals to chronologically evaluate frailty and ability across different stages from healthy aging to end of life is required.

Intrinsic capacity (IC) is "the composite of all physical and mental capacities that an individual can draw on" [4]. IC assessment, which focuses on maintaining physical and psychological functions rather than their decline to deliver effective interventions that prevent and delay functional decline progression, is highly significant in healthcare settings involving older individuals; the World Health Organization has developed the Integrated Care for Older People (ICOPE) guidelines [4]. The degree of health impairment usually increases with age, whereas some physical and psychological functions, especially positive aspects like happiness, life satisfaction, and vitality, do not necessarily decline in parallel [5,6]. However, most healthcare professionals lack guidance or training to recognize capacity [4]. Social networks and self-reported health are important components of life satisfaction for frail older adults [7]. To ensure the well-being of all, even if physical functions decline, not only the degree of health impairment but also ICs, including psychological health and motivation, should be assessed to maintain and support these positive aspects. Recently, it was reported that declines in IC functions may precede frailty progression [8]. However, the trajectories of physical frailty phenotypes [9] and the IC trajectory [10] were found to vary considerably among individuals; moreover, health-related determinants were diverse among older adults. Therefore, in later life, rather than uniform health guidance, individualized intervention strategies based on a comprehensive understanding of each individual's functional abilities and living environment should be proposed with the goal of improving quality of life.

An index with both dimensions, health impairment and IC, can facilitate individual abilities that prevent frailty progression. Previous studies developed various frailty indices based on participants in primary care [7] and hospital settings [11,12]. However, an index incorporating the concept of IC and focusing on individuals from relatively healthy to end-of-life stages remains to be developed.

Therefore, we developed a new frailty-IC (FR-IC) index based on a deficit model combined with the concept of IC across diverse cohorts, from relatively healthy to severely frail older adults. During its construction, items were selected using previously described methods [13] and questionnaires widely used in Japan's health, medical, and welfare sectors [14–16] to retrospectively calculate the FR-IC index. Our final goal is to deliver a useful frailty index that can assess IC by validating it at the community level, in medical settings, and in caregiving environments. As the first step, this study aimed to construct and validate the FR-IC index for predicting future disability in relatively healthy older adults in community settings.

Methods

Study cohort

Data were collected as part of the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA), a community-based study. This cohort study assessed normal aging over time using detailed questionnaires, medical checkups, anthropometric measurements, physical fitness tests, and nutritional examinations. The details of the NILS-LSA have been reported previously [17]. The initial NILS-LSA survey involved 2267 men and women aged 40–79 years and age-stratified by sex and decade, selected randomly from individuals living in Obu City and Higashiura Town in Aichi Prefecture, Japan. These participants were followed up every 2 years from the first (1997 to 2000) to the sixth (2008 to 2010) and seventh (2010 to 2012) study waves. Data were obtained from the seventh wave of the NILS-LSA, which included 1179 participants aged $\geq$60 years (mean age $\pm$standard deviation [SD]: 71.3 $\pm$ 7.4 years; 51 % men).

FR-IC index construction

A 35-item FR-IC index comprises 15 domains: basic activities of daily living (ADL), vision, hearing, polypharmacy, instrumental ADL, locomotion, nutrition, oral function, going out/falling, sleep, disease, cognitive function, vitality, social relations, and psychological well-being. Key domains of IC [4] were incorporated as vision (IC-Vision), hearing (IC-Hearing), locomotion (IC-Locomotor capacity), cognitive function (IC-Cognition), vitality (IC-Vitality), and psychological well-being (IC-Psychological capacity).

The 35-item FR-IC index (comprising items No. 1–6, [11] No. 7–8, [12] No. 9, [18] No. 10, [19] No.11 [20], No. 12 [21], No.13 [14], No. 14 [22], No. 15–19 [14], No. 20 [23], No. 21–26 [24], No. 27 [25], No.28 [14], No. 29 [26], No. 30 [27], No. 31 [28], No. 32 [29], No. 33 [30], No. 34 [31,32], and No. 35 [32,33], with each item score ranging from 0 to 1; Table 1) was constructed based on the method and concept introduced by the accumulation model described by Theou et al. [13], comprehensive geriatric assessments [15], the long-term care information system for evidence (LIFE) in Japan [16], and the *Kihon* checklist developed by the Japanese Ministry of Health, Labour and Welfare to identify older individuals at risk of requiring care/support [14]. eText and eFigure 1 outline the study framework in detail.

These items were selected and determined based on the opinions of a multidisciplinary team of geriatric specialists, pharmacists, registered dietitians, physical therapists, public health nurses, psychologists, caregiving practitioners, and epidemiologists. Priority was given to items that were 1) easily assessable by the public, regardless of multiple healthcare professions; 2) routinely collected in Japanese health, medical, and nursing care settings; and 3) measurable in both preventive medicine and caregiving fields. Duplicated items were removed, e.g., both Katz [11] and Barthel indexes are parts of ADL assessments, but the FR-IC index only includes the Barthel index.

FR-IC scoring

The total score of the FR-IC index was calculated using 32 of the 35 items, because three items (No. 15, lost 2 kg or more in the past 6 months; and No. 16, 17, oral function; Table 1) were missing in this study cohort. Because data for item No. 15 were available for a subset of participants, additional analysis was conducted in the discussion. Among the 35 items, the three missing items comprised $<$20 % of all items; therefore, 32 items were evaluated on the basis of a previous study [13]. Three variables (No. 11 [20], able to use a mobile phone; No. 12 [21], moves around the house independently; No. 30 [27], greets or talks to people voluntarily) were alternatively assessed. As all individuals participated voluntarily and scheduled their participation in this observational study [17], we considered that all study participants met the criteria "able to use a mobile phone" and "greets or talks to people voluntarily." Participants who could move around the facility (survey center) without assistance were considered to meet the criteria "moves around the house independently." The final FR-IC index was calculated by dividing the total score for all 32 items by 32. The FR-IC score (ranging from 0 [no deficit] to 1 [full deficit]) was calculated for each participant, and the participants were categorized based on their

Table 1
35-item FR-IC comprising 15 domains and their prevalence rates in the NILS-LSA cohort.

35-item FR-IC				NILS-LSA cohort (n=1,179)
No.	Questionnaire	Cutoff values and scores	Ref.	Prevalence
Basic ADLs*				
1	Takes a bath independently	Independence=0 Partial assistance=0.5 Dependence=1	[11]	Independence (100%) Partial assistance (0%) Dependence (0%)
2	Puts on clothes, shoes, orthotics, and corsets independently	Independence=0 Partial assistance=0.5 Dependence=1		Independence (100%) Partial assistance (0%) Dependence (0%)
3	Goes to the toilet independently (uses a portable toilet or urinal for washing and handrails or assistive devices, but can do everything on his/her own)	Independence=0 Partial assistance=0.5 Dependence=1		Independence (100%) Partial assistance (0%) Dependence (0%)
4	Moves in and out of beds or chairs unassisted	Independence=0 Partial assistance=0.5 Dependence=1		Independence (100%) Partial assistance (0%) Dependence (0%)
5	Exercises complete control over urination and defecation (patients with spinal cord or other injuries may use suppositories or enemas; patients with such injuries must be able to put on and take off the urinary incontinence device and clean it)	Independence=0 Partial assistance=0.5 Dependence=1		Independence (100%) Partial assistance (0%) Dependence (0%)

(*continued on next page*)

Table 1 (*continued*)

6	Gets food from a plate into the mouth without help, within an appropriate time frame (can wear self-help devices but eats meals without assistance)	Independence=0 Partial assistance=0.5 Dependence=1		Independence (100%), Partial assistance (0%) Dependence (0%)
Vision (IC-Vision)				
7	Vision problems (including when using glasses, contact lenses, etc.)	Can see well enough=0 Can see a little=0.5 Cannot see=1	[12]	Can see well enough (63.1%) Can see a little (36.9%) Cannot see (0%)
Hearing (IC-Hearing)				
8	Hearing problems (including when using hearing aids, etc.)	Hears well enough=0 Hears not enough=0.5 Cannot hear=1	[12]	Hears well enough (43.2%) Hears not enough (56.8%) Cannot hear (0%)
Polypharmacy				
9	Takes more than five medications per day	No=0 Yes=1	[18]	No (66.3%) Yes (33.7%)
Instrumental ADLs				
10	Does general household chores by him/herself (excluding heavy lifting)	Yes=0 No=1	[19]	Yes (99.6%) No (0.4%)
11	Able to use a mobile phone	Yes=0 No=1	[20]	Yes (100%) No (0%)
Locomotion (IC-Locomotor capacity)				
12	Moves around the house independently	Independence=0 Partial assistance=0.5	[21]	Independence (100%) Partial assistance (0%) Dependence (0%)

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Table 1 (*continued*)

		Dependence=1		
13	Walks continuously for about 15 minutes	Yes=0 No=1	[14]	Yes (95.7%) No (4.3%)
Nutrition				
14	BMI	BMI ≥18.5 kg/m^2 (<70 years), ≥20.0 kg/m^2 (≥70 years)=0 BMI <18.5 kg/m^2 (<70 years), <20.0 kg/m^2 (≥70 years)=1	[22]	BMI ≥18.5 kg/m^2 (<70 years), ≥20.0 kg/m^2 (≥70 years) (87.8%) BMI <18.5 kg/m^2 (<70 years), <20.0 kg/m^2 (≥70 years) (12.2%)
15	Lost 2 kg or more in the past 6 months[†]	No=0 Yes=1	[14]	Yes (9.4%) No (90.6%)
Oral function				
16	Has difficulty eating tough food (including when using dentures or similar)	No=0 Yes=1	[14]	Missing[‡]
17	Sometimes choking on tea or soup	No=0 Yes=1		Missing[‡]
Going out/falls				
18	Goes out at least once a week (including day service use, etc.)	Yes=0 No=1	[14]	Yes (99.5%) No (0.5%)
19	Does have a fear of falling while walking?	No=0 A little=0.5 Very=1		No (39.2%) A little (46.1%) Very (14.7%)
Sleep				
20	Bad overall sleep quality (when taking sleeping pills, the answer is “yes”)	No=0 Yes=1	[23]	No (96.9%) Yes (3.1%)

(*continued on next page*)

Table 1 (*continued*)

Disease				
	Have you been diagnosed with any of the following diseases?			
21	Cerebrovascular disease (stroke)	No=0 Yes=1	[24]	No (93.7%) Yes (6.3%)
22	Cardiovascular disease (heart disease)	No=0 Yes=1		No (82.1%) Yes (17.9%)
23	Malignant tumor (cancer)	No=0 Yes=1		No (91.0%) Yes (9.0%)
24	Diabetes mellitus	No=0 Yes=1		No (89.8%) Yes (10.2%)
25	Parkinson's disease	No=0 Yes=1		No (100%) Yes (0%)
26	Rheumatoid arthritis or knee osteoarthritis	No=0 Yes=1		No (61.7%) Yes (38.3%)
Cognitive function (IC-Cognition)				
27	Reads newspapers, books, or magazines, and watches or listens to educational programs on TV or radio	Yes=0 No=1	[25]	Yes (97.5%) No (2.5%)
28	People around you tell you that you are forgetful, such as "you always ask the same thing"	No=0 Yes=1	[14]	No (96.1%) Yes (3.9%)
Vitality (IC-Vitality)				
29	Has an appetite	Yes=0 No=1	[26]	Yes (99.6%) No (0.4%)
30	Greets or talks to people voluntarily	Greets or talks voluntarily=0 Responds and smiles to greetings and invitations=0.5 No response=1	[27]	Greets or talks voluntarily (100%) Responds and smiles to greetings and invitations (0%) No response (0%)

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Table 1 (*continued*)

Social relations				
31	Participates in social activities such as work, volunteer work, hobby groups, etc. (alternatively, has roles in institutions, homes, etc.)	Yes=0 No=1	[28]	Yes (98.4%) No (1.6%)
32	Talks to someone at least once a day (including healthcare professionals, etc.)	Yes=0 No=1	[29]	Yes (95.3%) No (4.8%)
33	Has people who care and consider him/her (including healthcare professionals, etc.)	Many=0 A little=0 Not at all=1	[30]	Many (99.8%) A little (0%) Not at all (0.2%)
Psychological well-being (IC-Psychological capacity)				
34	Enjoyment in daily life	Yes=0 A little=0 Not at all=1	[31,32]	Yes (97.1%) A little (0%) Not at all (2.9%)
35	Overall life satisfaction	Yes=0 A little=0 No=1	[32,33]	Yes (93.6%) A little (0%) No (6.4%)

Note. Abbreviations: FR-IC, frailty-intrinsic capacity; NILS-LSA, National Institute for Longevity Sciences-Longitudinal Study of Aging; ADLs, activities of daily living; BMI, body mass index.
*If you do not normally do that (use it), please answer assuming you would do that (or use it).
†"Lost 2 kg or more in the past 6 months (No.15)" is based on n = 1091 participants with body weight data in both the sixth and seventh waves.
‡These two items are missing in this cohort.

FR-IC index quartile.

Incident disability and incident support care

At baseline (2010–2012), all participants were fully independent (100 % independence in basic ADLs No. 1–6, Table 1) and not certified as requiring long-term care. Incident functional disability was defined as care level 1 or higher in the Long-term Care Insurance System in Japan until January 2021. This mandatory national social insurance assists disabled and older adults in their ADLs [34]. It includes two levels of support care (support required) and five levels of nursing care (care levels 1 to 5).

Incident functional disability was defined as care level 1 or higher, while incident support care was defined as support care level 1 or 2 in the Long-term Care Insurance System in Japan until January 2021.

Assessment of phenotypic physical frailty

To examine the relationship between the degree of physical frailty and the FR-IC index, phenotypic physical frailty was assessed based on the modified Cardiovascular Health Study criteria; these criteria were specifically modified for older Japanese adults [35], as follows: 1) weight loss (weight loss of ≥5 % in the previous 2 years, i.e., as compared to the participant's weight in the NILS-LSA, sixth wave [2008–2010]); 2) weakness (a maximum grip strength <28 kg for men and <18 kg for women within four trials for both hands with two trials per hand); 3) exhaustion (a response of "≥1 day within the past week" to either of the following two questions from the Center for Epidemiologic Studies of Depression Scale [CES-D]: [36] "I felt that everything I did was an effort" and "I could not get 'going'"); 4) slowness (gait disturbances or a gait speed of <1.0 m/s in a 10-m walk test using a comfortable walking speed); and 5) low physical activity (the lowest 20 % metabolic equivalents of leisure-time physical activity by sex, which was assessed based on the modified Minnesota Leisure-time Physical

Activity Questionnaire [37]). Phenotypic physical frailty was considered present when ≥3 criteria were met. Among the 1179 study participants, 1088 participated in both the sixth and seventh waves. These participants could be evaluated for phenotypic physical frailty and were categorized as robust (0 criteria), pre-frail (1–2 criteria), or frail (3–5 criteria; Table 2).

Other measurements

Medical history (yes/no, including cerebro-cardiovascular disease, malignant tumor, diabetes mellitus, dementia, rheumatoid arthritis, and knee osteoarthritis), smoking status (current, former, or never), and educational level (years) were obtained using a self-administered questionnaire. Medical doctors and trained staff confirmed the responses to the self-reported questionnaire.

Statistical analysis

Continuous variables are presented as mean±SD and categorical data as percentage. The study participants were grouped by the FR-IC index quartile. Characteristics differences in proportions and continuous variables according to the FR-IC index quartile were tested using the chi-squared test (or Fisher's exact test when the expected frequency was <5) and analysis of variance, respectively. The time to incident disability was described using Kaplan–Meier curves, with participants stratified by FR-IC index quartiles. To test predictive validity, we used Cox proportional hazard models to estimate hazard ratios (HRs) for incident disability across FR-IC index quartiles. Model 1 was adjusted for age (years, continuous), and Model 2 was adjusted for sex and age. The area under the curve (AUC) of the FR-IC index for incident disability was calculated using a logistic regression model (Model 3).

We conducted two sub-analyses: 1) FR-IC index as a predictor of incident support care (pre-disability level) even in healthy participants defined as robust based on the phenotypic physical frailty assessment, and 2) significance of incorporating IC into the assessment index. Age- and sex-adjusted Cox proportional hazard models were used to estimate HRs for incident support care across FR-IC index tertiles among robust participants ($n = 439$, $n = 437$ were free from support care) at baseline and age- and sex-adjusted HRs for incident disability across 10 items from which items related to IC components (IC-Vision, IC-Hearing, IC-Locomotor capacity, IC-Cognition, IC-Vitality, and IC-Psychological capacity) were removed.

All reported P-values were two-sided, and $P < 0.05$ was considered statistically significant. All statistical analyses were conducted using Statistical Analysis System VIYA software version STable 2024.10 (SAS Institute Inc., Cary, NC, USA).

Ethics approval

The NILS-LSA followed the principles of the Declaration of Helsinki and Ethical Guidelines for Epidemiological Research in Japan. This study was approved by the Ethics Committee of XXXX (No. 1665–2,1875). Written informed consent was obtained from all participants.

Results

During a mean follow-up period of 9.0 ± 2.8 years, 284 (24 %) individuals developed disability. Table 2 shows the characteristics of the participants according to their FR-IC index quartiles. The mean FR-IC index was 0.08±0.05 (range: 0.00–0.31); the distribution of the FR-IC index was skewed toward lower values (eFigure 2).

The mean age of participants in the group with higher FR-IC scores was increased (Table 2). The proportions of men and individuals with >9 years of education were lower in the group with a higher FR-IC index. As the FR-IC index increased, the number of participants with cerebro-cardiovascular disease, malignant tumor, diabetes mellitus, and rheumatoid arthritis also increased. Among the 1088 participants with available data from both the sixth and seventh waves to estimate their phenotypic physical frailty, the prevalence rates of robust, pre-frail, and frail categorizations were 40.4 %, 52.9 %, and 6.8 %, respectively. The prevalence rates of robust categories decreased while those of frail categories increased in the group with a higher FR-IC index. None of the participants were categorized as having deficits in basic ADLs (bathing, clothing, toilet, movement, exercise, and eating; Table 1). More than 30 % participants took >5 medications (polypharmacy) and self-reported the presence of rheumatoid arthritis or knee osteoarthritis. eFigure 3 shows the crude HRs for incident disability, and Table 3 shows the HRs for incident disability by FR-IC index quartile. More than 30 % of participants with an FR-IC index above the median (0.063, approximately 2.0 original points) required care (Q3 and Q4, Table 3). Compared with the lowest FR-IC index quartile, the sex- and age-adjusted HRs for incident disability through the second to fourth quartiles were 2.32 [95 % confidence interval: 1.15–5.33], 3.18 [1.64–7.15], and 4.15 [2.14–9.32], respectively (trend $P < 0.0001$). AUC of the FR-IC index for incident disability was 0.86 (eFigure 4). In sub-analyses of the 32 items

Table 2
Characteristics of the study participants by FR-IC index quartile.

			Total (n = 1179)		Quartile of the FR-IC index						P†	trend P
					Q1 (n = 162)		Q2 (n = 298)		Q3 (n = 399)		Q4 (n = 320)			
FR-IC index		Range	0.00–0.313		0.00–0.016		0.031–0.047		0.063–0.094		0.109–0.313			
		Median	0.063		0.016		0.047		0.078		0.125			
Men		n (%)	604	(51.2)	104	(64.2)	156	(52.4)	188	(47.1)	156	(48.8)	0.002	0.001
Age, years		mean (SD)	71.3	(7.4)	67.4	(5.9)	69.0	(6.6)	71.5	(7.2)	75.1	(7.2)	<0.001	<0.001
Educational years >9		n (%)	846	(71.8)	121	(74.7)	221	(74.2)	298	(74.7)	206	(64.4)	0.008	0.005
Current smoker		n (%)	111	(9.4)	24	(14.8)	27	(9.1)	34	(8.5)	26	(8.1)	0.087	0.021
Cerebrovascular disease		n (%)	74	(6.3)	0	(0.0)	2	(0.7)	18	(4.5)	54	(16.9)	<0.001	<0.001
Cardiovascular disease		n (%)	211	(17.9)	0	(0.0)	22	(7.4)	65	(16.3)	124	(38.8)	<0.001	<0.001
Malignant tumor		n (%)	106	(9.0)	0	(0.0)	14	(4.7)	33	(8.3)	59	(18.4)	<0.001	<0.001
Diabetes mellitus		n (%)	120	(10.2)	0	(0.0)	8	(2.7)	37	(9.3)	75	(23.4)	<0.001	<0.001
Dementia		n (%)	3	(0.3)	0	(0.0)	1	(0.3)	0	(0.0)	2	(0.6)	0.337	0.154
Rheumatoid arthritis or knee osteoarthritis		n (%)	452	(38.3)	0	(0.0)	68	(22.8)	183	(45.9)	201	(62.8)	<0.001	<0.0001
			Total (n = 1088*)		Q1 (n = 151)		Q2 (n = 279)		Q3 (n = 374)		Q4 (n = 284)		P†	
Phenotypic physical frailty	Robust	n (%)	439	(40.4)	97	(64.2)	136	(48.8)	136	(36.4)	70	(24.7)	<0.001	–
	Pre-frail	n (%)	575	(52.9)	54	(35.8)	131	(47.0)	227	(60.7)	163	(57.4)		
	Frail	n (%)	74	(6.8)	0	(0.0)	12	(4.3)	11	(2.9)	51	(18.0)		

Note. FR-IC, frailty-intrinsic capacity.
* Among 1179 participants, 1088 were able to assess their weight loss since they had participated in both the sixth and seventh waves.
† Chi-squared test (or Fisher's exact test when the expected frequency was less than five) or analysis of variance.

Table 3
Hazard ratios for incident disability by FR-IC index quartile.

		Quartile of the FR-IC index (n = 1179)				Trend P
		Q1 (n = 162)	Q2 (n = 298)	Q3 (n = 399)	Q4 (n = 320)	
	FR-IC index, median	0.016	0.047	0.078	0.125	
Incident disability	n (%)	8 (4.9)	42 (14.1)	104 (26.1)	130 (40.6)	<0.001
Hazard ratios for incident disability (95 % confidence interval)	Crude	ref	3.06 (1.52–7.04)	6.00 (3.12–13.40)	11.35 (5.94–25.26)	<0.001
	Age-adjusted	ref	2.26 (1.12–5.19)	3.02 (1.56–6.77)	3.91 (2.02–8.79)	<0.001
	Sex- and age-adjusted	ref	2.32 (1.15–5.34)	3.18 (1.64–7.15)	4.15 (2.14–9.32)	<0.001

Note. FR-IC, frailty-intrinsic capacity.

used in the main analysis, AUCs of the FR-IC index for incident disability were 0.86 for 22 items (32 items excluding IC components).

Among the healthy participants, defined as robust by the phenotypic physical frailty assessment at baseline ($n = 437$) in the sub-analyses, 78 (18 %) developed support care during the follow-up (Table 4). Compared with the lowest FR-IC index tertile, the sex- and age-adjusted HRs for incident support care through the second to third tertiles were 1.72 [0.79–4.30] and 2.51 [1.17–6.22], respectively (trend $P = 0.028$). AUC of the FR-IC index for incident disability was 0.82.

Discussion

In this study, we developed the FR-IC index based on a deficit model combined with the concept of IC and validated it as a predictor of future disability among relatively healthy, older, community-dwelling adults. The 5-item assessment of phenotypic physical frailty showed an apparent dose–response relationship with the FR-IC index score, with the latter being higher for participants with frailty. Although the prevalence of phenotypic physical frailty was low (6.8 %), more than 30 % participants with an FR-IC index above the median (0.063) required care during a 9-year follow-up.

While research has developed various frailty indices based on participants in primary care and hospital settings, a comprehensive index focusing on individuals in relatively healthy to end-of-life stages is lacking [38,39]. The major advantage of the FR-IC index is that it can be applied to not only populations at risk of disability, as targeted by the ICOPE guidelines [4], conventional cumulative deficit models [2], and the Clinical Frailty Scale [40], but also independent older adults prior to the onset of disability. Moreover, because the only measured variable is BMI, the index can be easily used by nonspecialists and is also suitable for self-management of individual health.

A recent report indicated that satisfaction with everyday life is lower among frail individuals later in life, whereas enjoyment in daily life or overall life satisfaction is not; this makes a brief well-being assessment worthwhile [32]. Our results suggest that motivation, social relationships, and psychological well-being could be relatively preserved during frailty progression, even as physical function declines.

The FR-IC index was developed based on an accumulation model [13] with >30 items. The indices show certain characteristics: a positive association with age, a left-skewed frequency distribution, higher mean frailty index scores for women than for men, and scores <0.7 for at least 99 % samples. Our newly developed FR-IC index is reasonable because its score increased with age and was skewed toward lower values [41], a higher proportion of women belonged to the group with a higher FR-IC index, and >99 % participants had a score of ≤0.7. However, accumulation models [13] should exclude variables when coded deficits are too rare (<1 %) or too common (>80 %). The newly developed FR-IC index included ADL although <1 % participants had disabilities. However, we selected ADL-related items because the FR-IC index was designed to evaluate frailty over time and various frailty stages. We also incorporated major items from established Japanese assessment tools such as comprehensive geriatric assessments [15], the LIFE database [16], and the *Kihon* Checklist [14] in order to facilitate broad implementation in Japan's healthcare and preventive care systems.

Preventing frailty progression using individual abilities identified through the new frailty index is important, as is understanding the extent of frailty and utilizing these identified individual abilities to implement personalized interventions. While developing the FR-IC index, the concepts of IC, which are not assessed by existing methods, were evaluated. In sub-analyses of the 10 items excluding IC components, the prognostic ability was still high, with areas under the receiver operating characteristic curves for the three scores being almost the same (0.86 for 32 items and 0.86 for 22 items).

Thus, one study limitation was that the significance of incorporating IC into the assessment index was not fully apparent in this study population. However, incorporation of IC enables linkage to the WHO's functional capacity framework, thus providing a pathway toward targeted interventions. The prevalence of physical frailty was low in this relatively healthy population, and the significance of including IC and psychological measures requires further studies in less healthy populations. Another limitation was that some items, including those related to oral health, were selected by various professions; however, we

Table 4
Hazard ratios for incident support care (pre-disability level) by FR-IC index tertile among robust participants.

		Tertile of the FR-IC index (n = 437)*			Trend P
		T1 (n = 97)	T2 (n = 188)	T3 (n = 152)	
	FR-IC index, median	0.016	0.047	0.094	
Incident support care	n (%)	7 (7.2)	28 (14.9)	43 (28.3)	<0.001
Hazard ratios for incident support care (95 % confidence interval)	Crude	ref	2.22 (1.03–5.52)	4.44 (2.13–10.80)	<0.001
	Age-adjusted	ref	1.69 (0.78–4.20)	2.38 (1.12–5.86)	0.037
	Sex- and age-adjusted	ref	1.72 (0.79–4.30)	2.51 (1.17–6.22)	0.028

Note. FR-IC, frailty-intrinsic capacity.
* Among 439 robust participants, 437 were free from support care at baseline.

were unable to evaluate these items because they were missing from our study cohort. The significance of these items, including oral frailty, which is associated with adverse health outcomes [42], remains unverified. Because body weight loss was assessed only in a subset of participants, we reanalyzed the data using 33 items (including weight loss; $n = 1091$). The main results remained unchanged, with a slight improvement in AUC to 0.87. The full 35-item index might be more strongly associated with future disability. Moreover, we developed the FR-IC index using accumulation model methods [13] and existing tools including comprehensive geriatric assessments [15], the Japanese LIFE dataset [13], and the Kihon checklist [14]. Therefore, historical scores can be calculated with this index, enabling time-series assessments. In Japan, with its universal health insurance system and the integration of medical and long-term care data under the "My Number system," [43] this index could potentially be linked to national databases in the future, enabling individual-level longitudinal monitoring of the frailty risk.

Other limitations must be considered. We prioritized limiting the number of items to ≤35, incorporating as many existing measures as possible, integrating ICOPE domains, ensuring applicability from independence to end of life, and excluding most measured values (except BMI). As a result, some items—such as oral function and basic ADL impairments—were included despite limited validity or rarity among healthy participants. The median frailty score was low (0.063), and further studies are needed to examine its distribution and predictive performance among individuals with care needs. Future work will involve validation of the FR-IC scale in clinical and long-term care settings and examining its relationship with the Clinical Frailty Scale and national long-term care certification data. In addition, because the FR-IC items were selected with consideration of Japan's social, cultural, and philosophical contexts, adaptation of item wording may be necessary for use in other cultural settings.

The strength of this study was that the 35-item FR-IC index was constructed by a multidisciplinary geriatric team, which is the first to incorporate the IC concept proposed by WHO. This approach not only allows the evaluation of frailty but also facilitates the development of specific intervention strategies. The number of items is relatively close to the minimum of 30 [10], and assessments are easy because most items are routinely evaluated in Japanese healthcare settings; moreover, because it requires no measured values other than BMI, it can be administered by nonspecialists. Furthermore, the FR-IC index is able to predict the need for support care in healthy subjects, which has been difficult with previous phenotypic models. This indicates the importance of using the FR-IC index to prevent frailty from the early stage, even in robust older adults.

In conclusion, the FR-IC index, including the IC concept, can predict future disability in relatively healthy, community-dwelling older Japanese adults. Integrating IC into frailty assessment provides a more comprehensive measure of aging, addressing physical, cognitive, and psychological dimensions.

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Data statement

All data generated in the current study are included in this article (or its supplementary materials) or are available upon reasonable request and with permission of the NILS-LSA investigators (https://www.ncgg.go.jp/research/lab/cgss/department/ep/index.html); as the data are under license for the current study, some restrictions to data sharing may apply.

CRediT authorship contribution statement

Rei Otsuka: Writing – original draft, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Yukiko Nishita:** Writing – review & editing, Investigation, Funding acquisition, Conceptualization. **Hyuma Makizako:** Writing – review & editing, Funding acquisition, Data curation, Conceptualization. **Kaori Kinoshita:** Writing – review & editing, Investigation, Data curation, Conceptualization. **Chikako Tange:** Writing – review & editing, Investigation, Data curation. **Mana Tateishi:** Writing – review & editing, Investigation. **Shu Zhang:** Writing – review & editing, Investigation. **Sayaka Kubota:** Writing – review & editing, Investigation. **Kanno Fujikawa:** Writing – review & editing, Investigation. **Fujiko Ando:** Writing – review & editing, Supervision, Investigation. **Hiroshi Shimokata:** Writing – review & editing, Project administration, Methodology, Investigation. **Fumihiro Mizokami:** Writing – review & editing, Methodology. **Tomoe Ogayu:** Writing – review & editing, Methodology. **Mai Kabayama:** Writing – review & editing, Project administration, Funding acquisition. **Kei Kamide:** Writing – review & editing, Supervision. **Shosuke Satake:** Writing – review & editing, Supervision, Methodology, Funding acquisition. **Hidenori Arai:** Writing – review & editing, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jarlif.2025.100042.

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