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Original Article

Association of Composite and Domain-Specific Intrinsic Capacity and Frailty Among Older Adults in India: Evidence from the Longitudinal Ageing Study in India (LASI)

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Abstract

Objectives: Frailty and intrinsic capacity (IC), central constructs in the WHO healthy ageing framework, reflect vulnerability and resilience, respectively. Although both are linked to adverse outcomes, population-level evidence from India examining their relationship remains limited. This study explored the association between IC and frailty among older Indian adults. **Methods**: Data from 26,943 community-dwelling adults aged ≥60 years from the Longitudinal Ageing Study in India (LASI Wave 1) were analysed. Frailty was assessed using Fried's phenotype. IC was measured across cognition, locomotion, sensory, vitality, and mood domains, generating a composite score (0–10). Associations between IC and frailty status were examined using chi-square tests and multinomial logistic regression adjusted for sociodemographic factors and comorbidities. **Results**: Median age was 67 (63–72) years, and 48.4% were male. Frail individuals had lower median IC scores [6 (5–7)] than pre-frail and robust participants [7 (6–8); p<0.001]. Higher IC scores were inversely associated with pre-frailty (RRR: 0.79, 95% CI: 0.75-0.84) and frailty (RRR:0.67, 95% CI:- 0.64-0.71). Poor cognition, locomotion, vitality, and mood were significantly associated with frailty, whereas sensory impairment was not. **Conclusion**: Lower IC is strongly associated with frailty among older Indian adults, supporting IC-based geriatric assessment for early identification of frailty progression.

Keywords: Intrinsic capacity, Frailty, Older adults, LASI, India

Introduction

Population ageing is a global phenomenon, with low- and middle-income countries like India experiencing especially rapid demographic shifts[1]. As life expectancy increases, individuals often undergo multi-system dysregulation and a gradual decline in physiological reserves, which in turn increases their vulnerability to adverse outcomes, including disability, dependence, hospitalisation, and death[2]. Consequently, maintaining functional ability and independence in older adults has become an important public health concern.

Frailty — a multidimensional geriatric syndrome that reflects diminished resilience to stressors — has become a strong predictor of these adverse outcomes[3]. It has been operationalised in various ways. One widely

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used and validated model is Fried's frailty phenotype, which categorises individuals based on five clinical signs: unintentional weight loss (shrinking), weakness (grip strength), exhaustion, slowness (gait speed), and low physical activity. The presence of three or more criteria indicates frailty; one or two criteria suggest pre-frailty, and none indicates robustness[4]. This serves as a valuable clinical and public health framework for identifying older adults at high risk.

To complement this vulnerability-focused framework, the World Health Organization (WHO) has introduced the concept of intrinsic capacity (IC). IC is defined as the composite of all physical and mental abilities an individual can utilise at any given time and is typically conceptualized across five interconnected domains: cognition, locomotion, sensory ability, vitality (nutrition/energy), and psychological health[5,6]. Unlike frailty, which emphasizes vulnerability, IC reflects a resilience-oriented approach, emphasising functional capacities that can be maintained or improved throughout the entire lifespan. IC is central to WHO's healthy ageing framework, as it concentrates on positive qualities and pathways across life[7].

Although frailty and IC appear conceptually different, emerging evidence suggests they are closely related and may represent complementary perspectives of healthy ageing rather than competing constructs. Recent conceptual frameworks propose that declines in intrinsic capacity and the development of frailty occur along a continuum from resilience to vulnerability, with neither construct fully substituting for the other[8-11]. Declines in IC have been shown to precede the onset of frailty and predict poor outcomes, including falls, disability, and mortality[12-14]. Longitudinal analyses demonstrate that worsening IC trajectories are strongly linked to the progression of frailty and disability, while higher IC acts as a safeguard against functional decline[8,15]. Furthermore, impaired domains such as locomotion and vitality often serve as early indicators of frailty transitions[16,17]. These findings support the idea that interventions aimed at preserving or restoring IC could delay or prevent frailty and its impacts[8,13,18].

In India, the Longitudinal Ageing Study in India (LASI, wave 1, 2017-18) provides a nationally representative dataset to examine both these concepts[19]. Recent LASI-based research has shown that only about one-quarter (≈ 24.6%) of older adults (aged ≥ 60 years) can be classified as having "high intrinsic capacity," and that socio-demographic and lifestyle factors such as age, physical activity, tobacco use, and education are strongly linked to IC domains[20,21]. Meanwhile, analyses of frailty using phenotype models indicate a high prevalence of frailty and pre-frailty (≈ 29.2% frailty; ≈ 58.8% pre-frailty) among older adults in India, with greater vulnerability observed among women, rural residents, and individuals with lower levels of education.

Despite conceptual agreement and encouraging early results from high-income and some middle-income regions, there is a notable lack of population-level research from India that explicitly links WHO-defined IC (composite and domain scores) with frailty status. Given India's large demographic scale and within-country diversity, understanding how overall IC and its individual domains relate to frailty in older Indian adults is crucial for guiding integrated, capacity-focused geriatric care models and regionally appropriate public health strategies. Therefore, this study aims to explore the association between intrinsic capacity and frailty among older Indian adults using data from the nationally representative LASI Wave-1.

Methods

LASI main overview

The Longitudinal Ageing Study in India (LASI) utilized a multistage, stratified sampling strategy to ensure both national and state-level representation, drawing upon the 2011 Census as its framework. In this design, districts and tehsils (sub-districts) functioned as primary sampling units, while villages in rural areas and wards in urban areas were selected as secondary units. A detailed description of the study design, including the use of survey weights and sampling methodology, has been previously published[19]. For this analysis, we included data from 26,943 community-dwelling individuals aged 60 years and older. All participants gave informed consent prior to participation, having received an information sheet that explained the study objectives, confidentiality procedures, and safety protocols related to health assessments. The first wave of LASI was approved by the Indian Council of Medical Research (ICMR) and adhered to the ethical principles of the Declaration of Helsinki.

Frailty assessment

Frailty was defined using Fried's phenotypic frailty criteria, which include five components: unintentional weight loss, weakness, exhaustion, slowness, and low physical activity. Weight loss was assessed through a self-reported question on unintentional weight loss in the past year. Weakness was evaluated using handgrip strength and classified as low based on sex- and BMI-specific cut-offs. For men, the cut-offs were <29 kg for BMI ≤24, <30 kg for BMI 24.1–26 and 26.1–28, and <32 kg for BMI >28. For women, the cut-offs were <17 kg for BMI ≤23, <17.3 kg for BMI 23.1–26, <18 kg for BMI 26.1–29, and <21 kg for BMI >29. Slowness was assessed using a 4-meter gait speed test, with slow gait defined according to sex- and height-specific thresholds. For men, the cut-off was <0.65 m/s for height ≤173 cm and <0.76 m/s for height >173 cm. For women, the corresponding cut-offs were <0.65 m/s for height ≤159 cm and <0.76 m/s for height >159 cm.

Low physical activity was determined based on a self-reported question regarding the frequency of physical activity, with responses of "never" or "rarely" classified

as low activity. Exhaustion was assessed using the item "everything was an effort," and participants who responded "often" or "most/all of the time" were considered to have exhaustion. Participants who did not meet any of the five criteria were classified as robust, those meeting one or two criteria were classified as pre-frail, and those meeting three or more criteria were classified as frail.

Intrinsic capacity scoring

IC was assessed across five domains: cognition, locomotor capacity, sensory, vitality, and mood. For the cognition domain, we included multiple components: memory (immediate and delayed recall), orientation (to time and place), arithmetic function (backward counting and computation), executive function (paper folding and pentagon drawing), and object naming. A composite cognitive score was derived by summing the component scores. To account for educational differences, we stratified participants into three groups based on educational attainment: no formal education, education up to middle school, and secondary or higher education. Within each educational category, cognition scores were divided into tertiles, and participants were assigned scores of 0 (lowest tertile), 1 (middle tertile), or 2 (highest tertile), reflecting cognitive capacity adjusted for educational background.

The sensory domain was evaluated based on self-reported difficulty in hearing and vision. Participants with no reported impairment in either domain were scored 2, those with impairment in one domain were scored 1, and those with impairment in both were scored 0. Locomotor capacity was assessed using the semi-tandem balance test. Participants who were able to maintain the position for 10 seconds were assigned a score of 2, those who could maintain it for 3.0 to 9.9 seconds received a score of 1, and those unable to maintain the position for at least 3 seconds were scored 0.

Vitality was assessed using body mass index (BMI). Participants with BMI ≤18.4 kg/m^2 (underweight) were assigned a score of 0, those with BMI between 18.5–24.9 kg/m2 (normal weight) were scored 1, and those with BMI ≥25.0 kg/m^2 (overweight or obese) were scored 2. The mood domain was assessed using two questions: "Have you felt sad, blue, or depressed for two weeks or more in a row?" and "Have you lost interest in most things like hobbies, work, or activities?" Participants who responded "yes" to both questions were scored 0, "yes" to one question were scored 1, and "no" to both were scored 2.

The scores from all five domains were summed to generate a total intrinsic capacity score, ranging from 0 to 10, with higher scores indicating better overall intrinsic capacity.

Covariates

Covariates included age, sex (male or female), body mass index (BMI), place of residence (rural or urban), and living arrangements. Living arrangements were categorized as: living with spouse and children, living with spouse or children, living with others, and living alone. Socioeconomic status was assessed using monthly per capita expenditure (MPCE) quintiles. Marital status and education level were also included, with education categorized as: no formal education, primary to middle school (Class I to VIII), higher secondary or diploma, and graduation or post-graduation. Substance use variables included current use of tobacco and alcohol. Comorbid conditions were based on self-reported physician diagnoses and included diabetes, hypertension, heart disease, stroke, high cholesterol, bone and joint disorders, and chronic lung disease. Multimorbidity was defined as the presence of two or more of these chronic conditions.

Statistical Analysis

Statistical analyses were conducted using Stata version 17.0 (StataCorp. Stata Statistical Software: Release 17. College Station, TX: StataCorp LLC; 2021), and graphs were generated using GraphPad Prism version 8 (GraphPad Software, San Diego, CA). Descriptive statistics were used to summarize the study variables. Categorical variables were presented as absolute frequencies and percentages, while continuous variables were reported as mean with standard deviation (SD) or median with interquartile range (IQR), depending on the distribution. The Shapiro–Wilk test was used to assess normality.

Associations between frailty status (categorized as robust, pre-frail, and frail) and categorical variables were examined using the chi-squared test. For continuous variables, one-way analysis of variance (ANOVA) or the Kruskal–Wallis test was used, based on the normality of the data. To explore the association between frailty status and total intrinsic capacity score and individual IC domains, multinomial logistic regression analysis was performed, using the robust group as the reference category. Three models were constructed: Model 1 was unadjusted; Model 2 was adjusted for age and sex; and Model 3 was further adjusted for age, sex, monthly per capita expenditure (MPCE), and the presence of diabetes, hypertension, heart disease, stroke, high cholesterol, bone and joint disease, and chronic lung disease. Self-rated health was not included in adjusted models because it was considered a global health-status indicator with substantial conceptual overlap with both frailty and intrinsic capacity, raising the possibility of overadjustment. Results are reported as relative risk ratios (RRRs) with 95% CIs, as appropriate. A p-value of <0.05 was considered statistically significant.

Results

Baseline characteristics

This analysis included 26,943 community-dwelling older adults (Figure 1). The median age (interquartile

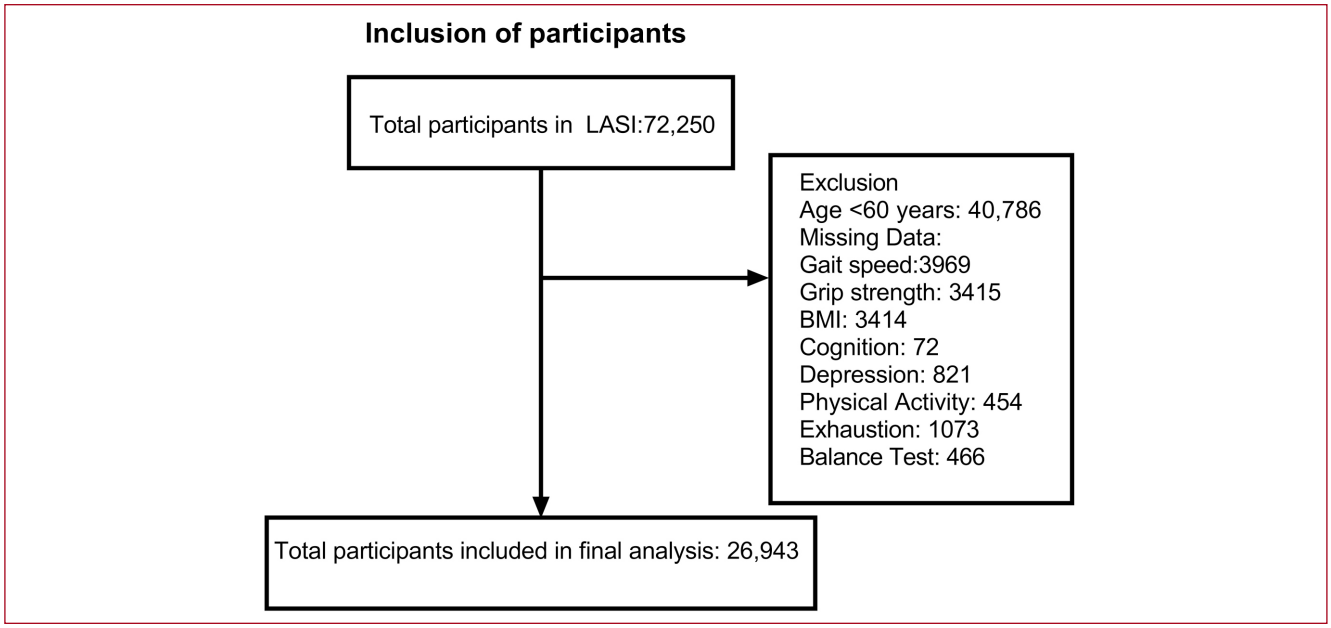

Figure 1. Flow chart depicting the inclusion of participants.

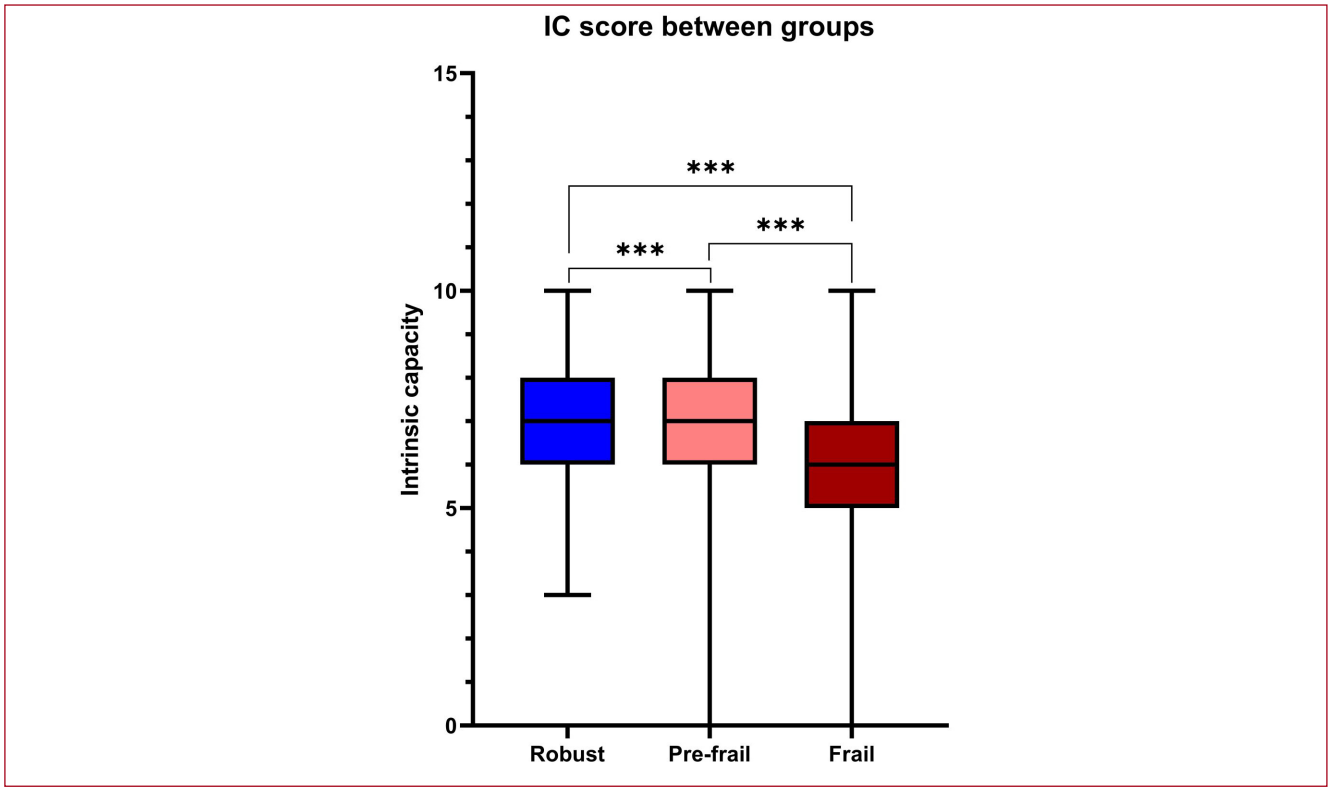

Figure 2. Bar and whisker plot showing intrinsic capacity score between frailty groups.

Table 1. Baseline characteristics of study population (n= 26,943)

Variables	Robust (n=792)	Pre-frail (n=16,488)	Frail (n=9,663)	p-value
Age [Median (IQR)]	65 (62-68)	65 (62-70)	70 (65-76)	<0.001
60-74 years	743 (93.81)	14382 (87.23)	6585 (68.15)	<0.001
75 years and above	49 (6.19)	2106 (12.77)	3078 (31.85)	
Sex				
Male	451 (56.94)	8402 (50.96)	4192 (43.42)	<0.001
Female	341 (43.06)	8086 (49.04)	5467 (56.58)	
Body mass index [Median (IQR)]	23.58 (21.06-25.81)	21.81 (18.98-24.95)	20.81 (18.07-24.45)	<0.001
Residence				
Rural	412 (52.02)	10914 (66.19)	6696 (69.30)	<0.001
Urban	380 (47.98)	5574 (33.81)	2967 (30.70)	
Living arrangements				
Living with spouse and children	444 (56.06)	7971 (48.34)	3486 (36.08)	<0.001
Living with children or spouse	312 (39.39)	7083 (42.96)	4923 (50.95)	
Living with others	17 (2.15)	691 (4.19)	617 (6.39)	
Living alone	19 (2.40)	743 (4.51)	637 (6.59)	
MPCE				
Poorest	117 (14.77)	3251 (19.72)	2156 (22.31)	<0.001
Poorer	144 (18.18)	3379 (20.49)	2057 (21.29)	
Middle	171 (21.59)	3399 (20.61)	1990 (20.59)	
Richer	158 (19.95)	3312 (20.09)	1848 (19.12)	
Richest	202 (25.51)	3147 (19.09)	1612 (16.68)	
Marital Status				
Married	633 (79.92)	11564 (70.14)	5349 (55.36)	<0.001
Widowed	152 (19.19)	4603 (27.92)	4108 (42.51)	
Divorced	6 (0.76)	184 (1.12)	117 (1.21)	
Never married	1 (0.13)	137 (0.83)	89 (0.92)	
Education				
No formal education	245 (30.93)	8172 (49.56)	5931 (61.38)	<0.001
I to VIII standard	265 (33.46)	5524 (33.50)	2767 (28.63)	
IX-X	108 (13.64)	1401 (8.50)	521 (5.39)	
Higher secondary or diploma	63 (7.95)	644 (3.91)	224 (2.32)	
Graduation or post-graduation	111 (14.02)	747 (4.53)	220 (2.28)	
Tobacco use	274 (34.64)	6639 (40.28)	3763 (38.95)	0.002
Alcohol	148 (18.69)	3019 (18.31)	1524 (15.77)	<0.001
Self-rated health				
Poor	39 (4.92)	1627 (9.87)	1745 (18.06)	<0.001
Fair	210 (26.52)	5157 (31.28)	3478 (36.00)	
Good	320 (40.40)	6456 (39.16)	3153 (32.63)	
Very good	169 (21.34)	2714 (16.46)	1100 (11.38)	
Excellent	54 (6.82)	532 (3.23)	186 (1.93)	

Table 1. *(Cont. from previous page).*

Variables	Robust (n=792)	Pre-frail (n=16,488)	Frail (n=9,663)	p-value
Comorbidities				
Diabetes	140 (17.68)	2508 (15.22)	1385 (14.33)	0.015
Hypertension	288 (36.36)	11089 (32.73)	6160 (36.24)	<0.001
Heart disease	43 (5.43)	801 (4.86)	485 (5.02)	0.683
Stroke	9 (1.14)	255 (1.55)	291 (3.01)	<0.001
High cholesterol	45 (5.68)	634 (3.85)	315 (3.26)	0.001
Bone and joint disease	115 (14.52)	2588 (15.70)	1968 (20.37)	<0.001
Chronic lung disease	44 (5.56)	1111 (6.74)	870 (9.00)	<0.001
Multimorbidity	181 (22.85)	3565 (21.62)	2393 (24.76)	<0.001

Table 2. The relation between frailty and intrinsic capacity and individual domains.

Variables	Robust (n=792)	Pre-frail (n=16,488)	Frail (n=9,663)	p-value
Total IC score [Median (IQR)]	7 (6-8)	7 (6-8)	6 (5-7)	<0.001
Total IC score [Mean (SD)]	7.08 (1.29)	6.57 (1.43)	6.09 (1.57)	<0.001
Cognition				
Good	391 (49.37)	6729 (40.81)	3031 (31.37)	<0.001
Fair	301 (38.01)	6228 (37.77)	3474 (35.95)	
Poor	100 (12.63)	3531 (21.42)	3158 (32.68)	
Sensory				
Both intact	49 (6.19)	987 (5.99)	844 (8.73)	<0.001
One impaired	459 (57.95)	8287 (50.26)	4896 (50.67)	
Both impaired	284 (35.86)	7214 (43.75)	3923 (40.60)	
Locomotor				
Good	787 (99.37)	16005 (97.07)	8391 (86.84)	<0.001
Fair	5 (0.63)	416 (2.52)	1015 (10.50)	
Poor	0 (0.00)	67 (0.41)	257 (2.66)	
Vitality				
Good	259 (32.70)	4072 (24.70)	2151 (22.26)	<0.001
Fair	458 (57.83)	8995 (54.55)	4729 (48.94)	
Poor	75 (9.47)	3421 (20.75)	2783 (28.80)	
Mood				
Good	676 (85.35)	13683 (83.02)	7365 (76.26)	<0.001
Fair	62 (7.83)	1484 (9.00)	1171 (12.12)	
Poor	54 (6.82)	1315 (7.98)	1122 (11.62)	

range) of the study population was 67 (63-72) years, with nearly half of them male (13,049, 48.43%). Two-thirds of the population (18,022, 66.89%) reside in rural areas. The association between frailty status (robust, pre-frail, and frail) and demographic factors is reported in Table 1. We observed that a significantly greater proportion of participants aged 75 years and above and females were frail. Frail older adults had significantly lower BMI (20.81

Table 3. Results of multinomial regression analysis Model 3[#].

Variable	Pre-frail		Frail	
	RRR (95% CI)	p-value	RRR (95% CI)	p-value
IC score	0.79 (0.75-0.84)	<0.001	0.67 (0.64-0.71)	<0.001
Individual domains				
Cognition				
Good	1 (ref)		1 (ref)	
Fair	1.14 (0.97-1.33)	0.099	1.27 (1.09-1.49)	0.003
Poor	1.75 (1.39-2.19)	<0.001	2.52 (2.00-3.16)	<0.001
Sensory				
Both intact	1 (ref)		1 (ref)	
One impaired	0.95 (0.69-1.28)	0.727	0.78 (0.57-1.07)	0.122
Both impaired	1.32 (0.96-1.81)	0.086	1.12 (0.81-1.54)	0.499
Locomotor				
Good	1 (ref)		1 (ref)	
Fair	3.29 (1.35-7.98)	0.009	9.79 (4.04-23.74)	<0.001
Poor	-	-	-	-
Vitality				
Good	1 (ref)		1 (ref)	
Fair	1.19 (1.01-1.40)	0.041	1.11 (0.94-1.32)	0.213
Poor	2.56 (1.95-3.36)	<0.001	3.44 (2.61-4.53)	<0.001
Mood				
Good	1 (ref)		1 (ref)	
Fair	1.18 (0.91-1.55)	0.210	1.74 (1.33-2.28)	<0.001
Poor	1.21 (0.91-1.61)	0.177	1.91 (1.44-2.55)	<0.001

Base outcome: Robust. [#]Model 3: adjusted for age, sex, MPCE, diabetes, hypertension, heart disease, stroke, cholesterol, bone and joint disease, chronic lung disease.

in frail vs 21.81 in pre-frail vs 23.58 in robust). Place of residence, living arrangements, socioeconomic status (measured by MPCE), education, and marital status were also associated with frailty. Multimorbidity (presence of two or more comorbidities) was higher among frail older adults (p<0.001).

Intrinsic capacity and frailty

The total IC score was lower among frail older adults [6 (5-7)] compared to pre-frail [7 (6-8)] and robust older adults [7 (6-8)] (Table 2, Figure 2). The analysis of individual IC domains revealed that poor cognition was more common among frail individuals (12.63% vs 21.42% vs 32.68%, p<0.001), while sensory impairment was more prevalent among pre-frail older adults (35.86% vs 43.75% vs 40.60%, p<0.001). Fair locomotor performance (0.63% vs 2.52% vs 10.50%, p<0.001), poor vitality (9.47% vs 20.75% vs 28.80%, p<0.001), and poor mood (6.82% vs 7.98% vs 11.62%, p<0.001) were significantly associated with frailty status. IC score decreased gradually with increasing age (Supplementary Figure 1).

Multinomial regression analysis

The results of multinomial regression analysis (Model 1 and Model 2) are reported in Supplementary Table 1. Model 1 is unadjusted, whereas Model 2 is adjusted for age and sex. Model 3, which is adjusted for age, sex, MPCE, diabetes, hypertension, heart disease, stroke, cholesterol, bone and joint disease, and chronic lung disease, is reported in Table 3. We found that intrinsic capacity (IC score) decreased significantly in pre-frail (RRR: 0.79; 95% CI 0.75-0.84) and frail (RRR: 0.67; 95% CI 0.64-0.71).

Among individual IC domains, poor cognition was associated with an increased risk of being pre-frail (RRR:

1.75; 95% CI 1.39-2.19) and frail (RRR: 2.52; 95% CI 2.00-3.16). Fair locomotor capacity was associated with both pre-frail (RRR: 3.26; 95% CI 1.35-7.98) and frail status (RRR: 9.79; 95% CI 4.04-23.74). Poor vitality was associated with pre-frailty (RRR: 2.56; 95% CI 1.95-3.36) and frailty (RRR: 3.44; 95% CI 2.61-4.53). Poor mood was associated with frailty (RRR: 1.91; 95% CI 1.44-2.55). The sensory domain was not significantly associated with frailty status in our population.

Discussion

In this nationally representative study, we found a strong and consistent association between lower Intrinsic Capacity (IC) and both pre-frailty and frailty. Poor mood and cognition, low vitality, and limited locomotor capacity were the IC domains most significantly associated with frailty. To our knowledge, population-level evidence examining the relationship between intrinsic capacity and frailty in India remains limited. Our study extends the growing international literature by providing evidence from a large nationally representative sample of older Indian adults.

The findings of our current study align with recent literature[12,16] that demonstrate the close relationship between the two ends of the resilience-vulnerability spectrum in both community and hospital settings. In the study by Shen S et al., declined composite IC scores were associated with frailty [Odds Ratio (OR) = 0.45] and a higher risk of falls (OR = 0.64) among older hospitalised patients[12]. A recent systematic review of 13 observational studies identified adverse IC trajectory patterns associated with increased frailty, mortality, disability, and fall risk[23]. In the secondary longitudinal analysis from the 10/66 study across eight LMIC countries, declining IC was linked to a significantly higher risk of frailty, disability, and dementia than in those with high IC, with strong predictive validity (Mortality Hazard Ratio = 4.60, 95% CI 4.16; 5.09)[15]. Our LASI results extend these findings by offering large-scale, population-level evidence from India.

Poor cognition and impaired mood were independently associated with frailty in our study. This aligns with previous observational studies that have shown psycho-social factors to be closely linked with frailty in older adults[24,25]. In the longitudinal Multi-domain Alzheimer's Preventive Trial study[26], they did not find a significant association between cognitive decline and frailty, but reported a 47% increase in the risk of incident frailty with each additional IC impairment. Conversely, few prospective studies have shown that decline in cognitive capacity is among the earliest predictors of frailty transition in older adults[16]. Additionally, with the emergence of the concept of cognitive frailty[27], several recent longitudinal studies have reported a significant association between frailty trajectories and incident cognitive decline[28,29]. These findings emphasise the bi-directional relationship and synergistic effect of frailty and IC impairment on adverse health outcomes in older adults.

The association between poor vitality and frailty in our study also resonates with previous research highlighting malnutrition and sarcopenia as common biological bases linking IC loss and frailty[18]. In the existing literature, vitality or energy homeostasis has been suggested as the highest hierarchical level of the physiological system, which can serve as a biological basis for the other IC domains[30,31]. Yu et al., in their research, proposed that vulnerability in an older person's vitality can lead to a gradual decline in other IC domains, resulting in different frailty phenotypes and severity[18].

The current study found that a decline in locomotor capacity is associated with both pre-frail and frail status. This agrees with earlier studies[16], which suggest that locomotor impairment can contribute to slowness, a key component of physical frailty. Mobility is considered a core part of the disabling cascade[32], and Gonzalez-Bautista E et al., in the 10/66 study, highlighted that mobility impairment can serve as an early clinical marker of this cascade[15]. Although some conceptual overlap exists between locomotor performance and frailty phenotype components, the association observed in our study reinforces the importance of mobility as a marker of declining physiological reserve. The locomotor domain demonstrated a pronounced ceiling effect, with nearly all robust participants classified as having good locomotor function and none classified as having poor locomotion. This resulted in sparse data for some locomotor categories and prevented estimation of relative risk ratios for poor locomotor status because of complete separation.

Unlike cognition, locomotion, vitality, and mood, sensory impairment was not independently associated with frailty after multivariable adjustment. This finding suggests that sensory deficits may have a weaker or more indirect relationship with frailty than other intrinsic-capacity domains. While sensory impairment has been reported as a risk factor for functional decline and falls in studies[33,34], its association with development of frailty may depend on context, varying with cultural and environmental compensatory mechanisms[14]. It is also possible that the self-reported sensory measures available in LASI were insufficiently sensitive to detect clinically meaningful impairment.

The sociodemographic gradients observed in our study are also noteworthy. Frailty was more prevalent among women, the oldest-old, rural residents, and those with lower education and socioeconomic status, consistent with previous Indian studies[20,22]. Importantly, these groups have been shown to have lower IC levels[21]. This suggests that interventions aimed at maintaining or improving IC could be especially beneficial for disadvantaged subpopulations.

Our nationwide population-based current study provides valuable insight into the intricate relationship between IC and frailty in community-dwelling older adults in India. While

future waves of LASI are needed to shed light on the causal link between these trajectories, the study also emphasises the utility of IC as a positive, capacity-oriented framework to complement frailty screening and interventions in geriatric practice. The VIVIFRAIL multicomponent exercise program has been found to be an effective strategy to strengthen IC, especially in the domains of locomotion, vitality, and cognition[35]. Incorporating IC assessments into India's National Programme for the Healthcare of the Elderly (NPHCE) could support proactive interventions to delay frailty progression, extend functional ability, and reduce the healthcare burden, but longitudinal studies are needed to establish temporal relationships and evaluate predictive validity before widespread implementation.

Strengths and Limitations

This study has several strengths. First, it uses data from the LASI, which employed a multistage, stratified sampling design to ensure national and state-level representativeness of older adults, thereby enhancing the generalizability of the findings. Second, frailty was assessed using Fried's phenotypic criteria, a well-established and validated framework that allows for comparability with international studies. Third, IC was comprehensively evaluated across all five domains—cognition, locomotor capacity, sensory, vitality, and mood—using structured assessments, and a total IC score was generated to capture overall functional reserve. Additionally, cognitive scoring was adjusted for educational attainment by categorizing participants into tertiles within education strata, helping to minimize the confounding effect of educational disparities on cognitive assessment. The use of multinomial logistic regression with sequentially adjusted models and inclusion of a broad set of sociodemographic and clinical covariates further strengthens the analytical robustness of the study.

However, several limitations should be noted. The cross-sectional nature of the data precludes causal inference and limits the ability to assess changes in frailty or IC over time. Many key variables, including comorbidities, physical activity, and sensory impairments, were based on self-report and may be prone to recall bias or misclassification. Some overlap exists between components of Fried's frailty phenotype and specific intrinsic-capacity domains, particularly locomotion and vitality. Consequently, part of the observed association may reflect shared underlying constructs. However, intrinsic capacity additionally incorporates cognition, sensory function, and psychological health, which are not included in Fried's phenotype. Therefore, the observed associations likely reflect both shared and distinct dimensions of healthy ageing. Some IC domains, such as mood and sensory function, were assessed using limited questions rather than comprehensive clinical tools, which may affect the precision of domain-specific scoring. Although the models adjusted for a wide range of covariates, residual confounding from unmeasured factors such as nutritional status, inflammation, or sarcopenia cannot be ruled out. Finally, the absence of longitudinal follow-up data limits the ability to evaluate trajectories of frailty and intrinsic capacity over time; future waves of LASI will be essential to address these gaps.

Conclusion

Intrinsic capacity is strongly and inversely associated with frailty among older Indian adults. Declines in cognition, locomotion, vitality, and mood are key markers of frailty. These findings highlight the potential of incorporating IC-based assessments into geriatric care to identify high-risk individuals and guide early interventions. Capacity-oriented approaches may play a crucial role in promoting healthy ageing and delaying frailty in India's older population.

Ethics approval

The data is freely available in the public domain and survey agencies that conducted the field survey for the data collection have collected prior consent from the respondents. The Indian Council of Medical Research (ICMR) and all partner institutions extended the necessary guidance and ethical approval for conducting the LASI. The LASI data can be accessed for free at the International Institute for Population Sciences website (https://www.iipsindia.ac.in/content/LASI-data).

Consent to participate

The survey agencies that conducted the field survey for the data collection have collected prior informed consent from all subjects and/or their legal guardian(s).

Authors' contributions

All authors met the criteria for authorship as follows: study concept and design (Sudeep M. George, Kritartha Kashyap), acquisition of data (Abhijith R. Rao), analysis and interpretation of data (Abhijith R. Rao), and preparation of manuscript (Sudeep M. George, Kritartha Kashyap, Abhijith R. Rao,Minakshi Dhar, Vasu Digra, Parul Bhutani, Pankhuri Saxena, Rajkumar Tata, Bhabhor K Narsinhbhai, Shreya Biswal, Pramod K Mehta, Prasun Chatterjee, Avinash Chakrawarty, Naveet Wig,). No unnamed contributor played a role in manuscript preparation. All the authors read and approved the final version of the manuscript and accept responsibility for the integrity and accuracy of the article's content.

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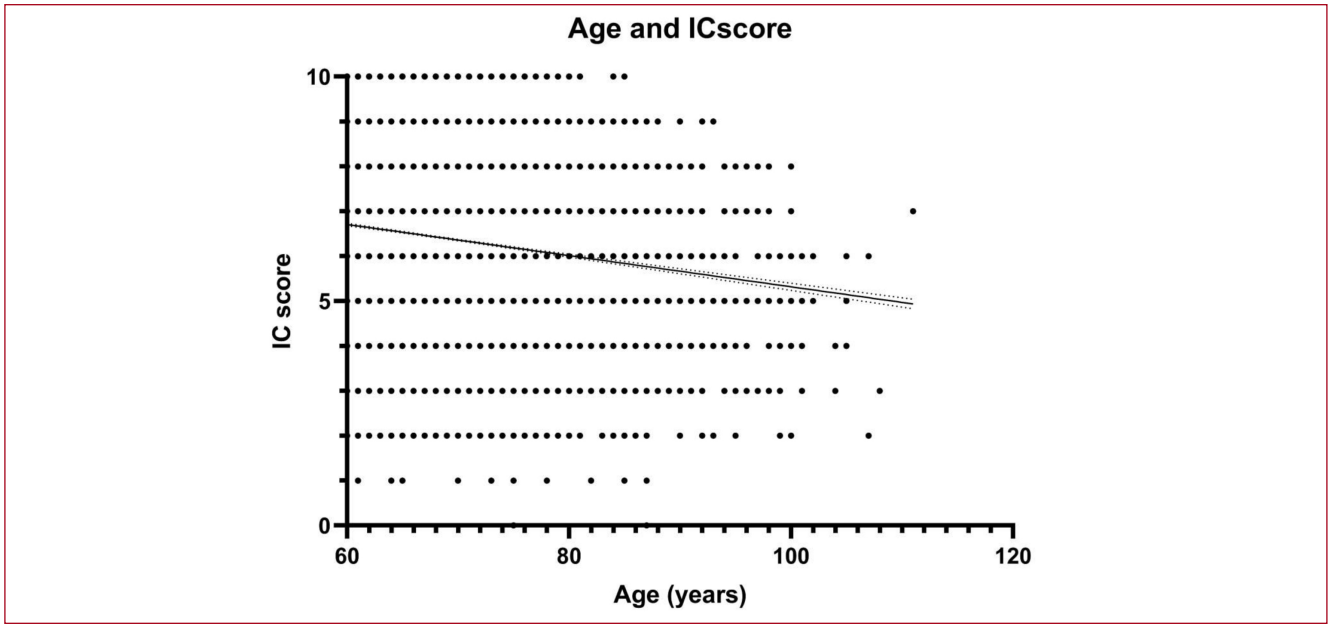
Supplementary Table 1. Results of multinomial regression analysis Model 1 and Model 2.

Variables	Model 1#		Model 2##	
	Pre-frail RRR (95% CI)	Frail RRR (95% CI)	Pre-frail RRR (95% CI)	Frail RRR (95% CI)
IC score	0.77 (0.74-0.82)***	0.62 (0.59-0.66)***	0.78 (0.74-0.82)***	0.66 (0.63-0.70))***
Individual domains	**RRR (95% CI)**	**RRR (95% CI)**	**RRR (95% CI)**	**RRR (95% CI)**
Cognition				
Good	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Fair	1.20 (1.03-1.40)*	1.49 (1.27-1.74)***	1.16 (0.99-1.35)	1.30 (1.11-1.53)**
Poor	2.05 (1.64 -2.56)***	4.07 (3.25 -3.10)***	1.82 (1.45-2.28)***	2.67 (2.12-3.35)***
Sensory				
Both intact	1 (ref)	1 (ref)	1 (ref)	1 (ref)
One impaired	0.89 (0.66-1.21)	0.62 (0.45-0.84)**	0.96 (0.70-1.30)	0.78 (0.57-1.06)
Both impaired	1.26 (0.92-1.72)	0.80 (0.58-1.09)	0.78 (0.57-1.06)	1.18 (0.86-1.62)
Locomotor				
Good	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Fair	4.09 (1.68-9.91)**	19.04 (7.88-45.99)***	3.27 (1.35-7.94)**	9.94 (4.10-24.07)***
Poor	-	-	-	-
Vitality				
Good	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Fair	1.25 (1.07-1.46)**	1.24 (1.06-1.46)**	1.25 (1.06-1.46)**	1.15 (0.97-1.35)
Poor	2.90 (2.23-3.77)	4.47 (3.43 to 5.81)***	2.82 (2.16-3.66)***	3.70 (2.84-4.83)***
Mood				
Good	1 (ref)	1 (ref)	1 (ref)	1 (ref)
Fair	1.18 (0.91-1.54)	1.73 (1.32-2.26)***	1.18 (0.91-1.54)	1.77 (1.35-2.32)***
Poor	1.20 (0.90-1.59)	1.91 (1.43-2.53)***	1.21 (0.91-1.60)	1.95 (1.47-2.61)***

*Base outcome: Robust. #Model 1: unadjusted. ##Model 2: adjusted for age and sex. *p-value<0.05. **p-value<0.01. ***p-value<0.001.*



Supplementary Figure 1. Scatter plot with fitter line showing association between age and intrinsic capacity score.