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Cover Page

Title: A holistic approach to cognitive frailty in community-dwelling older adults in India: Evidence from a nationally representative survey

Running title: Cognitive frailty in India

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Abstract

Background and objectives: Cognitive frailty (CF), the complex overlap of physical frailty (PF) and cognitive impairment (CI), remains underexplored in India. Given CF's association with dementia and its potential reversibility, this study aims to (1) estimate the national prevalence of CF, (2) examine regional disparities in its distribution, and (3) identify associated factors with CF in community-dwelling older adults in India.

Research design and methods: This cross-sectional study used data from the Longitudinal Ageing Study in India (LASI-Wave I), a nationally representative survey of 27,379 adults aged ≥60 years (13,293 males; 14,086 females). CF was defined as the co-occurrence of PF and CI, excluding dementia. PF was assessed using a modified Community-Oriented Frailty Index (a 20-item deficits-based measure). CI was operationalised as a composite score derived from five cognitive domains and seven instrumental activities of daily living difficulties.

Results: The weighted prevalence of CF was 4.8% in the overall sample, with the highest prevalence observed in Western regions (5.7%). Significant associations were identified for age ≥80 years (AOR:6.3, 95%CI:5.3–7.5), female gender (AOR:1.6, 95%CI:1.4–1.9), and low educational attainment (AOR:10.6, 95%CI:6.2–17.8). Self-reported poor health (AOR:2.6, 95%CI:2.3–3.0), low social participation (AOR:2.3, 95%CI:2.0–2.6), depression (AOR:1.9, 95%CI:1.6–2.3), and low life satisfaction (AOR:1.4, 95%CI:1.2–1.6) also showed significant associations.

Conclusions: This study highlights the prevalence, regional disparities, and multifactorial contributors to CF in India. Findings underscore the urgency of adopting holistic interventions—integrating physical, function and psychosocial strategies—into public health policies to mitigate CF and promote healthy ageing.

Keywords: Cognition; Holistic health; India; LASI; Physical Frailty

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Introduction

India, the world's most populous country, is undergoing a significant demographic transition, with individuals aged 60 and above comprising 10.5% of the population, a figure projected to increase to over 20% (347 million people) by 2050 (UNFPA, 2023). This demographic shift underscores the need for a holistic healthcare approach that integrates physical, mental, and social well-being to effectively address age-related health challenges (Ventegodt et al., 2016). Among these challenges, cognitive impairment (CI) and frailty are emerging as critical public health concerns. CI, characterised by declines in memory, reasoning, and decision-making, has been reported in 7.14% of older men and 20.03% of older women in India, with prevalence varying across geographical regions (Sharma & Pradhan, 2023; Muhammad et al., 2023; Jadenur et al., 2022). As India's population ages, this prevalence is expected to increase, making CI a significant public health concern. Similarly, frailty—a multidimensional condition associated with declines in physical, psychological, and social capacities, leading to increased morbidity, healthcare burden, and mortality (Pilotto et al., 2020; Xu, 2011; Fried et al., 2001)—affects approximately 27.9% of men and 33.2% of women in India (Das & Prasad, 2023). A global systematic review, which compared and pooled data on the prevalence of frailty among community-dwelling older people, highlighted a wide variation in frailty prevalence within the community, ranging from 4.0% to 59.1% (Collard et al., 2012). The review concluded that the overall weighted prevalence of frailty was 10.7%, which emphasises that the prevalence of frailty in India exceeds the global average.

Cognitive frailty (CF) is a relatively recent concept in the field of geriatric medicine and public health, presenting a multifaceted condition that amalgamates elements of physical frailty and cognitive impairment, which commonly co-occur (Kelaiditi et al., 2013; Panza et al., 2021). While traditional frailty primarily concentrates on physical aspects, CF also encompasses cognitive functions, including memory, executive function, and attention. It can

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be defined as a condition where individuals experience both physical frailty and cognitive impairment in the absence of dementia (Kelaiditi et al., 2013; Buchman and Bennett, 2023). While the sharing of several risk factors between CF and dementia (Livingston et al., 2024) suggests a greater likelihood of the development of neurodegenerative conditions, it is important to note that not all individuals with CF progress to dementia. Although the CF state is significant because it elevates the risk of dementia, it is highly important because of its characterisation as a reversible state (Ruan et al., 2015; Ruan et al., 2020; Hwang et al., 2023). This quality makes CF a compelling focus for interventions aimed at mitigating its impact, suggesting that targeted strategies could be employed to address and potentially reverse CF. Understanding and addressing the factors contributing to CF could pave the way for effective interventions that enhance cognitive and physical well-being and potentially reduce the risk of dementia and later life dependence. Therefore, CF emerges as a critical area for research and intervention, emphasising the importance of early identification and management to potentially reduce the risk of dementia and enhance the quality of life for older adults (Shimada et al., 2018; Wang et al., 2022; Corral-Pérez et al., 2023). A comprehensive understanding of CF is imperative for healthcare professionals, as it demands a multidimensional approach, including assessments covering both physical and psychosocial domains, as well as broader socio-demographic risk factors. Early detection and intervention strategies are vital for improving the well-being of older adults and alleviating the associated healthcare and social burdens.

Conceptual framework: Biopsychosocial Model

The present study adopts the Biopsychosocial Model (Engel, 1977) as its conceptual framework to understand the multidimensional nature of CF. This model provides a holistic perspective by integrating biological, psychological, and social determinants of health. It is particularly relevant for studying CF, as this condition emerges from complex interactions

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between physiological vulnerabilities, cognitive processes, and social-environmental influences. Worldwide, sociodemographic characteristics such as age, gender, residence status, geographical region and living arrangements have been extensively studied, revealing their significant association with CF (Ruan et al., 2020; Zhang et al., 2022; Das, 2022; Corral-Pérez et al., 2023; Holland et al., 2024). Higher education, employment status, and economic standing also play pivotal roles, underscoring the complex relationships with CF (Facal et al., 2021; Wada et al., 2022; Lee e al., 2023), as they are associated with enhanced overall health outcomes, reflecting the influence of intellectual stimulation and access to resources.

Beyond sociodemographic determinants, evidence also recognises the profound impact of environment and lifestyle choices in terms of health-related behaviour such as weight management or food habits. These choices, as well as environmentally related stresses, significantly influence vascular health, oxidative stress, and inflammation, contributing to physical frailty and variability in cognitive function. Life events such as bereavements or hospital stays can also have an impact on CF (Feng et al., 2017), introducing both physical and mental stressors that can affect overall health and psychosocial factors, such as depression, social participation, and sleeping habits, which also have complex impacts on CF mechanisms (Navarro-Pardo et al., 2020; Zhao et al., 2021; Zou et al., 2023).

Despite the growing body of international evidence, research on CF in India remains limited. Existing studies have also highlighted its associations with sociodemographic, physical, and psychological factors (Das, 2022; Mallick and Santra, 2023; Sharma et al., 2024). However, these studies predominantly relied on the frailty phenotype scale (Fried et al., 2001), whereas the present study employs and adapted Community-Oriented Frailty Index (COMFI), specifically designed for community-dwelling populations (Garner et al., 2020). Notably, previous methodologies, such as those adopted by Mallick and Santra (2023) and Sharma and colleagues (2024), assessed CF primarily as a combination of physical frailty and cognitive

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impairment, often overlooking the role of mild cognitive impairment without dementia, as outlined by Kelaiditi and colleagues (2013) in the pioneering framework of CF. This limitation can result in an overestimation of CF prevalence, misclassifying advanced cognitive decline as CF, and obscuring opportunities for early intervention—limiting clinical relevance and cross-study comparability (Sugimoto et al., 2018; Qiu et al., 2021). These limitations underscore the necessity for nuanced frameworks, such as the dementia-exclusive CF definition aligned with Kelaiditi et al. (2013), as adopted in this study.

Study objectives and significance

India, characterised by its diverse geographical and cultural landscape, has witnessed considerable research on geographical variations in physical frailty (Ghosh et al., 2023) and cognitive impairment (Jadenur et al., 2022). However, the specific variations in cognitive frailty remain largely unexplored. This gap highlights the urgent need for greater awareness among academia, policymakers, and the broader community. To address these, the present study pursues three key objectives: (1) to determine the national prevalence of cognitive frailty, (2) to examine its regional variations, and (3) to explore its holistic associations among community-dwelling populations in India.

This study adopts a novel approach by integrating a national survey with the biopsychosocial model, providing a comprehensive understanding of cognitive frailty. Establishing a baseline understanding of its prevalence across India will generate critical data to inform healthcare planning and interventions. Moreover, identifying geographical differences will enable the development of region-specific strategies, while examining the intersection of sociodemographic, physical and psychosocial health factors will facilitate the design of targeted, evidence-based interventions.

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Methods

Study sample and data selection

This study utilised data from the Longitudinal Ageing Study in India (LASI) Wave-1 (2017-19), a nationally representative survey encompassing over 73,000 individuals aged 45 years and above, along with their spouses, from all Indian states and union territories. The survey employed a multistage, stratified sampling design, ensuring comprehensive national representation. In rural settings, a three-stage sampling process was implemented, whereas urban settings utilised a four-stage approach that included an additional step for the random selection of Census Enumeration Blocks (CEBs). Within each selected household, consenting individuals completed a structured individual survey schedule. As India's most extensive ageing study, LASI offers a critical evidence base on the health, social, and economic conditions of older adults, underpinning policy development. For this analysis, the sample focused on adults aged 60 years and above (N=27,379), comprising 13,293 men and 14,086 women. Figure 1 illustrates the identification of the sample, including exclusion of participants with incomplete data. The detailed methodology of the survey is available in https://lasi-india.org as well as in the published survey report (IIPS, 2020).

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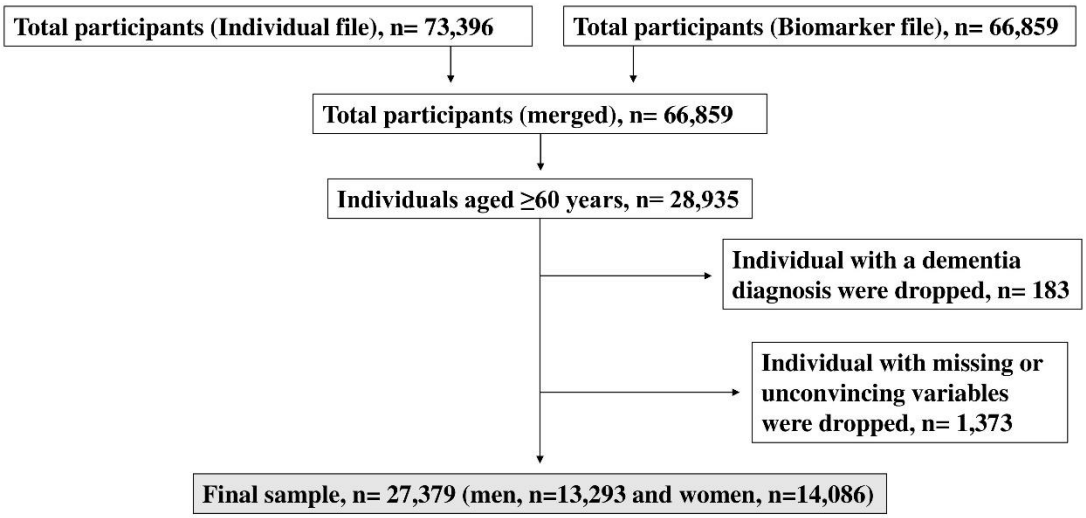

Figure 1: Flow chart of the study sample selection, LASI Wave-1 data

Outcome variable

The outcome variable for this study was 'cognitive frailty' (CF), assessed according to the definition provided by Kelaiditi and colleagues (2013). In the present study, cognitive frailty was defined as the simultaneous presence of both physical frailty (PF) and cognitive impairment (CI) without dementia.

- Physical frailty (PF) was evaluated based on the modified Community-Oriented Frailty Index (COM-FI) (Garner et al., 2020), an accumulation of deficits frailty index. We developed a 20-item frailty index based on physical deficits (Details of the COM-FI components are available in Appendix A.1). Deficits in each domain were scored as 0 (no problem) or 1 (problem). Then frailty scores for participants *i*, obtained by summing over the 20 deficits denoted as *j*, were calculated using the following formula, yielding values between 0 and 1:

$$FI_i = \frac{\sum_{j=1}^{20} Deficit_{i.j}}{20}$$

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The study categorises scores 0.25 and above as frail and those below 0.25 as non-frail (Gordon et al., 2021). The assessment of construct reliability revealed a Cronbach's alpha of 0.764 (n=20), and predictive validity of COM-FI scale was also examined based on LASI wave 1 data, the full details provided in Appendix A.2.

- Cognitive Impairment (CI) was assessed by evaluating composite scores for both cognitive domains and Instrumental Activities of Daily Living (IADL). Kelaiditi and colleagues (2013), in their pioneering framework of cognitive frailty, operationalised cognitive impairment as mild cognitive impairment (MCI), defined by a Clinical Dementia Rating (CDR) score of 0.5. While the LASI wave 1 cognitive function tests can identify general cognitive impairment (IIPS, 2020), they lack specificity for MCI. To strengthen the measurement, the present study integrates the IADL scale alongside domain-specific cognitive assessments. Traditional cognitive tests often fail to capture early-stage functional declines in real-world tasks (e.g., managing medications or spatial navigation), which may reflect executive function or visuospatial deficits before they manifest on standardised cognitive assessments. Incorporating IADL addresses this gap by evaluating functional performance in cognitively demanding activities, thereby enhancing the detection of early MCI indicators (Jekel et al., 2015; Marshall et al., 2019).

  The cognitive domain score comprises five components: i) memory, ii) orientation, iii) arithmetic ability, iv) executive functioning and visuospatial functioning skills, and v) object naming. The cognitive domain score ranges from 0 to 43, with higher values indicating better cognitive function (Muhammad et al., 2023; Sharma and Pradhan, 2023). Additionally, the IADL scale includes seven components: i) preparing a hot meal, ii) shopping for groceries, iii) making telephone calls, iv) taking medications, v) doing work around the house or garden, vi) managing money, and vii) getting around

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or finding an address in an unfamiliar place. The composite IADL score ranges from 0 to 7, with higher values indicating greater disability (Chauhan et al., 2022; Kumar et al., 2023). Further details regarding the components and scoring methodology for cognitive domains and IADLs are provided in Appendix A. 3. To merge both scales, we reversed the IADL score, resulting in a total score range of 0 to 50, where higher scores indicate lower cognitive impairment. The lowest 10^{th} percentile was used to identify cognitive impairment (CI).

- In LASI wave 1, dementia assessment was conducted by asking participants about any neurological or psychiatric diagnoses, specifically dementia. If an affirmative response was received, individuals were subsequently excluded from the study based on the cognitive frailty criteria (Kelaiditi et al., 2013). While the integration of the IADL scale with domain-specific cognitive assessments provides a more comprehensive evaluation of early-stage functional declines, this approach may inadvertently include individuals with undiagnosed dementia, a limitation that is elaborated on in detail in the limitations section.

Predictor variables

Sociodemographic factors included were **(i)** age (60-69 years, 70-79 years, 80 years and above), **(ii)** gender (man, woman), **(ii)** residence (rural, urban), **(iii)** educational status (less than primary, primary completed, secondary and above), **(iv)** living arrangement (alone, co-residing), and **(v)** employment status (currently working, not working). Other than that, the **(vi)** geographical regions were categorised (IIPS, 2020) based on all states and Union Territories (UTs) in India as follows: North (Jammu and Kashmir, Himachal Pradesh, Punjab, Chandigarh, Uttarakhand, Haryana, Delhi, Rajasthan), Central (Uttar Pradesh, Chhattisgarh, Madhya Pradesh), East (Bihar, West Bengal, Jharkhand, Odisha), Northeast (Sikkim,

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Arunachal Pradesh, Nagaland, Manipur, Mizoram, Tripura, Meghalaya, Assam), West (Gujarat, Daman and Diu, Dadra and Nagar Haveli, Maharashtra, Goa), and South (Andhra Pradesh, Karnataka, Lakshadweep, Kerala, Tamil Nadu, Pondicherry, Andaman and Nicobar, Telangana). **(vii)** Religion was categorised into three major groups: Hindu, Muslim, and individuals identifying as 'None of the above,' reflecting the diverse religious landscape, which also includes Christian, Sikh, Buddhist/neo-Buddhist, Jain, Jewish, Parsi/Zoroastrian, and others. This categorisation in the LASI survey is designed to encompass the rich tapestry of religious diversity in the country (IIPS, 2020). **(viii)** Caste is a unique feature in India, where the Government of India recognises four main groups: Scheduled Tribe (ST), Scheduled Caste (SC), Other Backward Class (OBC), and 'General' (None of the above) for those who do not belong to any of these categories. This classification is also followed in the LASI survey (IIPS, 2020). ST and SC typically experience more pronounced disadvantages due to historical discrimination, social exclusion, economic and educational disparities. The OBC also face disadvantages compared to the 'None of the above' group. However, the extent of these disadvantages varies based on specific contexts, highlighting the importance of recognising and addressing the unique challenges each group faces for inclusive development. Lastly, **(ix)** Economic status was assessed based on Monthly Per Capita Consumption Expenditure (MPCE) in Rupees (₹) (IIPS, 2020). Food expenditure was collected based on a reference period of seven days, and non-food expenditure was collected based on reference periods of 30 days and 365 days. Both food and non-food expenditures have been standardised to the 30-day reference period. The MPCE was computed and used as the summary measure of consumption, categorised as (poorest, poorer, middle, richer, richest).

Physical health includes self-reported health, hospital stays, and food insecurity. **(i)** Self-Reported Health (SRH) of the respondents was evaluated using the question, Overall, how is your health in general? Would you say it is very good, good, fair, poor, or very poor? In our

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analyses, we dichotomised this variable where 'poor' and 'very poor' were coded as "poor" SRH, and 'very good,' 'good,' and 'fair' were coded as "good" SRH (Rana et al., 2022). **(ii)** Hospital stays were identified based on the question, Over the last 12 months, how many times were you admitted as a patient to a hospital/long-term care facility for at least one night? If the response was one or more times, it was categorised as "yes;" otherwise, it was categorised as "no" (Dumka et al., 2023). **(iii)** Food insecurity was measured using four questions: (a) In the last twelve months, did you ever reduce the size of your meals or skip meals because there was not enough food in your household? (b) In the last twelve months, were you hungry but didn't eat because there was not enough food in your household? (c) In the past twelve months, did you ever not eat for a whole day because there was not enough food in your household? (d) Do you think that you have lost weight in the last twelve months because there was not enough food in your household? The present study considered respondents who answered "yes" to at least one of these questions to be 'food insecure' (Lee et al., 2011).

Psychosocial health characteristics include sleep problems, major depression, social participation, life satisfaction and everyday discrimination. **(i)** Sleep problems were assessed using four questions adapted from the Jenkins Sleep Scale (JSS-4): (a) How often do you have trouble falling asleep? (b) How often do you have trouble waking up during the night? (c) How often do you have trouble waking up too early and not being able to fall asleep again? (d) How often did you feel unrested during the day, no matter how many hours of sleep you had? Response options included 'never,' 'rarely' (1–2 nights per week), 'occasionally' (3–4 nights per week), and 'frequently' (5 or more nights per week) (item d was reverse coded). Sleep problems were coded as "Yes" if any of the four symptoms occurred frequently (Pengpid and Peltzer, 2021). The scale demonstrated excellent reliability (Cronbach α= 0.873, n=4). **(ii)** Major depression was assessed using the Composite International Diagnostic Interview short-form (CIDI-SF) scale, consisting of ten questions. Responses, except for items two and three,

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were binary ('No' coded as 0 and 'Yes' coded as 1). Individuals who felt sad, blue, or depressed all day long or most of the day were coded as 'Yes'; similarly, those who felt sad, blue, or depressed every day or almost every day were coded as 'Yes'. The CIDI-SF, ranging from 0 to 10, categorised respondents with a score of 5 and more as "Depressed" and those with a score of 4 and less as "Not depressed" (Rashmi et al., 2022a). **(iii)** Social participation was assessed based on engagement in social activities, including (a) eating out, (b) going to parks/beaches, (c) visiting relatives/friends, (d) attending cultural performances/shows/cinema, (e) participating in religious functions/events, and (f) attending community/political/organisation group meetings. Respondents reporting participation in any of these activities at least once a month were considered to have "low social participation" (1 = at least once a month, 0 = rarely or never) (Nagargoje et al., 2022) (Cronbach's alpha: 0.677, n=11). **(iv)** Life satisfaction was evaluated using statements regarding overall life contentment. Responses were categorised as 'strongly disagree,' 'somewhat disagree,' 'slightly disagree,' 'neither agree nor disagree,' 'slightly agree,' 'somewhat agree,' and 'strongly agree.' Scores ranged from 5 to 35, with higher scores indicating greater life satisfaction. The scale was further categorised into tertiles: "low satisfaction" (5–20), "medium satisfaction" (21–25), and "high satisfaction" (26–35) (Srivastava et al., 2022). This scale demonstrated excellent reliability (Cronbach α= 0.899, n=5). **(v)** Everyday discrimination experiences were assessed with the six-item Everyday Discrimination Scale (Cronbach's alpha: 0.862, n=6). Responses ranged from 1 = 'Almost every day' to 6 = 'never' and were dichotomised into 'never' = "no discrimination" and 'ever' (collapsing those reporting 'less than once a year' or greater into one category) = "high discrimination" (Pengpid and Peltzer, 2021).

Statistical analysis

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Analyses were conducted using R statistical software (version 4.3.3) (https://www.r-project.org), incorporating individual-level weights for India. Detailed information on the generation of LASI individual weight can be found in Perianayagam et al. (2022). A two-tailed p-value of <0.05 was considered statistically significant. The study adhered to STROBE guidelines (https://www.strobe-statement.org). First, descriptive statistics were used to summarise the background characteristics of the study population, categorised by cognitive frailty (CF) status. Differences in categorical variables between individuals with and without CF were assessed using the chi-square (χ^2) test. Second, before performing multivariate regression analyses, multicollinearity among exploratory variables was evaluated using the Variance Inflation Factor (VIF) test (Appendix A.4). The results indicated no multicollinearity, as all VIF values were below 2. Consequently, all significant predictor variables were retained for subsequent statistical analyses. Finally, a binary logistic regression model was used to examine factors associated with cognitive frailty. Initially, unadjusted odds ratios (ORs) were estimated to assess the association between each exploratory variables and CF. Subsequently, an adjusted binary logistic regression analysis was conducted, controlling all covariates. The final model reported adjusted odds ratios (AORs) with 95% confidence intervals, along with the -2 log-likelihood statistic, Pearson's χ^2, and Nagelkerke's R^2.

Results

Prevalence of cognitive frailty

The study included 27,379 participants from LASI Wave 1, with weighted percentages indicating an overall cognitive frailty prevalence of 4.8% (Table 1). A majority (60.8%) were aged 60–69 years, 29.5% were 70–79 years, and 9.7% were 80 or older. Women comprised 52.2% of the sample, and 71.8% resided in rural areas. Geographical region shows that the East (24.1%), Central (21.3%) and South (21.1) regions had the highest representation. 82.7%

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identified as Hindu religion, and 45.8% belonged to Other Backward Class Caste group. Most participants (68.0%) had less than primary education, 32.6% were currently employed, and economic status was distributed relatively evenly across quintiles (21.5% poorest). Health-related characteristics showed 77.4% reported good health, 7.5% had hospital stays in past 12 months, and 10.4% food insecurity. Psychosocial factors included 11.8% with a sleep problem, 8.4% with major depression, 18.4% reporting everyday discrimination, and 31.3% reporting low life satisfaction.

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Table 1. Participants characteristics, LASI wave 1 (N= 27,379)				
Characteristics		**Sample**	**Unweighted %**	**Weighted %**
Cognitive frailty status	No	26167	95.6	95.2
	Yes	1212	4.4	4.8
Age	60-69	17018	62.2	60.8
	70-79	7843	28.6	29.5
	80+	2518	9.2	9.7
Gender	Man	13293	48.6	47.8
	Woman	14086	51.4	52.2
Residence	Urban	9043	33.0	28.2
	Rural	18336	67.0	71.8
Region	North	5004	18.3	12.9
	Central	3707	13.5	21.3
	East	5099	18.6	24.1
	Northeast	3574	13.1	3.0
	West	3635	13.3	16.6
	South	6360	23.2	22.1
Religion	Hindu	19999	73.0	82.7
	Muslim	3179	11.6	10.8
	None of the above	4201	15.3	6.4
Caste	General	7831	28.6	27.3
	Scheduled caste	4441	16.2	18.9
	Scheduled tribe	4626	16.9	8.1
	Other backward caste	10481	38.3	45.8
Educational status	Secondary and higher	4077	14.9	13.9
	Primary completed	5299	19.4	18.1
	<Primary	18003	65.8	68.0
Employment status	Currently working	8458	30.9	32.6
	Currently not working	18921	69.1	67.4
Economic status	Poorest	5607	20.5	21.5
	Poorer	5663	20.7	21.5
	Middle	5649	20.6	20.9
	Richer	5410	19.8	19.6
	Richest	5050	18.4	16.4
Living arrangement	Co-residing	25966	94.8	94.3
	Living alone	1413	5.2	5.7
Self-reported health status	Good	21520	78.6	77.4
	Poor	5859	21.4	22.6
Hospital stays in last 2 years	No	25336	92.5	92.5
	Yes	2043	7.5	7.5
Food insecurity	No	25015	91.4	89.6
	Yes	2364	8.6	10.4
Sleep problem	No	24409	89.2	88.2
	Yes	2970	10.8	11.8
Major depression	No	25529	93.2	91.6
	Yes	1850	6.8	8.4
Low social participation	No	21921	80.1	77.0
	Yes	5458	19.9	23.0
Everyday discrimination	No	23096	84.4	81.6
	Yes	4283	15.6	18.4
Life satisfaction	High	12701	46.4	46.4
	Medium	6525	23.8	22.3
	Low	8153	29.8	31.3

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Distribution of cognitive frailty by participant characteristics

The sociodemographic characteristics of the study population in India (N=27,379) were analysed in relation to CF status (Table 2). The prevalence of CF demonstrated a clear age-related increase, particularly among individuals aged 70–79 years (6.4%, p<0.01) and those aged 80 years and above (17.2%, p<0.01). Gender disparities were evident, with women exhibiting a higher prevalence (5.2%, p<0.01). Urban-rural residence emerged as a significant factor, with rural areas displaying higher CF rates (5.8%, p<0.01). Significant regional differences were observed, with the highest prevalence reported in the Western region (5.7%, p<0.01), followed by the Southern (5.1%, p<0.01) and Eastern regions (5.1%, p<0.01). Religious affiliation also influenced CF prevalence, with higher rates among Muslims (5.7%, p<0.01) and individuals from other religious groups (6.5%, p<0.01) compared to Hindus. Similarly, caste-based disparities were apparent, with Scheduled Tribes (7.9%, p<0.01) and Scheduled Castes (6.4%, p<0.01) exhibiting higher prevalence than their counterparts. Educational attainment showed a strong inverse association with CF, as lower education levels were linked to increased prevalence (6.7%, p<0.01). Living alone was associated with higher CF prevalence (6.0%, p<0.01) compared to co-residing with others. Furthermore, individuals who were not currently employed (6.4%, p<0.01) and those in the poorest economic strata (6.4%, p<0.01) faced significantly higher CF risk, underscoring the complex interplay between sociodemographic factors and CF among older adults in India.

This table (Table 2) also highlighted the health status of the participants, it shows a robust association between SRH status and CF ($p < 0.01$), with 11.4% of individuals reporting poor health being in the CF category and only 2.9% of those with good health showing CF. Hospital stays in past 12 months ($p < 0.01$), and food insecurity ($p < 0.01$) were also significantly associated with CF status. In psychosocial health, sleep problems, social participation, low life satisfaction, and everyday discrimination (all $p < 0.01$) showed strong

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associations with CF status, with CF being more likely in those with each negative issue. Major depression was also significantly associated with CF ($p < 0.01$), with 11.5% of individuals with depression being in the CF category and only 4.2% of those without depression.

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Table 2. Distribution of Cognitive Frailty by Participant Characteristics, LASI Wave 1 (N=27,379)				
Characteristics		**Cognitive frailty status (weighted %)**		
		No	**Yes**	**p-value**
Age	60-69	97.9	2.1	<0.01
	70-79	93.6	6.4	
	80+	82.8	17.2	
Gender	Man	95.6	4.4	<0.01
	Woman	94.8	5.2	
Residence	Urban	97.6	2.4	<0.01
	Rural	94.2	5.8	
Region	North	96.1	3.9	<0.01
	Central	95.7	4.3	
	East	94.9	5.1	
	Northeast	96.0	4.0	
	West	94.3	5.7	
	South	94.9	5.1	
Religion	Hindu	95.4	4.6	0.001
	Muslim	94.3	5.7	
	None of the above	93.5	6.5	
Caste	General	96.1	3.9	<0.01
	Scheduled caste	93.6	6.4	
	Scheduled tribe	92.1	7.9	
	Other backward caste	95.8	4.2	
Educational status	Secondary and higher	99.7	0.3	<0.01
	Primary completed	98.8	1.2	
	<Primary	93.3	6.7	
Employment status	Currently working	98.4	1.6	<0.01
	Currently not working	93.6	6.4	
Economic status	Poorest	93.6	6.4	<0.01
	Poorer	94.7	5.3	
	Middle	95.6	4.4	
	Richer	96.0	4.0	
	Richest	96.3	3.7	
Living arrangement	Co-residing	95.2	4.8	0.012
	Living alone	94.0	6.0	
Self-reported health status	Good	97.1	2.9	<0.01
	Poor	88.6	11.4	
Hospital stays in last 2 years	No	95.4	4.6	<0.01
	Yes	92.0	8.0	
Food insecurity	No	95.6	4.4	<0.01
	Yes	91.7	8.3	
Sleep problem	No	95.8	4.2	<0.01
	Yes	90.2	9.8	
Major depression	No	95.8	4.2	<0.01
	Yes	88.5	11.5	
Low social participation	No	96.8	3.2	<0.01
	Yes	89.6	10.4	
Everyday discrimination	No	95.5	4.5	<0.01
	Yes	93.7	6.3	
Life satisfaction	High	96.5	3.5	<0.01
	Medium	95.7	4.3	
	Low	92.9	7.1	

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Prevalence of cognitive frailty in India by region

The prevalence of cognitive frailty varied widely across different states (Appendix A.5). Figure 2 provides a spatial map showing that states with higher prevalence (divided into five quantile classes) had rates ≥5.7%, while the lowest prevalence was less than 2.8%. Southern and western states, including Telangana (7.9%), Maharashtra (6.2%), Andhra Pradesh (6.4%), and Tamil Nadu (5.4%) exhibit relatively higher cognitive frailty rates. In contrast, states such as Nagaland (0.5%), Puducherry (0.9%), and Manipur (1.1%) report the lowest prevalence. Lower prevalence is also observed in few northern and central states such as Punjab (2.5%), Haryana (2.3%), and Uttarakhand (2.6%). The value of this map lies in revealing localised variations that may be overlooked in broader regional trends. By providing a detailed visual representation, this map complements the statistical findings, offering a more nuanced understanding of where interventions are most needed. This geographic distribution highlights the necessity for targeted interventions addressing cognitive frailty, particularly in high-prevalence regions.

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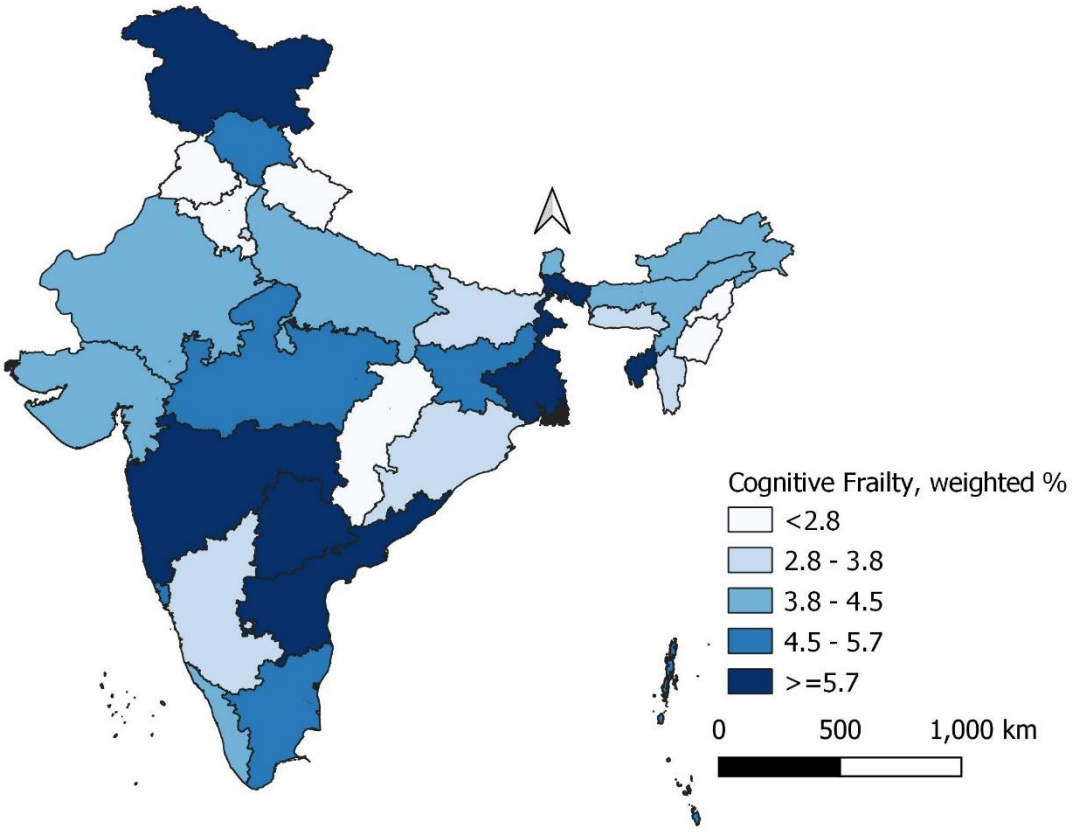

Figure 2. Prevalence of Cognitive Frailty among older adults aged 60 years and above in India by its states, LASI Wave 1

Association of cognitive frailty with socio-demographic and health characteristics

Table 3 showed the adjusted odds ratios explaining the associated factors influencing CF in the study population. Age displayed a graded effect, with the 70-79 age group showing an adjusted odds ratio (AOR) of 2.6 (95% CI: 2.22-3.01, $p < 0.01$) and the 80+ age group exhibiting the

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highest AOR of 6.30 (95% CI: 5.32-7.46, $p < 0.01$) compared to the reference group (60-69). Being female was associated with a higher likelihood of CF (AOR= 1.6, 95% CI: 1.4–1.9, $p < 0.01$). Regional variations were observed, with individuals from the West (AOR = 2.3, 95% CI: 1.8–2.9, $p < 0.01$) and South region of India (AOR = 1.6, 95% CI: 1.3–1.9, $p < 0.01$) demonstrating higher odds. Other significant predictors included rural residence (AOR = 1.3, 95% CI: 1.1–1.6, $p < 0.01$), educational status below primary level (AOR = 10.6, 95% CI: 6.2–17.8, $p < 0.01$), currently not working (AOR = 3.4, 95% CI: 2.7–4.1, $p < 0.01$), poor self-reported health (AOR = 2.6, 95% CI: 2.3-3.0, $p < 0.01$). Hospital stays in last 12 months (AOR = 1.4, 95% CI: 1.6–1.7, $p < 0.01$), and food insecurity (AOR = 1.3, 95% CI: 1.1–1.6, $p < 0.01$) also exhibited high odds for CF status. Psychosocial health factors such as sleep problems (AOR = 1.8, 95% CI: 1.6–2.1, $p < 0.01$), major depression (AOR = 1.9, 95% CI: 1.6–2.3, $p < 0.01$), low social participation (AOR = 2.3, 95% CI: 2.0–2.6, $p < 0.01$), everyday discrimination (AOR= 1.2, 95% CI 1.0-1.4, p=0.020), and low life satisfaction (AOR = 1.4, 95% CI: 1.2–1.6, $p < 0.01$), also demonstrated significant associations with cognitive frailty. Model fit statistics, including -2 log-likelihood, χ^2, degrees of freedom, and Nagelkerke R^2, demonstrate the model's robustness in explaining CF variance. Unadjusted odds ratios for these associations are provided in Appendix A.6 for further support of the results.

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Table 3. Result of binary logistic regression (final model) analysis (N=27,379)				
		AOR	**95% CI**	**p-value**
Age	60-69®			
	70-79	2.587	2.221-3.013	<0.01
	80+	6.298	5.321-7.456	<0.01
Gender	Man®			
	Woman	1.632	1.441-1.851	<0.01
Residence	Urban ®			
	Rural	1.339	1.139-1.574	<0.01
Region	North ®			
	Central	0.358	0.893-0.700	0.358
	East	0.414	1.096-0.880	0.414
	Northeast	0.474	0.902-0.680	0.474
	West	2.276	1.807-2.867	<0.01
	South	1.570	1.271-1.939	<0.01
Religion	Hindu ®			
	Muslim	1.249	1.034-1.509	0.021
	None of the above	0.909	0.731-1.131	0.392
Caste	General®			
	Scheduled caste	1.111	0.904-1.364	0.317
	Scheduled tribe	1.581	1.279-1.954	<0.01
	Other backward caste	0.930	0.780-1.108	0.418
Educational status	Secondary and higher®			
	Primary completed	2.893	1.641-5.099	<0.01
	<Primary	10.561	6.242-17.781	<0.01
Employment status	Currently working®			
	Currently not working	3.350	2.696-4.163	<0.01
Economic status	Poorest®			
	Poorer	0.979	0.815-1.176	0.818
	Middle	1.106	0.842-1.226	0.871
	Richer	0.911	0.747-1.111	0.357
	Richest	0.856	0.688-1.066	0.165
Living arrangement	Co-residing®			
	Living alone	0.779	0.603-1.005	0.165
Self-reported health status	Good®			
	Poor	2.631	2.309-2.996	<0.01
Hospital stays in last 12 months	No®			
	Yes	1.414	1.157-1.726	0.001
Food insecurity	No®			
	Yes	1.303	1.081-1.570	0.005
Sleep problem	No®			
	Yes	1.818	1.552-2.129	<0.01
Major depression	No®			
	Yes	1.897	1.571-2.292	<0.01
Low social participation	No®			
	Yes	2.278	1.991-2.607	<0.01
Everyday discrimination	No®			
	Yes	1.208	1.031-1.416	0.020
Life satisfaction	High®			
	Medium	1.048	0.885-1.242	0.586
	Low	1.365	1.176-1.584	<0.01
-2 log-likelihood Final model fitting statistics	**χ^2**	**df**	**p-value**	**Nagelkerke R^2**
6187.86	2384.00	31	<0.001	0.374

®refers to reference group; AOR = adjusted odds ratio; the adjusted odds ratio accounts for potential confounders and controls for all variables in the model; CI = confidence interval.

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Discussion

The first objective of this study was to examine the national prevalence of CF in India. While increased longevity in India is to be celebrated, the rapid increase in the older population in India brings an urgent need for understanding the current and potential health status and care needs of the older population. This understanding is crucial to develop policy and public health strategies with the purpose of reducing prevalence of serious late-life impairments. Developing understanding and risks for CF is an important part of this, as is development of potential interventions for this reversible (Ruan et al., 2015; Ruan et al., 2020; Hwang et al., 2023), but high-risk condition (Feng e al., 2017; Livingston et al., 2024; Zhang et al., 2022; Das, 2022, Corral-Pérez et al., 2023). In a descriptive review, Sugimoto and colleagues (2018) demonstrated a prevalence of 1.0-1.8% of CF in community-based samples, with higher levels in clinical samples (e.g. in participants recruited from specific disease groups or hospital frailty units). They also noted higher levels when neurodegenerative conditions such as dementia were not excluded, and that levels increased with the age of the sample. In a meta-analysis, Qiu and colleagues (2021) carefully excluded studies that did not exclude participants with dementia, and showed that pooled prevalence of CF was higher, at 9%, although this study did include studies with higher age ranges (e.g. one study only considered participants aged over 90 years). However, no review or meta-analysis could be found that included any studies from India. Furthermore, no prior national prevalence estimates of CF in India have excluded dementia in their assessments—a methodological divergence from established frameworks (e.g., Kelaiditi et al., 2013). The sole exception is a regional study in rural West Bengal (Das, 2022), which reported a CF prevalence of 21.8% among adults aged ≥60 years but remains limited in generalisability. The present study found a national prevalence of CF of 4.8% which is higher than many previous studies based on the general over 60s population (Sugimoto et al., 2018).

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In response to our second objective, our study demonstrated significant variance by geographical region of India with the highest prevalence of CF in Western and Southern states. On a local level within these regions, some areas were noted as having higher prevalence rates surpassing the national prevalence of 4.8%. It is already well-established that South region of India has become a major driver of the ageing population in India, compared to other regions, with an increasing trend in the burden of geriatric health problems (Mathuranath et al., 2010; Bharati et al., 2011; Dey et al., 2012; Ahmad and Saxena, 2023; UNFPA, 2023). A population-based study from the state of Telangana reported that every fifth older adult had at least one disability, and every third individual had at least one non-communicable disease (NCD) (Marmamula et al., 2021). In our study, this state showed the highest prevalence of CF among Southern India, at 7.9%. It is also reported that, compared to older adults in Southern India, those in Northern, Eastern, North-Eastern, and Western India had lower levels of other psychosocial health issues like loneliness (Srivastava and Srivastava, 2023). On the other hand, Patel and colleagues (2023) highlighted a high burden of multimorbidity in both Western and Southern India, emphasising the need for increased attention to these states in the country. The regional variation in CF prevalence in the present study suggests a need for a significant focus on state-level policy making, considering the upcoming demographic transition.

The third objective of this study was to consider the association of CF with potential multidimensional risk factors, using the Biopsychosocial Model (Engel, 1977) that includes a range of intrinsic and extrinsic variables. The study first examined socio-demographic variables such as age and gender, confirming expectations of an increase in prevalence with age (e.g. to 17.2% of the over 80s) in this age related condition, although this was still lower than the prevalence of 50.3% found in Hao and colleagues' (2018) study of people aged over 90 years in the Sichuan region of China, and lower than the prevalence of 43.9% found amongst over 80s in the smaller study by Navarro-Pardo and colleagues (2020) in Spain. The present

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study also confirmed previously noted disparities between men and women, with women showing a 5.2% prevalence of CF compared to 4.4% in men and an odds ratio indicating they were 1.6 times more likely to be cognitively frail than men in the adjusted model. Higher frequency of CF in older women has been related to longer life expectancy in women, to reduced opportunities for education and occupational or social roles (reducing lifetime intellectual stimulation and so cognitive reserve) (Lee et al., 2014; Rashmi et al., 2022b), as well as to differential underlying biological changes related to hormonal changes (Ruan et al., 2017).

The effect of having less than primary education (6.7% CF prevalence) was striking as compared with having secondary education (0.3% CF) and showing an adjusted odds ratio of 10.6 times the risk of CF than in those with secondary education or above. As the strongest effect in the study, this suggests that policies that increase the proportion of people with secondary education or higher in India could gradually have a very significant impact on the health of people in older age. From the data in the LASI dataset, it can be seen that more than 65.0% of over 60s have less than primary education (Muhammad et al., 2022; Seligman et al., 2023). World bank data (2011) indicates that only 40% of Indian adolescents attend secondary school, but 95% of younger children are now attending primary school. While there are many economic reasons for increasing the educational level of a population, the present study shows long-term impacts on the health, independence and potential care needs of India's ageing population.

Living alone and not working were also associated with a higher adjusted odds ratio of CF, although both may also be associated with other aspects of ageing such as retirement. Living alone or having to stop working may not necessarily be a risk factor, but rather a consequence of existing higher CF. However, an indicator of social support and also socially and intellectually stimulating activity can be seen in the measure of social participation, which

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included a range of activities. In the adjusted model, lower social participation was associated with increased odds of cognitive frailty. Mechanisms of the effects of social participation include strengthening of cognitive reserve, particularly important in a population with low education or lower-level employment but also impacts on loneliness and availability of support in stressful situations. People who are more socially active outside the home are also more likely to be more physically active, reducing or ameliorating the impact of physical frailty on cognition (Ruan et al., 2020; Foong et al., 2021), and potentially impacting nutrition by being more likely to eat with other people.

While economic status based on income did not show any association with CF in the adjusted model, food insecurity showed consistent increased odds of CF including in the adjusted model. Mechanisms by which poverty and inequalities impact on likelihood of CF in older age include impact on potential nutritional deficiencies. Poor or restricted diet and particularly low protein intake in older adults can lead to weight loss and reductions in muscle mass, both indicators of PF. Associations between nutrition and cognition have been well researched, with several previous studies providing evidence of a link with both PF and CI (Adachi et al., 2018; Chye et al., 2018), and lower consumption of some nutrient groups including whole grains, vegetables, fruit, meat and nuts. In addition, low vitamin D and omega 3 polyunsaturated fatty acids has been associated with coexisting PF and CI (Chhetri et al., 2018). A previous study using the LASI data (Kumar et al., 2021) found that food security was strongly associated with cognitive function in terms of word recall and the arithmetic tests described in this study, with those older adults who did have food security being 0.71 and 0.45 times less likely (respectively) to show impairment in these cognitive tests than those who reported food insecurity. Other studies have also shown a strong link between food insecurity and cognitive decline in older age; for example, a longitudinal study in a Puerto Rican population in the United States showed, in a fully adjusted model, that food insecurity was

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associated with a faster decline in executive function (but not memory) (Wong et al., 2020). The distinction between executive function and memory is important as CF is commonly associated with the former more than the latter (Bunce et al., 2019).

Another potential impact of inequalities examined was the impact of experiences of everyday discrimination. While this may also be associated with religious affiliation, caste or poverty which separately impacted odds for CF, this variable indicated one mechanism whereby issues like religious affiliation and caste may have an impact on wellbeing. Psychological health was also considered, where depression, sleep disorder and life satisfaction all showed significant effects on adjusted odds of CF. While again these issues could all be bidirectional, with CF resulting in depression or lower life satisfaction, previous longitudinal studies have specifically demonstrated the role of depression as a mediator in the relationship between baseline frailty and later cognitive impairment (Resciniti et al., 2023), highlighting it as a potential important target for intervention. Self-reported poor health status, and having had a hospital stay were all associated with odds for CF although one may argue that they may also be consequences of CF. It must be borne in mind that this is a cross-sectional study, given that the LASI has not yet published the second wave of data collection. Future analyses could examine this question of direction of association by examining risk of occurrence of CF at Wave 2 in those who were not living with CF at Wave 1.

Moreover, the findings of this study align with the biopsychosocial model, which emphasises the interplay of biological, psychological, and social factors in understanding health outcomes (Engel, 1977). This holistic framework not only elucidates the multi-dimensional risk factors contributing to CF but also underscores the importance of integrated interventions. Addressing cognitive frailty requires strategies that go beyond medical approaches to include educational attainment, social participation, and nutritional security. By considering the broader social determinants of health alongside biological vulnerabilities, the

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biopsychosocial model offers a comprehensive foundation for developing targeted public health interventions and policies aimed at reducing cognitive frailty among India's ageing population.

Strengths and limitations

A key strength of this study is that it represents the first analysis of the prevalence and multidimensional risk factors of CF in India, offering a comprehensive overview of a diverse population, the largest in the world. The study provides a broad range of prevalence data that captures population and regional variability, which can serve as a foundation for future, more targeted research in specific regions or groups. Given India's demographic diversity, including socio-economic, cultural, and healthcare differences, these findings are critical for understanding CF's impact.

However, the primary limitation of this study is its cross-sectional design, which provides a snapshot of CF prevalence and associated risk factors but cannot establish causality or track progression over time. Future waves of the LASI will enable predictive models to explore CF trajectories and inform early intervention strategies. The data's specificity to India limits comparisons with other countries due to its unique ethnic, cultural, economic, and caste complexities, although certain factors, such as educational access, may be comparable (Ge et al., 2020). While this reduces generalisability, it strengthens the study's focus on CF predictors within India's ageing population. Additionally, the measures used to assess cognitive impairment have certain limitations. The cognitive measures did not align with widely used tools such as the Montreal Cognitive Assessment (MoCA). Mild Cognitive Impairment is typically defined by a specific band of cognitive scores (e.g., MoCA scores between 18 and 25), where scores below the lower limit (<18) often indicate more severe cognitive decline or probable dementia. In this study, the absence of a lower score cutoff and reliance on percentile-

based thresholds may result in the inclusion of participants with more advanced cognitive impairment. MoCA is more suitable for assessing CF but is less commonly included in large datasets. However, the LASI cognitive composite score, which incorporates aspects of executive function and IADL, proved useful. Future studies would benefit from broader measures of executive function to enhance the assessment of CF.

Implications for policy and practice

The most significant variables influencing the odds of CF include several modifiable factors. Educational background had the greatest impact, potentially linked to regional, economic, ethnic, and gender disparities (Kumar et al., 2022). Increasing secondary education completion is crucial, as education enhances cognitive reserve, which can delay neurodegenerative effects. Cognitive reserve can also be developed through occupational learning and intellectually stimulating leisure activities throughout life. Social participation was another key factor increasing CF odds, with the need for research into social isolation and loneliness specifically within the diverse cultural contexts of India's regions. Additionally, food insecurity is a critical policy issue, as India is home to a significant proportion of the world's undernourished population. Inadequate food intake and vitamin deficiencies, particularly among older adults, are associated with earlier cognitive impairment (WFP, 2019), underscoring the importance of focusing on nutrition in India's ageing population (Fong et al., 2023).

Conclusions

This is the first study to describe the prevalence of cognitive frailty across India, showing higher prevalence than may be expected based on global figures for the general over 60s community population, with clear regional disparities. The study examined a range of risk factors related to both individual factors such as depression, life satisfaction and social

participation, as well as a range of sociocultural and socioeconomic determinants such as level of education, experiences of discrimination, income and food insecurity. The study highlighted the impact of several of these in an adjusted model, framed within a biopsychosocial model that integrates biological, psychological, and social factors to provide a more comprehensive understanding of cognitive frailty risk. The findings also considered potential implications for policy. Future availability of longitudinal data and specific in-depth investigations will be important to build on this work.

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Conflict of interest

The Author(s) declare(s) that there is no conflict of interest.

Research ethics

This study addresses ethical issues related to the collection and use of data from the LASI Wave 1 (2017-19) survey. In LASI wave 1, ethical approval was granted by the Indian Council of Medical Research (ICMR), India, ensuring adherence to relevant guidelines and regulations. Informed consent was also obtained from all subjects involved in the study. Additionally, necessary ethical clearance for utilising secondary data was obtained from the Lancaster

University Faculty of Health and Medicine Ethics Committee (FHMREC), UK, with the ethics reference FHM-2023-3659-DataOnly-1 dated 24th May 2023.

Data availability statement

Data and materials are located at https://lasi-india.org. The datasets analysed in this study are also accessible through the Institute for Population Sciences (IIPS) Mumbai, India, repository (Located at: https://www.iipsindia.ac.in/content/LASI-data). IIPS Mumbai served as the designated entity for data collection on behalf of the Ministry of Health and Family Welfare, Government of India. Researchers and policymakers can obtain the data and materials of the LASI Wave-1 by formally requesting access from the IIPS.

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Supplementary Material

A holistic approach to cognitive frailty in community-dwelling older adults in India: Evidence from a nationally representative survey

Web Appendix

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1. Components of Modified Community-Oriented Frailty Index (COM-FI)

Variable	**Variable description**	**Coding**	
Exhaustion	Did you feel tired out or low on energy all the time	Yes=1 No=0	
Low body weight	Body Mass Index (BMI) in the lowest quintile	Men	Women
		BMI≤18.1= 1 BMI>18.1= 0	BMI≤18.5= 1 BMI>18.5= 0
Low grip strength	Handgrip (HG) strength in the dominant hand in the lowest quintile	Men	Women
		HG ≤18.3= 1 HG >18.3= 0	HG ≤11.8= 1 HG >11.8= 0
Low walking speed	Walking speed in the lowest quintile for men and women	Men	Women
		Walk ≥ 4.3min.= 1 Walk < 4.3min.= 0	Walk ≥ 4.8min.= 1 Walk < 4.8min.= 0
Low physical activity	How often do you take part in sports or vigorous activities, such as running or jogging, swimming, going to a health center or gym, cycling, or digging with a spade or shovel, heavy lifting, chopping, farm work, fast bicycling, cycling with loads	One to three times a month / Hardly ever or never= 1 Every day/More than once a week/Once a week=0	
Hypertension	Hypertension or high blood pressure (self-reported)	Yes=1 No=0	
Diabetes	Diabetes or high blood sugar (self-reported)	Yes=1 No=0	
Lung disease	Chronic lung disease such as asthma, chronic obstructive pulmonary disease/Chronic bronchitis or other chronic lung problems (self-reported)	Yes=1 No=0	
Heart disease	Chronic heart diseases such as coronary heart disease (heart attack or Myocardial Infarction), congestive heart failure, or other chronic heart problems (self-reported)	Yes=1 No=0	
Stroke	Stroke (self-reported)	Yes=1 No=0	
Bone problems	Arthritis or rheumatism, Osteoporosis or other bone/joint diseases (self-reported)	Yes=1 No=0	
Neurological problems	Any neurological, or psychiatric problems such as depression, unipolar/bipolar disorders, convulsions, Parkinson's etc. (but excluding dementia) (self-reported)	Yes=1 No=0	
Polypharmacy	How many prescribed medications do you take?	≥4 =1 <4 =0	
Injury	In the past two years, have you sustained any major injury	Yes=1 No=0	
Dressing	Difficulties dressing, including putting on chappals, shoes, etc.	Yes=1 No=0	
Walking	Difficulties in walking across a room	Yes=1 No=0	
Bathing	Difficulties in bathing	Yes=1 No=0	
Eating	Difficulties in eating	Yes=1 No=0	
Bed	Difficulties in getting in and out of bed	Yes=1 No=0	
Toilet use	Difficulties in using the toilet, including getting up and down	Yes=1 No=0	

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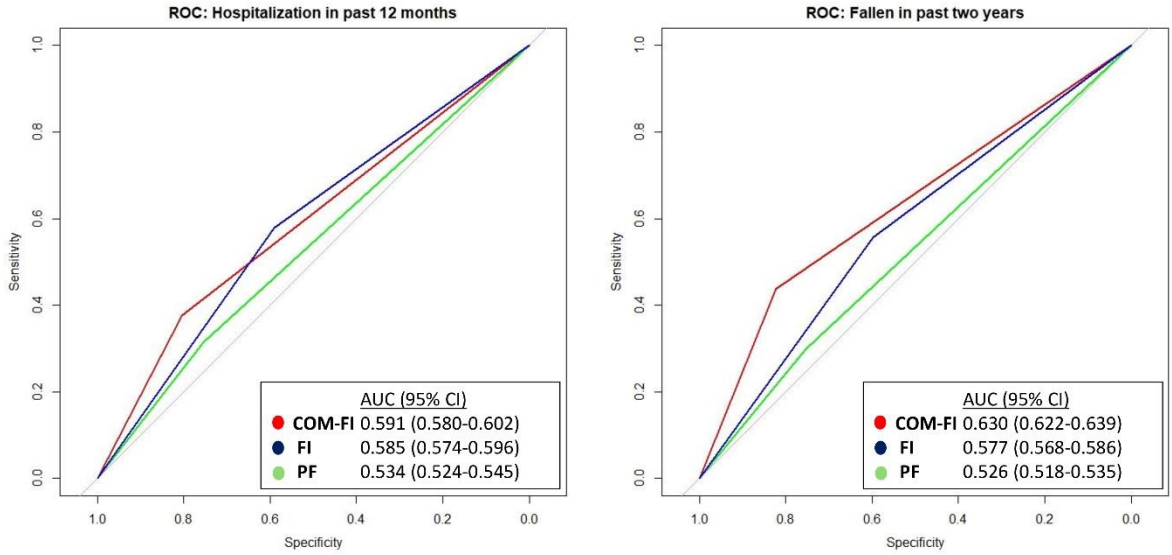
2. Validity test for the COM-FI Scale

DeLong's Test Comparison for AUCs of COMFI, PF, and FI Scales						
Comparison	**Z-Statistic**	**P-Value**	**95% Confidence Interval**	**AUC (COMFI)**	**AUC (PF)**	**AUC (FI)**
Hospitalization - COMFI vs PF	9.3382	<0.001	0.0445 to 0.0682	0.5907	0.5344	-
Hospitalization - COMFI vs FI	0.9249	0.355	-0.0062 to 0.0172	0.5907	-	0.5852
Hospitalization - PF vs FI	-7.4834	<0.001	-0.0642 to -0.0375	-	0.5344	0.5852
Fall - COMFI vs PF	21.981	<0.001	0.0945 to 0.1130	0.6304	0.5266	-
Fall - COMFI vs FI	11.231	<0.001	0.0439 to 0.0625	0.6304	-	0.5772
Fall - PF vs FI	-9.218	<0.001	-0.0613 to -0.0398	-	0.5266	0.5772

Kelaiditi and colleagues (2013)[1] defined cognitive frailty as the coexistence of physical frailty and cognitive impairment in the absence of dementia. To determine the most appropriate scale for assessing frailty, we conducted a Receiver Operating Characteristic (ROC) curve analysis and used DeLong's Test to compare the two most widely used frailty scales in India: Physical Frailty (PF)[2] and Frailty Index (FI)[3] scales based on the LASI survey wave 1. These scales were evaluated based on their ability to predict two outcomes strongly associated with frailty in the literature:[4,5] hospitalization within the past 12 months and falls within the last 2 years.

Comparison of ROC Curves for COM-FI, PF, and FI Scale



The results indicate that the COM-FI scale had significantly higher Area Under the Curve (AUC) values compared to the PF scale for both hospitalization (COM-FI: 0.5907 vs. PF: 0.5344) and falls (COM-FI: 0.6304 vs. PF: 0.5266). While the COM-FI scale performed similarly to the FI scale for hospitalization (COM-FI: 0.5907 vs. FI: 0.5852), it outperformed the FI scale for falls (COM-FI: 0.6304 vs. FI: 0.5772). Although the AUC scores were modest (all below 0.7), the COM-FI scale demonstrated consistent and statistically significant predictive validity. This suggests that the COM-FI scale is a more reliable and versatile tool for assessing physical frailty among community-dwelling older adults in India.

[1] Kelaiditi, E., Cesari, M., Canevelli, M., Van Kan, G. A., Ousset, P. J., Gillette-Guyonnet, S., ... & Vellas, B. (2013). Cognitive frailty: rational and definition from an (IANA/IAGG) international consensus group. The Journal of nutrition, health and aging, 17(9), 726-734.doi: 10.1007/s12603-013-0367-2

[2] Das, S., & Prasad, J. (2023). Gender differences in determinants of the components of the frailty phenotype among older adults in India: Findings from LASI Wave-1. International Journal of Environmental Research and Public Health, 20(4), 3055. doi: 10.3390/ijerph20043055

[3] Ghosh, A., Kundu, M., Devasenapathy, N., Woodward, M., & Jha, V. (2023). Frailty among middle-aged and older women and men in India: findings from wave 1 of the longitudinal Ageing study in India. BMJ open, 13(7), e071842. doi: 10.1136/bmjopen-2023-071842

[4] Kojima, G. (2016). Frailty as a predictor of hospitalisation among community-dwelling older people: a systematic review and meta-analysis. J Epidemiol Community Health, 70(7), 722-729. doi: 10.1136/jech-2015-206978

[5] Yang, Z. C., Lin, H., Jiang, G. H., Chu, Y. H., Gao, J. H., Tong, Z. J., & Wang, Z. H. (2023). Frailty is a risk factor for falls in the older adults: a systematic review and meta-analysis. The journal of nutrition, health & aging, 27(6), 487-495. doi: 10.1007/s12603-023-1935-8

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3. Components of cognitive domains and IADLs

Variable	Variable Description	Measure	Coding
1) Cognitive domains			
Memory	Assessed through immediate word recall (0-10) and delayed word recall (0-10)	Cognitive Function	Range: 0-20
Orientation	Evaluated through time (0-4) and place (0-4) orientation	Cognitive Function	Range: 0-8
Arithmetic Ability	Executive function assessed via backward counting (0-2), serial 7s subtraction task (0-5), and two computations (0-2)	Cognitive Function	Range: 0-9
Executive & Visuospatial Functioning	Assessed through paper folding (0-3) and pentagon drawing (0-1)	Cognitive Function	Range: 0-4
Object Naming	Naming two objects	Cognitive Function	Range: 0-2
Range: 0-43 (Higher value = Better cognitive function)			
2) Instrumental Activities of Daily Living (IADL) Disability			
Preparing a Hot Meal	Difficulty in cooking and serving food	Functional Disability	Yes=1, No=0
Shopping for Groceries	Difficulty in purchasing necessary food items	Functional Disability	Yes=1, No=0
Making Telephone Calls	Difficulty in making and receiving calls	Functional Disability	Yes=1, No=0
Taking Medications	Difficulty in remembering and taking medications on time	Functional Disability	Yes=1, No=0
Doing Housework/Gardening	Difficulty in performing household chores	Functional Disability	Yes=1, No=0
Managing Money	Difficulty in handling financial transactions and tracking expenses	Functional Disability	Yes=1, No=0
Navigating Unfamiliar Places	Difficulty in getting around or finding an address in an unfamiliar place	Functional Disability	Yes=1, No=0
Range: 0-7 (Higher value = Higher disability)			

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4. Multicollinearity Test Results

Multicollinearity statistics					
	Summary				**Collinearity statistics**
Characteristics	**Estimate**	**Standard Error**	**t-test values**	**Significance**	**VIF test**
(Intercept)	-0.069	0.005	-14.477	0.000	
Age group	0.049	0.002	25.813	0.000	1.108
Gender	-0.010	0.003	-3.904	0.000	1.252
Residence	0.009	0.003	3.104	0.002	1.202
Region	0.005	0.001	7.004	0.000	1.108
Religion	0.003	0.002	4.028	0.008	1.023
Caste	-0.002	0.001	-2.891	0.049	1.107
Educational status	0.020	0.002	10.777	0.000	1.384
Employment status	0.027	0.003	9.588	0.000	1.204
Economic status	-0.002	0.001	-2.134	0.033	1.112
Living arrangement	-0.014	0.005	-2.606	0.009	1.046
Self-Reported Health	0.052	0.003	17.368	0.000	1.087
Hospitalization	0.016	0.005	3.413	0.001	1.026
Food Insecurity	0.016	0.004	3.716	0.000	1.065
Sleep Problem	0.035	0.004	8.917	0.000	1.046
Major Depression	0.043	0.005	8.762	0.000	1.061
Low Social Participation	0.049	0.003	15.613	0.000	1.106
Everyday discrimination	0.007	0.003	2.009	0.045	1.057
Life Satisfaction	0.005	0.001	3.732	0.000	1.068

The table provides multicollinearity test results for the study, with cognitive frailty status as the outcome (dependent) variable. The table includes estimates, standard errors, t-test values, significance levels, and Variance Inflation Factor (VIF) statistics for exploratory variables such as age group, gender, residence, region, religion, caste, educational status, employment status, economic status, living arrangements, self-reported health status, hospitalization for the past 12 months, food insecurity, sleep problem, major depression, low social participation, everyday discrimination and life satisfaction. All explanatory variables show statistically significant associations with cognitive frailty, as indicated by low p-values (≤ 0.05) and high t-test values. The VIF values are well below the threshold of 2, confirming the absence of multicollinearity and ensuring that each predictor independently contributes to the model. These results validate the reliability and robustness of the variables in explaining the variations in cognitive frailty by the study participants.

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5. State-wise cognitive frailty prevalence

Cognitive Frailty status by region		
State Name	**Yes, weighted %**	**No, weighted %**
Jammu and Kashmir	9.3	90.7
Himachal Pradesh	5.0	95.0
Punjab	2.5	97.5
Chandigarh	2.0	98.0
Uttarakhand	2.6	97.4
Haryana	2.3	97.7
Delhi	3.3	96.7
Rajasthan	4.1	95.9
Uttar Pradesh	4.3	95.7
Bihar	3.5	96.5
Sikkim	4.3	95.7
Arunachal Pradesh	4.5	95.5
Nagaland	0.5	99.5
Manipur	1.1	98.9
Mizoram	3.3	96.7
Tripura	5.8	94.2
Meghalaya	2.9	97.1
Assam	4.4	95.6
West Bengal	7.9	92.1
Jharkhand	5.5	94.5
Odisha	3.4	96.6
Chhattisgarh	2.8	97.2
Madhya Pradesh	4.7	95.3
Gujarat	4.5	95.5
Daman and Diu	3.8	96.2
Dadra and Nagar Haveli	7.3	92.7
Maharashtra	6.2	93.8
Andhra Pradesh	6.4	93.6
Karnataka	3.5	96.5
Goa	5.7	94.3
Lakshadweep	5.4	94.6
Kerala	4.2	95.8
Tamil Nadu	5.4	94.6
Puducherry	0.9	99.1
Andaman and Nicobar	5.1	94.9
Telangana	7.9	92.1
Total	**4.8**	**95.2**

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6. Result of binary logistic regression analysis

Result of binary logistic regression analysis (N=27,379)				
		OR	**95% CI**	**p-value**
Age	60-69®			
	70-79	3.502	3.030-4.408	**<0.01**
	80+	10.562	9.059-12.315	**<0.01**
Gender	Man®			
	Woman	1.856	1.118-1.911	**<0.01**
Residence	Urban ®			
	Rural	1.898	1.649-2.184	**<0.01**
Region	North ®			
	Central	1.203	0.969-1.494	0.094
	East	1.291	1.060-1.573	**0.011**
	Northeast	0.841	0.661-1.070	0.159
	West	1.608	1.312-1.971	**<0.01**
	South	1.376	1.142-1.658	**<0.01**
Religion	Hindu ®			
	Muslim	1.263	1.069-1.492	**0.006**
	None of the above	0.830	0.698-0.988	**0.036**
Caste	General®			
	Scheduled caste	1.545	1.291-1.848	**<0.01**
	Scheduled tribe	1.600	1.343-1.908	**<0.01**
	Other backward caste	1.272	1.091-1.482	**<0.01**
Educational status	Secondary and higher®			
	Primary completed	3.678	2.104-6.428	**<0.01**
	<Primary	18.067	10.843-30.104	**<0.01**
Employment status	Currently working®			
	Currently not working	4.996	4.080-6.119	**<0.01**
Economic status	Poorest®			
	Poorer	0.805	0.681-0.951	**0.011**
	Middle	0.768	0.648-0.910	**0.002**
	Richer	0.677	0.567-0.809	**<0.01**
	Richest	0.558	0.461-0.676	**<0.01**
Living arrangement	Co-residing®			
	Living alone	1.354	1.075-1.706	**0.010**
Self-reported health status	Good®			
	Poor	4.334	3.857-4.871	**<0.01**
Hospital stays in last 12 months	No®			
	Yes	1.826	1.530-2.179	**<0.01**
Food insecurity	No®			
	Yes	2.107	1.796-2.472	**<0.01**
Sleep problem	No®			
	Yes	2.729	2.377-3.134	**<0.01**
Major depression	No®			
	Yes	2.976	2.538-3.489	**<0.01**
Low social participation	No®			
	Yes	3.599	3.200-4.046	**<0.01**
Everyday discrimination	No®			
	Yes	1.582	1.376-1.819	**<0.01**
Life satisfaction	High®			
	Medium	1.206	1.031-1.412	**<0.01**
	Low	2.001	1.755-2.281	**<0.01**

®refers to reference group
OR = odds ratio, the odds ratio represents the odds of the outcome occurring for a given category relative to the reference group. An OR greater than 1 indicates increased odds, while an OR less than 1 indicates decreased odds for the event of interest. CI = confidence interval.

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