



Original Research



Prevalence of intrinsic capacity decline and its association with activities of daily living among pre-frail and frail older adults in a community-based geriatric services hub model

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ABSTRACT

Introduction: As Singapore's population rapidly ages, there is a growing need to proactively address frailty and intrinsic capacity (IC) decline to delay disability and preserve independence. This study aims to a) determine prevalence of IC decline in frail older patients referred to the geriatric service hub (GSH), stratified by age and frailty status and b) determine its association with activity of daily living (ADL).

Methodology: A cross-sectional study was conducted from July 2019 to March 2022. Community-dwelling older adults (≥ 65 years) identified as pre-frail or frail in selected primary care clinics and eldercare centers were referred to the GSH for further evaluation. All participants received a comprehensive geriatric assessment, which included Clinical Frailty Scale (CFS) scoring and evaluation of six IC domains: locomotion, vitality, cognition, sensory (vision and hearing), psychological, and continence. Functional status was assessed using the Modified Barthel Index and self-reported ADL and instrumental ADL (IADL).

Results: Among 372 participants, 52.2 % were aged 65–79 (old) and 47.8 % were ≥ 80 years (old-old). Approximately two-thirds were classified as CFS 4 or 5. IC decline was significantly more prevalent in the "old-old" group, especially in locomotion (94.4 %), vitality (94.5 %), cognition (68.4 %), vision (78.7 %), and hearing (33.1 %). Despite IC decline, up to two-thirds of participants remained independent or only mildly dependent in ADL. IC impairment increased progressively with advancing frailty and age. In multivariate logistic regression, moderate to severe ADL dependency was independently associated with impaired locomotion (aOR 5.105; 95 % CI 1.023–25.477) and vision impairment (aOR 2.607; 95 % CI 1.234–5.508).

Conclusion: IC screening in primary care is a feasible and effective approach that may contribute to detection of early functional decline. The high burden of multidomain IC impairment, particularly among the oldest and most frail, supports the need for upstream, integrated, and age-inclusive screening and intervention strategies in community settings.

1. Introduction

Singapore is one of the top ten countries with the longest life expectancy and fastest aging population [1,2]. By 2030, one quarter of the population will be 65 years and older [3,4]. With aging population, the prevalence of frailty, dementia and disability will increase, putting a strain on the health and social care system. Globally, countries are prioritizing the strengthening of preventive healthcare systems.

Singapore's Healthier SG initiative implemented since July 2023 signals a national shift toward preventive, community-based care, emphasizing early identification and management with goal directed personalized care plan [5]. Similarly, Singapore's Refreshed Action Plan for Successful Ageing in 2023 outlined strategic goals to promote health, engagement, and security for older adults, including the use of technology and co-creation through community partnerships to extend care beyond institutional settings [4]. The Frailty Strategy Policy Report by

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Singapore's Ministry of Health published during the same year outlined ongoing gaps in frailty prevention, detection, and intervention and recommended strategies on evidence based policies, integration of health and social care, and a whole-of-society approach to ensure inclusive environments that support healthy aging [6]. Within this framework, screening for intrinsic capacity (IC) decline was recommended for those with mild frailty thereby enabling timely interventions before significant functional loss occurs.

The World Health Organization defines intrinsic capacity (IC) as "the composite of all the physical and mental capacities of an individual" which, together with the environment, contributes to developing and maintaining functional ability. The recently released second edition of the Integrated Care for Older People (ICOPE) Handbook offers a structured, person-centered framework—from basic to in-depth assessments, to developing personalized care plans, and ongoing monitoring—with integration of health and social care at every step [7,8]. Two thirds of community dwelling older adults have decline in IC [9]. Not only is IC decline associated with frailty, functional decline and mortality [10], it has also been shown to precede and potentially predict frailty [11,12], with some studies showing a near-linear relationship between the two [13]. This suggests that preserved IC may provide resilience against frailty, highlighting the need for further investigations. Equally important is the relationship between IC and ADL. ADL is an indicator of functional independence and is a key outcome of healthy ageing. IC decline has been shown to potentially predict functional impairment [14] and understanding this relationship further may allow for early detection and targeted interventions. The domains of locomotion, cognition and vitality decline specifically has been associated with poor outcomes [15]. Embedding IC screening into routine primary care and community programs can complement national strategies by facilitating early detection, targeted support, and the potential to reduce downstream healthcare burden through personalized, upstream interventions [16].

The Geriatric Services Hub (GSH) model in Singapore is a community-based initiative aimed at systematic case finding of frail older adults, delivering targeted Comprehensive Geriatric Assessment (CGA), and developing personalized care plans co-created with older persons and their primary care physicians, supported by structured referral pathways [17–19]. In 2019, five GSH hubs were established within primary care and eldercare centers. Notably, one GSH site under Ng Teng Fong General Hospital (part of the National University Health Cluster) adopted an enhanced model that involved co-leading assessments and conducting multidisciplinary case discussions with primary care physicians, nurses and case managers using the 4Ms framework (What Matters, Medication, Mobility, and Mentation) [19,20]. This approach aimed to upskill primary care teams to promote sustainability and scalability of the model. From July 2019 to March 2022, a total of 288 training sessions were conducted, with 38 healthcare professionals—including doctors, nurses, and center managers—completing the training. A recent study reported increased utilization of primary care and specialist outpatient services in the first year following enrolment, with a non-significant trend toward shorter hospital stays [21].

The GSH model primarily focused on frailty identification, CGA, and multidisciplinary person-centered care for those with Clinical Frailty Scale (CFS) scores ranging from 4 to 7 [22]. A critical component of care in the community and primary care is to rationalize care through rapid and effective assessments [23,24]. Frailty is defined as declining functional reserve whereas IC is a measure of functional reserve within each of the frailty category [25]. Screening for IC decline can play a pivotal role in this context by swiftly identifying older adults who exhibit signs of declining intrinsic capacity, so that appropriate interventions can be deployed without delay. There is currently a paucity of studies specifically examining the decline in intrinsic capacity within the GSH population who may be mildly frail but still independent. Community-based studies have reported that declines in intrinsic capacity are observed in

approximately 15–20 % of robust older adults, about 40–45 % in those classified as pre-frail or vulnerable, and as many as 70–75 % among the frail population [15,26]. These statistics, while not directly mapped to the GSH population, offer a benchmark for understanding the potential scope of IC decline amongst these population and screening for IC decline may be more appropriate in the setting of limited specialist resources—calling for a model that is accessible, sustainable, and adaptable to the dynamic landscape of community healthcare in Singapore. The aim of this study is to a) determine prevalence of IC decline in frail older patients referred to the geriatric service hub (GSH), stratified by age and frailty status and b) determine its association with activity of daily living (ADL).

2. Methodology

This was a cross-sectional, observational study conducted from July 2019 to March 2022 across selected sites in Western Singapore, including National University Polyclinics and eldercare centres.

2.1. Participants and recruitment

Older adults aged 65 years and above were screened for frailty in primary care using the FRAIL scale [24]. The FRAIL scale is a 5-point questionnaire assessing fatigue, resistance, ambulation, illnesses and weight loss. Pre-frail was defined as a score of 1–2 while frail was defined as a score of 3 or more. Individuals identified as pre-frail or frail and who had not previously undergone geriatric evaluation were referred to the GSH for further assessment upon agreement by the referring physician and patient. Inclusion criteria included being community-dwelling, aged ≥ 65 years, and classified as pre-frail or frail. Participants who consented were assessed by the GSH multidisciplinary team through a structured workflow (Fig. 1). All participants underwent a CGA, which included the CFS, evaluation of IC domains, medication reconciliation, and development of a personalised care plan. Assessment and data entry was done by trained GSH team members such as clinical care coordinators and nurses. IC was assessed across six domains: locomotion, vitality, cognition, psychological, sensory (vision and hearing), and continence. We defined 'old' as those who were between 65 and 79 years of age and 'old-old' as those who were 80 years of age and above.

Locomotion was measured using the 10 m walk test and five times sit to stand (STS). Those with gait speed $< 1\text{m/s}$ or $5 \times \text{STS} > 14\text{ s}$ were classified into impaired locomotion group. Vitality, defined by the presence of any of the following—self-reported weight loss, poor appetite, or low handgrip strength. Low handgrip strength was determined based on the Asian Workgroup Group for Sarcopenia cut-off of $< 28\text{ kg}$ for men and $< 18\text{ kg}$ for women [27]. Continence, vision, and hearing decline were self-reported. Cognitive domain impairment was identified using either a modified Chinese Mini-Mental State Examination (CMMSE) score < 24 or Abbreviated Mental Test score < 7 [28]. Psychological domain decline was evaluated using the Patient Health Questionnaire 2 (PHQ-2) with a cut-off score ≥ 3 was defined as positive for depression [29].

2.2. Functional assessment and multimorbidity

Functional status was assessed using both the self-reported Modified Barthel Index (MBI) and IADL measures. The MBI is a 10-item scale that evaluated independence in the domains of chair/bed transfers, ambulation, ambulation/wheelchair, stair climbing, toilet transfers, bowel control, bladder control, bathing, dressing, personal hygiene, and feeding. A score of 100 suggests full independence, 91–99 suggests slight dependency, and ≤ 90 suggests moderate to total dependency [30]. IADLs were assessed using the Lawton IADL scale. Impairment in at least one of the IADLs was defined as IADL dependent. Chronic diseases of hypertension, hyperlipidaemia, diabetes mellitus, chronic kidney

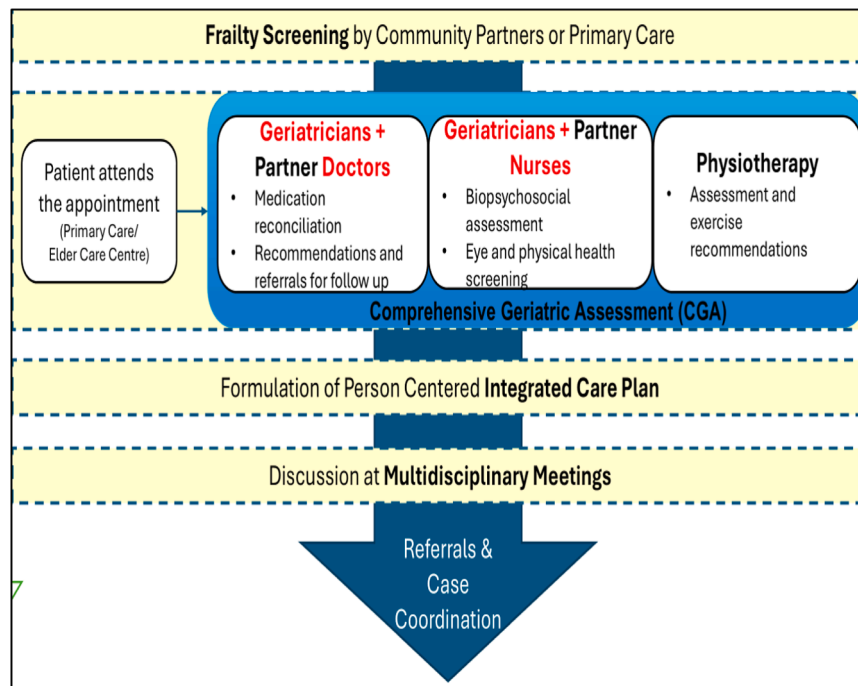


Fig. 1. Patient workflow for GSH.

disease, ischaemic heart disease and heart failure were self-reported. Multimorbidity was defined as having ≥ 2 of the abovementioned chronic diseases.

2.3. Statistical analysis

Statistical analysis was conducted using IBM SPSS Version 28.0. Categorical variables were summarized as frequencies and percentages, and continuous variables were reported as means with standard deviations. The Pearson χ^2 test was used to compare categorical variables, while the Mann-Whitney U test was applied for continuous variables due to non-normal distribution. A two-tailed p-value of <0.05 was considered statistically significant.

To assess the association between IC domain impairments and ADL defined by MBI (100: independent, 91–99: mildly dependent, 0–89: moderate to totally dependent), we conducted both univariate and multivariate logistic regression analyses. Odds ratios (OR) and 95 % confidence intervals (CIs) were calculated. Three models were constructed: Model 1 was unadjusted; Model 2 adjusted for age and gender; and Model 3 adjusted for age, gender, education and multimorbidity. Multicollinearity was assessed using variance inflation factors (VIF), with all domains showing $VIF < 5$. No formal correction for multiple testing in Table 1 was applied as the comparisons were exploratory and aimed at describing the sample characteristics. Psychological domain was excluded from regression analyses due to a small number of affected participants.

2.4. Ethical considerations

All participants provided informed consent. The study was conducted in accordance with institutional ethical guidelines and approved by the relevant institutional review board.

3. Results

3.1. Demographics

A total of 372 participants were included in this study, of which 52.2

% were between 65 and 79 years old ('old' group) and 47.8 % were 80 years old and above ('old-old' group). Among them, 59.4 % were female, 75.3 % from the Chinese ethnic group, 16.1 % Malays and 8.1 % Indian ethnic group (Table 1). Almost half of the old-old group received no education compared to slightly more than one quarter of the old group. In the entire study population, prevalence of hypertension was 80.4 %, hyperlipidaemia 71.8 %, diabetes mellitus (DM) 53.5 % and chronic kidney diseases 25.3 %. The prevalence of DM was significantly higher in the 'old' group (61.9 %) compared with the 'old-old' age group (44.4 %). Almost two-thirds of the participants were classified under CFS 4 (32.1 %), and CFS 5 (32.3 %), followed by CFS 6 (25.3 %) and CFS 7 (8.4 %). The prevalence of those with CFS 5 was 30 % higher and CFS 7 almost double in the 'old-old' group.

The decline in intrinsic capacity domains was also significantly higher in the 'old-old' age group across all domains except for psychological and urinary incontinence. In the 'old-old' compared with the 'old' group, the prevalence of locomotion decline was 94.4 % vs 84.8 %, impaired vitality 94.5 % vs 82.6 %, impaired cognition 68.4 % vs 42.0 %, impaired hearing 33.1 % vs 10.4 % and vision 78.7 % vs 63.7 %. The prevalence of psychological impairment was lower in the old-old group (6.2 %) compared to the old group (11.5 %) although this was not found to be significant. ADL impairment was observed in 61.2 % and IADL impairment in 79.3 % of participants. The prevalence was significantly higher in the 'old-old' group compared to the 'old' group for both ADL impairment (71.9 % vs 51.3 %) and IADL impairment (91.0 % vs 68.6 %). In terms of functional impairment in the 'old-old' compared with the 'old', the prevalence of slow gait speed was 91.4 % vs 77.2 %, low handgrip strength 92.4 % vs 79.4 %, low cMMSE 62.4 % vs 39.9 % and low 5x-STs was 81.5 % vs 68.6 %.

3.2. Patterns of intrinsic capacity decline between CFS and age groups

The number of impaired IC domains increased significantly with higher CFS scores (Fig. 2). Among the 'old' group with CFS 4, 5.0 % had no IC decline, while the majority of CFS 4 (83.0 %) and CFS 5 (56.9 %) participants had impairments in three or fewer IC domains. In contrast, the 'old-old' group showed a lower proportion with three or fewer domain declines: 63.9 % for CFS 4 and 42.7 % for CFS 5. In the CFS 6

Table 1
Demographics and intrinsic capacity (IC).

Demographic	Overall n = 372	65–79 years n = 194 (52.2)	≥ 80 years n = 178 (47.8)	P- Value
Gender				0.017
Male	151 (40.6)	90 (46.4)	61 (34.3)	
Female	221 (59.4)	104 (53.6)	117 (65.7)	
Ethnicity				<0.001
Chinese	280 (75.3)	130 (67.0)	150 (84.3)	
Malay	60 (16.1)	38 (19.6)	22 (12.4)	
Indian	30 (8.1)	25 (12.9)	5 (2.8)	
Others	2 (0.5)	1 (0.5)	1 (0.5)	
Type of Residence				0.147
HDB	335 (90.1)	178 (91.8)	157 (88.2)	
Condo	5 (1.3)	2 (1.0)	3 (1.7)	
Landed Property	20 (5.4)	6 (3.1)	14 (7.9)	
Rental	12 (3.2)	8 (4.1)	4 (2.2)	
Living Arrangement				0.108
Alone	25 (6.7)	15 (7.7)	10 (5.6)	
Spouse	55 (14.8)	34 (17.5)	21 (11.8)	
Family	217 (58.3)	112 (57.7)	105 (59.0)	
Helper Family and Helper	15 (4.0) 56 (15.1)	3 (1.5) 28 (14.4)	12 (6.7) 28 (15.7)	
Tenant	4 (1.1)	2 (1.0)	2 (1.0)	
Education Level				<0.001
No formal	137 (36.8)	54 (27.8)	83 (46.6)	
Primary	146 (39.2)	87 (44.8)	59 (33.1)	
Secondary	76 (20.4)	48 (24.7)	28 (15.7)	
Diploma	13 (3.5)	5 (2.6)	8 (4.5)	
Co-Morbidities				
Hypertension	299 (80.4)	162 (83.5)	137 (77.0)	0.113
Hyperlipidaemia	267 (71.8)	141 (72.7)	126 (70.8)	0.685
Diabetes Mellitus	199 (53.5)	120 (61.9)	79 (44.4)	<0.001
Chronic Kidney Disease	94 (25.3)	42 (21.6)	52 (29.2)	0.094
Heart Failure	10 (2.7)	4 (2.1)	6 (3.4)	0.436
Ischaemic Heart Disease	79 (21.2)	37 (19.1)	42 (23.6)	0.287
Pain	142 (38.8)	75 (39.5)	67 (38.1)	0.076
Clinical Frailty Scale (CFS)				<0.001
CFS 2 (Well)	2 (0.5)	1 (0.5)	1 (0.5)	
CFS 3 (Managing Well)	5 (1.4)	5 (2.6)	0 (0.0)	
CFS 4 (Vulnerable)	118 (32.1)	82 (42.3)	36 (20.7)	
CFS 5 (Mildly Frail)	119 (32.3)	51 (26.3)	68 (39.1)	
CFS 6 (Moderate Frail)	93 (25.3)	44 (22.7)	49 (28.2)	
CFS 7 (Severe Frail)	31 (8.4)	11 (5.7)	20 (11.5)	
Decline in Intrinsic Capacity (IC)				
Locomotion	329 (89.4)	162 (84.8)	167 (94.4)	0.003
Vitality*	240 (88.2)	119 (82.6)	121 (94.5)	0.002
Cognition	202 (54.6)	81 (42.0)	121 (68.4)	<0.01
Psychological	33 (8.9)	22(11.5)	11 (6.2)	0.100

Table 1 (continued)

Demographic	Overall n = 372	65–79 years n = 194 (52.2)	≥ 80 years n = 178 (47.8)	P- Value
Hearing	79 (21.3)	20 (10.4)	59 (33.1)	<0.001
Vision	263 (70.9)	123 (63.7)	140 (78.7)	0.002
Urinary incontinence	96 (25.9)	53 (27.5)	43 (24.2)	0.468
Referral Recommendations				
Medical Social Worker	87 (23.4)	54 (27.8)	33 (18.5)	0.034
Community Nursing	100 (26.9)	51 (26.3)	49 (27.5)	0.788
Day Care, Day Rehab or Intermediate and Long-term Care (ILTC)	31 (8.3)	15 (7.7)	16 (9.0)	0.661
Functional Impairment				
ADL Impairment	227 (61.2)	99 (51.3)	128 (71.9)	<0.001
IADL impairment	295 (79.3)	133 (68.6)	162 (91.0)	<0.001
Low Gait Speed	285 (83.8)	139 (77.2)	146 (91.3)	<0.001
Low Handgrip strength*	213 (85.5)	104 (79.4)	109 (92.4)	0.004
Low cMMSE	188 (50.7)	77 (39.9)	111 (62.4)	<0.001
Low 5x STS	278 (74.7)	133 (68.6)	145 (81.5)	0.004

n (%), cMMSE:Chinese Mini Mental State Examination, 5x STS: Five times sit to stand, Activity of daily living (ADL) impairment: (MBI Score ≤ 99), IADL: Instrumental activities of daily living.

* n = 239; ^n = 118.

category, nearly half (47.7 %) of the ‘old’ group and one-third (34.7 %) of the ‘old-old’ had three or fewer declines. However, in the CFS 7 category, this gradient was less apparent. Notably, a greater proportion of ‘old-old’ participants experienced impairments across all six IC domains compared to the ‘old’ group.

Locomotion and vitality were consistently the most impaired domains, especially among those with CFS scores between 5 and 7. The ‘old-old’ group also had significantly higher rates of cognitive, vision, and hearing impairments compared to the ‘old’ group (Fig. 3). Additionally, the prevalence of urinary incontinence increased significantly with increasing frailty: from 14.8 % to 63.6 % across CFS 4 to 7 in the ‘old’ group, and from 19.4 % to 35.0 % in the ‘old-old’. Overall, the spider chart illustrates a clear pattern of multidomain IC decline with advancing frailty and age, reinforcing the importance of early IC screening in older adults.

3.3. ADL impairment, frailty and decline in IC domains

ADL impairment, by MBI scores, increased significantly with higher CFS scores and age (Fig. 4). In the ‘old’ group, two thirds of CFS 4 (66.7 %) and half of CFS 5 (52.9 %) were independent. Conversely, in the ‘old-old’ group, half of those in CFS 4 (50.0 %) were independent, and slightly less than half of the CFS 5 (45.0 %) were independent. For CFS 6 and CFS 7, the majority were moderate to severely dependent for both the ‘old’ (70.5 % and 100 % respectively) and the ‘old-old’ (53.1 % and 95.0 % respectively). In multivariate logistic regression analysis, moderate to total ADL dependence (defined by MBI < 90) was significantly associated with impaired locomotion (aOR 5.105; 95 % CI 1.023–25.477) and vision impairment (aOR 2.607; 95 % CI 1.234–5.508), compared to those who were fully independent (MBI = 100) (Table 2).

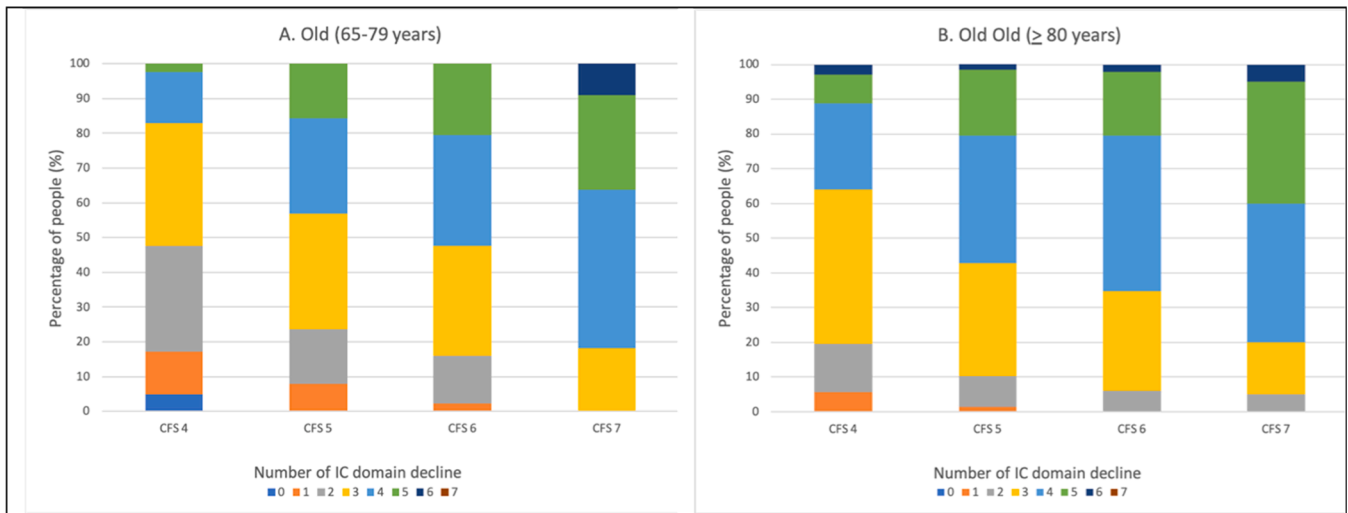


Fig. 2. Number of IC domain decline by CFS between (A) old and (B) old.

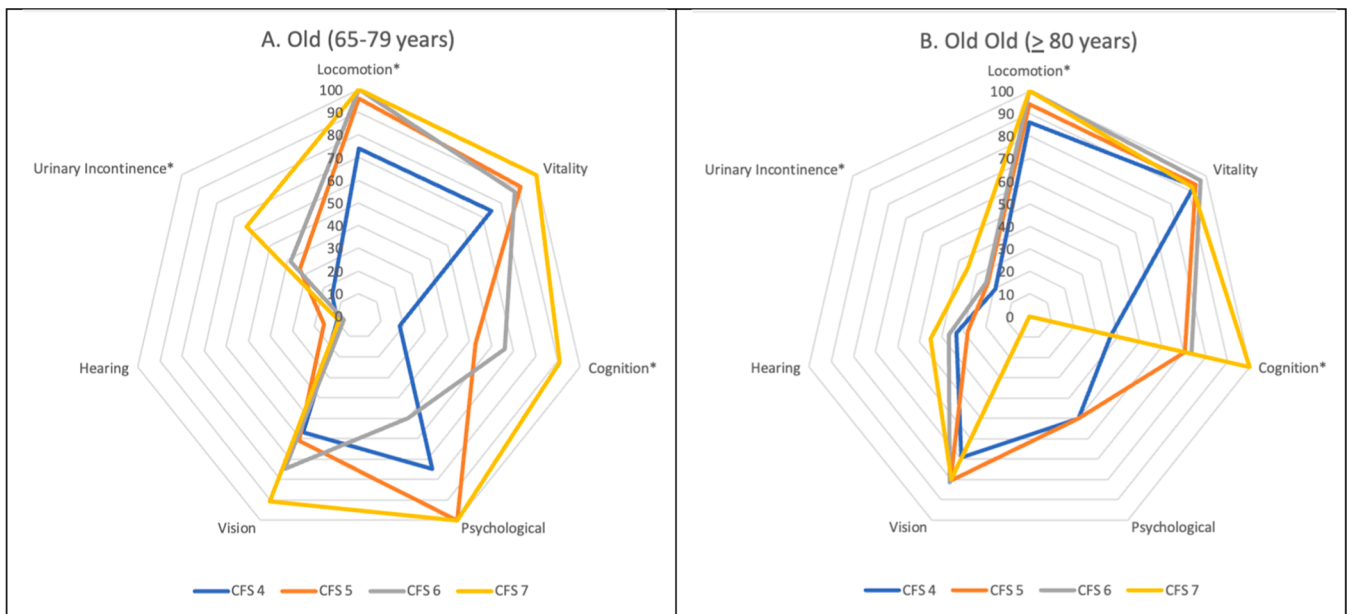


Fig. 3. Individual IC domain decline by clinical frailty scale between (A) old and (B) old.

4. Discussion

This study demonstrates the utility of IC screening among older adults with established frailty, as assessed within the GSH model. Nearly two-thirds of participants were classified as mildly frail (CFS 4 or 5), with a substantial burden of IC decline observed even among those still independent in their basic ADLs. The prevalence of IC decline was significantly higher in the ‘old-old’ and those with increasing frailty. Within the mildly frail group, the prevalence of IC domain decline and ADL dependency was lower in the ‘old’ group. This is consistent with other studies that have shown that IC becomes more impaired with age [31,32] and increasing frailty [11]. Frailty represents the accumulation of health deficits and loss of physiological reserves which leads to impairment in several systems, contributing to impairment in the different IC domains. Other factors that may explain this finding include the higher burden of co-morbidities associated with aging and frailty that may have synergistic effects leading to accelerated decline in IC. Biological and cellular aging processes may also play a role.

While the use of a multidisciplinary team, including geriatricians,

provides comprehensive assessment and shown to improve quality of life [33], such a resource-intensive approach may not be scalable or cost-effective in routine primary care. Furthermore, CGA is time-consuming and not always practical for primary care providers, many of whom lack the capacity or training to interpret the results meaningfully. Screening for IC decline offers a pragmatic alternative—a simplified form of CGA that can be conducted by patients themselves, caregivers, or any healthcare professional with minimal training [34]. Compared with frailty screening tools, IC screening may be preferred due to its potential for earlier detection of impairment and intervention preceding the onset of established frailty and disability. Furthermore, it focuses on individuals’ capacities promoting a more person-centred approach to assessment and targeted intervention. Further studies could also evaluate the combined utility of both frailty and IC screening in identifying at-risk individuals. Identifying early declines in IC allows for targeted intervention and streamlined referral pathways. However, as this is a cross-sectional study, it does not permit inference of temporal relationships or causal association. While early detection of decline in IC is important, longitudinal studies are needed to determine whether IC

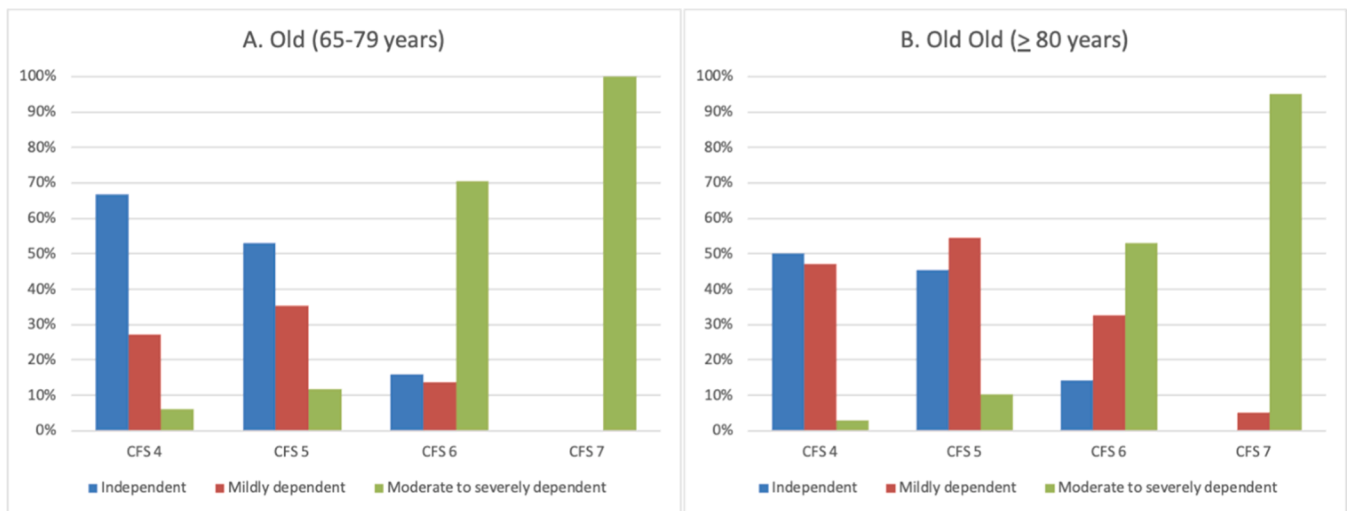


Fig. 4. ADL impairment (mean modified barthel score) by clinical frailty scale (CFS) and age.

Table 2
Associations of impaired IC domains with ADL impairment (Referenced to being completely independent, Modified Barthel Index =100).

	Moderate to totally dependent (MBI ≤ 90)	p-value	Mildly dependent (MBI 91–99)	p-value
<i>Model 1</i>				
Impaired locomotion	5.289 (1.143–24.470)	0.033	3.652 (1.145–11.653)	0.029
Impaired cognition	2.046 (1.056–3.964)	0.034	1.097 (0.598–2.011)	0.765
Impaired vitality	1.861 (0.651–5.319)	0.246	2.632 (0.965–7.178)	0.059
Hearing impairment	0.695 (0.294–1.644)	0.407	1.339 (0.643–2.787)	0.435
Vision impairment	2.291 (1.119–4.688)	0.023	1.734 (0.917–3.281)	0.091
<i>Model 2</i>				
Impaired locomotion	5.106 (1.061–24.581)	0.042	2.901 (0.882–9.548)	0.080
Impaired cognition	1.728 (0.868–3.439)	0.119	0.810 (0.420–1.563)	0.530
Impaired vitality	1.631 (0.549–4.845)	0.379	2.575 (0.895–7.411)	0.079
Hearing impairment	0.598 (0.238–1.499)	0.273	1.177 (0.546–2.536)	0.678
Vision impairment	2.364 (1.138–4.912)	0.021	1.705 (0.872–3.334)	0.119
<i>Model 3</i>				
Impaired locomotion	5.105 (1.023–25.477)	0.047	2.728 (0.815–9.133)	0.104
Impaired cognition	1.775 (0.852–3.696)	0.125	0.739 (0.367–1.487)	0.396
Impaired vitality	1.573 (0.519–4.765)	0.423	2.552 (0.888–7.340)	0.082
Hearing impairment	0.552 (0.215–1.415)	0.216	1.135 (0.524–2.459)	0.748
Vision impairment	2.607 (1.234–5.508)	0.012	1.753 (0.893–3.440)	0.103

Model 1 was unadjusted; Model 2 adjusted for age and gender; and Model 3 adjusted for age, gender, education and multimorbidity. Bold: significant association.

screening can lead to preservation of function or delay in the onset of disability.

Most recent studies recommend composite scores when measuring IC [35]. However, individual IC domain decline is just as crucial. Jia et al. showed that transition of IC but not frailty which was associated with incident disability [15]. In the same study, baseline frailty status, locomotion and vitality decline were significantly associated with frailty

decline. This is consistent with our study that showed locomotion and vitality were the most impaired domains especially with increasing frailty. The physical frailty components of weight loss and reduced gait speed may be partly driven by impairments in these IC domains. Vitality and sensory domains were associated with worsened IC. Yu et al. describe vitality as "energy homeostasis," a concept that may play a key role in the progression from pre-frailty to frailty and serve as a foundation for decline in other IC domains [25]. In our study, both locomotion and vision impairment were significantly associated with moderate to severe ADL impairment. A recent systematic review by Cheng et al., which included 15 longitudinal studies involving 53,648 participants, found that declines in locomotion, cognition, psychological function, and vitality were associated with an increased risk of ADL impairment, with locomotion showing the strongest association which was similar in our study population [36]. As locomotion is essential for mobility-related ADLs such as transferring, toileting and showering, impairment in locomotion would directly lead to ADL disability. The MAPT study showed that mobility decline, vision impairment and depressive symptoms was associated with higher incident of frailty, ADL and IADL decline over 5 years [37]. Vision impairment is associated with frailty, cognitive impairment and ADL decline [37,38]. The Leiden 85-plus study reported accelerated decline in IADL and ADL in those with visual impairment, and increased mortality in those with severe visual impairment [38]. These are consistent with our study population. Vision is likewise essential for performing daily tasks and its impairment has a direct impact on function. Additionally, vision impairment can contribute to mobility difficulties contributing to further ADL disability, further supportive of our findings. Although vitality decline was highly prevalent among frail participants, it was not significantly associated with moderate to severe functional dependency possibly due to different study populations, and this could be evaluated with further studies. Additionally, the prevalence of psychological domain decline was found to be lower among the old-old group in our study population. It is not known if this could be due to under-reporting where another study similarly reported a depression prevalence of 3 % in the local setting [39].

Almost two thirds of our study participants were still independent or only mildly dependent in ADL despite significant decline in multidomain IC. There are multiple effective interventions for locomotion, cognitive and psychological function such as home-based exercise, lower limb strengthening, gait/muscle training, cognitive behavioural therapy and cognitive stimulation therapy especially before the onset of disability [16]. Multidomain exercises incorporating nutrition and physical exercise have shown moderate effectiveness in improving vitality [16].

There are numerous studies which have shown that correction of vision and / or vision rehabilitation can improve functional ability and social participation [40–42].

Future models should consider adopting IC-based screening as a scalable, person-centered strategy to support healthy aging and frailty prevention in the community. This study has several strengths. It employed a cross-sectional analysis within a real-world primary care and community setting, providing practical insights into the importance of IC decline in frail older adults and its association with ADL. The integration of the GSH within the National University Polyclinics allowed for multidimensional assessments via the CGA but may not be sustainable long term, hence the importance of screening for IC decline.

However, several limitations should be acknowledged. First and foremost, referral to GSH was based on doctors' discretion and patients' willingness after being screened to be frail or pre-frail. Hence, selection bias is an important limitation to consider. This could have led to underestimation of the prevalence and severity of IC and ADL decline, and of the strength of associations between IC impairment, age, and frailty. In particular, psychological impairment and urinary incontinence may have been underrepresented, as these domains could be more prevalent among older individuals or those who are frail. Future studies should consider including broader cohorts, beyond the scope of community-based models, to more comprehensively capture this segment of the older adult population. Second, the absence of longitudinal follow-up data limits the ability to assess whether screening for IC decline, impact of CGA and subsequent referrals led to improved health outcomes or functional ability. Third, we lacked data on prior interventions such as social prescribing, community service engagement, rehabilitative therapies, or lifestyle factors—including perceived health, physical activity, and exercise participation which may influence IC trajectories. Fourth, several variables, including urinary incontinence, sensory impairment, psychological symptoms, and aspects of ADL/IADL, were based on self-report, which is susceptible to recall and social desirability bias [32]. In particular, self-reported vision impairment identified as a significant predictor of ADL impairment may have been under- or overestimated depending on participants' perception or reporting tendencies, potentially affecting its observed prevalence and associations. Future studies should incorporate objective assessments of these domains. Finally, some regression models yielded wide confidence intervals, likely due to small sample sizes, low event frequency in specific IC domains, and underlying variability in participant characteristics. These should be interpreted with caution.

5. Conclusion

Among frail older adults referred to the GSH, there was a high prevalence of multidomain IC decline, particularly in locomotion and vitality. These impairments were more pronounced in the older age group and those with greater frailty severity. Notably, impaired locomotion and vision were independently associated with moderate to severe dependence in ADL. The substantial burden of IC decline among the oldest and most frail individuals underscores the importance of implementing upstream, integrated, and age-inclusive screening and intervention strategies in community settings. Longitudinal studies are warranted to examine the impact of targeted IC interventions on ADL trajectories in this vulnerable population.

CRedit authorship contribution statement

Lydia Au: Visualization, Supervision, Resources, Project administration, Methodology, Investigation, Conceptualization. **Izza Elyana Bte Azhar:** Writing – review & editing, Writing – original draft, Visualization, Formal analysis, Conceptualization. **Jer En Lee:** Supervision, Resources, Project administration, Methodology, Conceptualization. **Jasmine Shimin Lim:** Project administration, Investigation. **Alexa Lai:** Project administration, Investigation. **Bernice MH Chua:** Project

administration, Investigation. **Yu Ann Tan:** Project administration, Investigation. **Reshma A. Merchant:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Formal analysis, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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