Original Research

Social Frailty and Executive Function: Association with Geriatric Syndromes, Life Space and Quality of Life in Healthy Community-Dwelling Older Adults

M. Ong[1], K. Pek[1], C.N. Tan[1], J. Chew[1,2], J.P. Lim[1,2], S. Yew[1], A. Yeo[1], W.S. Lim[1,2]

1. Institute of Geriatrics and Active Ageing, Tan Tock Seng Hospital, Singapore; 2. Department of Geriatric Medicine, Tan Tock Seng Hospital (TTSH), Singapore

Corresponding Author: Ms. Melissa Ong, TTSH Annex 2, Level 3, 11 Jalan Tan Tock Seng, Institute of Geriatrics and Active Ageing, Tan Tock Seng Hospital, Singapore 308433, Telephone: +65 6359 6327, Email: Melissa_HM_ONG@ttsh.com.sg

Abstract

BACKGROUND: Despite emerging evidence about the association between social frailty and cognitive impairment, little is known about the role of executive function in this interplay, and whether the co-existence of social frailty and cognitive impairment predisposes to adverse health outcomes in healthy community-dwelling older adults.
OBJECTIVES: We aim to examine independent associations between social frailty with the MMSE and FAB, and to determine if having both social frailty and cognitive impairment is associated with worse health outcomes than either or neither condition.
METHODS: We studied 229 cognitively intact and functionally independent community-dwelling older adults (mean age= 67.2±7.43). Outcome measures comprise physical activity; physical performance and frailty; geriatric syndromes; life space and quality of life. We compared Chinese Mini Mental State Examination (CMMSE) and Chinese Frontal Assessment Battery (FAB) scores across the socially non-frail, socially pre-frail and socially frail. Participants were further recategorized into three subgroups (neither, either or both) based on presence of social frailty and cognitive impairment. Cognitive impairment was defined as a score below the educational adjusted cut-offs in either CMMSE or FAB. We performed logistic regression adjusted for significant covariates and mood to examine association with outcomes across the three subgroups.
RESULTS: Compared with CMMSE, Chinese FAB scores significantly decreased across the social frailty spectrum (p<0.001), suggesting strong association between executive function with social frailty. We derived three subgroups relative to relationship with socially frailty and executive dysfunction: (i) Neither, N=140(61.1%), (ii) Either, N=79(34.5%), and (iii) Both, N=10(4.4%). Compared with neither or either subgroups, having both social frailty and executive dysfunction was associated with anorexia (OR=4.79, 95% CI= 1.04-22.02), near falls and falls (OR= 5.23, 95% CI= 1.10-24.90), lower life-space mobility (odds ratio, OR=9.80, 95% CI=2.07-46.31) and poorer quality of life (OR= 13.2, 95% CI= 2.38-73.4).
CONCLUSION: Our results explicated the association of executive dysfunction with social frailty, and their synergistic relationship independent of mood with geriatric syndromes, decreased life space and poorer quality of life. In light of the current COVID-19 pandemic, the association between social frailty and executive dysfunction merits further study as a possible target for early intervention in relatively healthy older adults.

Key words: Social frailty, cognitive performance, executive dysfunction, Frontal Assessment Battery, older adults.

Introduction

Frailty refers to a geriatric syndrome whereby there is increased vulnerability to adverse outcomes after a stressor event due to diminishing homeostatic reserves, leading to increased risk of functional decline, dependency and/or mortality (1, 2). A holistic approach targeted at addressing the multi-dimensional determinants of frailty is needed to prevent and reverse frailty in older adults (1, 2). Amongst these dimensions, social frailty is the least understood, but has gained traction over time for its importance in contributing to the trajectory of frailty in older adults (1-3). Based on Bunt's conceptual framework premised upon the Theory of Social Production Function, social frailty is defined as a continuum of being at risk of losing, or having lost, social resources, general resources and social activities or abilities that are important for fulfilling one or more basic social needs during their lifetime (3). Previous studies have reported associations between social frailty with increased risk of disability, depressive symptoms, malnutrition, lower physical activity and performance, and cognitive dysfunction amongst community-dwelling older adults (3-9). Social frailty is particularly germane in light of the ongoing COVID-19 pandemic, with emerging evidence that pandemic control measures can exacerbate social frailty with concomitant impact on mood and lifestyle activity in relatively healthy older adults (10).

There is a growing body of evidence which substantiates the relationship between social frailty and cognition (6, 11-13). A previous study of community-dwelling older adults in China reported a high prevalence of social frailty amongst participants who had dementia, subjective memory decline, and cognitive impairment as measured by the Mini-Mental State Examination (MMSE) (13). This was corroborated by a Japanese study which showed an independent association between those socially pre-frail and frail presenting with deficits in at least two tests in a neuropsychological battery assessing cognitive domains of memory, attention, executive function and processing speed (6). In tandem with these findings, depression is a key determinant often associated with social frailty and cognitive impairment in older adults (5, 13, 14).

However, gaps remain in our understanding of the relationship between social frailty and cognition. The

majority of earlier studies did not adopt a theory-grounded definition of social frailty (5-8, 13). There exists uncertainty about which cognitive domain is associated with social frailty, with cognitive impairment largely defined by general memory-based evaluations such as the MMSE or loosely based on the observation of poor scores in components of a neuropsychological battery (6, 13). With recent evidence suggesting that declines in executive function predicted onset of physical frailty and preceded declines in memory-biased domains in relatively healthy older adults (15, 16), it will be important to ascertain the relative contribution of executive function vis-à-vis amnestic domains. Specifically, the Frontal Assessment Battery (FAB) assesses executive functioning and is able to discern early cognitive impairment in older adults (17-19). Furthermore, the combined effect of both social frailty and cognitive impairment on daily activities and overall health in older adults remains largely unexplored. The confounding effect of depressive symptoms on social frailty and cognition is often unaccounted for in earlier studies.

This provided the impetus for the current study to examine the relationship between social frailty and cognition in a representative cohort of relatively healthy community-dwelling older adults. We aim to: (i) examine independent associations of social frailty with the MMSE and FAB; (ii) describe the prevalence of subgroups (neither, either or both) of social frailty and cognitive impairment; and (iii) determine if physical activity, physical frailty and performance, geriatric syndromes, life space mobility and quality of life are more adversely affected in 'either' or 'both' groups compared with 'neither'. Better understanding of the relationship between social frailty and cognition will shed light on whether community screening programs should aim to detect both conditions as opposed to either alone.

Methods

Study Population

The "Longitudinal Assessment of Biomarkers for characterization of early Sarcopenia and Osteosarcopenic Obesity in predicting frailty and functional decline in community-dwelling Asian older adults Study" (GeriLABS-2) is a prospective cohort study involving functionally independent community-dwelling adults aged 50 and older. Participants independent in both basic and instrumental activities of daily living (ADL) and non-frail as defined by the FRAIL criteria (FRAIL ≤3) (20) were recruited from December 2017 to March 2019. Participants were excluded if they had prior diagnosis of dementia; scored ≤21 on the modified Chinese Mini-Mental State Examination (CMMSE) (21); were unable to walk 8m independently; or resided in a long-term institutional care facility. The study was protocol was approved by the Domain Specific Review Board of the National Health Group. Written consent was obtained from all participants prior to study participation.

8-item Social Frailty Scale (SFS-8)

Social frailty was assessed with the locally validated eight-item Social Frailty Scale (SFS-8) guided by Bunt's framework on social frailty (3, 22), with items summed to yield a total score (range: 0-8 points) (4). A score of 0-1 indicates social non-frailty (SNF), 2-3 indicates social pre-frailty (SPF), and ≥4 indicates social frailty (SF). SFS-8 measures the three domains of social resources, social activities and financial resources, and social need fulfilment.

Cognitive assessments

Cognitive function was assessed with the CMMSE and the locally validated Chinese FAB (17, 18, 21). The CMMSE consists of 28 questions that assesses six specific cognitive function domains: orientation to time, orientation to place, registration, attention and calculation, recall and language and praxis (23). Impairment in cognitive function was determined by education-adjusted cut-offs (CMMSE ≤21 for ≤6 years education and ≥24 for >6 years education) as previously described (21). The locally validated Chinese FAB assesses executive functioning in two domains across six different subtests. The first domain of cognitive control measures conceptualization, mental flexibility, and motor programming. The second domain of behavioural control measures sensitivity to interference, mental flexibility, and environmental autonomy (18, 19). Impairment in executive functioning was determined by education-adjusted cut-offs (Chinese FAB score ≤13 for ≤6 years education, and ≤14 for >6 years education) (18).

Covariates

We collected demographic data such as age, gender, medical history and assessed body mass index (BMI). Functional status was assessed by the Barthel's index for basic activities of daily living (ADL) and the Lawton and Brody's index for instrumental ADL (24, 25). Mood was evaluated using the 15-item Geriatric Depression Scale (26).

Outcome measures

We collected data on four main groups of outcome measures: (i) physical activity, (ii) physical frailty and performance, (iii) geriatric syndromes, and (iv) life space and quality of life. Physical activity was determined by both the International Physical Activity Questionnaire (IPAQ) which converts responses to Metabolic Equivalent Tasks (METs) and the Frenchay Activity Index (FAI) (27, 28). Low physical activity was measured by IPAQ score of <2826 METS and FAI score ≤29 using cohort quintile cut-offs (4). Physical frailty was measured by the modified Fried criteria where a score of 1-2 denotes pre-frailty and ≥3 denotes physical frailty (29). We assessed physical performance via maximal hand grip strength using the North Coast Exacta™ hydraulic hand dynamometer, the Short Physical Performance Battery (SPPB), the three-meter walk comfortable gait speed test, and the five-time sit-to-stand

chair test (30). The following cut-offs determined poor physical performance: SPPB scores <11 (31); maximal handgrip strength <28kg for males and <18kg for females; gait speed <1.0m/s; and five-time-sit-to-stand chair test ≥12s, based on the Asian Working Group for Sarcopenia (AWGS) 2019 consensus (32). For geriatric syndromes, we studied near falls or falls, risk of malnutrition, and mood. The occurrence of near falls or falls during the past 12 months was recorded as a single self-reported event, risk of malnutrition due to anorexia of aging was evaluated by the simplified nutritional appetite questionnaire (SNAQ) with a locally validated cut-off at ≤15 (22).

Lastly, life-space mobility was measured by the life-space assessment (LSA), which comprises five life-space levels corresponding to mobility outside the bedroom, home, neighbourhood, outside the neighbourhood and beyond (33). LSA score <76 denotes low life-space mobility (33). Quality of life (QoL) was assessed using index scores of the five-level version of the EuroQol five-dimensional (EQ-5D-5L) questionnaire based on Singapore preference weights derived using an indirect interim mapping method (34, 35). Poor QoL was denoted by the cohort quintile cut-off of EQ-5D-5L index scores <0.881.

Statistical analysis

We performed statistical analyses using IBM SPSS version 23.0 (IBM Corporation, Armonk, NY, USA). All statistical tests were two-tailed with p<.05 considered statistically significant. Continuous variables were expressed as mean (standard deviation) or as median (interquartile range). Categorical variables were expressed as counts and percentages.

To ascertain the cognitive domain (amnestic versus non-amnestic) that is more strongly associated with social frailty, we compared CMMSE and Chinese FAB total and factor scores across SFS-8 categories of socially non-frail, pre-frail and frail. We classified participants as cognitively impaired if their total scores on CMMSE and Chinese FAB were below age and education-adjusted cut-offs (17, 21). We conducted Shapiro-Wilk test to check for assumption of normality. Parametric continuous variables were analysed using one-way analysis of variance with Bonferroni correction for post-hoc comparisons, and non-parametric continuous variables were analysed with the Kruskal-Wallis test. We conducted chi-squared test to analyse categorical variables.

Next, we constructed a 2x2 table for social frailty (non-frail vs pre-frail/frail) and cognitive domain (normal vs impaired). We based the choice of cognitive domain (either CMMSE or Chinese FAB) on which test showed a stronger relationship with social frailty. We then categorized participants into three subgroups: (1) Neither socially frail or cognitively impaired, (2) Either socially frail or cognitively impaired, (3) Both socially frail and cognitively impaired (Figure 1). We compared baseline demographics, functional and frailty status, geriatric syndromes, and outcome measures (physical performance, physical activity, life-space mobility, and quality of life) across the three subgroups.

To determine the independent association of social frailty and cognition with the pre-specified outcomes, logistic regression was performed for significant variables (p <.05) to determine the odds ratio (OR) and their 95% confidence intervals (CI). We performed unadjusted analysis, followed by model 1 adjusting for age, gender, education, and hypertension, and finally model 2 which additionally adjusted for GDS, as depressive symptoms have been shown to be a significant determinant of both social frailty and cognition (4, 5, 14, 36).

Results

Amongst 229 participants in this study, the mean age was 67.2±7.4 years, with an average education of 10.7±4.4 years and of predominantly Chinese (92.6%) ethnicity. Comorbidities included hypertension (35.8%), hyperlipidemia (56.8%) and type II diabetes mellitus (14.4%). The median (IQR) for the Barthel basic ADL index, Lawton's instrumental ADL index, and SPPB were 100 (95.0-100), 23.0 (22.0-23.0) and 12.0 (11.0-12.0) respectively, attesting to the fairly robust health state of the participants. Correspondingly, 51.5% were classified as physically robust, 44.5% as physically pre-frail and only 3.9% physically frail based on the Modified Fried criteria (Table 1).

Figure 1. Classification of social frailty vs executive dysfunction groups
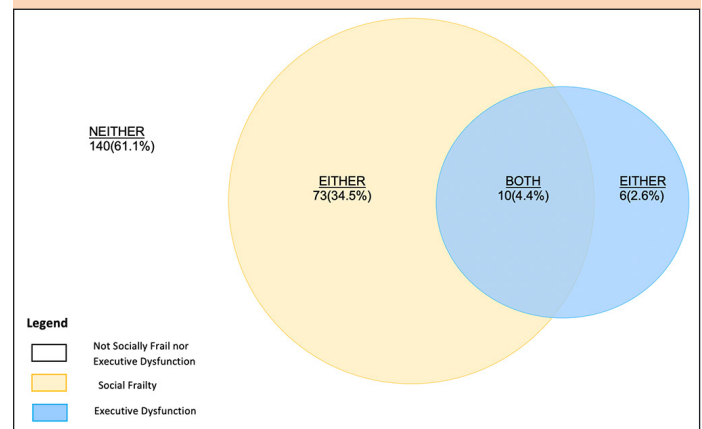
Relationship between CMMSE vs Chinese FAB with Social Frailty

Total Chinese FAB scores significantly decreased moving from SNF through to SPF and SF (mean±SD: 16.9±1.7 vs 15.7±2.1 vs 15.7±2.4, p<.001), with SPF/SF significantly lower than SNF in post-hoc comparison (p<.05, Bonferroni correction). In contrast, total CMMSE scores did not differ across social frailty (Table 2). Correspondingly, there was an increase in proportion with cognitive impairment for Chinese FAB (p=.077) but not CMMSE (p=.151) across the spectrum of social frailty. In terms of Chinese FAB factor scores, cognitive control (p<.001) but not behavioural control domain was significantly different. For CMMSE, only the non-amnestic domains of orientation to time and place as well as language and praxis were significant (p≤.001 and p=.012 respectively); the recall domain was not significant (p=.154).

Table 1. Social frailty and executive dysfunction: Comparison of neither, either and both groups

	Total n=229	Neither n=140	Either n=79	Both n=10	p-value
Demographics					
Age, years	67.2±7.43	65.9±6.53	68.6±8.14	75.4±6.90 †,‡	<0.001
Female	166 (72.5)	97 (69.3)	63 (79.7)	6 (60.0)	0.166
Chinese ethnicity	212 (92.6)	128 (91.4)	74 (93.7)	10 (100)	0.973
Education, years	10.7±4.36	11.8±4.24	9.61±3.86	5.40±4.20 †,‡	<0.001
Body Mass Index, kg/m^2	23.9±3.23	23.9±2.98	23.9±3.74	22.8±2.23	0.551
Comorbidities					
Hypertension	82 (35.8)	42 (30.0)	34 (43.0)	6 (60.0)	0.041
Hyperlipidaemia	130 (56.8)	81 (57.9)	42 (53.2)	7 (70.0)	0.549
Diabetes	33 (14.4)	22 (15.7)	8 (10.1)	3 (30.0)	0.188
Ischemic heart disease	5 (2.19)	4 (2.86)	0 (0.00)	1 (10.0)	0.087
Atrial fibrillation	7 (3.07)	5 (3.57)	2 (2.56)	0 (0.00)	0.778
Stroke	4 (1.75)	2 (1.43)	2 (2.53)	0 (0.00)	0.762
Osteopenia/Osteoporosis	177 (77.3)	104 (74.3)	64 (81.0)	9 (90.0)	0.322
Smoking	19 (8.30)	12 (8.57)	5 (6.33)	2 (20.0)	0.330
Functional Status					
Basic ADL (0-100)	100 (95.0-100)	100 (96.3-100)	100 (95.0-100)	95.0 (90.0-100) †,‡	0.012
Instrumental ADL (0-23)	23.0 (22.0-23.0)	23.0 (22.3-23.0)	23.0 (22.0-23.0)	22.0 (21.8-23.0) †,‡	0.027
Physical Activity					
FAI (0-45)	33 (30.0-36.0)	32.6 (30.0-36.0)	33.0 (30.0-35.0)	30.5 (22.3-32.3)†,‡	0.005
IPAQ, METs	4932 (31923-6798)	5598 (3875-7038)	3786 (2502-5698)	4818 (2056-5313)	<0.001
Physical Frailty and Performance					
Modified Fried score	0.72±0.89	0.53±0.74	0.92±0.92	1.80±1.40	<0.001
Robust	118 (51.5)	86 (61.4)	30 (38.0)	2 (20.0)	<0.001
Pre-Frail	102 (44.5)	53 (37.9)	43 (54.4)	6 (60.0)	
Frail	9 (3.93)	1 (0.07)	6 (7.59)	2 (20.0)	
SPPB (0-12)	12.0 (11.0-12.0)	12.00 (12.0-12.0)	12.00 (11.0-12.0)	11.5 (11.0-12.0)	<0.001
Gait Speed, m/s	1.17 (1.02-1.28)	1.17 (1.07-1.32)	1.10 (0.99-1.28)	1.00 (0.90-1.10)	0.003
5-times repeated chair stand, sec	9.46±3.03	8.64±2.70	10.70±3.16	11.20±2.41†	<0.001
Geriatric syndromes					
Near falls/ falls	48 (21.0)	23 (16.4)	19 (24.1)	6 (60.0)	0.003
SNAQ (0-20)	16.0 (15.0-17.0)	16.0 (15.0-17.0)	15.0 (15.0-17.0)	15.0 (14.0-16.3)	0.035
GDS (0-15)	1.00 (0.00-2.00)	1.00 (0.00-1.00)	1.00 (0.00-2.00)	1.50 (1.00-2.00)†,‡	0.004
Life Space and Quality of Life					
Life-Space Assessment (0-120)	92.0 (80.0-102)	94.0 (82.0-104)	92.0 (78.0-100)	75.0 (67.0-96.6)†	0.057
Life-Space Level 1, (0-8)	8.00 (8.00-8.00)	8.00 (8.00-8.00)	8.00 (8.00-8.00)	8.00 (8.00-8.00)	0.872
Life-space Level 2, (0-16)	16.0 (16.0-16.0)	16.0 (16.0-16.0)	16.0 (16.0-16.0)	16.0 (11.0-16.0)	0.001
Life-space Level 3, (0-24)	24.0 (12.0-24.0)	24.0 (12.0-24.0)	18.0 (12.0-24.0)	15.8 (4.50-24.0)	0.133
Life-space Level 4, (0-32)	16.0 (16.0-32.0)	16.0 (16.0-32.0)	20.0 (16.0-32.0)	20.0 (14.0-32.0)	0.532
Life-space Level 5, (0-40)	30.0 (20.0-40.0)	30.0 (20.0-40.0)	20.0 (20.0-30.0)	20.0 (10.0-22.5)	0.001
EQ-5D-5L	1.00 (0.910-1.00)	1.00 (0.910-1.00)	1.00 (0.910-1.00)	0.91 (0.750-1.00)	0.020
EQ-5D Utility value <0.881*	28 (12.2)	11 (7.86)	13 (16.5)	4 (40.0)	0.004

Values are expressed as mean±SD; median (interquartile range); or N (%).; ADL: Activities of Daily Living; EQ-5D-5L: five-level dimension EuroQoL questionnaire; FAI: Frenchay Activity Index; GDS: Geriatrics Depression Scale; IPAQ: International Physical Activity Questionnaire; SNAQ: Short Nutritional Assessment Questionnaire; SPPB: Short Physical Performance Battery.; *N (%) of individuals with poor self-reported health status based on an EQ-5D utility value less than 0.881 (33); †p<0.05 compared with 'neither' group in post-hoc test.; ‡p<0.05 compared with 'either' group in post-hoc test.

Table 2. CMMSE and CFAB: Comparison of total and factor scores by social frailty subgroups

	Total n=229	Social Non-Frail n=146	Social Pre-Frail n= 66	Social Frail n=17	p-value
CMMSE					
Total score (0-28)	26.1±1.73	26.3±1.67	26.1±1.85	25.4±1.66	0.120
Cognitively impaired	9 (3.93)	6 (4.11)	1 (1.52)	2 (11.76)	0.151
Factor Scores					
Orientation to time	4.14±2.65	3.96±0.23	2.62±0.67	2.29±0.69†,‡	0.001
Orientation to place	3.76±0.52	3.82±0.45	3.74±0.54	3.29±0.77†,‡	<0.001
Registration	2.98±0.19	3.00±0.00	2.94±0.35	3.00±0.00	0.083
Attention and Calculation	4.13±1.05	4.13±1.07	4.05±1.12	4.47±0.51	0.333
Recall	2.58±0.64	2.60±0.62	2.62±0.67	2.29±0.69	0.154
Language and Praxis	8.70±0.59	8.74±0.53	8.73±0.65	8.29±0.77†,‡	0.012
Chinese FAB					
Total score (0-18)	16.5±1.92	16.9±1.66	15.7±2.08	15.7±2.42†	<0.001
Cognitively impaired	16 (6.97)	6 (4.11)	8 (12.12)	2 (11.76)	0.077
Factor Scores					
Cognitive control	7.72±1.51	8.10±1.25	7.09±1.70	7.00±1.77†,‡	<0.001
Behavioural control	8.73±0.66	8.78±0.62	8.65±0.71	8.65±0.79	0.356

Values are expressed in mean±SD (continuous variables) and N(%) (categorical variables); CMMSE: Chinese Mini-Mental State Examination; FAB: Frontal Assessment Battery; †p<0.05 compared with Social Non-Frail in post-hoc test; ‡p<0.05 compared with Social Pre-Frail in post-hoc test.

Derivation of Social Frailty-Executive Dysfunction subgroups

Based on the above-mentioned results, we chose executive dysfunction (measured using Chinese FAB) as the cognitive domain to be analysed with social frailty. We derived three subgroups based on the relationship between social frailty and executive dysfunction, namely: (1) Neither, N=140 (61.1%); (2) Either, comprising either SPF/SF, N=73 (34.5%), or executive dysfunction, N=6 (2.6%); and (3) Both, N=10 (4.4%) (Figure 1).

Comparison across Social Frailty-Executive Dysfunction subgroups

There was a significant trend towards increase in age, fewer years of education, higher prevalence of hypertension and osteopenia/osteoporosis, lower BADL scores, lower iADLs scores and higher GDS (all p<.05) moving across 'neither' through to 'both' subgroups (Table 1). For outcomes, physical activity as measured by FAI and IPAQ were significantly different amongst the three subgroups, with 'both' performing the worst in FAI and 'either' the worst in IPAQ. Modified Fried scores were highest in the 'both' subgroup (20% classified as physically frail, compared with 7.59% and 0.07% in 'either' and 'neither' subgroups respectively), whilst 'both' performed the worst in SPPB, gait speed and repeated chair stand (p<.01, 1-way ANOVA). Compared with 'neither', there was a significant trend for near falls/falls, lower SNAQ, lower life space level 2 and total scores, and lower EQ-5D index scores in the 'either' and 'both' subgroups (all p<.05, 1-way ANOVA).

Logistic regression analysis for outcome measures

We performed logistic regression to determine independent associations with outcome measures (Table 3). In model 1, adjusting for age, gender, education, and hypertension, 'both' subgroup was significantly associated with risk of malnutrition, near falls/falls and life space mobility as compared with 'either' (SNAQ, OR= 5.67, 95%CI= 1.26-25.58 vs 2.09, 95%CI= 1.15-3.78; Near falls/falls, OR= 5.13, 95%CI=1.09-21.17 vs 1.52, 95%CI= 0.71-3.38 and LSA, OR= 10.56, 95%CI 2.26-49.36 vs 1.56, 95%CI= 0.75-3.26). These associations for the 'both' subgroup remained significant even with adjustment for mood in model 2 (SNAQ, OR= 4.79, 95%CI= 1.04-22.02; Near falls/falls, OR= 5.23, 95%CI= 1.10-24.90; LSA, OR= 9.80, 95%CI= 2.07-46.31). Similarly, quality of life had a much larger association with 'both' compared with 'either' subgroup, which remained significant after adjustment for mood (EQ-5D, OR= 13.2, 95%CI= 2.38-73.4 vs 2.89, 95%CI= 1.23-6.80). In contrast, for the outcomes of IPAQ, physical frailty and SPPB, there was a significant association with 'either' subgroup, even after adjusting for mood (all p<.05). FAI was not significant for 'either' or 'both' subgroups.

Discussion

Our paper corroborates the growing body of evidence about the relationship between social frailty and cognition by explicating the deleterious role of concomitant executive dysfunction amongst fairly robust community-dwelling older adults. Using a locally validated social frailty scale built on Bunt's framework, our results explicated the significant

Table 3. Social frailty and/or executive dysfunction: Logistic regression against different health outcomes

	Either Executive Dysfunction or Socially Frail						Both Executive Dysfunction and Socially Frail					
	Unadjusted Model		Model 1		Model 2		Unadjusted Model		Model 1		Model 2	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Physical Activity												
FAI	0.952	0.45-1.99	0.778	0.33-1.83	0.591	0.24-1.48	3.22	0.84-12.30	1.73	0.33-9.06	1.38	0.25-7.50
IPAQ	3.35†	1.67-6.71	3.77†	1.79-7.92	3.23†	1.50-6.94	3.10	0.73-13.15	3.85	0.76-19.62	3.39	0.66-17.46
Physical Frailty and Performance												
Modified Fried	2.60†	1.47-4.59	2.64†	1.40-4.97	2.27†	1.18-4.35	6.37†	1.30-31.13	4.18	0.70-25.03	3.52	0.57-21.9
SPPB	3.22†	1.42-7.28	2.49†	1.06-5.89	2.42†	1.00-5.84	1.30	0.15-11.25	0.57	0.06-5.61	0.55	0.05-5.50
Geriatric Syndromes												
SNAQ	2.10†	1.20-3.69	2.09†	1.15-3.78	1.77	0.96-3.27	4.77†	1.18-19.29	5.67†	1.26-25.58	4.79†	1.04-22.02
Near Falls/ Falls	1.52	0.74-3.15	1.52	0.71-3.27	1.55	0.71-3.38	4.00†	1.04-15.44	5.13†	1.09-21.17	5.23†	1.10-24.90
Life Space and Quality of Life												
LSA	1.50	0.75-2.99	1.56	0.75-3.26	1.43	0.67-3.04	7.63†	1.99-29.19	10.56†	2.26-49.36	9.80†	2.07-46.31
EQ-5D	3.62‡	1.66-7.88	3.35†	1.46-7.68	2.89†	1.23-6.80	10.7‡	2.70-42.13	15.0†	2.79-81.0	13.2†	2.38-73.4

Binary logistic regression was used to determine the odds ratios (OR) and 95% Confidence Intervals (95% CI) for the association between health outcomes and social frailty dysfunction (SF-ED); Model 1: adjusted for age, gender, years of education, and hypertension; Model 2: adjusted for age, gender, years of education, hypertension and GDS; EQ-5D-5L: five-level dimension EuroQoL questionnaire; FAI: Frenchay Activity Index; IPAQ: International Physical Activity Questionnaire; LSA: Life-Space Assessment; SNAQ: Short Nutritional Assessment Questionnaire; SPPB: Short Physical Performance Battery; †p<0.05; ‡p<0.01

association of executive dysfunction with social frailty in around 5% of our study cohort, and a possible synergistic relationship independent of mood which is associated with near-falls/falls, risk of malnutrition due to anorexia of aging, decreased life space mobility, and lowered quality of life. The strengths of our study include the use of a validated instrument to assess executive function; the comprehensive range of outcomes; statistical adjustment for depressive symptoms in regression analysis; and the relatively robust health status of our study participants which facilitates the exploration of socio-cognitive constructs in an older adult population. Taken together, our study highlights the potential deleterious impact of the co-existence of both social frailty and executive dysfunction, and the importance for community screening programs to detect both conditions as opposed to either alone.

The strong association between executive dysfunction and social frailty in our study, as opposed to the memory and non-memory cognitive domains in the CMMSE, suggests that executive function might be more sensitive to initial dysregulation in community-dwelling older adults. This corroborates reports from previous longitudinal studies that executive dysfunction may occur preclinically before the onset of physical frailty and disease-related memory changes in relatively robust older adults (15, 16). Notably, our results showed a strong association with the cognitive control rather than the behavioural control domain in the Chinese FAB. The conceptualization and mental flexibility items within the cognitive control domain showed discriminative ability to discern between normal and MCI groups (18), thereby supporting their utility to detect early impairment in executive function amongst relatively robust older adults with social frailty.

Our results also suggest a synergistic relationship between social frailty and executive dysfunction with poorer health outcomes. Even after adjusting for mood, our results showed

independent associations of having 'both' social frailty and executive dysfunction with malnutritional risk due to anorexia of aging, near falls/falls, poorer life-space mobility, and a poorer quality of life. Previous studies did not consistently demonstrate these associations because social frailty and executive dysfunction were examined in isolation, which is akin to the 'either' group in our study. Notably, the odds ratio for lower quality of life was 4.5 times higher in the 'both' subgroup compared with the 'either' subgroup, and corroborates the synergistic relationship above and beyond the independent contribution of executive function and social support on quality of life (37, 38). Significantly, social frailty rather than executive dysfunction is more prevalent in the 'either' subgroup in our study (Figure 1) and is likely the main driver in the observed associations with physical frailty, physical performance and physical activity, findings which are synonymous with evidence from earlier studies (4, 22).

Executive functioning plays an important role in enabling higher-level functions such as planning, making decisions and sourcing for new information, thus maintaining independence in daily life (16, 39). Earlier studies in healthy community-dwelling populations have reported that the inability to plan is one of the first signs of cognitive decline (18). Coupled with social frailty, these individuals will have increasing difficulty in maintaining their independence, leading to eventual disability (7, 11, 40). A longitudinal study recently demonstrated temporal associations between restricted life-space mobility with executive dysfunction at baseline (41). Recently, a novel concept described as motoric cognitive risk (MCR), characterised by slower gait and an increase in subjective memory complaints, despite being independent in daily activities of living, was associated with falls, disability and death in older adults (42). The association of the MCR syndrome with higher cognitive motor dual tasks costs was corroborated by recent evidence, suggesting impairment in

executive functioning of these older adults leading to lower cognitive performance and poorer motor function (43). Taken together, the association with restricted life-space mobility, near falls/ falls and anorexia of aging in our study could be explained by the interplay between social frailty and executive dysfunction. Because executive dysfunction is primarily mediated by alterations in the frontal lobes (43, 44), it is integral that neuro-imaging studies be conducted to ascertain and elucidate the association between neuro-pathological mechanisms with the observed changes in outcomes.

Taken together, our findings suggest that under the broad umbrella of frailty, a specific phenotype characterised by concomitant social and cognitive issues might exist even amongst relatively healthy older persons. The synergistic relationship of the social frailty-dysexecutive phenotype with geriatric syndromes, decreased life space and poorer quality of life, highlights the importance of early identification of at-risk older persons via a comprehensive assessment which includes both social domains and cognitive function. This can in turn facilitate early intervention via community support programs and innovative platforms to provide a safe yet effective means to engage older persons in social and cognitive dimensions. The implications are especially salient for early identification of frail populations for intervention planning in the COVID-19 era (45). The implementation of strict safe distancing measures to curb the COVID-19 contagion has resulted in social estrangement and a sharp decrease in physical activity due to restrictions on movement (10, 46, 47). This disruption to daily life poses a threat to health even amongst non-frail community dwelling older adults. Due to the lack of social interaction and cognitive stimulation, older adults who fulfil the social frailty-dysexecutive phenotype may be most vulnerable to the resultant adverse effects. Studies have shown that older adults who were socially isolated during the COVID_19 pandemic had 2.74 times higher likelihood of cognitive decline compared to those who did not (48). Earlier studies which have examined the social and cognitive impact of COVID-19 and the accompanying public health control measures on older persons, tend to examine these two constructs separately and in isolation (49). There is thus a need for well-designed studies with longitudinal outcomes to examine both social frailty and executive dysfunction in tandem in order to further understand their combined impact during the COVID-19 pandemic.

Limitations of the study and future work

The results of our study may not be generalizable to non-Asian populations or a frailer spectrum of older adults. Due to the cross-sectional analysis, reverse causality cannot be excluded and the association of social frailty and executive dysfunction with adverse health outcomes needs to be confirmed in well-conducted longitudinal studies with a larger sample size to establish causality. Lastly, executive function is a broad construct that captures various aspects including basic functions such as attention, inhibitory control, working memory, set switching, and higher order functions including planning, decision making, and problem solving. However,

assessment of executive function is limited to domains within the Chinese FAB in our study, and the sample size does not permit further analysis to determine which aspects of executive function drive the synergistic association of social frailty with adverse outcomes. Future studies should address the issue of whether this association of both social frailty and executive dysfunction holds true across different cultural populations, and to deconstruct the executive function domain to determine specific cognitive factors that contribute to the synergistic relationship we see between social frailty and executive dysfunction.

Conclusion

Our study highlights the association of social frailty with executive dysfunction, particularly the cognitive control domain, in relatively healthy older adult community dwellers. This synergistic relationship, independent of mood, is associated with higher risk for near-falls/falls, anorexia of aging, decreased life space mobility, and quality of life. Our results support the role of community screening programs for both cognitive impairment and social frailty, with a focus on those with co-existent executive dysfunction and social frailty as a possible target for early intervention, as opposed to social frailty or executive dysfunction in isolation. In light of the current COVID-19 pandemic, the association between social frailty and executive dysfunction merits further study as a possible target for early intervention in relatively healthy older adults.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Clegg A, Young J, Iliffe S, Rikkert MO, Rockwood K. Frailty in elderly people. The lancet. 2013;381(9868):752-62.
2. Wleklik M, Uchmanowicz I, Jankowska EA, Vitale C, Lisiak M, Drozd M, et al. Multidimensional approach to frailty. Front Psychol. 2020;11:564.
3. Bunt S, Steverink N, Olthof J, Van Der Schans C, Hobbelen J. Social frailty in older adults: a scoping review. Eur J Ageing. 2017;14(3):323-34.
4. Pek K, Chew J, Lim JP, Yew S, Tan CN, Yeo A, et al. Social frailty is independently associated with mood, nutrition, physical performance, and physical activity: Insights from a theory-guided approach. Int J Environ Res Public Health. 2020;17(12):4239.
5. Tsutsumimoto K, Doi T, Makizako H, Hotta R, Nakakubo S, Kim M, et al. Social frailty has a stronger impact on the onset of depressive symptoms than physical frailty or cognitive impairment: a 4-year follow-up longitudinal cohort study. J Am Med Dir Assoc. 2018;19(6):504-10.
6. Tsutsumimoto K, Doi T, Makizako H, Hotta R, Nakakubo S, Makino K, et al. Association of social frailty with both cognitive and physical deficits among older people. J Am Med Dir Assoc. 2017;18(7):603-7.
7. Makizako H, Shimada H, Tsutsumimoto K, Lee S, Doi T, Nakakubo S, et al. Social frailty in community-dwelling older adults as a risk factor for disability. J Am Med Dir Assoc. 2015;16(11):1003. e7-. e11.
8. Makizako H, Shimada H, Tsutsumimoto K, Hotta R, Nakakubo S, Makino K, et al. Social frailty leads to the development of physical frailty among physically non-frail adults: A four-year follow-up longitudinal cohort study. Int J Environ Res Public Health. 2018;15(3):490.
9. Suthutvoravut U, Tanaka T, Takahashi K, Akishita M, Iijima K. Living with family yet eating alone is associated with frailty in community-dwelling older adults: the Kashiwa study. J Frailty Aging. 2019;8(4):198-204.

10. Pek K, Tan CN, Yew S, Yeo A, Lim JP, Chew J, et al. COVID-19 Pandemic Control Measures: Impact on Social Frailty and Health Outcomes in Non-Frail Community-Dwelling Older Adults. J Nutr Health Aging. 2021.

11. Teo N, Gao Q, Nyunt MSZ, Wee SL, Ng T-P. Social frailty and functional disability: Findings from the Singapore Longitudinal Ageing Studies. J Am Med Dir Assoc. 2017;18(7):637. e13-. e19.

12. Teo N, Yeo PS, Gao Q, Nyunt MSZ, Foo JJ, Wee SL, et al. A bio-psycho-social approach for frailty amongst Singaporean Chinese community-dwelling older adults–evidence from the Singapore longitudinal aging study. BMC Geriatr. 2019;19(1):1-14.

13. Ma L, Sun F, Tang Z. Social frailty is associated with physical functioning, cognition, and depression, and predicts mortality. J Nutr Health Aging. 2018;22(8):989-95.

14. Santos NC, Costa PS, Cunha P, Cotter J, Sampaio A, Zihl J, et al. Mood is a key determinant of cognitive performance in community-dwelling older adults: a cross-sectional analysis. Age. 2013;35(5):1983-93.

15. Carlson MC, Xue Q-L, Zhou J, Fried LP. Executive decline and dysfunction precedes declines in memory: the Women's Health and Aging Study II. J Gerontol A Biol Sci Med Sci. 2009;64(1):110-7.

16. Gross AL, Xue Q-L, Bandeen-Roche K, Fried LP, Varadhan R, McAdams-DeMarco MA, et al. Declines and impairment in executive function predict onset of physical frailty. J Gerontol A Biol Sci Med Sci. 2016;71(12):1624-30.

17. Chong MS, Lim W, Chan SP, Feng L, Niti M, Yap P, et al. Diagnostic performance of the Chinese Frontal Assessment Battery in early cognitive impairment in an Asian population. Dement Geriatr Cogn Disord. 2010;30(6):525-32.

18. Goh WY, Chan D, Ali N, Chew A, Chuo A, Chan M, et al. Frontal Assessment Battery in Early Cognitive Impairment: Psychometric Property and Factor Structure. J Nutr Health Aging. 2019;23(10):966-72.

19. Wang T-L, Hung Y-H, Yang C-C. Psychometric properties of the Taiwanese (traditional Chinese) version of the Frontal Assessment Battery: A preliminary study. Appl Neuropsychol Adult. 2016;23(1):11-20.

20. Van Kan GA, Rolland Y, Bergman H, Morley J, Kritchevsky S, Vellas B. The IANA Task Force on frailty assessment of older people in clinical practice. J Nutr Health Aging. 2008;12(1):29-37.

21. Sahadevan S, Lim PiPJ, Tan NJL, Chan SP. Diagnostic performance of two mental status tests in the older Chinese: influence of education and age on cut-off values. Int J Geriatr Psychiatry. 2000;15(3):234-41.

22. Lau S, Pek K, Chew J, Lim JP, Ismail NH, Ding YY, et al. The Simplified Nutritional Appetite Questionnaire (SNAQ) as a Screening Tool for Risk of Malnutrition: Optimal Cutoff, Factor Structure, and Validation in Healthy Community-Dwelling Older Adults. Nutrients. 2020;12(9):2885.

23. Yu R, Morley JE, Kwok T, Leung J, Cheung O, Woo J. The effects of combinations of cognitive impairment and pre-frailty on adverse outcomes from a prospective community-based cohort study of older Chinese people. Front Med (Lausanne). 2018;5:50.

24. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. The gerontologist. 1969;9(3_Part_1):179-86.

25. Mahoney FI, Barthel DW. Functional evaluation: the Barthel Index: a simple index of independence useful in scoring improvement in the rehabilitation of the chronically ill. Md State Med J. 1965.

26. Lim KK, Chan A. Association of loneliness and healthcare utilization among older adults in Singapore. Geriatrics & gerontology international. 2017;17(11):1789-98.

27. Hurtig-Wennlöf A, Hagströmer M, Olsson LA. The International Physical Activity Questionnaire modified for the elderly: aspects of validity and feasibility. Public Health Nutr. 2010;13(11):1847-54.

28. Schuling J, De Haan R, Limburg Mt, Groenier K. The Frenchay Activities Index. Assessment of functional status in stroke patients. Stroke. 1993;24(8):1173-7.

29. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci. 2001;56(3):M146-M57.

30. Guralnik JM, Ferrucci L, Pieper CF, Leveille SG, Markides KS, Ostir GV, et al. Lower extremity function and subsequent disability: consistency across studies, predictive models, and value of gait speed alone compared with the short physical performance battery. J Gerontol A Biol Sci Med Sci. 2000;55(4):M221-M31.

31. Oh B, Cho B, Choi H-C, Son K-Y, Park SM, Chun S, et al. The influence of lower-extremity function in elderly individuals' quality of life (QOL): an analysis of the correlation between SPPB and EQ-5D. Arch Gerontol Geriatr. 2014;58(2):278-82.

32. Chen L-K, Woo J, Assantachai P, Auyeung T-W, Chou M-Y, Iijima K, et al. Asian Working Group for Sarcopenia: 2019 consensus update on sarcopenia diagnosis and treatment. J Am Med Dir Assoc. 2020;21(3):300-7. e2.

33. Peel C, Baker PS, Roth DL, Brown CJ, Bodner EV, Allman RM. Assessing mobility in older adults: the UAB Study of Aging Life-Space Assessment. Phys Ther. 2005;85(10):1008-19.

34. Luo N, Wang P, Thumboo J, Lim Y-W, Vrijhoef HJ. Valuation of EQ-5D-3L health states in Singapore: modeling of time trade-off values for 80 empirically observed health states. Pharmacoeconomics. 2014;32(5):495-507.

35. Van Hout B, Janssen M, Feng Y-S, Kohlmann T, Busschbach J, Golicki D, et al. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. Value Health. 2012;15(5):708-15.

36. Lockwood KA, Alexopoulos GS, van Gorp WG. Executive dysfunction in geriatric depression. Am J Psychiatry. 2002;159(7):1119-26.

37. Davis JC, Marra CA, Najafzadeh M, Liu-Ambrose T. The independent contribution of executive functions to health related quality of life in older women. BMC Geriatr. 2010;10(1):1-8.

38. de Labra C, Maseda A, Lorenzo-López L, López-López R, Buján A, Rodríguez-Villamil JL, et al. Social factors and quality of life aspects on frailty syndrome in community-dwelling older adults: the VERISAÚDE study. BMC Geriatr. 2018;18(1):1-9.

39. De Silva NA, Gregory MA, Venkateshan SS, Verschoor CP, Kuspinar A. Examining the association between life-space mobility and cognitive function in older adults: a systematic review. J Aging Res. 2019;2019.

40. Yamada M, Arai H. Social frailty predicts incident disability and mortality among community-dwelling Japanese older adults. J Am Med Dir Assoc. 2018;19(12):1099-103.

41. Poranen-Clark T, von Bonsdorff MB, Rantakokko M, Portegijs E, Eronen J, Pynnönen K, et al. The temporal association between executive function and life-space mobility in old age. J Gerontol A Biol Sci Med Sci. 2018;73(6):835-9.

42. Chhetri JK, Chan P, Vellas B, Cesari M. Motoric cognitive risk syndrome: predictor of dementia and age-related negative outcomes. Front Med (Lausanne). 2017;4:166.

43. Ward N, Menta A, Peach S, White S, Jaffe S, Kowaleski C, et al. Cognitive Motor Dual Task Costs in Older Adults with Motoric Cognitive Risk Syndrome. J Frailty Aging. 2021:1-6.

44. Harrington MG, Chiang J, Pogoda JM, Gomez M, Thomas K, Marion SD, et al. Executive function changes before memory in preclinical Alzheimer's pathology: a prospective, cross-sectional, case control study. PLoS One. 2013;8(11):e79378.

45. Cerami C, Canevelli M, Santi GC, Galandra C, Dodich A, Cappa SF, et al. Identifying Frail Populations for Disease Risk Prediction and Intervention Planning in the Covid-19 Era: A Focus on Social Isolation and Vulnerability. Frontiers in Psychiatry. 2021;12.

46. Steinman MA, Perry L, Perissinotto CM. Meeting the care needs of older adults isolated at home during the COVID-19 pandemic. JAMA Intern Med. 2020;180(6):819-20.

47. Launay CP, Cooper-Brown L, Ivensky V, Beauchet O. Frailty and Home Confinement during the COVID-19 Pandemic: Results of a Pre-Post Intervention, Single Arm, Prospective and Longitudinal Pilot Study. J Frailty Aging. 2021:1-2.

48. Noguchi T, Kubo Y, Hayashi T, Tomiyama N, Ochi A, Hayashi H. Social Isolation and Self-Reported Cognitive Decline Among Older Adults in Japan: A Longitudinal Study in the COVID-19 Pandemic. J Am Med Dir Assoc. 2021.

49. Manca R, De Marco M, Venneri A. The impact of COVID-19 infection and enforced prolonged social isolation on neuropsychiatric symptoms in older adults with and without dementia: a review. Front Psychiatry. 2020;11:1086.