Original Article

Multidomain Geriatric Screen and Physical Fitness Assessment Identify Prefrailty/Frailty and Potentially Modifiable Risk Factors in Community-Dwelling Older Adults

Laura BG Tay, [1] *MBBS, MRCP*, Melvin PW Chua, [1] *MBChB, FRCP*, Ee Ling Tay, [2] *MSc*, Hiu Nam Chan, [3] *MBDietSt*, Shi Min Mah, [2] *MSc*, Aisyah Latib, [4] *BSc*, Cheryl QY Wong, [4] *BSc*, Yee Sien Ng, [1] *MBBS, FRCP*

Abstract

Introduction: Frailty begins in middle life and manifests as a decline in functional fitness. We described a model for community frailty screening and factors associated with prefrailty and frailty and fitness measures to distinguish prefrail/frail from robust older adults. We also compared the Fatigue, Resistance, Ambulation, Illnesses and Loss of weight (FRAIL) scale against Fried frailty phenotype and Frailty Index (FI). Materials and Methods: Community-dwelling adults ≥55 years old were designated robust, prefrail or frail using FRAIL. The multidomain geriatric screen included social profiling and cognitive, psychological and nutritional assessments. Physical fitness assessments included flexibility, grip strength, upper limb dexterity, lower body strength and power, tandem and dynamic balance and cardiorespiratory endurance. Results: In 135 subjects, 99 (73.3%) were robust, 34 (25.2%) were prefrail and 2 (1.5%) were frail. After adjusting for age and sex, depression (odds ratio [OR], 2.90; 95% confidence interval [CI], 1.05-7.90; *P* = 0.040) and malnutrition (OR, 6.07; 95% CI, 2.52-14.64; *P* <0.001) were independently associated with prefrailty/frailty. Prefrail/frail participants had significantly poorer performance in upper limb dexterity (*P* = 0.030), lower limb power (*P* = 0.003), tandem and dynamic balance (*P* = 0.031) and endurance (*P* = 0.006). Except for balance and flexibility, all fitness measures differentiated prefrail/frail from robust women. In men, only lower body strength was significantly associated with frailty. Area under receiver operating characteristic curves for FRAIL against FI and Fried were 0.808 (0.688-0.927, *P* <0.001) and 0.645 (0.546-0.744, *P* = 0.005), respectively. Conclusion: Mood and nutrition are targets in frailty prevention. Physical fitness declines early in frailty and manifests differentially in both genders.

Ann Acad Med Singapore 2019;48:171-80

Key words: Elderly, Frail, Function

Introduction

Frailty is a geriatric syndrome characterised by increased vulnerability to adverse health outcomes following minor stressor events.[1] There are 2 established models in the study of frailty: physical frailty phenotype and cumulative deficit model.[2,3] Brief screening instruments have also been developed, but frailty assessment in the community is not widely endorsed. This may reflect concerns about the feasibility of systematic search for cases of frail elderly and uncertainty towards the utility of frailty instruments in informing clinical practice.

Additionally, Comprehensive Geriatric Assessment (CGA) remains the current standard in management of underlying causes of extreme vulnerability,[4] but it is constrained by lack of resources in many contexts. As a multidimensional, inter-disciplinary diagnostic tool to effectively examine multiple health domains—functional, medical and psychological—in a frail elderly person, CGA relies on a core team that comprises a geriatrician, nurse, physiotherapist, occupational therapist and social worker along with appropriate specialty referrals to deliver an individualised care plan. Community CGA programmes

[1]Department of General Medicine, Sengkang General Hospital, Singapore
[2]Physiotherapy Department, Sengkang General Hospital, Singapore
[3]Department of Dietetics, Sengkang General Hospital, Singapore
[4]Health Services Research and Evaluation, SingHealth, Singapore
Address for Correspondence: Dr Laura Tay Bee Gek, Department of General Medicine, Sengkang General Hospital, 110 Sengkang East Way, Singapore 544886.
Email: laura.tay.b.g@singhealth.com.sg

with a preventive focus have typically involved home assessments and follow-up visits which may not be efficient as they are an expensive model for primary case finding.[5] Instead, outpatient CGA consultations that target patients at higher risk of hospitalisation and address their adherence to programme recommendations are more likely to be effective.[5] Hence, brief evaluation tools such as Rapid Geriatric Assessment[6]—which may be completed without extensive geriatric training—may facilitate wider community screening and referrals for a full CGA.

When measuring frailty, one must ensure that the measurement tool has been validated and its choice is guided by the objectives of the assessment and resources available at one's disposal.[7] The self-reported Fatigue, Resistance, Ambulation, Illnesses and Loss of weight (FRAIL) scale—combining elements from Fried's frailty phenotype and the multidimensional Frailty Index (FI)—appeals because of its sheer simplicity of use and is recommended for clinical use by the International Academy on Nutrition and Aging (IANA).[8] As a rapid screening tool, FRAIL has demonstrated its feasibility to be used as a stepping stone to a more comprehensive evaluation. However, poor follow-up attendance may limit the effectiveness of screening.[9,10] Building on the work of Woo et al,[10] we developed a community programme that integrates screening for physical frailty with its potential determinants to guide targeted interventions.

Unlike frailty, maintenance of functional fitness is associated with successful ageing.[11,12] However, a decline in physical fitness—represented by agility, endurance, flexibility and strength—may begin as early as in middle life. After the age of 50, the annual decline of 1% to 2% in muscle mass is matched by a progressive loss of 1.5% to 3% in muscle strength every year.[13] Additionally, a significant drop in aerobic capacity is observed after the age of 40 and this loss may reach as much as 30% by the age of 65.[14] By convention, weakness in frailty criteria has included only grip strength and it is the most salient feature[15,16] even though loss of muscle strength in the lower limbs is typically greater than in upper limbs.[12,17] It is also interesting to note that physical exhaustion is observed much later in the frailty cycle despite the loss of nearly 10% of aerobic ability after every decade.[15,18] Since deterioration in physical fitness typically precedes functional dependence,[19] a comprehensive physical fitness assessment can be included in conventional measures of frailty to facilitate early detection and prevention of frailty.

We described our experience with a pilot community frailty screening programme that integrates multidomain geriatric screen with a physical fitness assessment. Using data from our pilot cohort, we examined: 1) potentially modifiable factors associated with prefrailty and frailty which were defined using FRAIL; and 2) physical fitness measures that differentiate prefrail and frail older adults from their robust counterparts (with specific reference to gender differences). We hypothesised that a multidomain geriatric screen will allow identification of clinical risk factors for frailty in community-dwelling older adults, and that prefrail/frail older adults will perform poorer across a battery of physical fitness tests. Finally, we compared the diagnostic performance of FRAIL against Fried's frailty phenotype and FI.

Materials and Methods

The Individual Physical Proficiency Test for Seniors (IPPT-S) is a community-based programme that was designed to promote fitness and prevent or delay frailty progression in older adults. For ease of access, we designed IPPT-S as a mobile platform based at the void decks of public housing blocks, senior activity centres (SACs), senior care centres (SCCs) or community clubs. The platform is maintained at each site for 2 to 3 weeks and is managed by members of our multidisciplinary team. Each site is visited yearly for follow-up. This is an ongoing prospective cohort study and participants have provided written informed consent. Ethics approval was obtained from SingHealth Institutional Review Board.

Eligible participants must be ≥55 years old, community-dwelling and ambulate independently (with or without walking aid). Individuals who were unable to ambulate at least 4 m independently were excluded, as well as residents of sheltered and nursing homes. As a pragmatic programme that seeks to extend frailty assessment to the community, we worked systematically to reach seniors through all the SACs and resident committees located in the northeastern region of Singapore which is served by a regional healthcare facility, Sengkang General Hospital.

Multidomain Geriatric Screen

The multidomain geriatric screen included frailty screening and cognitive, psychological and nutritional assessments using a structured questionnaire administered by a trained interviewer. We used the 5-item FRAIL scale to assess self-reported fatigue, resistance, ambulation, illnesses and weight loss[9] and to categorise participants as frail (score of 3-5), prefrail (1-2) or robust (0). Cognition was assessed using the locally validated version of Chinese Mini Mental State Examination (CMMSE).[20] Mood was assessed using the 15-item Geriatric Depression Scale (GDS).[21] Nutritional status was assessed using the Mini Nutritional Assessment-Short Form (MNA-SF) questionnaire.[22,23]

To assess social vulnerability in our participants, we adapted questions from Woo et al.[24] The questions examined 3 groups of social determinants: socioeconomic status (question on job type was modified to active employment status and housing type was included as another surrogate of socioeconomic status in the local context), lifestyle factors (questions on dietary intake were excluded since nutrition was assessed separately in our study) and social support and network.[24]

Functional performance in activities of daily living (ADL) and instrumental ADL (IADL) was evaluated using the Barthel Index and Lawton and Brody's scale, respectively.[25,26] Data on falls in the past year was captured via standardised questions.

Frailty Phenotype and Cumulative Deficit Model

We modified Fried's criteria to assess physical frailty with the use of 5 components: exhaustion (using the question on fatigue from FRAIL scale), slow gait, weak grip strength, low body mass index (BMI) <18.5 kg/m^2 and low physical activity.[2] Frailty is indicated when the result is positive for 3 components and prefrailty is identified when 1 to 2 components are present.

Grip strength was measured with a JAMAR Plus Hand Dynamometer (Sammons Preston, Bolingbrook, IL, USA). The higher reading taken from 2 trials for each hand was used for analysis. Gait speed was measured based on duration of walking 10 m at a normal pace. Weakness (<18 kg for women and <26 kg for men) and slowness ($\leq$0.8 m/s) were measured against reference values described in the Asian Working Group for Sarcopenia.[27] We used Physical Activity Vital Sign to quantify engagement in moderate to vigorous physical activity[28] and used the lowest quartile as cut-off for physical inactivity.

FI was constructed based on 34 items that included medical comorbidities, functional performance, cognitive and sensory impairment and psychosocial problems. They were derived from data captured in the multidomain geriatric screen.[29] FI was tabulated based on the number of deficits identified in each participant against the maximum number of deficits listed in the scale. Based on their FI results, participants were designated frail ($\geq$0.25), prefrail (>0.08 and <0.25) or robust ($\leq$0.08).[30]

Physical Fitness Assessment

The physical fitness test was a modified version of the Senior Fitness Test.[31] Participants who reported feeling unwell during preassessment were exempted from fitness tests. Lower body strength and power was measured using the chair stand test. In this test, participants were instructed to rise as quickly as possible from a seated to a standing position, all the while keeping their arms folded across their chests.[32] The duration taken to complete 5 chair stands and their number completed within 30 seconds were documented.

Upper limb dexterity was assessed using the box-and-block test. Participants were instructed to briskly pick up blocks from 1 side of a box and place them on another side across a barrier. The number of blocks transferred within 1 minute was recorded.[33] Similar to grip strength, the higher reading taken from 2 trials for each arm was used for analysis.

Flexibility in the upper and lower body was measured using the back scratch and chair sit-and-reach tests, respectively.[31,34] Similarly, the higher reading from 2 attempts in each test was used in the analysis. In the back scratch test, participants were asked to place 1 hand over a shoulder and the other up the middle of their back with the fingers extended. The distance (in centimetres) in which the middle fingers of both hands overlapped with each other or failed to meet was recorded as positive (+) and negative (-) scores, respectively. In the chair sit-and-reach test, participants sat on the edge of a chair with 1 leg extended before them and reached forward to touch their toes with their fingers. Likewise, the distance (in centimetres) in which the extended third finger reached beyond the toe or failed to touch the toe was documented as positive (+) and negative (-), respectively.

Dynamic balance or agility was assessed on the Timed Up and Go (TUG) test. In this test, participants were requested to rise from a seated position, walk briskly round a cone that was placed 3 m away from their chair, return to the chair and resume a fully seated position.[35] Additionally, we used the side-by-side, semi-tandem and full-tandem standing tests in the Short Physical Performance Battery (SPPB) to assess their balance.[36]

Cardiorespiratory endurance was evaluated with the 6-minute walking test (6MWT). Participants had to walk down a 20-metre path with constant encouragement throughout the test. The distance traversed in 6 minutes was recorded and participants were allowed to rest at any time during the test.[37] We scored each participant on SPPB for a composite measure of physical performance and applied established cut-offs in the individual tests of gait speed, balance and chair stand.[36]

Statistical Analysis

Univariate analyses that compared robust against prefrail/frail subjects were performed with independent samples t-test and Mann-Whitney U test for parametric and non-parametric continuous variables. Chi-square and Fisher's Exact tests were performed on categorical variables. To identify risk factors that were independently associated with prefrailty/frailty, multiple logistic regression analysis was performed on univariate variables with *P* <0.1 and adjusted for age and gender.

To examine raw agreement between FRAIL against Fried and FI, kappa test was used to correct for chance agreement. Receiver operating characteristic (ROC) curve analysis was used to examine area under ROC curve (AUROC) for FRAIL against Fried and FI. Statistical analysis was performed using SPSS software version 24.0 (IBM, Armonk, NY, USA). All statistical tests were two-tailed and a value of *P* ≤0.05 was considered statistically significant.

Results

A total of 135 participants with a mean age of 70.0 years were screened in 2 SACs. FRAIL showed 99 (73.3%) were robust, 34 (25.2%) were prefrail and 2 (1.5%) were frail. Since only 2 subjects were frail, they were grouped with prefrail participants for comparison against the robust group. Age, ethnicity and gender were similar between the robust and prefrail/frail groups.

We observed a trend of more prefrail/frail older adults who reported living alone than in the robust group (22.2% vs 10.1%, *P* = 0.067) and lacked a confidant (16.7% vs 8.1%, *P* = 0.082). Cognitive performance was similar in both groups (Table 1). However, prefrail/frail participants were significantly more likely to have GDS ≥5 (52.8% vs 16.2%, *P* <0.001) and at risk of malnutrition or were malnourished (*P* <0.001).

Of the 96 female participants, 23 (24.7%) were prefrail/frail. They were significantly more likely than their robust peers to live alone (30.4% vs 9.6%, *P* = 0.014) with higher prevalence of depression (52.2% vs 17.8%, *P* = 0.001) and malnutrition (*P* <0.001). In male participants, prevalence of prefrailty/frailty was 33.3% (Table 1). Prefrail/frail men reported less frequent contact with relatives or friends (*P* = 0.054). Compared to their robust counterparts, depression was significantly more prevalent in prefrail/frail men (53.8 vs 11.5%, *P* = 0.008) and they were significantly more likely to be at risk of malnutrition (53.8% vs 7.7%, *P* = 0.003).

Using prefrailty/frailty as the outcome variable, multiple logistic regression analysis of the entire cohort—which included social factors (living alone and lack of confidant), mood and nutritional status, as well as age and gender—revealed that depression (odds ratio [OR], 2.90; 95% confidence interval [CI], 1.05-7.90; *P* = 0.040) and malnutrition (OR, 6.07; 95% CI, 2.52-14.64; *P* <0.001) remained independently associated with prefrailty/frailty (Table 2).

In the fitness tests, 12 participants did not complete the full assessment after individual components (n = 7) or the full battery (n = 5) were omitted. They tended to be prefrail/frail compared to those who completed the full battery of fitness tests (6.1% vs 16.7%, *P* = 0.056).

Grip strength was similar in both groups but robust participants demonstrated superior performance in the box-and-block test against their prefrail/frail peers (mean ± standard deviation [SD], 45.5 ± 9.4 vs 41.4 ± 8.6; *P* = 0.030). Prefrail/frail participants took longer to complete 5 chair stands with a median time of 12.36 seconds (interquartile range [IQR], 9.72-16.57) against 10.48 seconds (IQR, 8.30-12.32) in their robust peers (*P* = 0.003). They also achieved significantly fewer stands in 30 seconds. Gait speed was significantly slower in the prefrail/frail group and they had significantly poorer (median, 10.69; IQR, 8.29-14.67) performance in tandem and dynamic balance than their robust (median, 9.33; IQR, 7.79-10.61) counterparts in the TUG test (*P* = 0.031). In 6MWT, en-durance was significantly worse in the prefrail/frail group than the robust group (mean ± SD, 367.8 ± 143.7 m vs 449.4 ± 121.2 m; *P* = 0.006). Total SPPB score was significantly lower in prefrail/frail subjects than in robust participants. When the analyses were repeated after frail participants were excluded, all fitness measures—with the exception of flexibility and grip strength—remained significantly worse in prefrail subjects than their robust peers (Table 3).

In female participants, all physical fitness components except balance and flexibility revealed significant differences between the robust and prefrail/frail groups. The latter group also had significantly lower SPPB scores. In men, only lower body strength and power significantly differentiated the robust from prefrail/frail subjects, although male prefrail/frail participants also exhibited lower endurance (*P* = 0.063).

On the FI, 6 participants had missing data. In the remaining 129 subjects, FI was significantly higher in the prefrail/frail compared to the robust (mean ± SD, 0.215 ± 0.092 vs 0.105 ± 0.066, *P* <0.001). The overall agreement between FRAIL and FI was 45.7% (kappa = 0.137, *P* = 0.013). A total of 126 participants fulfilled Fried's criteria and the overall agreement between FRAIL and Fried was 64.3% (kappa = 0.264, *P* = 0.001). In subjects who were identified as robust on FRAIL, 52.6% were prefrail on FI and 5.3% were frail. Against Fried, 36.2% of subjects who were assessed as robust on FRAIL would be considered prefrail but none of them met the criteria as frail (Table 4). AUROC for FRAIL against FI and Fried were 0.808 (0.688-0.927, *P* <0.001) and 0.645 (0.546-0.744, *P* = 0.005), respectively.

Discussion

Our study supports the feasibility of a community programme to detect prefrailty/frailty and its potentially

Table 1. Clinical Characteristics Associated with Prefrailty/Frailty

Variable	Aggregate (n = 135)			Women (n = 96)			Men (n = 39)		
	Robust (n = 99)	Prefrail/Frail (n = 36)	*P* Value	Robust (n = 73)	Prefrail/Frail (n = 23)	*P* Value	Robust (n = 26)	Prefrail/Frail (n = 13)	*P* Value
Age	69.2 (7.4)	68.4 (7.4)	0.586	68.8 (7.0)	70 (7.3)		70.3 (8.5)	65.6 (6.9)	0.093
Female gender (%)	73 (73.7)	23 (63.9)	0.264						
Ethnicity (%)			0.169			0.195			0.494
Chinese	80 (80.8)	25 (69.4)		60 (82.2)	15 (65.2)		20 (76.9)	10 (76.9)	
Malay	6 (6.1)	7 (19.4)		5 (6.8)	5 (21.7)		1 (3.8)	2 (15.4)	
Indian/Others	13 (13.2)	4 (11.1)		8 (11)	3 (13)		5 (19.2)	1 (7.7)	
Education (%)			0.904			0.853			0.919
Primary and below	57 (57.6)	19 (54.3)		50 (68.5)	15 (65.2)		7 (26.9)	4 (33.3)	
Secondary	33 (33.3)	12 (34.3)		19 (26)	6 (26.1)		14 (53.8)	6 (50)	
Tertiary	9 (9.1)	4 (11.4)		4 (5.5)	6 (6.3)		5 (19.2)	2 (16.7)	
Housing type (%)			0.185			0.455			0.109
1 – 2 room flat	35 (35.4)	19 (52.8)		26 (35.6)	11 (47.8)		9 (34.6)	8 (61.5)	
3 – 4 room flat	43 (43.4)	11 (30.6)		30 (40.1)	9 (39.1)		13 (50)	2 (15.4)	
5 room flat/private	21 (21.2)	6 (16.7)		17 (23.3)	3 (13)		4 (15.4)	3 (23.1)	
Active employment (%)	18 (18.2)	5 (13.9)	0.557	11 (15.1)	4 (17.4)	0.751	7 (26.9)	1 (7.7)	0.229
Disposable income (“fair/more than enough”, %)	58 (59.2)	20 (55.6)	0.706	42 (57.5)	11 (47.8)	0.414	16 (64)	9 (69.2)	1.00
Social support (%)									
Living alone	10 (10.1)	28 (22.2)	0.067	7 (9.6)	7 (30.4)	0.014	3 (11.5)	1 (7.7)	1.00
Attends religious/community activities	87 (87.9)	31 (86.1)	0.784	67 (91.8)	22 (95.7)	1.00	20 (76.9)	9 (69.2)	0.704
Lack of confidant	8 (8.1)	6 (16.7%)	0.082	6 (8.2)	4 (17.4)	0.209	2 (7.7)	2 (16.7)	0.577
Weekly contact with friends/relatives	53 (54.6)	11 (37.9%)	0.114	40 (56.3)	10 (52.6)	0.773	13 (50)	1 (10)	0.054
Current/ex-smoker	13 (13.1)	7 (19.4)	0.361	3 (4.1)	0	1.00	10 (38.5)	7 (53.8)	0.361
CMMSE									
0 – 28	24.7 (3.0)	24.3 (3.0)	0.502	24.5 (3.2)	24.1 (3.3)	0.597	25.2 (2.7)	24.6 (2.6)	0.523
<21 (impaired, %)	12 (12.1)	6 (16.7)	0.492	10 (13.7)	5 (21.7)	0.354	2 (7.7)	1 (7.7)	1.00
GDS									
0 – 15	2.3 (2.3)	5.8 (4.0)	<0.001	2.4 (2.5)	5.8 (4.0)	<0.001	2.1 (2.0)	5.6 (4.3)	0.014
≥5 (depression, %)	16 (16.2)	19 (52.8)	<0.001	13 (17.8)	12 (52.2)	0.001	3 (11.5)	7 (53.8)	0.008

BI: Barthel Index; BMI: Body mass index; CMMSE: Chinese Mini Mental State Examination; GDS: Geriatric Depression Scale; IADL: Instrumental activities of daily living; MNA-SF: Mini Nutritional Assessment-Short Form

Table 1. Clinical Characteristics Associated with Prefrailty/Frailty (Cont'd)

Variable	Aggregate (n = 135)			Women (n = 96)			Men (n = 39)		
	Robust (n = 99)	Prefrail/Frail (n = 36)	P Value	Robust (n = 73)	Prefrail/Frail (n = 23)	P Value	Robust (n = 26)	Prefrail/Frail (n = 13)	P Value
MNA-SF									
0 – 14	13 (12 – 14)	11 (9 – 13)	<0.001	13 (12 – 14)	11 (8 – 13)	<0.001	13.5 (12.75 – 14)	11 (9.5 – 14)	0.058
12 – 14 (normal, %)	86 (86.9)	15 (41.7)	<0.001	62 (84.9)	9 (39.1)	<0.001	24 (92.3)	6 (46.2)	0.003
8 – 11 (at risk of malnutrition, %)	12 (12.1)	16 (44.4)		10 (13.7)	9 (39.1)		2 (7.7)	7 (53.8)	
<8 (malnourished, %)	1 (1)	5 (13.9)		1 (1.4)	5 (21.7)		0	0	
BMI	25.1 (3.8)	26.4 (7.6)	0.330	25.1 (4.2)	26.9 (6.9)	0.244	25.2 (2.5)	28.4 (5.4)	0.055
Consequences									
BI	20 (20 – 20)	20 (19 – 20)	0.001	20 (20 – 20)	20 (18 – 20)	<0.001	20 (0 – 20)	20 (19.5 – 20)	0.713
IADL	23 (21 – 23)	22 (20 – 23)	0.206	23 (22 – 23)	23 (20 – 23)	0.362	23 (20 – 23)	22 (19.5 – 23)	0.648
>2 falls in past year (%)	2 (2.0)	4 (11.1)	0.076	1 (1.4)	2 (8.7)	0.095	1 (3.8)	2 (15.4)	0.018

BI: Barthel Index; BMI: Body mass index; CMMSE: Chinese Mini Mental State Examination; GDS: Geriatric Depression Scale; IADL: Instrumental activities of daily living; MNA-SF: Mini Nutritional Assessment-Short Form

modifiable determinants, particularly depression and malnutrition, for targeted intervention in older adults. Physical fitness—in addition to conventional measures of grip strength and gait speed—also declines early in the frailty continuum and may manifest differentially in older men and women.

In our cohort, the prevalence of prefrailty (25.2%) and frailty (1.5%) on FRAIL is lower than other studies that employed similar criteria.[9,38] This finding may be attributed to the younger profile of our cohort whose cut-off age of 55 is lower than age 65 in earlier studies.[10,38] Additionally, our participants were predominantly well and functionally independent and this was reflected in their high ADL and IADL scores. They have a low prevalence of frailty (1.6%) on Fried criteria. However, a higher prevalence of prefrailty (44.4%) was observed but this finding was consistent with studies that employed the phenotypic definition.[39]

By focusing on physical frailty as a specific syndrome in the multidomain geriatric screen, we were able to explore other domains that could potentially contribute to frailty. Our finding that depression and malnutrition contribute to frailty—even in the early prefrail state—concurs with similar findings in current literature and reinforces the clinical importance to assess both conditions when screening for frailty in the community.[39-41] Despite their poor nutritional status, higher BMI in prefrail/frail older men has the same impact as sarcopenic obesity on frailty in healthy community-dwelling older individuals.[42] The impact of social isolation on frailty is well reported and it is supported by the association between prefrailty/frailty and living alone or lack of a confidant in our participants.[40,43] Although prefrail/frail women were more likely to live alone in our study, contact with friends or relatives was notably less frequent in older prefrail/frail men. This suggests that social vulnerability may manifest differently in older men and women.

Contrary to our findings, a recent study from Hong Kong had found that the impact of living alone on frailty was positively associated in older men but was inversely associated in older women.[44] The apparent disparity may reflect culturally unique social factors and a need to further explore social support networks in our community-dwelling older adults.

Compared to muscle strength, muscle power exerts a greater impact on functional tasks such as navigating stairs and rising from a chair. The loss of power typically precedes—and even exceeds—a decline in strength with ageing.[45,46] This may explain the observed differential performance in lower limb power between robust and prefrail/frail older adults despite similar grip strength. The chair stand test—a measure of lower limb strength and

Table 2. Multiple Logistic Regression Analysis of Prefrailty/Frailty

Variable	Odds Ratio (95% Confidence Interval)	*P* Value
Age	0.79 (0.920 – 1.042)	0.512
Female gender	0.454 (0.170 – 1.213)	0.115
Living alone	1.915 (0.490 – 7.480)	0.350
No one to turn to for help or confide in	1.669 (0.397 – 7.022)	0.485
Depression	2.898 (1.052 – 7.984)	0.040
Malnutrition risk/malnourished	6.069 (2.515 – 14.643)	**<0.001**

R^2 = 0.356 (35.6% of variability in prefrailty/frailty status is attributed to variables in the multiple regression model)

power—was the only test that consistently demonstrated poorer performance in our prefrail/frail participants in both genders. Yet, weakness in frailty criteria has typically been represented by grip strength, although the Study of Osteoporotic Fracture (SOF) has included inability to perform the chair stand test as one of its criteria.[47]

The modest correlation between handgrip and quadriceps strength in older people suggests that upper and lower limb strength measurements cannot be used interchangeably, but are associated with distinct health outcomes to distinguish the most vulnerable subpopulation of elderly.[48] Poor performance on the sit-to-stand test had been associated with Fried's frailty criteria,[49] similar to our observation of impaired lower limb strength in the prefrail/frail group. This finding provides further impetus to evaluate lower body strength and power separately.[49]

Falls also feature in adverse outcomes associated with frailty,[50] plausibly secondary to deterioration in balance and agility observed in our prefrail/frail group. Since aerobic endurance impacts on strength, balance and mobility,[51] a decline in 6MWT score in the prefrail state means endurance training is needed to improve cardiorespiratory fitness to prevent frailty. Interestingly, while grip strength and gait speed are intrinsically connected with frailty phenotype, both were associated with prefrailty/frailty only in the women in our study. The differential performance in lower body strength and power between robust and prefrail/frail older men is a strong indicator of developing frailty in men. This finding is consistent with reports of greater loss of muscle mass and strength in lower limbs than upper limbs in older men.[52]

Earlier studies that compared FRAIL against other frailty measures have largely focused on their predictive value. In our study, we observed low to modest agreement among FRAIL, FI and Fried phenotype, suggesting that different frailty tools may have been capturing distinct—but overlapping—populations.[53] Indeed, a recent scoping review on frailty measurement in Singapore has suggested that the identification of frailty is influenced by the tools and constructs employed by researchers.[54] Nonetheless, the validity of FRAIL as a screening tool is supported by significantly higher FI in prefrail/frail subjects compared to robust older adults. The higher prevalence of prefrailty and frailty on FI is expected since it encompassed multiple domains. In contrast, FRAIL and Fried are confined to physical frailty.

Although FRAIL was intended as a rapid screening tool after it was adapted from Fried, AUROC for FRAIL was lower when referenced against Fried compared with FI. This may be attributed to higher frailty prevalence detected on FI than on Fried and the psychological and social indicators captured by FI. An earlier local study had observed similarly high AUROC for FRAIL against FI, but in a population of acutely ill hospitalised older adults.[55] Unlike Fried which employs grip strength as an objective indicator of frailty, the use of lower—rather than upper—limb strength measures to differentiate the robust from the prefrail/frail group is similar to the question on weakness in FRAIL which assesses difficulty in navigating stairs.

Xue et al have demonstrated substantial discordance between physical frailty phenotype and FI in individuals, suggesting that these frailty measures may not be used interchangeably.[56] In our cohort, 40% and 3% of prefrail participants identified by FRAIL were actually considered frail in FI and modified Fried, respectively, and 5% of those assessed as robust on FRAIL would have been frail on FI with none of them considered as frail on modified Fried. Our findings suggest that FRAIL may be used as a rapid screening tool, but future studies should evaluate its cut-off for frailty in our local elderly.

Our study has several limitations. The under-representation of males could have contributed to type 2 error in associations between fitness measures and frailty in men. Participants in our study were neighbourhood residents and those who were not able to ambulate at least 4 m independently were excluded. This could have underestimated frailty prevalence in our study since frail individuals might not have been able to visit our study site. The cross-sectional analysis also limits our inference on causality. However, this study presents pilot data from an ongoing programme and longitudinal follow-up will clarify the temporal relationship between frailty and its

Table 3. Association between Physical Fitness Tests and Prefrailty/Frailty

Variable	Aggregate (n = 135)			Women (n = 96)			Men (n = 39)		
	Robust (n = 99)	Prefrail/Frail (n = 36)	*P* Value	Robust (n = 73)	Prefrail/Frail (n = 23)	*P* Value	Robust (n = 26)	Prefrail/Frail (n = 13)	*P* Value
Flexibility (mean ± SD)									
Back scratch test	6.51 ± 16.59	4.85 ± 25.27	0.728	4.84 ± 14.73	3.60 ± 24.97	0.829	11.32 ± 20.65	7.04 ± 26.78	0.596
Chair sit-and-reach	1.67 ± 10.5	0.77 ± 14.2	0.370	3.36 ± 9.72	2.67 ± 12.41	0.787	3.22 ± 11.19	6.79 ± 15.65	0.431
Strength and power									
Upper limb									
Grip strength (kg)	23.8 (6.7)	22.8 (8.2)	0.517	21.6 (4.6)	18.7 (5.3)	0.017	30.1 (7.7)	30.1 (7.3)	1.00
Weak grip (%)*	21 (21.6)	11 (33.3)	0.178	13 (18.1)	9 (42.9)	0.019	8 (32)	2 (16.7)	0.445
Lower limb (chair stand)									
Median duration of 5 stands (IQR)	10.48 (8.30 – 12.32)	12.36 (9.72 – 16.57)	0.003	10.94 (8.76 – 12.34)	12.51 (10.00 – 16.88)	0.019	9.70 (6.68 – 12.50)	12.0 (9.56 – 16.60)	0.024
Stands completed in 30 seconds (mean ± SD)	14.4 ± 4.9	12.4 ± 3.7	0.036	13.8 ± 4.4	12.4 ± 3.7	0.208	16.1 ± 5.8	12.3 ± 3.9	0.055
Dexterity (box-and-block test, mean ± SD)	45.5 ± 9.4	41.4 ± 8.6	0.030	46.5 ± 9.1	41.0 ± 9.4	0.017	42.4 ± 9.8	42.1 ± 7.4	0.912
Mobility									
Gait speed (mean ± SD)	1.38 ± 0.27	1.19 ± 0.35	0.001	1.37 ± 0.28	1.15 ± 0.28	0.002	1.41 ± 0.25	1.25 ± 0.45	0.265
Slow gait (%)*	–	5 (15.2)	0.001	–	3 (14.3)	0.001	–	2 (16.7)	0.099
Balance and agility									
Standing balance (>10 seconds, %)									
Side-by-side	96 (99)	32 (97)	0.445	71 (98.6)	20 (95.2)	0.403	25 (100)	12 (100)	–
Semi-tandem	95 (97.9)	31 (93.9)	0.267	70 (97.2)	19 (90.5)	0.219	25 (100)	12 (100)	–
Tandem	84 (86.6)	22 (66.7)	0.036	62 (86.1)	14 (66.7)	0.121	22 (88.0)	8 (66.7)	0.093
Dynamic balance									
Median TUG (IQR)	9.33 (7.79 – 10.61)	10.69 (8.29 – 14.67)	0.031	9.39 (7.79 – 10.61)	10.43 (8.65 – 15.78)	0.088	9.30 (7.85 – 10.84)	10.74 (8.04 – 14.29)	0.215
Endurance (6MWT, mean ± SD)	449.4 ± 121.2	376.8 ± 143.7	0.006	446.0 ± 125.1	379.7 ± 149.2	0.041	459.5 ± 110.7	371.4 ± 155.2	0.063
Median SPPB score (IQR)	12 (11 – 12)	11 (8.25 – 12)	0.011	11.5 (10 – 12)	11 (8.25 – 11.75)	0.031	12 (11 – 12)	11 (8 – 12)	0.195

6MWT: 6-minute walking test; IQR: Interquartile range; SD: Standard deviation; SPPB: Short Physical Performance Battery; TUG: Timed Up and Go test
*Based on cut-off for weak grip strength (<18 kg in women and <26 kg in men) and slow gait speed (≤0.8 m/s) from the Asian Working Group for Sarcopenia.

Table 4. Agreement between FRAIL, Frailty Index and Fried Phenotype

FRAIL (%)	Frailty Index					Fried Phenotype				
	Robust (≤0.08)	Prefrail (0.08 – 0.25)	Frail (≥0.25)	Total	Kappa (*P* Value)	Robust	Prefrail	Frail	Total	Kappa (*P* Value)
Robust	40 (42.1)	50 (52.6)	5 (5.3)	95 (73.6)		60 (63.8)	34 (36.2)	0	94 (74.6)	
Pre-frail	2 (6.3)	17 (53.1)	13 (40.6)	32 (24.8)		8 (26.7)	21 (70)	1 (3.3)	30 (23.8)	
Frail	0	0	2 (100)	2 (1.6)		1(50)	1 (50)	0	2 (1.6)	
Total	42 (32.6)	67 (51.9)	20 (15.5)	129	0.137 (0.013)	69 (54.8)	56 (44.4)	1 (0.79)	126	0.264 (0.001)

multiple antecedents. Although frailty screening is recommended in individuals >70 years old, we adopted a lower cut-off age (55 years old) since the antecedents of frailty may manifest as early as in middle age.[57] The exclusion of seniors who reside in sheltered or nursing homes—and who are expected to be more frail—from our study may also limit the generalisability of our findings.

Conclusion

We have shown that an integrated community screening programme that screens frailty and its concurrent risk factors such as mood, nutrition and social support can facilitate targeted intervention in older adults after it identifies them as prefrail. Additionally, the use of physical fitness tests provide older adults with an opportunity to monitor their own functional fitness and to promote healthy ageing in them. The test can also be used to create customised exercise programmes for older adults that target early decline in their physical fitness and early frailty.

Acknowledgements

This study was funded with grants (CGAug16C027 and GAug16M011) from National Medical Research Council. The authors would like to thank Germaine Chng, Steven Lim, Hannah Lim, Alice Lee and Enan Goh from the Strategic Planning Department in Sengkang General Hospital and Mohamad Rizal for their assistance in the operationalisation of IPPT-S. They also thank the staff of Ang Mo Kio Family Service Centre (Rivervale) and Pacific Activity Centre (Punggol Ripples) for their help with the attendance of the senior participants in IPPT-S.

REFERENCES

1. Fried LP, Ferrucci L, Darer J, Williamson JD, Anderson G. Untangling the concepts of disability, frailty, and comorbidity: implications for improved targeting and care. J Gerontol A Biol Sci Med Sci 2004;59:255-63.
2. Fried LP, Tangen CM, Walston JN, Newman AB, Hirsch C, Gottdiener J, et al. Frailty in older adults: evidence for a phenotype. J Gerontol A Biol Sci Med Sci 2001;56:146-56.
3. Rockwood K, Mitnitski A. Frailty in relation to the accumulation of deficits. J Gerontol A Biol Sci Med Sci 2007;62:722-7.
4. Dent E, Lien C, Lim WS, Wong WC, Wong CH, Ng TP, et al. The Asia-Pacific clinical practice guidelines for the management of frailty. J Am Med Dir Assoc 2017;18:564-75.
5. Pilotto A, Cella A, Pilotto A, Daragjati J, Veronese N, Musacchio C, et al. Three decades of comprehensive geriatric assessment: evidence coming from different healthcare settings and specific clinical conditions. J Am Med Dir Assoc 2017;18:192.e1-192.e11.
6. Morley JE, Adams EV. Rapid geriatric assessment. J Am Med Dir Assoc 2015;16:808-12.
7. Lim WS, Wong CH, Ding YY, Rockwood K, Lien C. Translating the science of frailty in Singapore: results from the National Frailty Consensus Discussion. Ann Acad Med Singapore 2019;48:25-31.
8. Abellan van Kan G, Rolland Y, Bergman H, Morley JE, Kritchevsky SB, Vellas B. The I.A.N.A Task Force on frailty assessment of older people in clinical practice. J Nutr Health Aging 2008;12:29-37.
9. Morley JE, Malmstrom TK, Miller DK. A simple frailty questionnaire (FRAIL) predicts outcomes in middle aged African Americans. J Nutr Health Aging 2012;16:601-8.
10. Woo J, Yu R, Wong M, Yeung F, Wong M, Lum C. Frailty screening in the community using the FRAIL scale. J Am Med Dir Assoc 2015;16:412-9.
11. Lin PS, Hsieh CC, Cheng HS, Tseng TJ, Su SC. Association between physical fitness and successful aging in Taiwanese older adults. PLoS ONE 2016;11:e0150389.
12. Milanović Z, Pantelić S, Trajković N, Sporiš G, Kostić R, James N. Age-related decrease in physical activity and functional fitness among elderly men and women. Clin Interv Aging 2013;8:549-56.
13. von Haehling S, Morley JE, Anker SD. An overview of sarcopenia: facts and numbers on prevalence and clinical impact. J Cachexia Sarcopenia Muscle 2010;1:129-33.
14. Kostić R, Uzunović S, Pantelić S, Đurašković R. A comparative analysis of the indicators of the functional fitness of the elderly. Facta Univ Ser Phys Educ Sport 2011;9:161-71.
15. Xue QL, Bandeen-Roche K, Varadhan R, Zhou J, Fried LP. Initial manifestations of frailty criteria and the development of frailty phenotype in the Women's Health and Aging Study II. J Gerontol A Biol Sci Med Sci 2008;63:984-90.
16. Op het Veld LP, van Rossum E, Kempen GI, de Vet HC, Hajema K, Beurskens AJ. Fried phenotype of frailty: cross-sectional comparison of three frailty stages on various health domains. BMC Geriatr 2015;15:77.
17. Landers KA, Hunter GR, Wetzstein CJ, Bamman MM, Weinsier RL. The interrelationship among muscle mass, strength, and the ability to perform physical tasks of daily living in younger and older women. J Gerontol A Biol Sci Med Sci 2001;56:B443-8.
18. Hawkins S, Wiswell R. Rate and mechanism of maximal oxygen consumption decline with aging: implications for exercise training. Sports Med 2003;33:877-88.
19. Gill TM, Williams CS, Tinetti ME. Assessing risk for the onset of functional dependence among older adults: the role of physical performance. J Am Geriatr Soc 1995;43:603-9.

20. Sahadevan S, Lim PP, Tan NJ, 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;15:234-41.
21. Yesavage JA. The use of self-rating depression scales in the elderly. In: Poon LW, Crook T, Davis KL, Eisdorfer C, Gurland BJ, Kaszniak AW, Thompson LW, editors. Handbook for Clinical Memory Assessment of Older Adults. Washington, DC: American Psychological Association, 1986; p. 213-7.
22. Vellas B, Villars H, Abellan G, Soto ME, Rolland Y, Guigoz Y, et al. Overview of the MNA—its history and challenges. J Nutr Health Aging 2006;10:456-65.
23. Persson MD, Brismar KE, Katzarski KS, Nordenström J, Cederholm TE. Nutritional status using mini nutritional assessment and subjective global assessment predict mortality in geriatric patients. J Am Geriatr Soc 2002;12:1996-2002.
24. Woo J, Goggins W, Sham A, Ho SC. Social determinants of frailty. Gerontology 2005;51:402-8.
25. Mahoney FI, Barthel DW. Functional evaluation: the Barthel Index. Md State Med J 1965;14:61-5.
26. Lawton MP, Brody EM. Assessment of older people: self-maintaining and instrumental activities of daily living. Gerontologist 1969;9:179-86.
27. Chen LK, Liu LK, Woo J, Assantachai P, Auyeung TW, Bahyah KS. Sarcopenia in Asia: consensus report of the Asian Working Group for Sarcopenia. J Am Med Dir Assoc 2014;15:95-101.
28. Greenwood JL, Joy EA, Stanford JB. The Physical Activity Vital Sign: a primary care tool to guide counseling for obesity. J Phys Act Health 2010;7:571-6.
29. Searle SD, Mitnitski A, Gahbauer EA, Gill TM, Rockwood K. A standard procedure for creating a frailty index. BMC Geriatr 2008;8:24.
30. Song X, Mitnitski A, Rockwood K. Prevalence and 10-year outcomes of frailty in older adults in relation to deficit accumulation. J Am Geriatr Soc 2010;58:681-7.
31. Jones CJ, Rikli RE. Measuring functional fitness of older adults. J Active Aging 2002:24-30.
32. Glenn JM, Gray M, Binns A. Relationship of sit-to-stand lower-body power with functional fitness measures among older adults with and without sarcopenia. J Geriatr Phys Ther 2017;40:42-50.
33. Desrosiers J, Bravo G, Hébert R, Dutil E, Mercier L. Validation of the Box and Block Test as a measure of dexterity of elderly people: reliability, validity, and norms studies. Arch Phys Med Rehabil 1994;75:751-5.
34. Jones CJ, Rikli RE, Max J, Noffal G. The reliability and validity of a chair sit-and-reach test as a measure of hamstring flexibility in older adults. Res Q Exerc Sport 1998;69:338-43.
35. Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic and functional mobility for frail elderly persons. J Am Geriatr Soc 1991;39:142-8.
36. Guralnik JM, Simonsick EM, Ferrucci L, Glynn RJ, Berkman LF, Blazer DG, et al. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. J Gerontol 1994;49:M85-94.
37. ATS Committee on Proficiency Standards for Clinical Pulmonary Function Laboratories. ATS statement: guidelines for the six-minute walk test. Am J Respir Crit Care Med 2002;166:111-7.
38. Merchant RA, Chen MZ, Tan LWL, Lim MY, Ho HK, van Dam RM. Singapore Healthy Older People Everyday (HOPE) study: prevalence of frailty and associated factors in older adults. J Am Med Dir Assoc 2017;18:734.
39. Buttery AK, Busch MA, Gaertner B, Scheidt-Nave C, Fuchs J. Prevalence and correlates of frailty among older adults: findings from the German health interview and examination survey. BMC Geriatr 2015;15:22.
40. Feng Z, Lugtenberg M, Franse C, Fang X, Hu S, Jin C, et al. Risk factors and protective factors associated with incident or increase of frailty among community-dwelling older adults: a systematic review of longitudinal studies. PLoS ONE 2017;12:e0178383.
41. Smit E, Winters-Stone KM, Loprinzi PD, Tang AM, Crespo CJ. Lower nutritional status and higher food insufficiency in frail older US adults. Br J Nutr 2013;110:172-8.
42. Chong MS, Tay L, Ismail NH, Tan CH, Yew S, Yeo A, et al. The case for stage-specific frailty interventions spanning community aging to cognitive impairment. J Am Med Dir Assoc 2015;16:1003.e13-9.
43. Makizako H, Shimada H, Doi T, Tsutsumimoto K, Hotta R, Nakakubo S, 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;15:490.
44. Yu R, Wu WC, Leung J, Hu SC, Woo J. Frailty and its contributory factors in older adults: a comparison of two Asian regions (Hong Kong and Taiwan). Int J Environ Res Public Health 2017;14:1096.
45. Foldvari M, Clark M, Laviolette LC, Bernstein MA, Kaliton D, Castaneda C, et al. Association of muscle power with functional status in community-dwelling elderly women. J Gerontol A Biol Sci Med Sci 2000;55:M192-9.
46. Bosco C, Komi PV. Influence of aging on mechanical behavior of leg extensor muscles. Eur J Appl Physiol Occup Physiol 1980;45:209-19.
47. Ensrud KE, Ewing SK, Taylor BC, Fink HA, Stone KL, Cauley JA, et al. Frailty and risk of falls, fracture, and mortality in older women: the study of osteoporotic fractures. J Gerontol A Biol Sci Med Sci 2007;62:744-51.
48. Chan OY, van Houwelingen AH, Gussekloo J, Blom JW, den Elzen WP. Comparison of quadriceps strength and handgrip strength in their association with health outcomes in older adults in primary care. Age (Dordr) 2014;36:9714.
49. Batista FS, Gomes GA, Neri AL, Guariento ME, Cintra FA, Sousa Mda L, D'Elboux MJ. Relationship between lower-limb muscle strength and frailty among elderly people. Sao Paulo Med J 2012;130:102-8.
50. de Vries OJ, Peeters GM, Lips P, Deeg DJ. Does frailty predict increased risk of falls and fractures? A prospective population-based study. Osteoporosis Int 2013;24:2397-403.
51. Tomás MT, Galán-Mercant A, Carnero EA, Fernandes B. Functional capacity and levels of physical activity in aging: a 3-year follow-up. Front Med (Lausanne) 2018;4:244.
52. Hughes VA, Frontera WR, Wood M, Evans WJ, Dallal GE, Roubenoff R, et al. Longitudinal muscle strength changes in older adults: influence of muscle mass, physical activity, and health. J Gerontol A Biol Sci Med Sci 2001;56:B209-17.
53. Aguayo GA, Donneau AF, Vaillant MT, Schritz A, Franco OH, Stranges S, et al. Agreement between 35 published frailty scores in the general population. Am J Epidemiol 2017;186:420-34.
54. Bautista MAC, Malhotra R. Identification and measurement of frailty: a scoping review of published research from Singapore. Ann Acad Med Singapore 2018;47:455-91.
55. Chong E, Ho E, Baldevarona-Llego J, Chan M, Wu L, Tay L. Frailty and risk of adverse outcomes in hospitalized older adults: a comparison of different frailty measures. J Am Med Dir Assoc 2017;18:638.e7-638.e11.
56. Xue QL, Tian J, Walston JD, Chaves PHM, Newman AB, Bandeen-Roche K. Discrepancy in frailty identification: move beyond predictive validity. J Gerontol A Biol Sci Med Sci 2019;pii:glz052.
57. Rockwood K, Song X, Mitnitski A. Changes in relative fitness and frailty across the adult lifespan: evidence from the Canadian National Population Health Survey. CMAJ 2011;183:E487-94.