Groningen Frailty Indicator–Chinese (GFI-C) for pre-frailty and frailty assessment among older people living in communities: Psychometric properties and diagnostic accuracy

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Research Article

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Abstract

Background

The early identification of pre-frail and frail older people is a global priority because of increasing incidence of frailty and associated adverse health outcomes. This study aimed to validate the Groningen Frailty Indicator-Chinese (GFI-C), a widely used screening instrument, and determine the optimal cut-off value in Chinese communities to facilitate pre-frailty and frailty screening.

Methods

This methodological study employed a cross-sectional and correlational design to examine the psychometric properties of GFI-C, namely, internal consistency, stability and concurrent and construct validity. The appropriate cut-off values for screening pre-frailty and frailty in the receiver-operating characteristic (ROC) curve were determined through sensitivity and specificity analysis.

Results

A total of 350 community older people had been assessed and interviewed by a nurse. The GFI-C showed satisfactory internal consistency (Cronbach's $\alpha = 0.87$) and two-week test-retest reliability (intra-class correlation coefficient = 0.87). Concurrent validity ($r = 0.76$, $p < 0.001$) showed moderate correlation with Fried's frailty phenotype. The known-groups method, hypothesis testing and confirmatory factory analysis (three-factor model; $\chi^2/df = 2.87$, TLI = 0.92, CFI = 0.93, GFI = 0.92, RMR = 0.014, RMSEA = 0.073) were suitable for establishing construct validity. Based on the ROC and Youden's index, the optimal cut-off GFI-C values were 2 (sensitivity, 71.5%; specificity, 84.7%) for pre-frailty and 3 for frailty (sensitivity, 88.2%; specificity, 79.6%).

Conclusions

Result indicates that GFI-C is a reliable and valid instrument for screening pre-frailty and frailty among older Chinese people in communities. For optimal diagnostic accuracy, cut-off values of 3 for frailty and 2 for pre-frailty were recommended.

Introduction

Frailty is one of the modern geriatric challenges to active and healthy ageing (Isaacs, 1965; Kua, 2021). As an age-associated syndrome of increased vulnerability and decreased resilience to stressors, frailty can lead to substantial decline in physiological, cognitive, functional and social capacities (Wu et al, 2018; Dent et al., 2019; Jiao et al., 2020). Compared with healthy older people, frail older people are more likely have low quality of life and high risk of adverse health-related outcomes, including increased risk of falls, disability, dependence for daily activities, frequent and prolonged hospitalisations, dementia and mortality (Reis et al., 2020; Bu et al., 2021; Chang et al., 2021; Ma, Chhetri & Chan, 2021, Zupo et al., 2021).

The worldwide prevalence of frailty and pre-frailty among community-dwelling older people has been highlighted in the systematic review and meta-analysis of Ofori-Asenso (2019). China has the world's largest rapidly ageing population (Ma et al., 2018; National Bureau of Statistics of China, 2021; Wu et al., 2021). The weighted incidence rate of frailty was 60.6 per 100 person-years, and regional differences in incident frailty were observed (44.8 per 1000 person-years in southeast; 93.0 per 1000 person-years in northwest; Xu et al., 2019). The overall polled prevalence of frailty and pre-frailty were 10% and 43%, respectively, among community-dwelling older people living in urban areas (He et al., 2019). Given the high prevalence of frailty and its associated health consequences, increasing demands for healthcare services have imposed considerable burden on health care cost and healthcare resource utilisation (Jin et al., 2020; Chi et al., 2021; Boreskie et al., 2022).

The risk of being frail and deterioration in frailty status increase with age (Ye et al., 2020), but frailty itself is not an inevitable part of the ageing process (Junius-Walker et al., 2018). Unlike the general perception of frailty as an 'ordinary consequence' of old age (Durepos et al., 2021; Cluley et al., 2021), pre-frailty and frailty lie along the non-linear fitness–frailty continuum, and their status is potentially reversible (Liu et al., 2019; Ye et al., 2020; Sezgin et al., 2022). Lifestyle protective factors, such frequent physical exercise and social interaction with neighbors, lower the risk of pre-frail (Ye et al., 2020). A longitudinal study conducted in China (Ye et al., 2020) showed that 70% of frail individuals showed no change in their frailty status and 7.8% showed improved status after changes in lifestyle factors. Modifiable risk factors and reversible state of frailty amplify the need for early assessment and intervention for delaying the deterioration of frailty status.

Translating the concept of frailty from research to public health and clinical practice has been a global priority over the last four decades (Fang et al., 2020; Kwak & Thompson, 2021). Using validated tools to identify pre-frail/frail older people is an essential step in estimating the community need and hence the formulation of preventative services (Verver et al., 2019; Fan et al., 2021). Various frailty assessment tools are available, but no tool for the Asia-Pacific region has been developed (Liu et al., 2021; Huang & Lam, 2021). Multiple frailty screening tools are not interchangeable and transferrable across different countries (Kwak & Thompson, 2021). Discrepancies in cultural adaptation, particularly potential incongruities in translating a language and concepts of frailty, inadequate psychometric analysis of reliability and construct validity of adapted tools and lack of cut-off points adjusted for Chinese populations may contribute to variability in prevalence estimates (Siriwardhana et al., 2019; Van der Elst et al., 2019). Another issue compromising prevalence estimates is whether unidimensional physical frailty phenotype (Fried et al., 2001) and multidimensional phenotype should be used in frailty assessment. The evolving definition of frailty encompasses physical, sensorial, social, cognitive, psychological and nutritional domains (Lozupone & Panza, 2020). The use of different scales in multi-dimensional frailty assessment without assessing inter-scale correlation poses a potential threat to convergent and divergent validity (Oviedo-Briones et al., 2021). The effectiveness and feasibility of existing frailty assessment tools, such as administration time and questionnaire administration method in frailty assessment, are rarely evaluated (Oviedo-Briones et al., 2021; Huang & Lam, 2021).

The Groningen Frailty Indicator (GFI) is a 15-item self-report version screening tool that includes four domains of frailty: physical (mobility function, multiple health problems, physical fatigue, vision and hearing), psychological (depressed mood and anxiety), cognitive (cognitive dysfunction) and social (emotional isolation; Steverink et al., 2001; Schuurmans et al., 2004; Peter, Boter, Buskens & Slaets, 2012; Metzelthin, Daniels et al., 2010). A score of 1 or 0 is assigned to any 'yes/sometimes' response or 'no' response, respectively. A total score of 4 or higher represents moderate to severe frailty (Schuurmans et al., 2004). The self-report version of the GFI shows good feasibility, whereby 84% of older people in the Netherlands (can read English) had no difficulty completing the GFI (Peters et al., 2012). The GFI demonstrates satisfactory reliability and validity in the subscales, including 1) daily Activities and psychosocial functioning (Daily Activities: Cronbach's $\alpha = 0.81$, $H_S = .84$, $r = -.62$; Psychosocial Functioning: Cronbach's $\alpha = 0.80$, $H_S = .35$, $r = -.48$); 2) Health Problems (Cronbach's $\alpha = .57$, $H_S = .35$, $r = -.48$) as reported in Bielderman et al. (2013)'s study.

Factor analysis examined three-factor model (i.e. daily activities, psychosocial functioning and health problems) and explained 50.6% of the variance (Bielderman et al., 2013; Peters et al., 2012). Good internal consistency, scalability and criterion validity were reported in the 'Daily Activities' (Cronbach's $\alpha = 0.81$, $H_S = .84$, $r = -.62$) and 'Psychosocial Functioning' subscales (Cronbach's $\alpha = 0.80$, $H_S = .35$, $r = -.48$). Acceptable internal consistency, scalability and criterion validity were reported in the 'Health Problems' subscale (Cronbach's $\alpha = .57$, $H_S = .35$, $r = -.48$). The GFI translated into Chinese (Huang & Lam, 2019) would be an appropriate frailty instrument for older people in Mainland China. A methodological study of validation of the GFI and determination of cut-off value for screening purpose in older people in Chinese communities were conducted in this study.

Methods

Design

This methodological study employed a cross-sectional and correlational design. Table 1 shows testing methods, statistical methods and required sample sizes of psychometric testing and diagnosis accuracy test.

Table 1 Testing and statistical methods of psychometric testing and diagnosis accuracy test

Psychometric Properties	Methods of Testing	Statistical Method and Cut-Off Standard	Testing Samples
Reliability			
Internal consistency	Cronbach's method	Cronbach's α statistic, >0.7 = satisfactory	All 350 older people
Stability	Two-week test-retest reliability	Intra-class correlation coefficient (ICC), > 0.75 = satisfactory	A subgroup of at least 50 older people (Giraudeau & Mary, 2001)
Validity			
Criterion-related validity	Concurrent validity: correlating GFI-C with the Fried's frailty phenotype	Pearson moment–product correlation coefficient, r > 0.7 = satisfactory	All 350 older people
Construct validity	1. Known-groups method: Comparing the GFI-C of older people in community and old age home	1. Independent sample t-test, significant result = satisfactory	All 350 older people
	2. Hypothesis testing: Correlating the frailty (GFI-C) with cognitive level (AMT) and physical ability (SBI)	2. Pearson moment-product correlation coefficient, r > 0.5 = satisfactory	All 350 older people
	3. Factor analysis	3. Confirmatory factor analysis χ^2/df < 5.0, TLI > 0.90, CFI > 0.90, GFI > 0.90, RMR < 0.05, RMSEA > 0.08.	All 350 older people
Diagnosis accuracy test			
Sensitivity and specificity analysis	Comparing GFI-C results with the Fried's frailty phenotype results	The receiver-operating characteristic (ROC) curve, sensitivity and specificity > 0.70	All 350 older people
	Inherent validity of this diagnostic accuracy test	The area under the curve (AUC), AUC > 0.70	

Study Participants

The sample size was based on sensitivity or specificity on phase 2, Buderer's formula (Buderer, 1996) was used. Prevalence of frailty was set at 9.9% according to the latest literature regarding community-dwelling older people (Ma et al., 2018). A conservative sample size of 350 was adopted. From November 2017 to March 2018, a cross-sectional study was carried out in Zhongshan City, Guangdong Province, southern China. All participants met the following inclusion criteria: (1) aged 65 or above, (2) older Chinese people, (3) can communicate in Mandarin or Cantonese (i.e. can read Chinese or listen to Chinese), (4) living in community or old age home (i.e. service centre for older people in community).

Study Instruments

Simplified Barthel Index (SBI)

The simplified Barthel index (SBI) was used in determining the degree of physical independence level of our sample in hypothesis testing. It establishes sound psychometric properties among various groups of a population (Sainsbury, 2005; Hartigan, 2007); Cronbach's alpha values ranged from 0.953 to 0.965 (Sherwood et al., 1977). Interrater reliability is good with an Intra-class correlation coefficient (ICC) value of 0.95–0.97 (Sainsbury et al., 2005). Predictive validity was demonstrated through correct prediction in discharge outcome among older people (i.e. community or residential care settings) in logistic regression analysis (Netten et al., 2001). The optimal cut-off values of SBI for determining the categories of high dependency is below 12 (sensitivity 97.2%, specificity 97.4%) in older adults with normal cognition (Lam, Lee & Yu, 2014).

Abbreviated Mental Test (AMT; Hong Kong Version)

The abbreviated mental test (AMT) was used in determining the cognitive level of our sample in hypothesis testing. It has the advantage of simplicity and brevity and has been widely used to screen impaired cognitive function in older people in Hong Kong (Chu et al., 1995). The best cut-off point is 7 (below 7 is considered cognitive impairment) with a sensitivity of 92.3% and specificity of 87.1% when used in older people in communities and nursing homes (Lam, Wong & Woo, 2010). The reliability (Cronbach's $\alpha = 0.814$; ICC = 0.993) and validity (content validity, 0.92; concurrent validation, correlation with the Chinese Mini-Mental State Examination, $r = 0.86$; construct validity, known-groups method, $t = 9.85$, $p < 0.001$) were satisfactory in a previous study (Lam et al., 2010).

Fried's Frailty Phenotype

Fried's frailty phenotype was used in concurrent validation and diagnostic accuracy test. It has been applied to multiple epidemiological studies and has predicted adverse clinical outcomes (i.e. mortality; Bandeen-Roche et al., 2006; Gill et al., 2010; Lee, Heckman & Molnar, 2015). It considered frailty by its physical characteristic or 'phenotype', which is assessed by the presence of at least three of the five parameters (weakness: low grip strength, slowness: slow walking speed, shrinking: unintentional weight loss of 4.5 kg or more in the previous year, exhaustion: low physical activity). Respondents without any of the parameters are non-frail, those meeting one or two parameters are classified as pre-frail and those having three or more of the parameters are frail (Vaingankar et al., 2016). Sensitivity and specificity were well tested in a previous study (Lee et al., 2017), and it is currently the gold standard for frailty screening and commonly adopted in the literature (Hoogendijk et al., 2019).

Psychometric Testing

Examining the reliability of GFI-C, internal consistency and stability is essential. The concurrent and construct validity of the GFI-C has been tested. In this study, we used known-groups method, hypothesis testing and confirmatory factor analysis (CFA) for construct validation (refer to table 1 for the details).

Diagnostic Accuracy Test

Sensitivity and specificity analyses were used in testing the diagnostic accuracy of the GFI-C for its precision and accuracy in screening frailty and pre-frailty in community-dwelling older Chinese people (Lang & Secic, 2006). The receiver-operating characteristic curve (ROC) was used in determining the optimal cut-off value of the GFI-C with reference to the frail cases and non-frail cases and the pre-frail cases and non-pre-frail cases determined by the gold standard (i.e. Fried’s frailty phenotype). A trained nurse conducted the entire frailty assessment. The Youden index measures the effectiveness of a diagnosis marker (i.e. Fried’s frailty phenotype in this study) and enables the selection of an optimal threshold value (i.e. cut-off value) for the diagnostic marker (Fluss, Faraggi & Reiser, 2005). The area under the curve (AUC) was computed in this test to indicate the discriminative properties of the GFI-C cut-off value (Portney & Watkins, 2009). Sensitivity and specificity are equally important and should be greater than 0.70 for a valid screening tool (Lam et al., 2017; Portney & Watkins, 2019).

Statistical Analysis

Most of data were processed and analysed using SPSS (version 24) except the CFA, which was processed using AMOS (version 22). Descriptive statistics including standard deviation (SD) and mean were initially examined for continuous variables, and the frequency of distribution and percentage were reported for categorical variables. The variables were used in data cleansing and sample description. As mentioned in the previous section of psychometric testing plan, inferential statistics was used in establishing reliability and validity of the GFI-C, including Cronbach’s α, ICC, Pearson product-moment coefficient of correlation and independent sample t-test. A p value of 0.05 was accepted as significant.

Results

Characteristics of the Participants

Of the 350 participants, nearly 70% of participants (n = 240) were females. Ages ranged from 65 years to 93 years, with a mean of 75.27 (SD 7.87). The majority of the study samples was from communities (n = 239, 68.3%), and the rest (n = 111, 31.7%) were from old age homes, which were located in communities. Nearly 80% of the participants (n = 277) were married. Almost 30% of the participants (n = 96) were illiterate. Regarding financial status, only 17.4% (n = 61) were economically independent. Over two-thirds (68.0%) had no religious belief, and 60% (n = 210) had a working experience.

Among the participants, about two-thirds (n = 237, 67.7%) had one or more co-morbidities. Hypertension (70.3%) and diabetes mellitus (22.8%) were the most common health problems among the older participants. On average, the numbers of daily drugs taken were 1.69 (SD 2.04). In general, over 80% of the study participants (n = 289) had not been hospitalised 1 year before the interview. The demographic characteristics of the study participants are displayed in Table 2.

Table 2 Demographic characteristics of the participants (n = 350)

Demographic characteristics	Overall
Age, mean (SD)	75.27 (7.87)
Gender, n (%)	
Male	110 (31.4)
Female	240 (68.6)
Recruitment source, n (%)	
OAH	111 (31.7)
Community	239 (68.3)
Marital status, n (%)	
Married	277 (79.1)
Not married (single, divorced, widowed and others)	73 (20.9)
No. of children, mean (SD)	2.62 (1.62)
Education level, n (%)	
Illiterate	96 (27.4)
Primary school education	144 (41.1)
Secondary school education or above	110 (31.4)
Financial status, n (%)	
Economic independence	61 (17.4)
Dependence on relatives	74 (21.1)
Dependence on social welfare	215 (61.4)
Religion, n (%)	
With religious belief	112 (32.0)
Without religious belief	238 (68.0)
Previous occupational status, n (%)	
No working experience	79 (22.6)
Housewife	61 (17.4)
Self-employed	32 (9.1)
Employed	178 (50.9)
No. of comorbidities, n (%)	

None	113 (32.3)
1	155 (44.3)
2	64 (18.3)
≥ 3	18 (5.1)
Prescribed with drugs, n (%)	
Yes	230 (65.7)
No	120 (34.3)
No. of daily drugs taken, mean (SD)	1.69 (2.04)
Hospitalised in past one year, n (%)	
Yes	61 (17.4)
No	289 (82.6)
GFI-C, n (%)	
Non-frail	133 (38)
Prefrail	48 (13.7)
Frail	169 (48.3)
Fried’s frailty phenotype, n (%)	
Non-frail	59 (16.9)
Prefrail	147 (42)
Frail	144 (41.1)
Instrument, mean (SD)	
SBI	18.29 (4.38)
AMT	7.99 (3.04)

Psychometric Testing

Reliability

The reliability results of the GFI-C were presented in terms of internal consistency and stability. The Cronbach’s alpha values of the GFI-C were 0.867 for the scale level and ranged from 0.687 to 0.755 for subscales, suggesting satisfactory internal consistency. All of the 50 invited participants completed the retest interviews (response rate = 100%). The value of the ICC was 0.865 (95% CI = 0.774–0.921) which was of satisfactory stability and ranged from 0.441 to 0.792 among the subscales.

Validity

Concurrent validity

The concurrent validity of the GFI-C was examined by comparing the scores of the GFI-C and Fried's frailty phenotype. The correlation between the total scores of the GFI-C and Fried's frailty phenotype was 0.756 ($p < 0.001$), indicating significant correlation and satisfactory strength of correlation.

Construct validity

KNOWN-GROUPS METHOD

The total score of the GFI-C indicated that older people in the old age homes had significantly higher GFI-C scores (mean = 6.12; SD 4.05) than community-dwelling older people (mean = 2.44; SD 2.73; $t = 8.26$; $p < 0.001$).

HYPOTHESIS TESTING

The correlation between the total scores of the GFI-C and SBI was −0.667 ($p < 0.001$), and that of the total scores of the GFI-C and AMT was −0.774 ($p < 0.001$), indicating that both correlations were significant with sufficient strength (Kraemer, 1980). Table 3 presented the detailed results of hypothesis testing.

Table 3 *Correlation matrix of the GFI-C between the SBI and the AMT*

	GFI-C				
	Total	**Physical**	**Cognitive**	**Social**	**Psychological**
SBI	−.667***	−.752***	−.236***	−.482***	−.352***
AMT	−.774***	−.749***	−.469***	−.682***	−.423***

Remark:

GFI-C = Groningen Frailty Indicator – Chinese version;

SBI = Simplified Barthel Index;

AMT = Abbreviated Mental Test (Hong Kong version);

***$p < 0.001$.

CONFIRMATORY FACTOR ANALYSIS (CFA)

Figure 1 lists the factor loading and parameter estimation of each item to the hypothesised subconstruct of the GFI-C. The results indicated that all the paths were significantly loaded to the hypothesised subconstructs (range of loadings = 0.21–1.49) and the factor loadings of 86.7% items were greater than 0.32. The goodness of fit indices demonstrated an acceptable data model fitted with an χ^2/df of 2.87, the

TLI of 0.92, CFI of 0.93, GFI of 0.92, RMR of 0.014 and RMSEA of 0.073. The findings suggested that the data of the GFI-C fitted well to a three-factor structure and provided additional evidence of the construct validity of the GFI-C. For the subscales, only physical subscale (0.792) was of good stability, subscale of 'social' (0.623) was of moderate stability and the other two subscales: 'cognitive' (0.477) and 'psychological' (0.441) were of poor stability (Koo & Li, 2016).

Diagnostic Accuracy Test

The sensitivity and specificity for the cut-off values of the GFI-C in relation to a validated instrument (i.e. Fried's frailty phenotype) were calculated and plotted in ROC curve (Table 4 & 5, Figure 2 & 3). Youden Index was calculated according to the sensitivity and specificity of the different cut-off values of the GFI-C scores. The largest value of Youden index was 0.678, and the corresponding score of the GFI-C was ≤3, which indicated that the optimal cut-off value of the GFI-C was 3 (sensitivity = 88.2%, [95% CI: 81.8%–93.0%]; specificity = 79.6%, [95% CI: 73.5%–84.9%]). Both the sensitivity and specificity of the GFI-C were over 0.7, which indicated that the GFI-C is an accurate screening tool for frailty. According to the ROC curve, the AUC was 0.911 (95% CI = 0.880–0.942), which indicated that the GFI-C had good diagnosis accuracy in this study. For the screening of pre-frailty, the optimal cut-off value was 2 (sensitivity = 71.5%, [95% CI: 65.9%–76.6%]; specificity = 84.7%, [95% CI: 73.0%–92.8%]), which was still acceptable as reflected by the AUC (0.814).

Table 4 *Sensitivity, specificity and Youden index for the GFI-C on frailty screening (n = 350)*

GFI score	Sensitivity	Specificity	Youden Index
≤1	0.979	0.364	0.343
≤2	0.965	0.621	0.587
≤3	0.882	0.796	0.678
≤4	0.764	0.893	0.657
≤5	0.667	0.937	0.604
≤6	0.569	0.956	0.526
≤7	0.500	0.966	0.466
≤8	0.375	0.971	0.346
≤9	0.326	0.981	0.307
≤10	0.243	1.000	0.243
≤11	0.160	1.000	0.160
≤12	0.090	1.000	0.090
≤13	0.042	1.000	0.042
≤14	0.014	1.000	0.014
≤15	0.007	1.000	0.007
≤16	0.000	1.000	0.000

Remark:

GFI-C = Groningen Frailty Indicator–Chinese version;

Frailty was diagnosed by a nurse using Fried’s Frailty Phenotype (FP).

Table 5 *Sensitivity, specificity and Youden Index for the GFI-C on pre-frailty screening (n = 350)*

GFI score	Sensitivity	Specificity	Youden Index
≤1	0.832	0.492	0.323
≤2	0.715	0.847	0.562
≤3	0.570	0.949	0.520
≤4	0.450	0.983	0.433
≤5	0.371	0.983	0.354
≤6	0.313	1.000	0.313
≤7	0.271	1.000	0.271
≤8	0.206	1.000	0.206
≤9	0.175	1.000	0.175
≤10	0.120	1.000	0.120
≤11	0.079	1.000	0.079
≤12	0.045	1.000	0.045
≤13	0.021	1.000	0.021
≤14	0.007	1.000	0.007
≤15	0.003	1.000	0.003
≤16	0.000	1.000	0.000

Remark:

GFI-C = Groningen Frailty Indicator–Chinese version;

Frailty was diagnosed by a nurse using Fried’s Frailty Phenotype (FP).

In summary, all the results of the psychometric properties of the GFI-C and diagnosis accuracy testing were shown in Table 6.

Table 6 *Comparison of psychometric properties and diagnostic accuracy of the GFI-C with previously published results*

	Current study methods	Statistic methods	Results	Previous study results[1]
Reliability[4]				
Internal Consistency Stability	KR-20 method 2-week test-retest reliability	Cronbach's α statistic Intra-class correlation coefficient	α = 0.87 r = 0.87, p < 0.001 (95% CI = 0.78–0.92)	α = 0.68 ICC = 0.939 (p < 0.001)[2]
Validity				
Face validity	Reviewed by samples living in community and old age home[5]	Frequency and percentage	100% acceptable	84% older persons had no difficulty completing the GFI
Content validity	Reviewed by six experts	Content validity index	CVI = 0.98	I-CVI = 0.83–1.0; S-CVI = 0.98 (S-CVI/UA = 0.66)[3]
Criterion-related validity	Concurrent validity[6]	Pearson moment-product correlation coefficient	r = 0.76, p < 0.001	-
Construct validity	1. Known-groups method	Independent sample t-test	t = 8.71, p < 0.001 (95% CI = 2.95–4.52)	Statistically significant
	2. Hypothesis testing	Pearson moment-product correlation coefficient; Correlation with GFI-C and AMT score	r = −0.77, p < 0.001	The correlations for the convergent (0.45–0.61) and discriminant validity (0.08–0.50) were also as hypothesised.
		Pearson moment–product correlation coefficient; Correlation with GFI-C and SBI score	r = −0.67, p < 0.001	
	The current study methods	**Statistic methods**	**Results**	**Previous study results[1]**
	3. Factor analysis	Confirmatory factor analysis	χ^2/df = 2.87, TLI = 0.92, CFI = 0.93, GFI = 0.92,	χ^2 = 235.02, df = 84, (p < 0.00001), GFI = 0.98, RMR = 0.0063, RMSEA = 0.074[2]

			RMR = 0.014, RMSEA = 0.073	
Diagnostic accuracy[6,7]				
Sensitivity for frailty Sensitivity for pre-frailty	Compared the score of GFI-C against Fried's Frailty Phenotype identified by nurses (score ≥ 3) Compared the score of GFI-C against Fried's frailty phenotype identified by nurses (score ≥ 1)	Calculated through a standard cross tabulation table and ROC curve	Cut-off value ≥ 3 Sensitivity = 88.2% (95% CI: 81.8%–93.0%) Cut-off value ≥ 2 Sensitivity = 71.5% (95% CI: 65.9%–76.6%)	Cutoff value ≥ 4, Sensitivity = 66% (95% CI: 56–75%)[7] Nil
Specificity for frailty Specificity for pre-frailty	Compared the score of GFI-C against Fried's frailty phenotype identified by nurses (score ≥ 3) Compared the score of GFI-C against Fried's frailty phenotype identified by nurses (score ≥ 1)		Cut-off value ≥ 3 Specificity = 79.6% (95% CI: 73.5%–84.9%) Cut-off value ≥ 2 Sensitivity = 84.7% (95% CI: 73.0%–92.8%)	Cutoff value ≥ 4, Specificity = 87% (95% CI: 76–94%)[7] Nil

[1] Previous study was based on Peters et al. (2012).

[2] This result was based on the previous study of Luh, Yu & Yang (2018).

[3] This result was based on the previous study of Xiang et al. (2019).

[4] The results were calculated based on 50 older people responded to 2 week retest.

[5] The result was based on 10 older people living in the community and another 10 living in old age home, all of them are without cognitive impairment.

[6] The result was based on 350 older people diagnosed by nurses using Fried's frailty phenotype.

[7] This result was based on the previous study of Baitar et al. (2013).

Discussion

In our study, the results demonstrated a satisfactory psychometric properties and diagnostic accuracy of the GFI-C. The 15-item three-factor structure GFI-C was a reliable and valid instrument for screening frailty and pre-frailty in community-dwelling older Chinese people.

Regarding internal consistency, the Cronbach's alpha of the total scores was 0.867, which indicated good internal consistency (Kline, 2000). This result was consistent with a previous study (Xiang et al., 2020; Olaroiu et al., 2014; Metzelthin et al., 2010). Except the subscale of 'psychological component', the Cronbach's alpha values of the total scores and subscales of 'physical components' and 'social component' were higher than 0.70, indicating satisfactory internal consistency for the GFI-C subscales of 'physical' and 'social' (Portney et al., 2009). The Cronbach's alpha of the 'psychological' component was slightly lower than 0.70 possibly because the items of 'psychological component' were few. The number of items in a scale or subscale considerably contributed to the magnitude of the internal consistency (Portney & Watkins, 2009). The finding was satisfactory in scale level (ICC = 0.865). Frailty would be affected by external and environmental factors. In this study, the plausible reason affecting the retest score might be historical event (Polit, 2014), which was Chinese New Year. The first interview of this study was implemented from November 2017 to February 2018. The Chinese New Year of 2018 was from February 15 to 22, and the retest of the GFI-C was just implemented after Chinese New Year. The percentages of agreement of items 14 and 15 were 74% and 76%, respectively, which were the lowest of the 15 items. Chinese New Year means a new beginning and happiness to all Chinese people, and hence participants for test–retest reliability might possibly provide positive answers for 'psychological' subscale in the second interview. These reasons in relation to the impact of Chinese New Year might lower the stability of the GFI-C. Implication for social influence of frailty and refusal to conduct retest after festival were recommended for future research.

The results of correlation matrix between the GFI-C and Fried's frailty phenotype indicated that the two instruments had a significant and strong correlation, showing the satisfactory concurrent validity of the GFI-C (Kraemer, 1980). In particular, four components of the GFI-C demonstrated significantly strong and moderate correlation with Fried's frailty phenotype. Such results added credibility to support the concurrent validity of the GFI-C. The theoretical hypothesis stated that the score of the GFI-C is correlated to the degree of cognitive impairment and physical capability of older people. The correlation of score of the GFI-C and SBI was negative, indicating that the participants rated as low physical dependency by the SBI (i.e. higher score) had a lower GFI-C score on average. The correlation of the scores of the GFI-C and AMT was negative, indicating that the participants rated as cognitively impairment (i.e. lower score) by the AMT had a higher GFI-C score on average. The significantly strong and moderate correlation between the GFI-C and AMT and the GFI-C and SBI results supported the hypothesis and indicated the construct validity of the GFI-C.

The CFA was used in examining construct validity of the GFI-C, and a three-factor model of the GFI was identified through principal component analysis in Bielderman's study with a sample size of 1508 persons. By examining the factor loading of 15 items, all paths were significantly loaded onto the hypothesised subconstructs, and 86.7% items obtained the loading of 0.32 or greater (range of loadings = 0.21–1.49). These items mainly belonged the subconstruct of 'Health Problems'. With respect to the results of internal consistency, corrected item–total correlation of items 8 and 9 were low, indicating weak homogeneity in the respective 'physical' component. Four items were cross-loaded: items 11 and 12 and items 3 and 4 with large modification indices (MIs) of 49.75 and 44.38 separately. As a large MI reveals the presence of factor cross-loadings and error covariance (Byrne, 2013), model re-specification or modification was used, and the model was re-estimated for the improvement of model fit (Kline, 2011). In summary, the goodness-of-fit indices generated by the CFA model for the three-factor structure of the GFI-C were acceptable. All paths were significantly loaded to the hypothesised subconstructs. The evidence supported the construct validity of the GFI-C of 350 older Chinese people and contained three factors: 'Daily Activities', 'Health Problems' and 'Psychosocial Functioning'.

By interpreting the results from ROC curves, a cut-off value of 2 (the maximum value of Youden Index) enriched the pre-frailty screening with the GFI-C, with acceptable sensitivity, specificity and AUC. For frailty screening, a cut-off value of 3 provided satisfactory sensitivity (88.2%) and specificity (79.6%) compared with that of a previous study (cut-off value ≥ 4, sensitivity = 66%, specificity = 87%; Baitar et al., 2013). All the results of sensitivity and specificity and the AUC supported a new cut-off value of 3/15 (i.e. a score of ≥3 indicated frailty). A conventional cut-off value of 4 for the GFI has been adopted in many frailty epidemiology studies since the development of the instrument (Steverink et al., 2001; Metzelthin et al., 2010; Peters et al., 2012; Baitar et al., 2013; Bielderman et al., 2013; Drubbel et al., 2013; Olaroiu et al., 2014; Luh, Yu & Yang, 2018; Xiang et al., 2020). However, the current study examined the optimal cut-off value with the well-accepted instrument of frailty (i.e. Fried's frailty phenotype), and frailty status was diagnosed by a nurse. The satisfactory and comparable sensitivity and specificity and the AUC results indicated a new cut-off value (i.e. 3), which is different from the original one (cut-off value of 4). The plausible reasons for the change in cut-off value are culture differences between older Western and Chinese people, differences in living habits and difference in the purpose of GFI-C screening. In the background of Chinese Confucian ideology, the noun 'face' not only means the outside appearance of a person but also represents the self-esteem, dignity and reputation of a person and is the invisible existence of social psychology in Chinese (Yan, et al., 2007; Lam, 2015). For instance, in item 5 of 'what mark do you give yourself for physical fitness?', Chinese people provided rate better score than Western people as they want to protect their ‘face’. In other words, they want other people to think that they are worthy of respect. However, in Western culture, people paid more attention to individual feelings than thoughts from other people. Thus, for item 5, older Chinese people might get a lower GFI-C score than older Western people. Another culture difference between China and Western countries is that in Chinese traditional Confucian ideology, ‘standards of filial piety’ is essential to Chinese traditional culture (Feng, 2017; Lam, 2015). Chinese families tended to live together and take care of older people owing to the traditional virtues of showing filial respect for older people. Given that the ‘face’ issue of older Chinese people and the fact of supporting family members, ‘social component’ with items 11–13 might have lower GFI-C scores than in older Western people, who were more likely to live alone or with their partner rather than their sons or daughters. Moreover, owing to the ‘psychological component’, older Chinese people might also answer in a positive way. All these reasons induced a low score of the GFI-C in the measurement of frailty in older Chinese people. A study published in 2010 stated that 22.8% adults in China never measured their body weights, and the lower their education levels are, the higher the proportion of weight gain is (Jiang et al., 2013). As the demographic data of our participants showed the average age of participants of this study was 75, and 27.4% of them were illiterate. However, item 8 of the GFI-C which was ‘during the past 6 months have you lost a lot of weight unwillingly?’ would require our participants to know their weights or have a habit of measuring their body weights regularly or recently. When the study results and the ‘face’ issue of Chinese people were considered, some of our older people participants provided ‘no’ answer to item 8 which presented as a lower score of the GFI-C. In addition, there was an old saying in Chinese is that ‘taking medications is just like taking poison’, which reflected the Chinese culture of not taking medications unless they were really ill. Moreover, Chinese traditional herbal medicine was more acceptable in China than Western medicine. Even though older people in China had to take medications, 91.8% of the community-dwelling older Chinese people did not know the names of medications and 55.6% had forgotten to take medications exactly as prescribed by their doctors (Jin et al., 2005). As item 9 of the GFI-C asked about the medication types of our participants, older people in China might not be able to correctly distinguish types of medications they were taking and sometimes they would not follow prescription and use Chinese herbal medicine or tea instead. Hence, their real medication status may be underestimated, and the score of the GFI-C may be low. As the plausible reason for lower score of the GFI-C rated by Chinese older people, a cut-off value of 3 might be attained. In the literature review, frailty was strongly linked to the adverse outcomes of older people, including fracture, falls, hospital admission and mortality (Cawthon et al., 2007; Topinková, 2008; Feng et al., 2017; Kane et al., 2012; Clegg et al., 2013). The early detection of frailty can reduce adverse outcomes in older people, and thus interventions for improving their health status can prevent them from becoming frail. Moreover, frailty can be detected early with a GFI-C instrument. The results of sensitivity and specificity of the GFI-C (Table 4) showed that at a cut-off value of 3, sensitivity (i.e. 88.2%) was better than that in previous studies (sensitivity = 66%), but specificity (i.e. 79.6%) was lower than that in previous studies (specificity = 87%; Baitar et al., 2013). However, when the cut-off value was 4, the sensitivity of the GFI-C changed to be 76.4%; and specificity, to 89.3%. The high sensitivity indicated few false negative of frailty, and low specificity indicated more false positives of the GFI-C at a cut-off value of 3. In other words, the low sensitivity indicated many false negatives of frailty, and high specificity indicated few false positives at a cut-off GFI-C value of 4. On the basis of the results of the GFI-C of 350 Chinese older people in the current study, the number of older people screened as frail was 169 at a cut-off value of 3, versus 132 at a cut-off value of 4. This result demonstrated that at a cut-off value of 3, the GFI-C can screen more older people as frail than when 4 was used as a cut-off value. As a screening tools, more conservative was important to reduce the chance of missing any frail case.

Limitation

Apart from the satisfactory results of the current study, two areas of limitations related to the generalisability of sample and methodological issues of this study should be noted. For the generalisability issue, owing to convenience sampling, the results of frailty prevalence rate cannot be generalised to the target population (i.e. all community-dwelling older people in China) because of the potential bias of the sampling method (Bornstein, Jager, & Putnick, 2013). The inclusion criterion that distinguishes frail but non-communicable individuals in communicable older people led were left out. For methodological issues, these limitations hinders the application of supplementary laboratory investigation to diagnosis accuracy tests.

Conclusion

The GFI-C is a validated and accurate tool for frailty status screening for community-dwelling older Chinese people. This study is the preliminarily step for health providers to screen for frailty in China and it can bring researchers closer to achieve a gold standard for screening frailty. Sustaining efforts for interventional studies and comparing different studies results in different parts of China or other Asia-Pacific region of the GFI-C might be useful to the development of the most suitable frailty instrument for older Chinese people.

Declarations

Ethical approval and consent to participate

Ethics approvals were obtained from Human Subjects Ethics Sub-committee of the Special Geriatric Committee of Zhongshan Medical Association (SGCZSMA20171001). All methods were carried out in accordance with relevant guidelines and regulations. Written consent was obtained from all participants.

Consent for publication

Not applicable

Data availability statements:

The datasets generated and/or analysed during the current study are not publicly available because of the restrictions imposed by the regulatory authorities. Requests to access the datasets should be directed to SL, simonlam@twc.edu.hk.

Competing interests

The authors declare that they have no conflict of interest regarding the publication of this paper.\

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Authors' Contributions

Study conception, design and methodology: EYH, SCL, JYWL, RYCK; Data collection: EYH, SCL; Data analysis: EYH, SCL; Manuscript draft: EYH, JC; Manuscript revision, review and editing: All. All authors have read and approved the final version of the manuscript.

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Figures

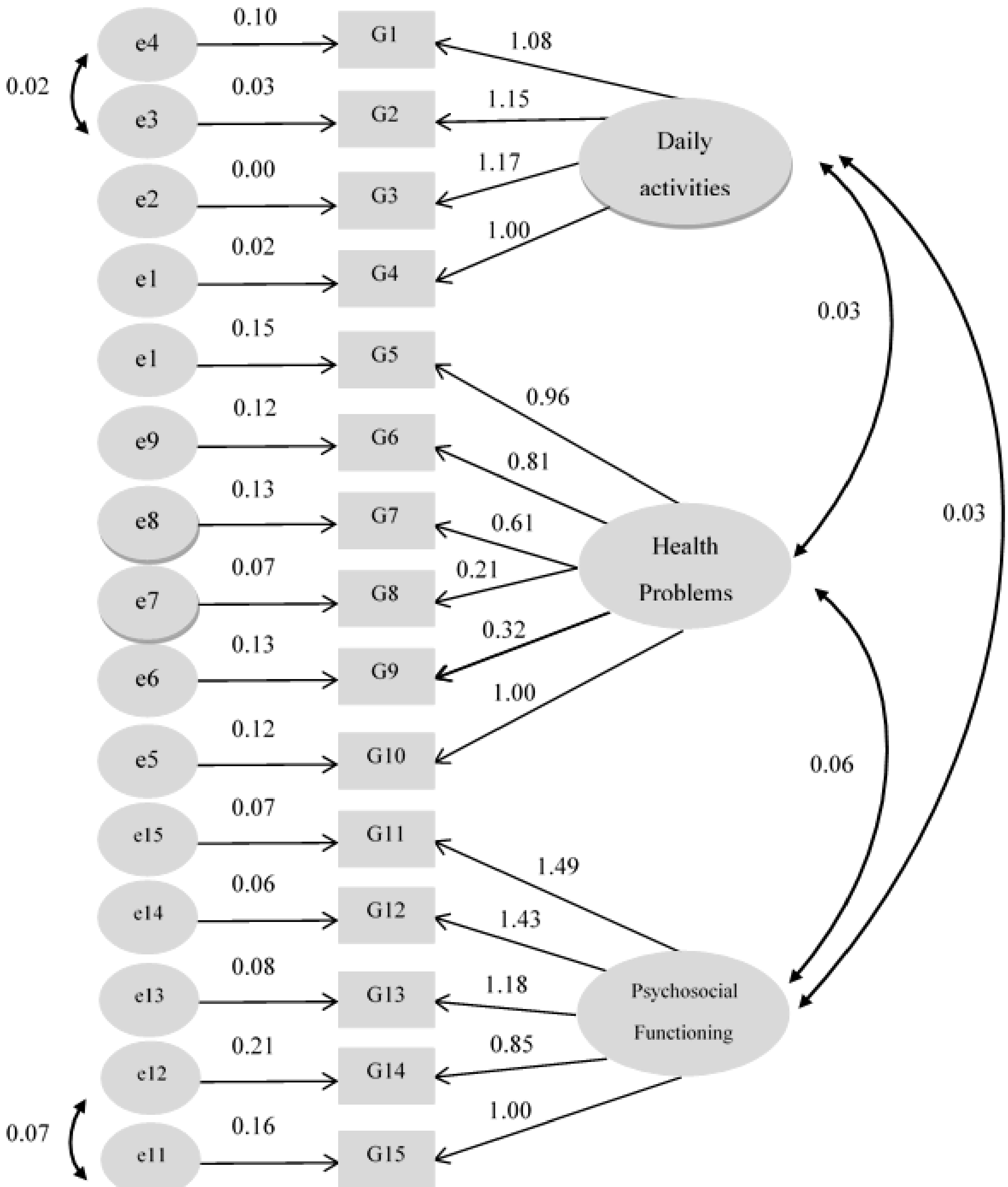

Figure 1

Confirmatory factor analysis model of the Groningen Frailty Indicator–Chinese version (GFI-C)

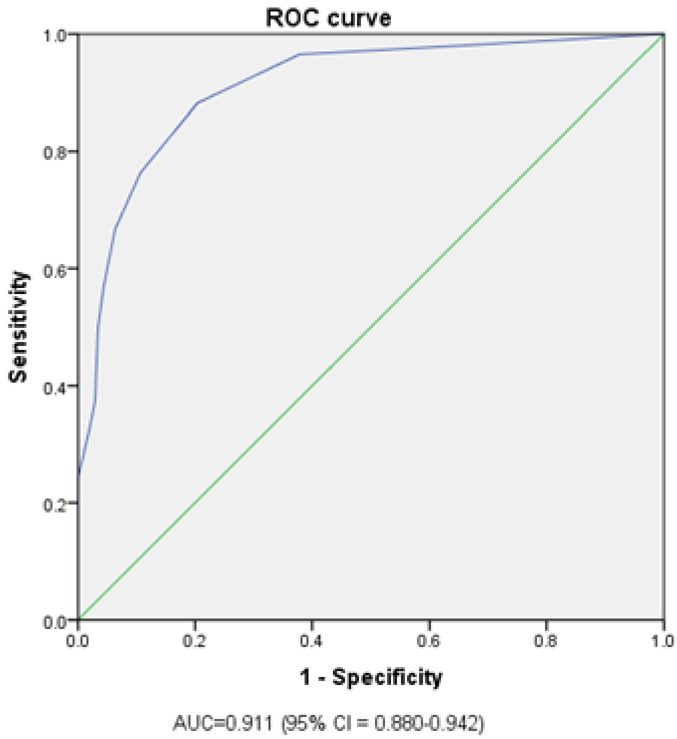

Figure 2

Area under the receiver operating characteristic (ROC) curve (AUC) for the GFI-C (n = 350) on frailty screening

Remark:

GFI-C = Groningen frailty indicator–Chinese version;

ROC = Receiver-operating characteristic;

AUC = Area under the curve;

Frailty was diagnosed by a nurse using Fried’s Frailty Phenotype (FP).

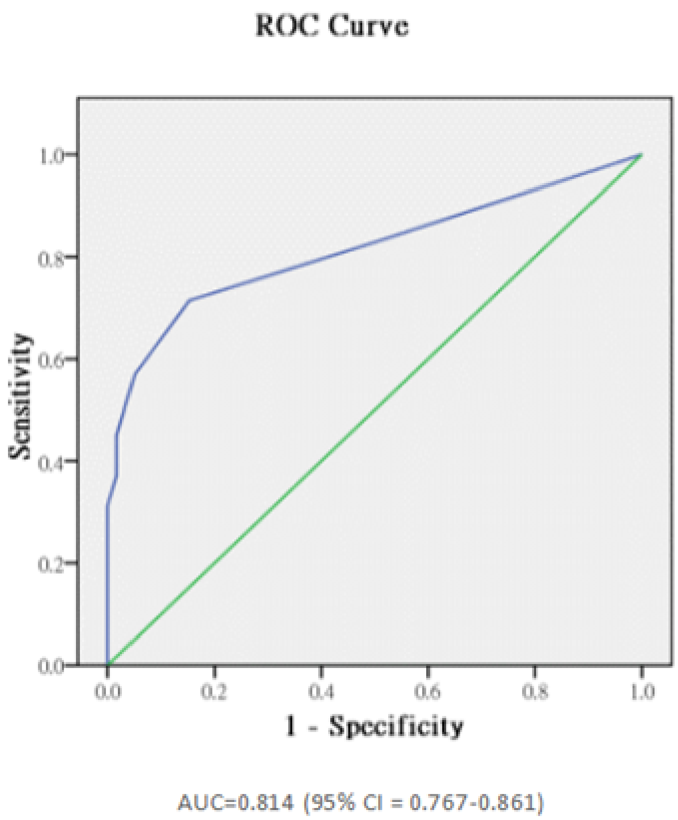

Figure 3

Area under the receiver operating characteristic (ROC) curve (AUC) for the GFI-C (n = 350) on pre-frailty screening

Remark:

GFI-C = Groningen frailty indicator–Chinese version*;*

ROC = Receiver-operating characteristic

AUC= The area under the curve

Pre-frailty was diagnosed by a nurse using Fried's Frailty Phenotype (FP).