

A cross-sectional survey of prevalence and related factors for frail status among middle-aged and elderly people in Chinese communities

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Abstract

Background: With the aggravation of social competition and work burden pressure, the health condition of the middle-aged and above population in China has declined significantly. Frailty can be used as a criterion for evaluating a person's unhealthy state. However, there is limited data on the prevalence and related factors of frail status in Chinese middle-aged and older people. The objective of this study was to explore the correlation between frail status, chronic diseases, abnormal physical examination indicators among middle-aged and older populations.

Methods: Participants were 9,985 community-dwelling adults over the age of 40 years living in China. Data were from the 2015 China Health and Retirement Longitudinal Survey which was a nationally representative sample and frailty phenotype was based on Fried frailty criteria. We analyzed the demographics of participants and multivariate-adjusted related factors for frail and pre-frail population.

Results: The overall prevalence of frailty and pre-frailty was 3.1% (95% CI: 2.8, 3.5) and 53.66% (95% CI: 52.7, 54.6) among the general Chinese population aged 40 years or older. Hypertension (OR: 1.8, 95% CI: 1.3, 2.593), pain (OR: 1.8, 95% CI: 1.3, 2.5), and hip fracture (OR: 2.2, 95% CI: 1.1, 4.4) were associated with prevalent frailty. Relative factors for frailty also included increased cystatin C (OR: 4.5, 95% CI: 3.0, 6.7) and glycated hemoglobin (OR: 1.2, 95% CI: 1.1, 1.4), as well as decreased peak expiratory flow (OR: 0.993, 95% CI: 0.991, 0.994).

Conclusions: Fried-defined frailty and pre-frailty are highly prevalent in the Chinese population over 40 years older. Hypertension, pain, hip fracture, low education, and underweight are major related factors for frailty. The decrease in peak expiratory flow and the increase in cystatin C and glycated hemoglobin are good indicators for detecting frailty. Thus, frailty is an increasingly common condition and will become a major important health issue for people over middle age.

Background

With the rapid development of China's social modernization and population aging, the aggravation of social competition and work burden has led to the obvious decline in the healthy condition of the middle-aged and above Chinese people. As an unhealthy status of individual body and mind, frailty has attracted more and more attention from researchers. There is a common agreement that frailty is a medical syndrome in which strength and physiological functions are reduced by multiple factors to increase individual vulnerability [1]. Fried phenotype of frailty is the most frequently used serve as a criterion for assessing a person's frail state in the literature [2]. The causes of frailty are multifaceted, including age, lower-income, polypharmacy, sarcopenia, depression, malnutrition, falls [3-13]. Several studies have also shown that some chronic diseases, such as hypertension, anemia, chronic obstructive pulmonary disease and diabetes are related to the occurrence of frailty [14-17].

China has the largest population base and the health of expenditure is a heavy economic burden for personal and societal cost is enormous [18]. Compared with developed countries, China's population has

great regional differences in diet and living habits, unbalanced economic status and medical services, and the number of patients with chronic diseases continues to grow rapidly [19-21]. Therefore, the related factors and chronic disease characteristics of the frail population in China may be very different from those in Europe and the United States [22]. However, most of the study evidence comes from developed countries, and the research on frailty in China has just started [23]. Based on 2011 China Health and Retirement Longitudinal Survey (CHARLS) data, Wu and his colleagues found that the prevalence of frailty among the Chinese community population aged 60 and older was 7% [24]. But their study did not include the middle-aged population, and did not calculate the prevalence of pre-frailty in our country. Some studies indicate that frailty and pre-frailty are identified in middle age (40 to 59 years old), which may have implications for prognosis and planned intervention, especially in individuals with multimorbidity [25]. The purpose of this study was to identify the prevalence of frailty and pre-frailty in middle-aged and elderly Chinese, and to explore related factors.

Methods

Data source and study design

In our study, we used the survey data from the 2015 CHARLS, which is a nationally representative longitudinal cohort study including community-dwelling mid-aged and elderly population collectively in China. It used a multistage stratified cluster sampling procedure to select the respondents and followed up every two years. A large-scale baseline survey was conducted from 2011 to 2012, covering all county-level units in mainland China (excluding Tibet). The sample includes 150 counties/districts (spread across 28 provinces and regions) and 450 villages / urban communities with a total of 17,708 people. The survey gathered information about socioeconomic characteristics, living habits, health status, and other demographic messages by face-to-face interviews and also presented biomarkers, blood data, anthropometric and other physical measurements. As specific measurements and questions for the CHARLS differed from the Cardiovascular Health Study in which Fried theorized the frailty phenotype by analyzing the data, we made minor modifications based on data availability for the Chinese version. According to Fried's frailty criteria, our definition of frail status was assessed through five aspects: walking speed, grip strength, fatigue, physical activity and weight loss. Table 1 shows our definitions in detail.

Biomarker and follow-up questionnaire data

In CHARLS, a trained interviewer measured blood pressure and pulse 3 times on the participants' left arm with an electronic blood pressure monitor (Omron HEM-7200 Monitor). We first calculated the mean value of the 3 blood pressure and pulse readings for every participant. According to the value of blood pressure, the population of hypertension is divided into 5 levels (Table 5) [26].

The interviewer measured twice on each hand of the participants by using an electronic grip dynamometer (Yuejian WL-1000 mechanical dynamometer), and the average value of the dominant hand was calculated as the final grip strength to be included in the analysis. Similarly, the interviewer

used a stopwatch to record the time at which the participant walked at a usual pace of 2.5 meters twice, taking the average time to calculate the pace. walking speed = 2.5 (m)/time (s). Interviewers measured and recorded participants' height, waist circumference and weight with stadiometer and scale.

Trained interviewers used the peak flow meter to conduct the peak expiratory flow (PEF) for three times. Participants opened their mouth and closed lips firmly around the outside of the mouthpiece, and then blew as hard and as fast as they can into the mouthpiece. We recorded the measurement readings and calculated the mean value.

According to answer these questions, such as “have you fallen down?” and “have you ever fractured hip”, and “are you troubled with body pains?”, participants were divided with “yes or no”. The definition of chronic diseases was based on participants self-reported diagnosis by a doctor. The ethical review committee approved the protocol of study and all study participants obtained written informed consent.

Statistical analysis

In our study, sociodemographic characteristics, self-reported health status, physical tests, and other relevant information (a little of date were missing) were summarized for non-frail, pre-frail and frail participants. We provided reliable estimates of the prevalence of frailty status for both men and women in five age groups. The prevalence of frailty status among men and women is presented as percentages with a 95% confidence interval (CI). Quantitative data conforming to normal distribution and homogeneity of variance tests were expressed in mean values and standard deviation, and were compared by one-way analysis of variance. Qualitative data was expressed in numbers and percentages, and compared with the Chi-squared test.

We assessed the association between frailty status and risk factors with univariate and multivariable logistic regression models. The different frailty status of chronic diseases was calculated odds ratios (OR), 95% CI, and P-value. All the important variables in the correlation analysis were included in the final model. We used SPSS 23.0 (IBM Corp., Armonk, NY, USA) software and Excel 2016 (Microsoft Corp., Redmond Washington, USA) to conduct statistical analyses, and the significance level was set at 0.05 (2 tail test).

Results

The baseline population was based on the second nationwide follow-up survey conducted in 2015, which included 16,730 people. After excluding individuals with unreliable physical tests and critical data missing, 9985 participants (4585 men and 5400 women) were included in the final analysis. General characteristics and partial related factors of the study population are summarized in Table 2, by grades of frailty and gender. In terms of frailty status, 4316, 5338, and 311 patients were classified as non-frail, pre-frail, and frail, respectively.

Table 3 showed the overall prevalence of Fried frailty phenotype defined frailty and pre-frailty were 3.1% (95% CI: 2.8, 3.5) and 53.7% (95% CI: 52.7, 54.6) among the general Chinese population aged 40 years or older. In a subgroup analysis of the prevalence of frailty, women (4.2%, 95% CI: 3.7, 4.8) were higher than men (1.8%, 95% CI: 1.4, 2.2), rural areas (3.3%, 95% CI: 2.9, 3.7) were higher than Urban (2.6%, 95% CI: 1.9, 3.2), under weight (10.9%, 95% CI: 8.5, 13.3) was higher than normal weight (1.6%, 95% CI: 1.3, 2.0), and illiterate (5.6%, 95% CI: 4.8, 6.5) was higher than elementary school (2.8%, 95% CI: 2.3, 3.3).

The results of serum and physical measurements classified by frailty status are shown in the table 4. The mean cystatin C levels in the frail, pre-frail and non-frail groups were 1.0 ± 0.5 mg/L, 0.9 ± 0.3 mg/L and 0.8 ± 0.2 mg/L, respectively ($P < 0.001$). There was significant difference in systolic blood pressure according to frailty status (frail: 133.8 ± 23.6 mmHg, pre-frail: 129.2 ± 21.0 mmHg, non-frail: 127.9 ± 19.1 mmHg, $P < 0.001$), however, diastolic blood pressure was lower in frail person (73.7 ± 11.8 mmHg) than pre-frail (74.7 ± 11.8 mmHg) or non-frail (76.3 ± 11.9 mmHg) ($P < 0.001$). The mean blood pressure of the different frailty status was in the normal range.

Table 5 shows the results of our unadjusted and fully adjusted logistic regression models of the overall population. In the univariate-unadjusted analyses, hypertension was more likely to develop frailty or pre-frailty. The higher the blood pressure, the greater the risk of frailty (Grade 3 hypertension, OR: 2.75, 95% CI: 1.67, 4.53; $P < 0.001$) and pre-frailty (Grade 3 hypertension, OR: 1.38, 95% CI: 1.10, 1.74; $P = 0.006$). Unadjusted analysis also showed that for every 1mg/L increase in serum cystatin C, the risk of frailty increased by more than 6.8 times (OR: 6.86 , 95% CI: 4.63, 10.15; $P < 0.001$). In multivariable-adjusted analyses, hypertension was still associated significantly with risk of frailty (OR: 1.82, 95% CI: 1.27, 2.59; $P < 0.001$) and pre-frailty (OR: 1.16, 95% CI: 1.02, 1.32; $P = 0.02$). Compared to normal blood pressure, person in grade 3 hypertension had a two-fold greater odds of frailty (OR: 2.14, 95% CI: 1.10, 4.17; $P = 0.024$). Multivariate analysis showed that gender (OR: 0.52, 95% CI: 0.47, 0.59; $P < 0.001$), pain (OR: 1.80, 95% CI: 1.31, 2.46; $P < 0.001$), hip fracture (OR: 2.18, 95% CI: 1.07, 4.43; $P = 0.032$), cystatin C (OR: 4.50, 95% CI: 3.01, 6.74; $P < 0.001$), glycated hemoglobin (OR: 1.07, 95% CI: 1.07, 1.40; $P = 0.003$), and peak expiratory flow (OR: 0.993, 95% CI: 0.991, 0.994; $P < 0.001$) were also relative factors with frailty.

Discussion

Our estimated prevalence of frailty was 3.1% among the Chinese population aged 40 years or older, which is very similar to the reported by Hanlon and colleagues that around 3% of people aged 37 to 73 were considered frail in the United Kingdom[25]. To our knowledge, our research is the first survey reporting the middle-aged of frailty in China, showing prevalence of 2.4% aged 40-49 and 3.6% aged 50-59, which was lower than the middle-age of frailty in community-dwelling Europeans was 4.1% and was much lower than reported the prevalence of frailty was 7.6% and 13.4% among adult white Americans aged 35-44 and 45-54, respectively[27,28]. It can be seen that frailty not only has a higher incidence in the elderly, but also occurs in the middle-aged population. Research has shown that the frailty of the body may lead to disability in the future, but in the early stages of intervention, this outcome can be changed [29]. So many studies published about the prevalence of pre-frailty, such as United States (45.0%), UK(38.0%), Japan

(48.1%), Israel (57.4%), similarly, the proportion of pre-frail Chinese in our research was also very high (53.7%) [3,25,30,31].

These distinctions might be mainly due to differences in socioeconomic background, ethnicity, and lifestyle of people living in different countries and regions [31]. In addition, using different frailty measurement tools for the same population, such as Fried frailty phenotype, Frail index, and FRAIL scales, would have an impact on the outcome of the prevalence of pre-frailty and frailty [32].

We found in the multivariate analysis, people who reported hypertension had 1.8 times the risk of developing frailty compared to those who did not, and the risk of pre-frailty is 1.1 times. Even after adjusting for potential confounding factors, the higher the blood pressure level, the greater the chance of suffering from frailty. Also in previous studies, there was a strong association between hypertension and frailty, and it was confirmed that patients with frailty and pre-frailty had significant subclinical vascular and cardiac changes [33,34]. However, the conclusions of blood pressure and frailty research are divergent, and some authors have shown that measured mean blood pressure was lower in frail compared to non-frail individuals [35]. They thought low blood pressure may reduce blood perfusion and oxygenation of vital organs, resulting in damage, loss of function, and a frail state [36]. This difference in blood pressure was explained that high blood pressure is harmful to people's health, whether the population was frail or not, it was possible to use antihypertensive treatment. Studies have shown that hypertension can cause frailty, and as a variable, frailty may affect changes in blood pressure. These findings raise questions about statistical differences regarding the blood pressure values in different frail states of the population require additional evidence.

We observed there was a strong association between frail status and elevated serum cystatin C. Multivariate analysis showed that participants with higher cystatin C had 4.5-fold increased risk of frailty and 2.4-fold increased risk of pre-frailty. Hart et al found that higher serum cystatin C was associated with increased risks of progression of frailty status and death [37]. Cystatin C is a low molecular weight protein with a stable productivity and can be freely filtered by the glomeruli [38], which is more appropriate for the group who are susceptible to be frail because it seems to be less affected by muscle mass or dietary protein intake [39]. Our findings, like those of other studies, suggest that cystatin C is more sensitive to the detection of frailty than other blood biomarkers such as creatinine [40]. These results may partially explain the increased sensitivity of cystatin C in identifying older people with less muscle. Because cystatin C was not affected by muscle mass or dietary protein intake, it was more reflective of changes in physical performance than other kidney function markers such as creatinine [39]. Inflammation may play a role as a potential mechanism linking cystatin C to frailty [41]. Due to the limitations of current frailty knowledge, the mechanism linking higher cystatin C to frailty was unclear and future research is needed to further explore this phenomenon [37].

In this study, we also identified other relative factors associated with frailty and pre-frailty in the Chinese community population. Gender, education level, BMI, glycated hemoglobin (HbA1C), PEF and pain are major relative factors for frailty. The prevalence of frailty and pre-frailty in women was higher than in

men, which is consistent with previously published studies [5,42]. We also found that higher education has a strong protective effect on the prevalence of frailty. The education level of individuals is one of the important indicators to measure their socioeconomic status [43]. Lower economic income is associated with an increased risk of frailty [5,28]. The prevalence of frailty increased with low BMI. Our findings corroborate the views that a lower BMI may indicate insufficient reserve capacity and weight loss, which was a key factor in the formation of frailty [44]. Underweight may be due to chronic illness or malnutrition and sarcopenia, which were also associated with increased risk of frailty [45].

Our study indicated that the decrease in PEF and the increase in HbA1C may be good indicators for detecting frailty. The result is similar to previous studies on respiratory function and frailty, in which PEF values were lower in frail elderly people than in non-frail people [46]. This mechanism may be related to decreased function of the respiratory muscles or chronic inflammation of the lungs that led to a decline in the body's energy reserves and physical strength [47]. Similarly, our results showed that for every 1 percent increased in serum HbA1C, the risk of frailty had higher odds. Several studies had shown that diabetes and HbA1C were risk factors for frailty and patients with poor blood sugar control had a higher risk of developing frailty [17,48]. Thus, frailty is an increasingly common condition and will become an increasingly important health issue for people over middle age. Next, how to prevent the frailty of the population should become one of the major medical concerns.

Our study has several limitations. First, the chronic diseases and symptoms were self-reported, therefore, it would cause reporting bias and recall bias. Second, because the biological and clinical characteristics of middle-aged people were different from those of the elderly, the concept of frailty, especially the definition of Fried frailty phenotype, when applied to non-elderly, the applicable conditions and principles of definition here need to be further studied in the future. Third, due to the survey of CHARLS was only included community-dwellers, not including those in hospitals and nursing homes, and some people who may have serious illnesses that cannot be interviewed and measured were excluded. In addition, the proportion of the elderly population in the surveyed population was low (age \geq 60 years had 48.1% and age \geq 80 years had 4.1%), while the elderly population was a high-risk group with frailty. Therefore, the actual incidence of frailty may be underestimated. Fourth, We found that in the above studies on the frailty and pre-frailty, due to the large or minor modifications to the Fried frailty phenotype or other frailty assessment instruments in order to accommodate the data, would have a significant impact on the estimation of frailty and pre-frailty population, and we should be cautious about the publication of this conclusion. The last, since this research was a retrospective cross-sectional study, there was insufficient clinical evidence to assess the role of chronic diseases in different stages of the frailty process, and we could not understand the causal and temporal relationship between frailty and chronic diseases. The next step is to conduct prospective cohort studies and randomized controlled trials to serve clinical guidelines.

Abbreviations

BMI: Body mass index; CHARLS: China Health and Retirement Longitudinal Study; CI: confidence interval; DBP: diastolic blood pressure; HbA1C: glycated hemoglobin; OR: odds ratios; SBP: systolic blood

pressure; PEF: peak expiratory flow;

Declarations

Ethics approval and consent to participate

The biomarker sample collection study protocol was approved by the ethical review committee (institutional review board) of Peking University (IRB 00001052–11014). Written informed consent was obtained from all study participants.

Availability of data and materials

All data used in the study and questionnaire can be accessed through after registering publicly online website (<http://charls.pku.edu.cn/en>).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

The individual contributions of each author are as follows: CS, YH, JY, LH, and XW conceived and designed the study. XW supervised the study. XL, CH, JX and RX did the statistical analysis. CS, YH, JX and YL contributed to data collection, analysis, and interpretation. CS, YH and XW drafted the report. All authors have read and approved the manuscript.

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Tables

Table 1. Definition of frailty criteria for middle-aged and old people in China ^a

Criteria	Definition
Walking speed ^b	Men: height ≤ 173 cm, time ≥ 3.85 s; height > 173 cm, time ≥ 3.29 s.
	Women: height ≤ 159 cm, time ≥ 3.85 s; height > 159 cm, time ≥ 3.29 s.
Grip strength	Men: BMI ≤ 24 kg/m ² , GS ≤ 29 kg; BMI 24.1~26.0 kg/m ² , GS ≤ 30 kg; BMI 26.1~28.0 kg/m ² , GS ≤ 30 kg; BMI > 28 kg/m ² , GS ≤ 32 kg.
	Women: BMI ≤ 23 kg/m ² , GS ≤ 17 kg; BMI 23.1~26.0 kg/m ² , GS ≤ 17.3 kg; BMI 26.1~29.0 kg/m ² , GS ≤ 18 kg; BMI ≥ 29.0 kg/m ² , GS ≤ 21 kg.
Physical activity	Do less than ten minutes of moderate or hard intensity physical activity or walking time less than 30 minutes a day during a usual week.
Weight loss	Measured weight in 2015 lost more than 4.5 kilograms or at least 5% weight loss within two years
Exhaustion	In the last week, there was a period of time (more than a day) that I often felt unable to move on, or felt that everything I did needed hard work.

Abbreviations: BMI, body mass index; GS, grip strength;

^a Note: Participants met 3 or more of the above 5 criteria were defined as frail, met 1 or 2 criteria were defined as pre-frail, and met none of the frailty criteria were defined as not frail or robust.

^b The participants' average walking time of 2.5 meters was measured twice, stratified by sex and height.

Table 2. Demographics of the general Chinese adult population aged 40 years or older in 2015 ^a

	men				P-value	women				P-value
	Total (n=4585)	Not frail (n=2540)	Pre-frail (n=1962)	Frail (n=83)		Total (n=5400)	Not frail (n=1776)	Pre-frail (n=3396)	Frail (n=228)	
Proportion of participants (%)	100%	55.4%	42.8%	1.8%		100%	32.9%	62.9%	4.2%	
Age (years)					0.337					0.007
40-49	857 (18.7%)	445 (17.5%)	399 (20.3%)	13 (15.7%)		1085 (20.1%)	380 (21.4%)	672 (19.8%)	33 (14.5%)	
50-59	1485 (32.4%)	841 (33.1%)	613 (31.2%)	31 (37.4%)		1757 (32.5%)	607 (34.2%)	1064 (31.3%)	86 (37.7%)	
60-69	1390 (30.3%)	786 (30.9%)	583 (29.7%)	21 (25.3%)		1621 (30.0%)	497 (28.0%)	1052 (31.0%)	72 (31.6%)	
70-79	650 (14.2%)	351 (13.8%)	288 (14.7%)	11 (13.3%)		730 (13.5%)	225 (12.7%)	471 (13.9%)	34 (14.9%)	
≥80	203 (4.4%)	117 (4.6%)	79 (4.0%)	7 (8.4%)		207 (3.8%)	67 (3.8%)	137 (4.0%)	3 (1.3%)	
Education level					< 0.001					< 0.001
No formal education (illiterate)	595 (13.0%)	241 (9.5%)	328 (16.7%)	26 (31.3%)		2137 (39.6%)	573 (32.3%)	1436 (42.3%)	128 (56.1%)	
Elementary school	2187 (47.7%)	1142 (45.0%)	1009 (51.4%)	36 (43.4%)		2139 (39.6%)	725 (40.8%)	1329 (39.1%)	85 (37.3%)	
Middle and high school	1688 (36.8%)	1097 (43.2%)	570 (29.1%)	21 (25.3%)		1079 (20.0%)	460 (25.9%)	605 (17.8%)	14 (6.1%)	
College degree and higher	106 (2.3%)	57 (2.2%)	49 (2.5%)	0 (0%)		39 (0.7%)	17 (1.0%)	22 (0.7%)	0 (0%)	
Marital status					< 0.001					< 0.001
Married and cohabitated	3937 (85.9%)	2249 (88.5%)	1625 (82.8%)	63 (75.9%)		4219 (78.1%)	1475 (83.1%)	2597 (76.5%)	147 (64.5%)	
Divorce, separated and Never married	265 (5.8%)	143 (5.6%)	118 (6.0%)	4 (4.8%)		289 (5.4%)	113 (6.4%)	169 (5.0%)	7 (3.1%)	
Widowed	382 (8.3%)	148 (5.8%)	218 (11.1%)	16 (19.3%)		892 (16.5%)	188 (10.6%)	630 (18.6%)	74 (32.5%)	
Current residence					0.977					0.102
Urban	1001 (21.8%)	557 (21.9%)	426 (21.7%)	18 (21.7%)		1213 (22.5%)	415 (23.4%)	759 (22.4%)	39 (17.1%)	
Rural	3574 (78.0%)	1975 (77.8%)	1534 (78.2%)	65 (78.3%)		4167 (77.2%)	1356 (76.4%)	2623 (77.2%)	188 (82.5%)	
Alcohol consumption ^b					< 0.001					0.060
Drink more than once a month	2065 (45.0%)	1237 (48.7%)	801 (40.8%)	27 (32.5%)		424 (7.9%)	147 (8.3%)	257 (7.6%)	20 (8.8%)	
Drink but less than once a month	462 (10.1%)	287 (11.3%)	174 (8.9%)	1 (1.2%)		351 (6.5%)	135 (7.6%)	208 (6.1%)	8 (3.5%)	
None of these	2052 (44.8%)	1013 (39.9%)	984 (50.2%)	55 (66.3%)		4621 (85.6%)	1491 (84.0%)	2930 (86.3%)	200 (87.7%)	
Smoking history ^c					0.075					0.022
Current smoker	2411 (52.6%)	1380 (54.3%)	990 (50.5%)	41 (49.4%)		283 (5.2%)	80 (4.5%)	189 (5.6%)	14 (6.1%)	
Former smoker	1192 (26.0%)	631 (24.8%)	535 (27.3%)	26 (31.3%)		152 (2.8%)	38 (2.1%)	102 (3.0%)	12 (5.3%)	
Never smoker	978 (21.3%)	528 (20.8%)	434 (22.1%)	16 (19.3%)		4963 (91.9%)	1656 (93.2%)	3105 (91.4%)	202 (88.6%)	
Body mass index (kg/m ²) ^d					< 0.001					< 0.001
≤18.5 (underweight)	322 (7.0%)	87 (3.4%)	208 (10.6%)	27 (32.5%)		322 (6.0%)	63 (3.6%)	217 (6.4%)	43 (18.9%)	
18.5-23.9 (normal weight)	2502 (54.6%)	1355 (53.4%)	1111 (56.6%)	36 (43.4%)		2377 (44.0%)	749 (42.2%)	1511 (44.5%)	44 (19.3%)	
24.0-27.9 (over weight)	1315 (28.7%)	842 (33.2%)	458 (23.3%)	15 (18.1%)		1867 (34.6%)	690 (38.9%)	1132 (33.3%)	45 (19.7%)	
≥28 (obesity)	422 (9.2%)	247 (9.7%)	171 (8.7%)	4 (4.8%)		812 (15.0%)	269 (15.2%)	523 (15.4%)	46 (20.2%)	

^a Data were weighted and expressed as number (%) and compared with χ^2 test

^b Alcohol consumption referred to drinking such as beer, wine or liquor in the past year.

^c Smoking history was defined as the habit of smoking more than 100 cigarettes in a lifetime, both now and in the past.

^d Weight (kg)/height (m)²

Table 3. Age-specific prevalence of frailty and pre-frailty in the general Chinese adult population aged 40 years or older in 2015

	Prevalence (%) of frailty (95% CI)			Prevalence (%) of pre-frailty (95% CI)		
	men	women	total	men	women	total
Overall	1.8% (1.4, 2.2)	4.2% (3.7, 4.8)	3.1% (2.8, 3.5)	42.8% (41.4, 44.2)	62.9% (61.6, 64.2)	53.7% (52.7, 54.6)
Age (years)						
40-49	1.5% (0.7, 2.3)	3.0% (2.0, 4.1)	2.4% (1.7, 3.0)	46.6% (43.2, 49.9)	61.9% (59.0, 64.8)	55.1% (52.9, 57.4)
50-59	2.1% (1.4, 2.8)	4.9% (3.9, 5.9)	3.6% (3.0, 4.3)	41.3% (38.8, 43.8)	60.6% (58.3, 62.8)	51.7% (50.0, 53.4)
60-69	1.5% (0.9, 2.2)	4.4% (3.4, 5.4)	3.1% (2.5, 3.7)	41.9% (39.3, 44.5)	64.9% (62.6, 67.2)	54.3% (52.5, 56.1)
70-79	1.7% (0.7, 2.7)	4.7% (3.1, 6.2)	3.3% (2.3, 4.2)	44.3% (40.5, 48.1)	64.5% (61.0, 68.0)	55.0% (52.4, 57.6)
≥80	3.4% (0.9, 6.0)	1.4% (0.2, 3.1)	2.4% (0.9, 3.9)	38.9% (32.2, 45.7)	66.2% (59.7, 72.7)	52.7% (47.8, 57.5)
Education level						
No formal education (illiterate)	4.4% (2.7, 6.0)	6.0% (5.0, 7.0)	5.6% (4.8, 6.5)	55.1% (51.1, 59.1)	67.2% (65.2, 69.2)	64.6% (62.8, 66.4)
Elementary school	1.6% (1.1, 2.2)	4.0% (3.1, 4.8)	2.8% (2.3, 3.3)	46.1% (44.0, 48.2)	62.1% (60.1, 64.2)	54.0% (52.6, 55.5)
Middle and high school	1.2% (0.7, 1.8)	1.3% (0.6, 2.0)	1.3% (0.8, 1.7)	33.8% (31.5, 36.0)	56.1% (53.1, 59.0)	42.5% (40.6, 44.3)
College degree and higher	0.0%	0.0%	0.0%	46.2% (36.6, 55.9)	56.4% (40.1, 72.7)	49.0% (40.7, 57.2)
Marital status						
Married and cohabitated	1.6% (1.2, 2.0)	3.5% (2.9, 4.0)	2.6% (2.2, 2.9)	41.3% (39.7, 42.8)	61.6% (60.1, 63.0)	51.8% (50.7, 52.9)
Divorce, separated and Never married	1.5% (0.0, 3.0)	2.4% (0.6, 4.2)	2.0% (0.8, 3.2)	44.5% (38.5, 50.6)	58.5% (52.8, 64.2)	51.8% (47.6, 56.0)
Widowed	4.2% (2.2, 6.2)	8.3% (6.5, 10.1)	7.1% (5.7, 8.5)	57.1% (52.1, 62.1)	70.6% (67.6, 73.6)	66.6% (64.0, 69.2)
Current residence						
Urban	1.8% (1.0, 2.6)	3.2% (2.2, 4.2)	2.6% (1.9, 3.2)	42.6% (39.5, 45.6)	62.6% (59.8, 65.3)	53.5% (51.4, 55.6)
Rural	1.8% (1.4, 2.3)	4.5% (3.9, 5.1)	3.3% (2.9, 3.7)	42.9% (41.3, 44.5)	62.9% (61.5, 64.4)	37.3% (36.3, 38.4)
Alcohol consumption ^a						
Drink more than once a month	1.3% (0.8, 1.8)	4.7% (2.7, 6.7)	1.9% (1.4, 2.4)	38.8% (36.7, 40.9)	60.6% (55.9, 65.3)	42.5% (40.6, 44.5)
Drink but less than once a month	0.2% (0.2, 0.6)	2.3% (0.7, 3.8)	1.1% (0.4, 1.8)	37.7% (33.2, 42.1)	59.3% (54.1, 64.4)	47.0% (43.5, 50.4)
None of these	2.7% (2.0, 3.4)	4.3% (3.7, 4.9)	3.8% (3.4, 4.3)	48.0% (45.8, 50.1)	63.4% (62.0, 64.8)	58.7% (57.5, 59.8)
smoking history ^b						
Current smoker	1.7% (1.2, 2.2)	4.9% (2.4, 7.5)	2.0% (1.5, 2.6)	41.1% (39.1, 43.0)	66.8% (61.3, 72.3)	43.8% (41.9, 45.6)
Former smoker	2.2% (1.4, 3.0)	7.9% (3.6, 12.2)	2.8% (1.9, 3.7)	44.9% (42.1, 47.7)	67.1% (59.6, 74.7)	47.4% (44.7, 50.1)
Never smoker	1.6% (0.8, 2.4)	4.1% (3.5, 4.6)	3.7% (3.2, 4.1)	44.4% (41.3, 47.5)	62.6% (61.2, 63.9)	59.6% (58.3, 60.8)
Body mass index (kg/m ²) ^c						
≤18.5 (underweight)	8.4% (5.3, 11.4)	13.4% (9.6, 17.1)	10.9% (8.5, 13.3)	64.6% (59.3, 69.8)	67.4% (62.2, 72.5)	66.0% (62.3, 69.7)
18.5-23.9 (normal weight)	1.4% (1.0, 1.9)	1.9% (1.3, 2.4)	1.6% (1.3, 2.0)	44.4% (42.5, 46.4)	63.6% (61.6, 65.5)	53.7% (52.3, 55.1)
24.0-27.9 (over weight)	1.1% (0.6, 1.7)	2.4% (1.7, 3.1)	1.9% (1.4, 2.4)	34.8% (32.3, 37.4)	60.6% (58.4, 62.9)	50.0% (48.2, 51.7)
≥28 (obesity)	0.9% (0.0, 1.9)	5.7% (4.1, 7.3)	4.1% (3.0, 5.2)	40.5% (35.8, 45.2)	64.4% (61.1, 67.7)	56.2% (53.5, 59.0)

Abbreviations: CI, confidence interval;

^a Alcohol consumption referred to drinking such as beer, wine or liquor in the past year.

^b Smoking history was defined as the habit of smoking more than 100 cigarettes in a lifetime, both now and in the past.

^c Weight (kg)/height (m)²

Table 4. Blood-based bioassays and physical measurements for frail status ^a

Variables (Unit)	Total (n=9985)	Not frail (n=4316)	Pre-frail (n=5358)	Frail (n=311)	P-value	Missing data
Systolic blood pressure (mmHg)	128.8 (20.3)	127.9 (19.1)	129.2 (21.0)	133.8 (23.6)	< 0.001	108
Diastolic blood pressure (mmHg)	75.3 (11.9)	76.3 (11.9)	74.7 (11.8)	73.7 (11.8)	< 0.001	85
Pulse (beat per minute)	74.1 (10.8)	73.7 (10.4)	74.2 (10.9)	76.6 (12.1)	< 0.001	85
Peak expiratory flow (L/min)	283.6 (116.5)	321.2 (116.6)	258.4 (107.3)	188.5 (95.5)	< 0.001	175
Waist circumference (cm)	85.0 (13.4)	85.3 (13.3)	84.9 (13.5)	83.6 (12.6)	0.042	23
Body mass index (kg/m ²)	23.8 (5.0)	24.0 (4.1)	23.8 (5.7)	21.9 (4.0)	< 0.001	45
Night sleep time (hours)	6.4 (2.0)	6.5 (1.8)	6.3 (2.1)	6.2 (2.4)	<0.001	335
White blood cell (1000/mm ³)	6.0 (1.8)	6.0 (1.9)	5.9 (1.8)	6.0 (1.9)	0.04	1646
Hemoglobin (g/dL)	13.7 (2.0)	14.0 (2.0)	13.4 (1.8)	12.9 (2.1)	< 0.001	1646
Hematocrit (%)	41.4 (5.7)	42.3 (5.9)	40.7 (5.3)	39.4 (6.1)	< 0.001	1646
Mean corpuscular volume (fL)	91.5 (7.8)	91.5 (7.5)	91.5 (8.0)	91.6 (8.2)	0.895	1646
Platelets (10 ⁹ /L)	203.5 (76.5)	204.4 (79.5)	202.7 (74.1)	204.9 (74.6)	0.571	1651
Triglycerides (mg/dL)	141.3 (89.3)	143.4 (93.6)	140.0 (86.5)	133.0 (70.3)	0.077	1588
Creatinine (mg/dL)	0.8 (0.3)	0.8 (0.3)	0.8 (0.3)	0.8 (0.4)	< 0.001	1590
Blood urea nitrogen (mg/dL)	15.7 (4.8)	15.6 (4.6)	15.7 (4.9)	16.4 (5.4)	0.022	1588
HDL cholesterol (mg/dL)	51.7 (11.9)	51.6 (11.7)	51.6 (11.9)	52.6 (12.9)	0.433	1588
LDL cholesterol (mg/dL)	102.8 (28.8)	103.2 (28.0)	102.4 (29.4)	104.8 (29.5)	0.281	1589
Total Cholesterol (mg/dL)	184.8 (36.6)	185.2 (35.9)	184.3 (37.1)	186.9 (37.0)	0.386	1588
Glucose (mg/dL)	103.2 (34.9)	101.5 (30.3)	104.3 (37.1)	106.8 (52.3)	< 0.001	1570
Uric acid (mg/dL)	4.9 (1.4)	5.1 (1.4)	4.8 (1.4)	5.0 (1.7)	< 0.001	1570
Cystatin C (mg/L)	0.9 (0.3)	0.8 (0.2)	0.9 (0.3)	1.0 (0.5)	< 0.001	1593
C-reactive protein (mg/L)	2.8 (6.2)	2.5 (5.5)	3.0 (6.4)	4.7 (11.6)	< 0.001	1590
HbA1C (%)	6.0 (1.0)	5.9 (0.8)	6.1 (1.1)	6.2 (1.3)	< 0.001	1554

Abbreviation: HbA1C, glycated hemoglobin; HDL, high-density lipoprotein; LDL, low-density lipoprotein; SD, standard deviation.

^a Data were weighted and expressed as mean (SD) and compared with ANOVA.

Table 5. Multiple-adjusted ORs for frailty and pre-frailty related factors for Chinese adults aged 40 and over

	frailty				pre-frailty			
	Univariate analysis		Multivariate analysis		Univariate analysis		Multivariate analysis	
	OR (95% CI)	P values	OR (95% CI)	P values	OR (95% CI)	P values	OR (95% CI)	P values
Male sex ^a	0.251 0.326)	(0.194, < 0.001	0.332 0.488)	(0.226, < 0.001	0.404 0.439)	(0.372, < 0.001	0.524 (0.465, < 0.001 0.590)	
Fall (yes vs no) ^a	1.789 2.350)	(1.362, < 0.001	1.125 1.614)	(0.784, 0.522	1.425 1.585)	(1.280, < 0.001	1.15 (1.012, 0.032 1.307)	
Hip fracture (yes vs no) ^a	2.818 4.877)	(1.628, < 0.001	2.175 4.426)	(1.069, 0.032	1.234 1.635)	(0.931, 0.143	1.014 (0.72, 0.939 1.427)	
Body pain (yes vs no) ^a	2.891 3.681)	(2.271, < 0.001	1.798 2.464)	(1.313, < 0.001	1.523 1.664)	(1.396, < 0.001	1.201 (1.078, 0.001 1.339)	
Hypertension (yes vs no) ^a	2.439 3.099)	(1.920, < 0.001	1.815 2.593)	(1.271, 0.001	1.393 1.532)	(1.267, < 0.001	1.161 (1.024, 0.02 1.316)	
Dyslipidemia (yes vs no) ^{a, b}	1.486 2.113)	(1.046, 0.027	1.154 1.871)	(0.711, 0.563	1.307 1.496)	(1.142, < 0.001	1.213 (1.026, 0.024 1.433)	
Chronic bronchitis, or emphysema (yes vs no) ^a	2.094 2.817)	(1.557, < 0.001	0.774 1.23)	(0.488, 0.279	1.253 1.422)	(1.105, < 0.001	0.879 (0.745, 0.126 1.037)	
Heart diseases (yes vs no) ^{a, c}	2.002 2.708)	(1.480, < 0.001	1.09 1.635)	0.726, 0.678	1.482 1.678)	(1.309, 0.001	1.115 (0.959, 0.157 1.296)	
Stroke (yes vs no) ^a	3.795 6.374)	(2.259, < 0.001	1.153 2.602)	(0.511, 0.731	1.686 2.235)	(1.271, < 0.001	1.065 (0.764, 0.71 1.486)	
Emotional, nervous, or psychiatric problems (yes vs no) ^a	2.799 5.398)	(1.451, < 0.001	2.079 5.013)	(0.862, 0.103	1.124 1.588)	(0.795, 0.508	0.807 (0.524, 0.331 1.243)	
Alzheimer's disease, Parkinson's disease, or brain atrophy (yes vs no) ^a	2.776 5.724)	(1.346, 0.006	0.974 2.983)	(0.318, 0.964	1.676 2.388)	(1.176, 0.004	1.304 (0.845, 0.231 2.014)	
Arthritis or rheumatism (yes vs no) ^a	1.696 2.138)	(1.346, < 0.001	1.209 1.643)	(0.889, 0.226	1.269 1.378)	(1.168, < 0.001	0.998 (0.902, 0.966 1.104)	
Asthma (yes vs no) ^a	3.264 4.847)	(2.197, < 0.001	1.568 2.866)	(0.858, 0.143	1.511 1.848)	(1.235, < 0.001	1.157 (0.895, 0.265 1.496)	
Classification of hypertension ^{a, d}								
Normal (SBP < 120 mmHg and DBP < 80 mmHg)	1.00 (ref)		1.00 (ref)		1.00 (ref)		1.00 (ref)	
High normal (SBP 120~139 mmHg and /or DBP 80~89 mmHg)	0.994 1.336)	(0.740, 0.971	0.924 1.361)	(0.627, 0.689	1.007 1.110)	(0.914, 0.882	1.030 (0.917, 0.623 1.157)	
Grade 1 hypertension (SBP 140~159 mmHg and /or DBP 90~99 mmHg)	1.232 1.700)	(0.893, 0.203	1.084 1.657)	(0.708, 0.712	1.032 1.154)	(0.923, 0.585	0.965 (0.840, 0.617 1.109)	
Grade 2 hypertension (SBP 160~179 mmHg and /or DBP 100~109 mmHg)	1.633 2.527)	(1.056, 0.028	1.12 2.078)	(0.604, 0.719	1.086 1.287)	(0.917, 0.340	1.071 (0.870, 0.518 1.320)	
Grade 3 hypertension (SBP ≥ 180mmHg and /or DBP ≥ 110 mmHg)	2.751 4.532)	(1.670, < 0.001	2.144 4.167)	(1.103, 0.024	1.379 1.737)	(1.095, 0.006	1.284 (0.967, 0.084 1.706)	
Body mass index (kg/m ²) ^a								
≤18.5 (underweight)	6.32 8.790)	(64.552, < 0.001	4.831 7.878)	(2.962, < 0.001	2.274 2.763)	(1.871, < 0.001	2.044 (1.611, < 0.001 2.593)	
18.5-23.9 (normal weight)	1.00 (ref)		1.00 (ref)		1.00 (ref)		1.00 (ref)	
24.0-27.9 (over weight)	0.539 0.731)	(0.397, < 0.001	0.495 0.740)	(0.331, 0.001	0.833 0.912)	(0.761, < 0.001	0.765 (0.680, < 0.001 0.861)	
≥28 (obesity)	0.640 0.994)	(0.412, 0.047	0.345 0.648)	(0.183, 0.001	1.079 1.226)	(0.950, 0.241	0.801 (0.669, 0.016 0.959)	
Night sleep time (hours) ^a								
≤6	1.692 2.213)	(1.294, < 0.001	0.991 1.384)	(0.709, 0.956	1.400 1.618)	(1.211, < 0.001	1.154 (1.036, 0.009 1.285)	
6-8	1.00 (ref)		1.00 (ref)		1.00 (ref)		1.00 (ref)	
≥9	2.060 3.026)	(1.402, < 0.001	1.455 2.326)	(0.911, 0.117	1.408 1.541)	(1.286, < 0.001	1.185 (1.003, 0.046 1.401)	
Alcohol consumption ^{a, e}								
Drink more than once a month	0.335 0.460)	(0.244, < 0.001	0.87 1.334)	(0.568, 0.523	0.489 0.538)	(0.445, < 0.001	0.822 (0.727, 0.002 0.930)	
Drink but less than once a month	0.210 0.412)	(0.107, < 0.001	0.463 1.011)	(0.212, 0.053	0.579 0.671)	(0.500, < 0.001	0.785 (0.661, 0.006 0.933)	
None of these	1.00 (ref)		1.00 (ref)		1.00 (ref)		1.00 (ref)	
Pulse (per one time increase) ^a	1.023 1.034)	(1.013, < 0.001	1.008 1.021)	(0.995, 0.248	1.004 1.008)	(1.001, 0.02	0.997 (0.992, 0.173 1.001)	
PEF (per one L/min increase) ^a	0.988 0.989)	(0.986, < 0.001	0.993 0.994)	(0.991, < 0.001	0.995 0.995)	(0.995, < 0.001	0.997 (0.997, < 0.001 0.998)	
Waist circumference (per one cm increase) ^a	0.991	(0.983, 0.029	1.02	(1.003, 0.019	0.997	(0.994, 0.098	1.004 (1.000, 0.081	

	0.999)	1.037)	1.000)	1.009)
Cystatin C (per one mg/L increase) ^a	6.855 10.148)	(4.631, < 0.001 4.504 (3.012, < 0.001 6.735)	1.001 (0.990, 0.892 1.012)	2.415 (1.866, < 0.001 3.126)
HbA1C (per one percentage increase) ^a	1.247 1.381)	(1.126, < 0.001 1.226 (1.072, 0.003 1.402)	1.142 (1.091, < 0.001 1.196)	1.11 (1.051, < 0.001 1.172)

Abbreviations: CI, confidence interval; HbA1C, glycated hemoglobin; OR, odds ration; PEF, peak expiratory flow; SBP, systolic blood pressure; DBP: diastolic blood pressure;

^a Variables introduced in Multivariate analysis.

^b Dyslipidemia included elevated total cholesterol, triglycerides, and low-density lipoprotein, or low high-density lipoprotein levels.

^c Heart diseases included coronary heart disease, heart attack, congestive heart failure, angina or other heart problems

^d The following was the classification and definition of blood pressure level, when SBP and DBP are of different grades, the higher grade shall prevail.

^e Alcohol consumption referred to drinking such as beer, wine or liquor in the past year.