Moderating Effect of Age on the Relationships between Pre-frailty and Body Measures

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Abstract

This study aims to investigate the relationship between body measures and the presence of two frailty-related phenotypes, and the moderating effect of age on this relationship. This is a secondary data analysis of the baseline data of an interventional study. The participants were residents of seven districts in Hong Kong, aged 55 or older, able to ambulate independently and to function well cognitively. Pre-frailty refers to the presence of two frailty-related phenotypes: low physical activity or poor handgrip strength or both. Included in the study were 199 individuals with a mean age of 73.43 (SD 7.54). Regression models showed that body weight (OR=0.95, 95% CI 0.92 – 0.99, $p<0.05$) was significantly associated with pre-frailty, as was body height (OR=0.88, 95% CI 0.83 – 0.94, p<0.001). Age is a significant moderator of the relationship between pre-frailty and body weight and body height. The effect of body weight (beta=-0.044, $p<0.05$) and height (beta=-0.16, $p<0.001$) on pre-frailty was significant and negative in the younger age groups. The findings indicate that raw body measures (i.e., body weight, body height) are more predictive of pre-frailty than BMI in older Chinese people. However, in the old-old group, these measures are not significant predictors of pre-frailty in Chinese community-dwelling adults. Practitioners should consider adopting body measures as predictors of pre-frailty in the younger-old population.

KEY WORDS

pre-frailty, frailty, body measures, moderating effect, body mass index, Chinese, age

What is known about this topic

- Frailty is prevalent among the old.
- Demographic and socioeconomic factors, as well as clinical and functional factors, are significantly associated with frailty.

What this paper adds

- Raw body measures (i.e., body weight and height) are significantly associated with pre-frailty in the young-old and old-old.
- For old people under the age of 75, body weight is negatively associated with pre-frailty; this is also the case with body height when the old are under 80.

1 Introduction

Frailty is an increasingly prevalent geriatric syndrome that reflects a state of decreased physiological reserve and increased vulnerability to stressors (Alonso Salinas et al., 2016). Frailty is a clinical syndrome with five frailty-related phenotypes (i.e., clinical manifestations): unintentional weight loss, poor handgrip strength, exhaustion, slowness, and low physical activity (Fried et al., 2001). Among these five criteria, low physical activity and poor handgrip strength are considered the main potential predictors of frailty status and adverse outcomes, and it has been suggested that their associations with frailty be prioritized over the remaining criteria (Ávila-Funes et al., 2011; Chung et al., 2014).

To prevent frailty in an aged population, we look for the population that is at risk of frailty and identify factors associated with that risk. Previous studies have identified a number of demographic and socioeconomic factors associated with frailty, including being older (Buttery, Busch, Gaertner, Scheidt-Nave, & Fuchs, 2015; Liu et al., 2015), being widowed (Pegorari & Tavares, 2014), being of lower socioeconomic status (Buttery et al., 2015), and living alone (Hoogendijk, Suanet, Dent, Deeg, & Aartsen, 2016). Gender and educational background are also said to be important demographic factors associated with frailty. Nevertheless, the findings are controversial. Some studies indicated that elderly individuals with frailty tend to be female and less educated (de Souto Barreto, Greig, & Ferrandez, 2012), while others have come to the opposite conclusion—that frailty is more likely to happen to males (Liu et al., 2015) and to those with a higher level of education (Camicioli et al., 2015). Another demographic factor, health literacy, has recently been identified as another important factor associated with frailty. Community-dwelling Japanese with high levels of overall health literacy are more likely to be non-frail (odds ratio, OR 1.64, 95% CI 1.03-2.61) (Shirooka et al., 2017). Among patients with heart failure (who are considered frail persons), low health literacy was found to be associated with all-cause mortality (Peterson et al., 2011). At this point, age is the most frequently reported factor associated with frailty. It has been shown that age has a positive association with frailty; that is, the older the person, the higher is the chance that frailty will exist. The existing evidence highlights the relationship between advanced age and frailty; however, it is unclear whether the different categories of old age (i.e., young-old, mid-old, and old-old) would have different influences on the factors causing frailty. This knowledge is important because it will inform us of at which stage in the life of an individual it would be most effective to modify risk factors to prevent frailty.

Clinical and functional factors are another type of predictor of frailty. The evidence indicates that a greater number of morbidities (de Souto Barreto et al., 2012), more chronic diseases (Buttery et al., 2015), and lower functional autonomy (Portegijs, Rantakokko, Viljanen, Sipilä, & Rantanen, 2016) are all associated with frailty. Specific diseases such as cardiovascular disease, diabetes, pain, osteoporosis (de Souto Barreto et al., 2012), and sarcopenia (Woo et al., 2015) are significantly correlated with frailty, while cognitive functioning (Robertson, Savva, Coen, & Kenny, 2014) and depression symptoms (Buttery et al., 2015; Woo et al., 2015) have also been found to be associated with frailty.

The relationship between body mass index (BMI) and frailty has often been investigated. Having a lower BMI has long been considered a predictor of frailty (Júnior et al., 2014). Another study has also found that a low BMI is one of the factors that significantly predicts the progression from non-frail to pre-frail (Gordon et al., 2020). However, some recent studies have disputed this, arguing that a high BMI (BMI $\geq$ 30 kg/m^2 or obesity) is an independent predictor of frailty (Ahmed et al., 2020) and that

BMI is positively associated with the prevalence of frailty (OR=1.05) (Pradhananga et al., 2019). These controversial findings have aroused our interest in further investigating the relationship between BMI and frailty.

The predictive effect of BMI on illnesses is under discussion. Although BMI has been shown to be a good reference in the prediction of cancer in pre-menopausal adults, it is not a good predictor of cancer in older adults (Wang et al., 2016). Another study showed that there was no strong association between BMI and the risk of developing diabetes in the subsequent 3 years among Chinese adults (Fan et al., 2020). In recent years, there has been much debate over the use of BMI as the only reference to determine obesity. In a cross-sectional study involving 4,300 Chinese adults, it was argued that people with normal BMI should be re-identified as members of a high-risk population because of the high prevalence of hypertension in the group with high body fat but normal BMI (He et al., 2019). Given these discussions, it is hypothesized that BMI may not be the best predictor of some illnesses, such as frailty.

Recent research has found that BMI is not a sensitive predictor of health conditions and functions in elderly Chinese people (Tsai, Lai, & Chang, 2012). This is probably because the stereotypical allometric equation representing body mass may not be appropriate for elderly Chinese. Whether the raw metrics on body mass (i.e., height and weight) can predict the health conditions of Chinese older adults is under discussion. In a large cohort study conducted in 2008 and 2013 involving 16,606 middle-aged and older adults in China, half (47%) of the participants had lost weight in those 5 years (Zhang et al., 2018). The loss of body weight is a result of sarcopenia and malnutrition that it leads to reduce BMI (Bales & Ritchie, 2002). Such change is a core feature of frailty (Fried et al., 2001). In a subgroup analysis, that study also showed that changes in body weight led to greater changes in blood pressure in obese or overweighed older adults (Zhang et al., 2018). The weight gain may be a result of sarcopenic obesity that it leads to increased BMI (Jarosz & Bellar, 2009). During aging process, body height inevitably declines that it will increase BMI. This decline may signify a vertebral fracture secondary to osteoporosis (Xu et al., 2011), which is also associated with frailty (Li et al., 2017; Sternberg et al., 2014). As a result, the underlying pathologies associated with frailty (i.e., weight loss caused by sarcopenia and nutrition, and height loss caused by vertebral fracture secondary to osteoporosis) may counteract with one another on the change of BMI that it makes BMI an insensitive marker to predict frailty. We therefore propose to investigate both body weight and body height, and their relationship with pre-frailty among older adults.

Based on existing knowledge of frailty in the aged population, we identified two key issues: 1) although BMI has been shown to be associated with frailty, it may not be the best predictor of frailty in a Chinese population. It may be worth investigating the association between frailty and BMI, body weight, and body height; 2) The aged population is considered a homogenous high-risk group for frailty when we consider advanced age as a risk factor for frailty, but the effects of age group on the other predictors of frailty have never been investigated.

Therefore, aim of the current study is to investigate the relationship between body measures (body weight and body height) and the presence of frailty-related phenotypes, as well as the moderating effect of age on this relationship. In this study, it is hypothesized that age is the moderator of the relationship between body measures and pre-frailty. The specific objectives of this study were: 1) to investigate which body measures (body weight and body height) are significant predictors of pre-frailty in the aged population, and 2) to test the moderating effect of age on the relationship between significant body measures and pre-frailty.

2 Methods

2.1 Population

This is a secondary data analysis of the baseline data of an interventional study conducted in Hong Kong aimed at encouraging patients with chronic diseases to engage in regular physical activity through a multi-component intervention derived from the concept of photovoice (Leung et al., 2019). Data were collected from 2014 to 2016. The participants were recruited from seven districts in Hong Kong (Central-Western, Eastern, Southern, Wan Chai, Sham Shui Po, Wong Tai Sin, and Sha Tin). Those who met the following criteria were included in the study: 1) aged 55 and older, 2) able to ambulate independently, and 3) cognitively intact (scoring 7 or above on the Short Portable Mental Status Questionnaire [SPMSQ]). A total of 252 participants were eligible for the study, but only 204 consented to take part. After data cleaning, 199 participants were included in the analysis.

2.2 Sample size calculation

The minimum sample size required for conducting regression analyses is 104 + m (where m is the number of predictors in the regression model) (Green, 1991). Assuming that there would be at least 8 predictors in the final regression model, we needed to have at least 112 participants in this study.

2.3 Measurement

Pre-frailty was the dependent variable in this study and was determined by two major frailty-related phenotypes as the criteria: low physical activity or poor handgrip strength or both (Fried et al., 2001). Physical activity was measured by wearing an accelerometer (Garmin Vivofit 1.0) for one week, and then taking the mean of the total amount of energy that is consumed in engaging in all kinds of physical activities per day. Female participants who consumed less than 270 kilocalories per day and male participants who consumed fewer than 383 kilocalories per day were considered to have low levels of physical activity (Fried et al., 2001). Handgrip strength was assessed using a dynamometer. Handgrip strength tests were performed twice. The average readings of the two tests on the dominant hand were used. Those with average handgrip strength readings at the gender-adjusted lowest quintile (female: 14.35 kg; male: 22.00 kg; within the lowest 20%, stratified by gender) were considered to have poor handgrip strength (Lee et al., 2017). Demographic, clinical, and functional factors associated with frailty, as shown in the literature review, were included in the analysis. Demographic factors included age, gender, marital status, living status, highest level of education, and health literacy. Health literacy was measured using the 24-item Chinese Health Literacy for Chronic Care (CHLCC) scale (Leung et al., 2013). A higher total score indicates a higher level of health literacy. The CHLCC has good internal consistency, with Cronbach's a = 0.91 (Leung et al., 2013), and consists of four subscales – remembering, understanding, applying, and analyzing – which represent the four domains of health literacy (Leung et al., 2013). The clinical and functional factors included in the analysis were various types of chronic illnesses (such as hypertension, diabetes, cataracts, osteoporosis, gout, stroke, and depressive symptoms) and lifestyle habits (including smoking and drinking). A dichotomous variable "comorbidity" (1=yes, 0=no) was created for the regression analysis. Comorbidity refers to having one or more kinds of chronic illness. Depressive symptoms were assessed using the 9-item Chinese version of the Patient Health Questionnaire (PHQ-9), with those scoring 5 or more (in a range from 0-19) considered as having mild to severe depressive symptoms (Cheng & Cheng, 2007). Body measures were assessed in terms of body weight and body height.

2.4 Ethical considerations

Before the data were collected, all of the participants gave their informed written consent for inclusion in the study. The protocol of the study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB) (reference number: UW14-447).

2.5 Statistical analyses

The means and standard deviations (SD) of continuous variables and the frequency and percentages of categorical variables were employed to describe the variables. Following the criteria proposed by Tabachnick and Fidell (2012), variables with less than 5% missing data are considered as 'acceptable'. Chi-square or Fisher's exact tests were used for multi-nominal variables, and Mann-Whitney U or independent t-tests were used for continuous variables in the bi-variate analysis of predictors and presence of frailty-related phenotypes.

Moderation effect was assessed by introducing an interaction term formed by the multiplication of an independent variable and a moderating variable (Brambor, Clark & Golder, 2006). Therefore, in this study, we examine the moderation effect of age by expressing the multiplication of 'age' and 'body weight' as 'age*body weight' and 'age and 'body height' as 'age*body height' and introduced these interaction terms in hierarchical logistic regression analyses. Before the independent variables were entered in the regression model, they were all centered at zero to reduce multicollinearity (Aiken, West, & Reno, 1991).

Gender, smoking, drinking, and comorbidity were adjusted in the regression. In the second round of regression models (Model 2 and Model 5), age and body height or age and body weight were entered respectively. In the third round of regression models (Model 3 and Model 6), interaction terms (age and body height; age and body weight) were entered respectively. The change in R^2 was observed and the significance of the effect of the new interaction term was assessed. In order to visualize the moderating effect of age on the relationships, we plotted a graph showing the different effects of body weight (or body height) on frailty for three different age groups: an old-old group (older than one standard deviation above the mean age of this sample), a mid-old group (at the age between one standard deviation above and below the mean age of this sample), and a young-old group (younger than one standard deviation below the mean age of this sample) (Aiken et al., 1991). The Johnson-Neyman technique was employed to identify regions where the effect of body measures (body weight or body height) on pre-frailty becomes statistically significant in the range of the moderating variable (age) (Hayes & Matthes, 2009). A significance level of 0.05 was used in the current study. The Hosmer-Lemeshow test were adopted to determine the goodness of fit of the regression models. The χ^2 values were reported and non-significant values ($p>0.05$) indicating that the models are good fit (Hosmer, Lemeshow, & Sturdivant, 2013). All analyses were conducted using the Statistical Package for the Social Sciences software version 25.0.

3 Results

A total of 199 individuals with a mean age of 73.43 (SD 7.54) (ranging from 57 to 97) were included in this study. Missing data of all variables were below 5%. The characteristics of the participants are presented in Table 1. The majority were female (76.4%). More than half of the participants were married (55.8%) and had a primary education or below as their highest level of education (53.8%). One-third were living alone (37.3%), and about a quarter had inadequate health literacy (24.6%). Most participants had at least one chronic illness, and the most prevalent five types of chronic disease were hypertension (68.8%), diabetes (25.6%), cataracts (22.1%), osteoporosis (15.6%), and gout (7.0%). About a quarter presented with symptoms of depression (27%). The majority of the participants were neither smokers (91.5%) nor consumers of alcohol (90.5%). The mean body weight of the participants was 59.31 kg (SD 10.82), while the mean body height was 153.87 centimeters (SD 8.48). The overall prevalence of frailty in this sample was 27.1% (54 out of 199).

Table 1 also showed the factors associated with pre-frailty in this sample**.** Individuals with pre-frailty were more likely to be older (p<0.001) and present with diabetes (p=0.029), cataracts (p<0.001), osteoporosis (p=0.016), gout (p=0.026), and stroke (p=0.044). There was no significant relationship between inadequate health literacy and pre-frailty. However, when we further investigated different components of health literacy (remembering, understanding, applying, analyzing), the component of "analyzing" was found to be significantly associated with pre-frailty (p=0.04). Lower body weight (p=0.021) and lower body height (p<0.001) were also significantly associated with the presence of pre-frailty symptoms, but there was no significant association between BMI categories (underweight, normal, overweight, and obese) and pre-frailty.

[Insert table 1 about here]

Table 2 presents a logistic regression summary of age, body weight, body height, and interaction terms regressed on pre-frailty. Model 1 shows that body weight (OR=0.95, 95% CI 0.92-0.99, p<0.05) were significantly associated with pre-frailty while Model 2 show the significant relationship between age and pre-frailty (OR = 1.09, 95% CI 1.04-1.15, p<0.01). In Model 3, when the interaction term (body weight*age) was added, the R^2 increased from 0.200 to 0.227 (p<0.001; Hosmer and Lemeshow Test: χ^2=5.892, df=8, p=0.659), and the interaction was significantly associated with pre-frailty (OR=1.01, 95% CI 1.00-1.01, p<0.05). Thus, age was a significant moderator of the relationship between body weight and pre-frailty. Model 4 showed that body height (OR=0.88, 95% CI 0.83-0.94. p<0.001) were significantly associated with pre-frailty.

In Model 6, when the interaction term (body height*age) was added, the R^2 increased from 0.257 to 0.290 (p<0.001; Hosmer and Lemeshow Test: χ^2=13.546, df=8, p=0.094), and the interaction was significantly associated with pre-frailty (OR=1.01, 95% CI 1.00-1.02. p<0.05).

[Insert table 2 about here]

Figure 1 shows the conditional effect of body weight on pre-frailty in different age groups (older group, mean age group, and younger group), while Figure 2 shows the conditional effect of body height on pre-frailty in these age groups. In Figure 1, referring to the lowest line, which represents the group aged 65.86 (1 SD lower than the mean age of the samples), the effect of body weight on pre-frailty was significant and negative (beta=-0.044, p<0.05). Referring to the middle line, which represents the mid-old group (mean age=73.23), the effect of body weight on pre-frailty was still significant and negative, but with a weaker effect (beta=-0.087, p<0.01). For the highest line, representing the old-old group (mean age=80.06), the effect of body weight on pre-frailty became insignificant (p=0.96). The results of using the Johnson-Neyman technique showed that the point of transition between a statistically significant and a statistically insignificant effect of body weight on pre-frailty occurred at 74.87 years old, or 1.64 above the mean age of 73.23 (using α = 0.05 as the level of significance). At that point, the effect of body weight is -0.035, meaning that an increase in body weight will result in a decreased probability of pre-frailty.

Figure 2 presents the conditional effect of body height on pre-frailty, using three lines. The lowest line demonstrates the significant and negative effect (beta=-0.16, p<0.001) of body height on pre-frailty in the young-old group (mean age=65.86). The middle line indicates the mid-old group (mean age=73.23), for whom body height still had a significant and negative effect on pre-frailty, but the effect was weaker (beta=-

0.089, p=0.001). An insignificant relationship between body height and pre-frailty was found in the old-old group (mean age=80.06), with an effect of -0.020 (p>0.05). The Johnson-Neyman technique identified 77.95 years old, or 4.72 above the mean age, as the point of transition between a statistically significant and a statistically insignificant effect of body height on pre-frailty (using $\alpha = 0.05$ as the level of significance). At that point, the effect of body height is -0.048, meaning that an increase in body height will result in a reduced probability of pre-frailty.

[Insert figures 1 and 2 about here]

4 Discussion

There are several key findings in this study. Pre-frailty (i.e., poor handgrip strength, and/or low physical activity) was positively associated with age. Although pre-frailty was not associated with BMI, it was negatively associated with both body weight and body height. Interestingly, based on the results of the logistic regression, there were significant interaction effects between both body weight and body height with age on pre-frailty. Specifically, the subgroup analysis showed that both body weight and body height were associated with pre-frailty in the young-old and mid-old group, but not in the old-old group.

In the literature, frailty is known to be positively associated with age because the risk of the accumulation of deficits and physiological degeneration (e.g., chronic inflammation, neuroendocrine dysregulation, and sarcopenia) increases over one's lifetime, even though many frail older people's functioning can still be normal (Fulop et al., 2010; Walston et al., 2006).

Body mass index (BMI) and frailty showed a u-shaped relationship in previous studies, indicating that people with an excessively high and excessively low BMI are at a higher risk of frailty (Hubbard, Lang, Llewellyn, & Rockwood, 2009). The insignificant correlation between BMI and frailty is likely because their relationship is not linear but u-shaped. As older people age, both their body weight and body height decrease gradually (Dey, Rothenberg, Sundh, Bosaeus, & Steen, 1999). While the decline in body height is quite steady, changes in body weight are more subject to disease-related factors (e.g., cancer) and life-style related factors (e.g., diet and physical activities) (Bamia et al., 2010). This causes the change in BMI along the process of normal ageing to vary, so that BMI is not a good predictor of frailty or pre-frailty.

Body weight and body height are associated with muscle strength (Samson et al., 2000). Body weight and body height were therefore observed in this study. This association can be better explained by the amount of skeletal muscle in an individual. However, this study found that these associations became insignificant in the old-old population. This may be because the higher body weight in the old-old is mainly caused by a gain in fat tissue instead of muscle (Kuk, Saunders, Davidson, & Ross, 2009).

All of these findings suggest that BMI should not be used to screen for frailty, while body weight and height should be used separately. However, in the old-old population, it is not recommended that body weight and body height be used to screen for risk of frailty because these two markers become insensitive. Further studies should be conducted to examine the reasons for this. Although advanced methods (e.g., DEXA and bioelectrical impedance) can be used to accurately determine body composition (e.g., fat-free tissue, lean tissue) because of their higher predictive power with regard to frailty (Kim & Kim, 2013), body weight and body height are still cost-effective measurements to use to identify the risk of frailty in older people. However, when interpreting the results, researchers and practitioners should also consider the age of the clients.

Contrary to our expectations, we found that there was no relationship between overall level of health literacy and pre-frailty. However, one of the domains of health literacy, analyzing ability, was shown to be negatively associated with frailty. This implies that those with a poorer ability to analyze health information are more likely to be in a pre-frail condition. Due to the cross-sectional nature of this study, we were not able to understand the effect of an individual's analytical ability on his/her frailty level or, alternatively, whether an individual's frailty level affects his/her ability to analyze health information. Further research is warranted to investigate the relationships between the different domains of health literacy and frailty education.

A significant association was found between pre-frailty and body weight and body height. The odds ratio of body weight in model 1 was lower than one; this indicated that people with a higher body weight had a lower chance of being pre-frail. Similarly, the odds ratio of body height in model 4 was small; this implied that those who were taller were less likely to be pre-frail. This result extends the findings of previous studies, which only focused on the association between BMI and frailty (Júnior et al., 2014).

Interestingly, age was found to moderate the relationship between pre-frailty and body weight and body height. Body weight was negatively associated with pre-frailty, which meant that people with a lower body weight were more likely to be in a pre-frail condition (Model 1). However, the effect of body weight on pre-frailty gradually faded as the individuals became older. A significant turning point occurred at the age of 75: for those who were older than 75, the effect of body weight on pre-frailty became insignificant. Health education should therefore be offered to older adults aged 74.9 or less to encourage them to maintain an appropriate body weight, avoiding becoming too slim to prevent frailty. This recommendation would be particularly useful to young older adults (for example, those aged 65 or less), as the lowest line in Figure 1 shows the deepest slope, indicating a significant and strong negative relationship between body weight and pre-frailty in this sub-group of the aged population.

A similar observation was made of the relationship between body height and pre-frailty. The results of the logistic regression model demonstrated that taller individuals were less likely to be in a pre-frail condition (Model 4). Age was also a moderator of this relationship; that is, at different ages, the negative relationship between body height and pre-frailty played out differently. It is worth noting that this relationship became weaker when the individuals became older. The significant turning point was age 80. Those 80 years of age or below and whose body height is lower than the average height of their peers should be made aware of the risk of frailty. It is recommended that this high-risk population regularly engage in physical activity or increase their levels of vitamin D (Vogt et al., 2015).

The current study contributes to a new direction for investigating the relationship between pre-frailty and two objective body measures (body weight and body height)—that of considering how this relationship plays out in different subgroups of the aged population. Identifying these characteristics in pre-frailty could guide our practices in health promotions to the aged population. It is clear that older adults are not a homogenous group. The recommendations made to this population could be tailored according to individual characteristics (body height, body weight, and age). This is in line with the advocacy of "individualized health care" in recent discussions on health promotions (Angstman, 2014). Addressing the characteristics of individuals when making recommendations enhances acceptance of these health messages, because these recommendations are then relevant and meaningful to individuals. Based on these findings, a frailty prevention program could be developed in the community and targeted at different groups within the aged population. For example, those aged 75 or below and whose body weight is lower than the average body weight of their peers could take nutritional cooking classes to prevent frailty. Screening for malnutrition may also be helpful for this population. For those aged 80 or below and whose body height is lower than the average body height of their peers, a walking buddy program with appropriate exposure to sunlight could be developed in a neighborhood, so that older adults could enjoy exercising regularly together in the sun (Leung et al., 2014). In Hong Kong, a population-based frailty screening and prevention program was carried out in 2017-2019, funded by the Hong Kong Jockey Club Charity Trust, targeting 9,000 people aged 50 or above (Cheng, 2018). This program, arranged by a university and two non-governmental organizations, took the form of a community initiative program. The Department of Health of the Hong Kong government has yet to include frailty as part of the standardized screening program in elderly health services. Little attention has been given to frailty in the region, although the prevalence of pre-frailty (52.4%) and frailty (12.5%) is high (Cheng, 2018). Frailty awareness and prevention programs are worth supporting in the community.

4.1 Limitations

This study is subject to at least three limitations. First, it did not use a population-based data set, and the sample size was small. Therefore, the findings may not be generalizable to the whole Hong Kong population and to elderly residents in institutions. Second, the cross-sectional design precludes conclusions about the direction of causality. Further research is warranted to investigate the relationship between health literacy and the presence of frailty symptoms. Third, we have selected only two (out of five) criteria of frailty, according to Fried's definition of frailty, as the outcome measure in this study. The original dataset did not include the other three phenotypes of frailty because the investigation of frailty was not an aim of the original study. It is necessary to be cautious in interpreting the findings of this study when developing interventions for the prevention of frailty because we have not covered all of the phenotypes of frailty.

4.2 Conclusion

This study provides some useful information about the factors (body weight, body height, and age) associated with pre-frailty in Chinese community-dwelling older adults, which could be helpful to researchers and practitioners in the further development of preventive programs for frailty.

5 Declarations

Part of the findings were presented in the Late Breaker Poster Presentation in the Gerontological Society of America's 69th Annual Scientific Meeting in New Orleans, USA in November 2016.

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Table 1. Factors associated with pre-frailty in community-dwelling older adults

Variables	Total n (%) (N=199)	Pre-frailty status: With pre-frailty n (%) (n=54)	Without pre-frailty n (%) (n=145)	*p* value
Demographics				
Age, mean±SD	73.43 ± 7.54	76.52 ± 6.83	72.21 ± 7.48	**<0.001**
Female	152 (76.4%)	40 (74.1%)	112 (77.2%)	0.779
Marital status				0.103
married	111 (55.8%)	24 (44.4%)	87 (60.0%)	
widowed or other	88 (44.2%)	30 (55.6%)	59 (40.0%)	
Living status				0.952
living alone	62 (31.3%)	17 (31.5%)	45 (31.0%)	
other	136 (68.7%)	37 (68.5%)	99 (69.0%)	
missing	1 (0.5%)	0 (0%)	1 (0.7%)	
Highest educational level				0.545
no formal	42 (21.1%)	13 (24.1%)	29 (20.0%)	
primary	65 (32.7%)	20 (37.0%)	45 (31.0%)	
lower secondary	35 (17.6%)	6 (11.1%)	29 (20.0%)	
upper secondary or above	57 (28.6%)	15 (27.8%)	42 (29.0%)	
Health literacy (HL)				
Inadequate HL (CHLCC≤35)	49 (24.6%)	14 (25.9%)	35 (24.2%)	0.129
Adequate HL (CHLCC > 35)	142 (71.4%)	38 (70.4%)	104 (71.7%)	
Missing	8 (4.0%)	2 (3.7%)	6 (4.1%)	
Total CHLCC score, mean ± SD		37.06 ± 10.23	39.54 ± 9.33	0.13
Subscale 1: remembering, mean ± SD		10.19 ± 4.05	11.13 ± 2.56	0.05
Subscale 2: understanding, mean ± SD		9.89 ± 2.83	9.81 ± 2.91	0.87
Subscale 3: applying, mean ± SD		8.94 ± 3.35	9.46 ± 3.00	0.30
Subscale 4: analyzing, mean ± SD		7.81 ± 4.12	9.06 ± 3.50	**0.04**
Chronic illnesses				
Hypertension	137 (68.8%)	33 (94.3%)	104 (89.7%)	0.523
Diabetes	51 (25.6%)	16 (84.2%)	35 (53.0%)	**0.029**
Cataracts	44 (22.1%)	22 (81.5%)	22 (36.7%)	**<0.001**
Osteoporosis	31 (15.6%)	12 (70.6%)	19 (33.9%)	**0.016**
Gout	14 (7.0%)	6 (50%)	8 (17.0%)	**0.026**
Stroke	9 (4.5%)	4 (40%)	5 (10.9%)	**0.044**
Depression symptoms (PHQ-9: 5-19)	53 (27%)	18 (33.3%)	35 (24.1%)	0.269
Comorbidity	96(48.2)	35 (64.8%)	61 (42.1%)	**0.004**
Lifestyles				
Smoking	17 (8.5%)	6 (11.1%)	11 (7.6%)	0.440
Drinking	19 (9.5%)	4 (7.4%)	15 (10.3%)	0.786
Body measures				
Body mass index (BMI)				0.158
Underweight	5 (2.5%)	0 (0%)	5 (3.4%)	
Normal	52 (26.1%)	18 (33.3%)	34 (23.4%)	
Overweight	49 (24.6%)	14 (25.9%)	35 (24.6%)	
Obese	89 (44.7%)	21 (38.9%)	68 (46.9%)	

Missing	4 (2.0%)	1 (1.9%)	3 (2.1%)	
Body weight (in kg)	59.31 ± 10.82	56.42 ± 10.35	60.40 ± 10.84	**0.021**
Body height (in cm)	153.87 ± 8.48	150.53 ± 7.66	155.13 ± 8.46	**<0.001**

Note: CHLCC = Chinese Health Literacy for Chronic Care; PHQ = Patient Health Questionnaire

Table 2. Age, body height, body weight, and interaction terms regressed on pre-frailty

	Model 1				Model 2				Model 3				Model 4				Model 5				Model 6			
	odds ratio	95% CI Lowe	Upper	p	odds ratio	95% CI Lowe	Upper	p	odds ratio	95% CI Lowe	Upper	p	odds ratio	95% CI Lowe	Upper	p	odds ratio	95% CI Lowe	Upper	p	odds ratio	95% CI Lowe	Upper	p
Constant	0.19			<0.001	0.18			<0.001	0.17			<0.001	0.14			<0.001	0.13			<0.001	0.13			<0.001
Gender	1.86	0.70	4.91	0.213	1.71	0.61	4.74	0.305	1.93	0.68	5.50	0.217	4.50	1.45	14.00	0.009	3.92	1.22	12.66	0.022	4.12	1.22	13.95	0.023
Smoking	1.56	0.44	5.55	0.490	1.47	0.40	5.44	0.564	1.24	0.32	4.78	0.751	1.39	0.36	5.37	0.635	1.33	0.34	5.23	0.688	1.11	0.27	4.62	0.888
Drinking	0.67	0.20	2.27	0.518	0.65	0.18	2.38	0.514	0.74	0.20	2.72	0.646	0.74	0.21	2.61	0.639	0.60	0.16	2.30	0.459	0.82	0.21	3.17	0.775
Comorbidity	2.45	1.26	4.75	0.008	2.54	1.27	5.09	0.008	2.52	1.25	5.08	0.010	2.63	1.31	5.27	0.006	2.77	1.35	5.67	0.005	2.55	1.23	5.26	0.012
Body weight	0.95	0.92	0.99	0.012	0.96	0.92	1.00	0.030	0.95	0.91	0.99	0.012												
Age					1.09	1.04	1.15	0.001	1.11	1.05	1.18	<0.001												
Age*weight									1.01	1.00	1.01	0.047												
Body height													0.88	0.83	0.94	<0.001	0.90	0.85	0.95	<0.001	0.88	0.82	0.94	<0.001
Age																	1.07	1.02	1.13	0.007	1.10	1.04	1.17	0.001
Age*height																					1.01	1.00	1.02	0.029
Nagelkerke R^2				0.116				0.200				0.227				0.210				0.257				0.290
p-value of model fit				0.006				<0.001				<0.001				<0.001				<0.001				<0.001
Hosmer and Lemeshow Test																								
Chi-square				5.260				16.618				5.892				7.253				15.359				13.546
DF				8				8				8				8				8				8
p-value				0.729				0.034				0.659				0.510				0.053				0.094

Figure legends:

Figure 1. Conditional effect of body weight on pre-frailty in different age groups

Figure 2. Conditional effect of body height on pre-frailty in different age groups

Figure 1. Conditional effect of body weight on pre-frailty in different age groups

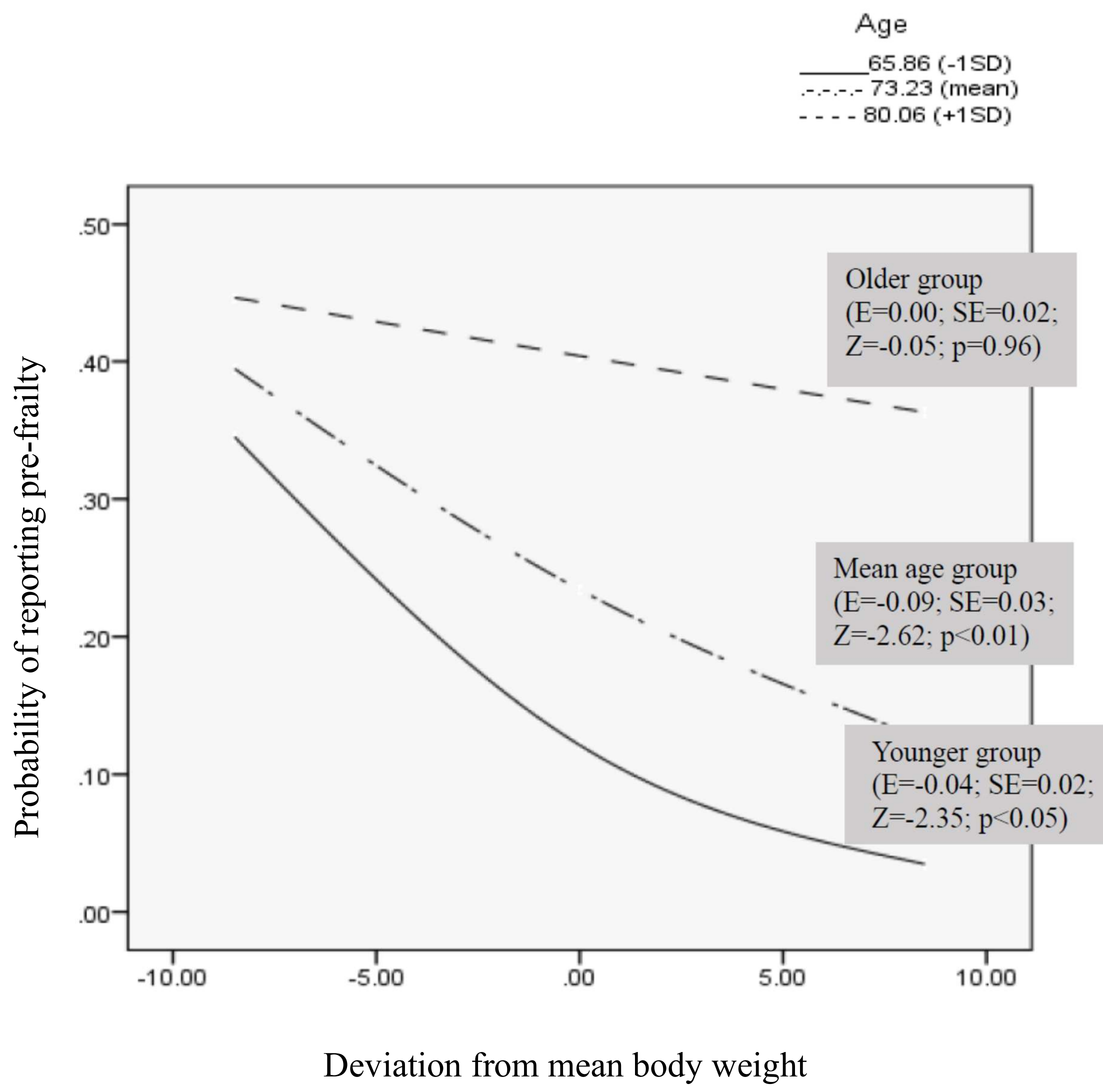

Figure 2. Conditional effect of body height on pre-frailty in different age groups