

Association of chronic pain and BMI with frailty among individuals aged 60 years and older in China: a cross-sectional study

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Article

Keywords: Frailty, Chronic pain, older adult, Community setting

Posted Date: June 10th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-9421235/v1>

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Additional Declarations: No competing interests reported.

Abstract

Purpose

This study aimed to determine the complex associations between frailty and multiple influencing factors.

Methods

This descriptive cross-sectional study was conducted among 629 community-dwelling older adults. Frailty was assessed using the FRAIL scale with key predictors. Three nested linear regression models were used to examine the main, quadratic, and interaction effects of these variables.

Results

Frail individuals had significantly lower cognitive function and higher pain levels than their non-frail counterparts. Pain in specific body regions (head, limbs, and back) were more common in the frail group. BMI significantly moderated the relationship between pain and frailty, with a stronger association observed at higher BMI levels.

Conclusions

Frailty is closely linked to pain, and cognitive decline, BMI amplifies the effect of pain on frailty risk. These findings underscore controlling weight and managing chronic pain in older adults may mitigate the risk of frailty and promote healthy aging.

Background

In recent years, the global population has experienced a marked demographic shift, driven by rapid population aging. In China, where population aging is particularly pronounced, the number of people aged ≥ 60 years is expected to reach 402 million by 2040¹. The growing proportion of older adults has brought increasing attention to the issue of frailty.

Frailty is a clinical syndrome characterized by reduced physiological reserves and increased vulnerability to stressors owing to a cumulative age-related decline in multiple organ systems². It is associated with adverse health outcomes including disability, hospitalization, institutionalization, and mortality³. With an aging global population, frailty has become a major predictor of physical, cognitive, and functional deterioration^{4,5}. In particular, epidemiological studies have shown that frailty is a key risk factor for falls, fractures, surgical complications, and all-cause mortality in community-dwelling older populations^{6–12}. In China, the prevalence of frailty among older adults aged ≥ 60 years is estimated to be around 10.1%,

with variability depending on diagnostic criteria. With the increasing number of older adults, identifying and managing risk factors for frailty, which is influenced by physiological and psychosocial factors including pain, cognitive function, and nutritional status, has become a pressing need ^{13–14}.

Chronic pain, defined as persistent or recurrent pain lasting for more than three months ¹⁵, is one of the most prevalent, costly, and debilitating conditions among older adults ¹⁶. Its prevalence increases with age and is often associated with chronic conditions, such as osteoarthritis and osteoporosis ¹⁷. Among Chinese adults aged 60 years, approximately 30.6% experience chronic pain ^{18–19}. However, due to the presence of comorbidities or cognitive impairment, the diagnosis and management of chronic pain in this population remains challenging ²⁰. Systematic reviews have confirmed this positive association and suggested that chronic pain may promote frailty through pathways such as reduced mobility, inflammation, sleep disturbances, and psychological distress ^{21,22}.

In addition to chronic pain, other individual characteristics such as age, body mass index (BMI), and cognitive function play important roles in the development of frailty ^{23–25}. Age is a well-established predictor of declining physiological reserves. BMI reflects both the nutritional status and body composition, whereas cognitive impairment has been linked to reduced functional capacity and increased vulnerability to stress. Although these factors are associated with frailty, most studies have examined them separately. Frailty arises from the accumulation of multiple interrelated biological and psychosocial deficits that may interact in complex and nonlinear ways.

Given the multifactorial nature of frailty, its development may be influenced by both linear and nonlinear associations among biological and psychosocial factors. Previous studies examined individual predictors. However, only a few studies have simultaneously assessed their potential nonlinear or interactive effects. To address this gap, this exploratory study aimed to investigate the complex associations between frailty and multiple influencing factors, with a particular focus on identifying potential nonlinear patterns and interaction effects using polynomial regression modeling.

Methods

Study design and participants

This study employed a population-based, cross-sectional design and was conducted in the Xinjiekou community of Beijing, China. Data collection occurred intermittently between July 2022 and September 2024 owing to COVID-19-related interruptions.

There were three recruitment criteria for participation: (1) residence in the Xinjiekou community, (2) age ≥ 60 years, and (3) ability to independently perform activities of daily living (ADLs), assessed using a simplified ADL self-report checklist. The exclusion criteria included a diagnosis of neurodegenerative disease or physical disabilities that precluded participation in the frailty assessments. All participants

were invited to the Radiology Department of Beijing Jishuitan Hospital (Xinjiekou Branch) for standardized measurements conducted by trained nurses.

The residents voluntarily participated in this study. None of the participants received any form of compensation for their involvement, and all provided written informed consent for the use and publication of their data. The study adhered to the principles outlined in the Declaration of Helsinki.

Ethical consideration

This study was approved by the Ethics Committee of the Beijing Jishuitan Hospital, Capital Medical University (Approval No. K2022-195-02). All the participants voluntarily provided informed consent before participating in the study.

Variables and measures

Measurement of frailty status

Frailty Phenotype (FP) can be applied at the first contact with the subject and is considered an important tool for the initial risk stratification of the population according to different profiles^{26,27}. Therefore, we used FP to assess the state of frailty. These criteria comprised the following five components: unintentional weight loss, low grip strength, exhaustion, slow gait speed, and low physical activity. Participants were categorized as robust (0), pre-frail (1–2), and frail (≥ 3) based on the number of frailty indicators present.

Unintentional weight loss was defined as a self-reported unintentional loss of > 4.5 kg or $> 5\%$ of the original body weight within the past 12 months.

Grip strength was measured using a handheld dynamometer (Jamar Hydraulic Hand Dynamometer, 2001b; Beijing Yuzhengzhongwei Technology Trade Co., Ltd.). The two measurements of the dominant hand were averaged. Weakness was stratified according to gender and BMI (kg/m^2) and defined using the maximum grip strength by the cutoffs stratified by sex: ≤ 29 kg for men and ≤ 17 kg for women.

Gait speed was measured using a 4-meter walking test at the individual's maximum walking speed. Slowness was defined as ≥ 7 seconds for both sexes. Walking time was measured in seconds. Slowness was defined using sex- and height-specific cutoff points, consistent with Fried et al. (26) (men: ≤ 173 cm, ≥ 7 seconds; > 173 cm, ≥ 6 seconds; women: ≤ 159 cm, ≥ 7 seconds; > 159 cm, ≥ 6 seconds). Physical activity was assessed with self-reported weekly walking duration and converted to kcal/week. Low activity was defined as < 383 kcal/week (2.5 h) for men and < 270 kcal/week (2 h) for women. Exhaustion was determined by a positive response to either of two questions, in the previous month: "I felt that everything I did was an effort" and "I can't move forward."

Assessment of chronic pain

Chronic pain is evaluated using the Brief Pain Inventory-Short Form (BPI-SF) ²⁸. The response choices were “yes” and “no”. If the answer was “yes,” the respondent was required to mark the affected musculoskeletal sites (eight areas: neck, shoulders, elbows, wrists/hands, hips, knees, feet, and lower back) on a body diagram. Those with more than one type of pain were asked about the most severe type.

Body composition and age

The participants’ body height and weight were measured with the participants wearing light clothing without shoes, and the BMI of each participant was computed by dividing the body weight (kg) by the square of the height (m²). Patient age was recorded in years.

Cognitive function

Cognitive status was evaluated using the Chinese Mini-Mental Status (CMMS), a culturally adapted cognitive assessment tool widely used in Chinese clinical and epidemiologic studies, including prior work conducted by our team ^{29,30}. The CMMS screenings were carried out by trained nurses and staff. CMMS scores ranged from 0 to 30. Higher scores indicate better cognitive function ³¹.

Statistical analysis

We conducted a series of three nested linear regression models to examine the relationship between frailty scores (0–5) and predictors. Model 1 included only the main effects; Model 2 added quadratic terms to assess nonlinear associations; and Model 3 further included all two-way interaction terms.

All continuous variables were mean-centered before model construction to reduce multicollinearity, particularly among higher-order and interaction terms. The model fit was evaluated by comparing the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) across the three models, with lower values indicating a better fit.

To evaluate the robustness of our main findings, we conducted a series of sensitivity analyses using negative binomial regression models. The interaction effects were visualized using predictive margin plots based on three representative BMI levels defined according to the Chinese BMI classification system across the full range of pain scores. All analyses were performed using Stata SE 16. Statistical significance was set at $\alpha = 0.05$ (two-tailed).

Results

Table 1
Characteristics of frail, pre-frail, and non-frail subjects

Variables	Total (n = 629)	Frail (n = 46)	Pre-frail (n = 256)	Non-frail (n = 327)	P value*
Sex, n (%)					0.039
Female	384 (61.0)	35 (76.1)	161 (62.9)	188 (57.5)	
Male	245 (39.0)	11 (23.9)	95 (37.1)	139 (42.5)	
Age, Mean (SD)	68.6 ± 4.85	70.3 ± 5.38	69.3 ± 5.07	67.7 ± 4.42	0.000
Age, n (%)					0.001
60–69	404 (64.2)	24 (52.2)	150 (58.4)	230 (70.3)	
70–79	202 (32.2)	20 (43.5)	89 (34.9)	93 (28.4)	
80–89	23 (3.7)	2 (4.3)	17 (6.7)	4 (1.2)	
BMI, Mean (SD)	25.2 ± 3.33	25.9 ± 3.56	25.2 ± 3.64	25.0 ± 3.03	0.171
Cognition, Mean (SD)	27.3 ± 2.15	25.7 ± 2.94	26.9 ± 2.22	27.8 ± 1.77	0.000
Pain, n (%)					0.000
Yes	432 (68.7)	39 (84.8)	191 (74.6)	202 (61.8)	
No	197 (31.3)	7 (15.2)	65 (25.4)	125 (38.2)	
Site of pain, n (%)					
Head	17 (3.9)	4 (10.3)	7 (3.7)	6 (3.0)	0.026
Neck	51 (12.0)	8 (23.1)	23 (12.0)	20 (9.9)	0.368
Shoulder	81 (18.8)	9 (23.1)	31 (16.2)	41 (20.3)	0.253
Upper limbs	48 (11.1)	6 (15.4)	25 (13.1)	17 (8.4)	0.043
Forechest	2 (0.1)	0 (0.0)	2 (0.1)	0 (0.0)	0.232
Abdomen	4 (0.1)	1 (2.6)	3 (1.6)	0 (0.0)	0.083
Upper back (chest)	7 (0.2)	3 (7.7)	1 (0.5)	3 (1.5)	0.001

Variables	Total (n = 629)	Frail (n = 46)	Pre-frail (n = 256)	Non-frail (n = 327)	<i>P</i> value*
Lower back (waist and below)	224 (51.9)	21 (53.8)	112 (58.6)	91 (45.0)	0.000
Hip	35 (0.8)	6 (15.4)	14 (7.3)	15 (7.4)	0.064
Lower limbs	280 (64.8)	25 (64.1)	122 (63.9)	133 (65.8)	0.092
Degree of pain, n (%)					0.031
Mild (0–3 score)	354 (81.9)	27 (69.2)	158 (82.7)	169 (83.7)	
Moderate (4–6 score)	74 (17.1)	12 (30.8)	29 (15.2)	33 (16.3)	
Severe (7–10 score)	4 (0.9)	0 (0)	4 (2.1)	0 (0)	

* T tests or chi-square test. Bold indicates statistical significance.

Table 1 summarizes the baseline characteristics of the study population according to frailty status (frail, pre-frail, and non-frail). Among the 629 participants, 46 (7.3%) were classified as frail, 256 (40.7%) as pre-frail, and 327 (52.0%) as non-frail. Frail participants were more likely to be female (76.1%) and older (mean age 70.3 ± 5.38 years) compared with pre-frail participants (62.9% female; mean age 69.3 ± 5.07 years) and non-frail participants (57.5% female; mean age 67.7 ± 4.42 years, $p < 0.001$). Cognitive function scores were significantly lower among frail individuals (mean CMMS 25.7 ± 2.94) than in the pre-frail (mean CMMS 26.9 ± 2.22) and non-frail (27.8 ± 1.77) groups ($p < 0.001$).

With respect to chronic pain, 84.8% of frail participants reported pain, compared to 74.6% of pre-frail and 61.8% of non-frail individuals ($p < 0.001$). Pain in the head, upper limbs, upper back, and lower back was significantly more common in the frail group (p values ranging from 0.001 to 0.043). Pain severity also differed significantly; frail participants reported a higher proportion of moderate pain (30.8% vs. 15.2% in the pre-frail and 16.3% in non-frail, $p = 0.031$). No significant differences were observed in the BMI between the groups ($p = 0.171$).

Table 2
Polynomial regression models for predictors of frailty

Variables	Model 1	Model 2	Model 3
Age (centered)	0.027*** (0.008)	0.029*** (0.008)	0.028*** (0.008)
BMI (centered)	0.003 (0.011)	-0.004 (0.012)	-0.003 (0.012)
CMMS (centered)	-0.13*** (0.021)	-0.109*** (0.023)	-0.110*** (0.023)
Pain score (centered)	0.120*** (0.031)	0.123* (0.052)	0.125* (0.054)
Female (1 = yes)	-0.072 (0.079)	-0.076 (0.079)	-0.071 (0.078)
Age ²	—	-0.000 (0.001)	-0.001 (0.001)
BMI ²	—	0.004 (0.002)	0.003 (0.002)
CMMS ²	—	0.010 (0.005)	0.009 (0.005)
Pain ²	—	-0.001 (0.013)	-0.005 (0.013)
Age × Pain	—	—	-0.001 (0.006)
BMI × Pain	—	—	0.030*** (0.007)
CMMS × Pain	—	—	0.000 (0.014)
Constant	0.810*** (0.065)	0.735*** (0.0872)	0.755*** (0.086)
Observations	629	629	629
R-squared	0.141	0.151	0.171
AIC	1684.1	1684.9	1675.8
BIC	1710.8	1729.3	1733.6
Standard errors in parentheses			
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$			

Table 2 presents the results of the polynomial regression models examining the associations between frailty and age, BMI, cognitive function, pain intensity, and sex. Variable inclusion was based on theoretical relevance and prior evidence rather than solely on univariate significance.

Model 1 (main effects only) showed that older age ($\beta = 0.0265$, $p < 0.001$), lower CMMS score ($\beta = -0.134$, $p < 0.001$), and higher pain score ($\beta = 0.120$, $p < 0.001$) were significantly associated with higher frailty scores. BMI and sex were not significantly associated with frailty.

Model 2 (adding quadratic terms) demonstrated similar patterns for the main effects. None of the quadratic terms for age, BMI, CMMS score, or pain reached statistical significance (all $p > 0.05$),

suggesting no meaningful curvilinear relationship between these variables and frailty.

Model 3 (full model with interaction terms) further identified a significant interaction between BMI and pain ($\beta = 0.0296$, $p < 0.001$). Other interaction terms, including age, pain, CMMS score, and pain, were not statistically significant (all $p > 0.05$).

Across the three models, model fit improved modestly with the inclusion of quadratic and interaction terms (Model 1: AIC = 1684.1; Model 2: AIC = 1684.9; Model 3: AIC = 1675.8). Model 3 showed the best fit, supporting the inclusion of BMI and pain interactions.

As shown in Fig. 1, the slope of pain-related frailty increase varied substantially with BMI. Frailty increased sharply with increasing pain among participants with higher BMI, increased moderately in those with a normal BMI, and showed minimal changes among those with a lower BMI. This pattern indicates that BMI amplified the effect of pain on frailty, with stronger effects observed at higher BMI levels.

Table 3
Negative binomial regression

Variable	Coef.	SE	z	P value	95% CI
Age (centered)	0.032	0.008	3.86	*0.000	[0.016, 0.049]
CMMS (centered)	-0.146	0.019	-7.75	*0.000	[-0.183, -0.109]
Sex (1 = Female)	-0.092	0.101	-0.91	0.363	[-0.291, 0.107]
BMI (centered)	-0.001	0.014	-0.10	0.921	[-0.028, 0.026]
Pain (centered)	0.101	0.033	3.06	*0.002	[0.036, 0.166]
BMI × Pain	0.017	0.006	2.81	*0.005	[0.005, 0.029]
Constant	-0.313	0.085	-3.67	*0.000	[-0.480, -0.146]
alpha	0.113	0.082			[0.027, 0.474]

SE = standard error. CI = confidence interval. * $p < 0.05$.

Negative binomial regression analysis identified significant associations between age, cognitive function, pain severity, and frailty (Table 3). Each one-unit increase in age was associated with a 3.2% increase in frailty score ($\beta = 0.032$, $p < 0.001$), whereas each unit increase in CMMS corresponded to a 14.6% decrease in frailty ($\beta = -0.146$, $p < 0.001$). Pain severity remained an independent predictor ($\beta = 0.101$, $p = 0.002$).

A significant interaction between BMI and pain ($\beta = 0.017$, $p = 0.005$) indicated a differential effect of pain on frailty across BMI levels, showing that individuals with higher BMI experienced a stronger pain-

related increase in frailty. No significant main effects were observed for BMI or sex. The estimated alpha value (0.113) indicated mild overdispersion and supported the negative binomial specification.

As shown in Fig. 2, the effect estimates derived from the linear and negative binomial regression models were highly consistent both in direction and magnitude for all key predictors. This indicates that the main conclusions of this study are robust with respect to model specification.

Discussion

Moderating role of BMI in the pain–frailty association

Our findings revealed a clear and clinically meaningful pattern: frailty increased with higher pain levels across all BMI categories, and the slope of this increase varied substantially with BMI. Older adults with higher BMI exhibited a markedly steeper increase in predicted frailty as pain intensified, indicating a synergistic deterioration in physical robustness when excess weight and chronic pain coexist. In contrast, individuals with low BMI showed a relatively flat or even slightly declining frailty trajectory across the pain spectrum, suggesting that low body weight may attenuate the functional consequences of pain, possibly due to a lower mechanical load on weight-bearing joints or differential inflammatory profiles.

This divergence in slopes supports the interpretation that BMI acts not only as a background factor but also as a physiological amplifier of pain-related frailty. Several mechanisms can explain this interaction. First, higher BMI increases axial and joint loading, which can exacerbate musculoskeletal pain and accelerate mobility loss, thereby promoting a cycle of frailty. Second, adipose tissue, driven by low-grade inflammation, may increase pain sensitivity and impair muscle function, compounding the frailty risk. Third, individuals with a higher BMI often engage in lower levels of physical activity, which can worsen both pain and sarcopenic decline, further magnifying their vulnerability to frailty.

Importantly, the absence of a direct association between BMI and frailty in our regression models underscores the fact that excess weight alone does not necessarily predict frailty; rather, its detrimental impact emerges when combined with pain, highlighting the conditional nature of this relationship. Clinically, this suggests that older adults who present with both chronic pain and elevated BMI constitute a high-risk subgroup that requires proactive screening, tailored rehabilitation strategies, and integrated pain–weight management interventions.

Biological pathways linking pain, inflammation, and functional decline

Persistent pain triggers neuroendocrine activation and stimulates the production of pro-inflammatory cytokines, thereby accelerating both the onset and progression of frailty³³. This aligns with the concept of “inflammation-aging,” which suggests that chronic low-grade inflammation serves as a fundamental

biological mechanism underlying various age-related disorders^{34,35}. Pain-induced reduction in physical activity often leads to prolonged sedentary behavior, which amplifies inflammatory processes and contributes to the deterioration of functional capacity. Among the middle-aged and older populations, chronic pain has been associated with slower gait, diminished grip strength, and poorer nutritional status, which are the core components of the frailty phenotype^{36,37}.

Importantly, pain has been previously identified as both a risk factor and consequence of frailty³⁸. Our study provides novel insights by demonstrating that the strength of the association between pain and frailty is significantly influenced by the BMI. The interaction between pain and BMI remained significant after adjusting for age and cognitive function, underscoring the robustness of this relationship. This may be due to the dual burden of musculoskeletal mechanical strain and systemic inflammation associated with excess weight, which could exacerbate the functional limitations caused by pain³⁸.

Musculoskeletal conditions are associated with pain, fatigue, physical activity, and obesity^{39,40}, many of which are included in frailty measures; frailty is rarely mentioned as a complication of musculoskeletal conditions. However, current clinical guidelines such as the NICE guidelines have not incorporated frailty screening into chronic pain management pathways⁴¹.

Contribution of age, cognitive function, and sex to frailty risk

Consistent with the findings of previous studies, we observed that advanced age, lower cognitive function, and higher pain levels were independently associated with increased frailty⁴². Age was positively associated with frailty status, with the mean age progressively increasing from the non-frail to the frail group. This supports the widely established notion that frailty is an age-related syndrome⁴³ and highlights the importance of age-specific screening strategies. Similarly, cognitive impairment was significantly more common in frail participants, which could lead to reduced self-care and mobility, with lower cognitive scores and a greater proportion scoring below 24, suggesting mild impairment. Lower cognitive scores and higher rates of cognitive impairment among frail individuals reinforce the concept of cognitive frailty, which has been recognized as a distinct and clinically meaningful phenotype⁴⁴. These findings highlight the multifactorial nature of frailty and emphasize the need for multidimensional interventions in geriatric care. Our findings revealed that females were disproportionately represented in the frail and pre-frail groups, a trend consistent with previous studies showing that women are more likely to be frail despite having a longer life expectancy⁴⁵. This may be due to lower muscle mass, postmenopausal hormonal changes, or differential patterns in chronic disease burden.

Pain characteristics and frailty screening

Further, in the degrees and areas of pain, moderate to severe pain was significantly more prevalent among the frail, and certain pain sites, particularly the head, upper limbs, and upper back, showed

significant differences between groups. This is potentially due to its greater interference with ADLs, balance, and physical functioning. A longitudinal study across multiple countries found that individuals in pre-frail state or frail state had a significantly higher prevalence and degree of pain than those in a robust state. This study also reported that pain in the head, neck, trunk, and extremities was strongly associated with frailty⁴⁶. Interestingly, frail participants reported more frequent pain in the head, upper limbs, back, and lower back regions, which are particularly sensitive to mechanical load and postural stress. These anatomical sites are also the most susceptible to the effects of excess body weight, suggesting a plausible physiological association between the observed pain distribution and the moderating role of BMI.

Limitations

This study had several limitations. First, the cross-sectional nature of the study prevents causal inference, and bidirectional relationships between BMI, pain, and frailty cannot be ruled out. Second, pain was assessed by self-reporting, which may have been subject to recall or reporting bias. Third, only a limited number of demographic covariates was included. This decision was primarily due to restrictions in data collection and the need to avoid overfitting in models with a modest sample size. Although major confounding variables were adjusted for, unmeasured confounders may still influence the results. Finally, the findings are based on community-dwelling older adults, and caution should be exercised when generalizing these findings to other populations.

Conclusions

This study identified complex and interrelated association between pain, BMI, cognitive function, and frailty in community-dwelling older Chinese adults. These findings suggest that pain and cognitive decline may jointly relate to body composition in ways that could increase vulnerability to frailty. Given these associations, early recognition of pain, cognitive changes, and weight-related factors may be helpful in clinical practice, but intervention effects require confirmation in longitudinal studies. Future research should examine the biological, psychological, and behavioral pathways linking pain, cognition, and BMI to frailty progression. In light of these findings, routine, multidimensional assessments of pain, cognition, and nutritional status may support community-based strategies that promote healthy aging and reduce frailty-related vulnerability.

Abbreviations

BMI - Body Mass Index

ADLs - Activities of Daily Living

FP - Frailty Phenotype

BPI-SF - Brief Pain Inventory-Short Form

CMMS - the Chinese Mini-Mental Status

AIC - Akaike Information Criterion

BIC - Bayesian Information Criterion

Declarations

Funding statement

This work is supported in part by the National Natural Science Foundation of China (Grant Nos. 82371957), the 2025 Beijing Key Clinical Speciality Construction Project (Nursing Department)

Ethics approval and consent to participate

The conduct of this study adhered to the Declaration of Helsinki. This study was approved by the Ethics Committee of the Beijing Jishuitan Hospital, Capital Medical University (Approval No. K2022-195-02). All the participants voluntarily provided informed consent before participating in the study.

Competing interests

The authors declare that they have no competing interests.

Consent for publication

Not applicable.

Authorship contribution statement

Design and conceptualization of the study: Y.H. and X.L; data collection and assembly: Y.H., D.Z., J.X. and L.W.; methodology: Y.H and X.L.; data analysis and interpretation: Y.H., D.Z. J.X.; writing—original draft preparation: Y.H., D.Z., J.X. and L.W; project administration: X.L.; funding acquisition: L.W. and X.L. All authors have read and agreed to the published version of the manuscript.

Acknowledgements

Not applicable

Clinical trial number

not applicable

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Figures

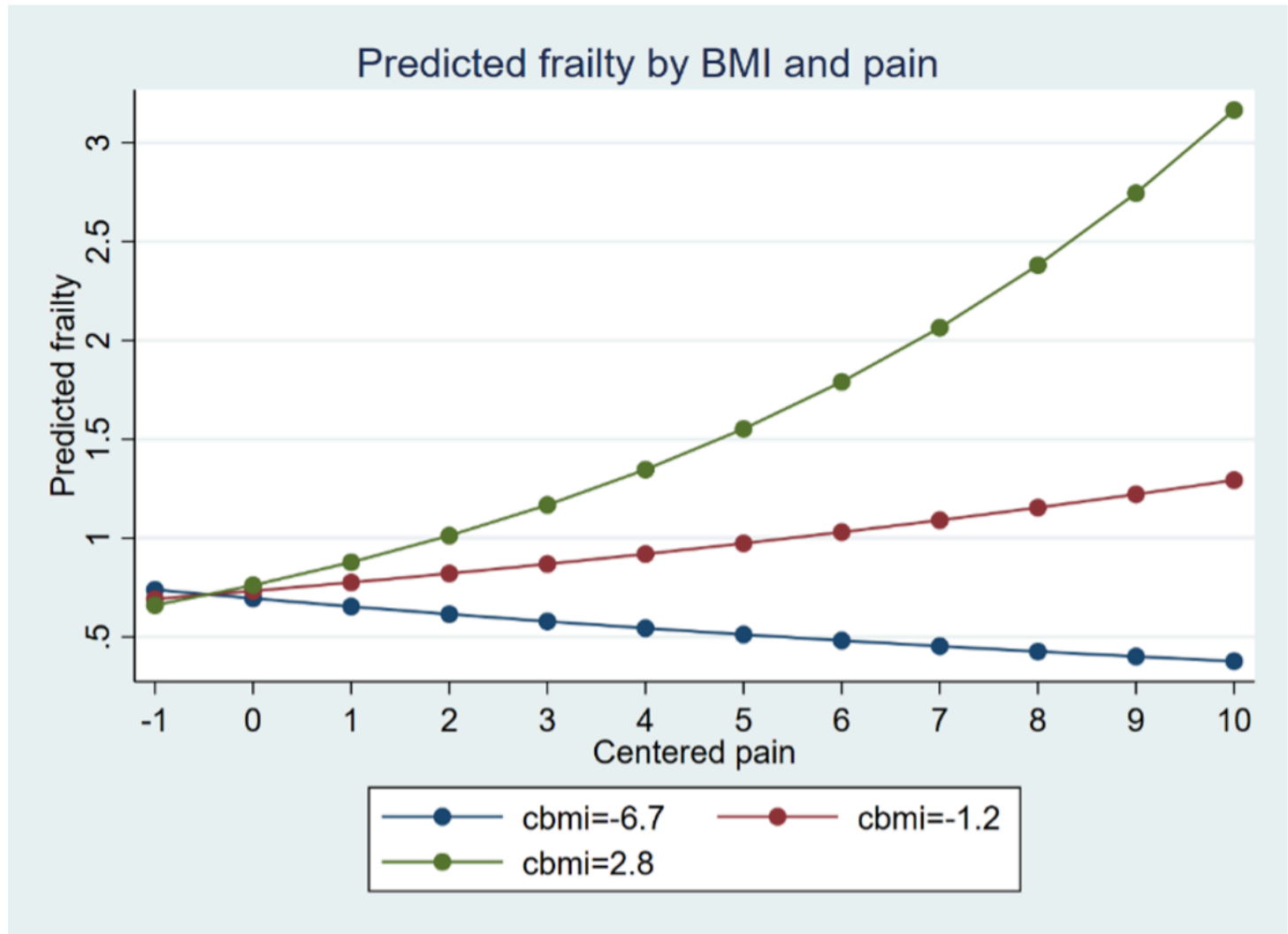


Figure 1

Interaction between pain and BMI on predicted frailty scores

To visually demonstrate the interaction between BMI and pain, we plotted the predicted frailty across pain levels at three BMI values representing the Chinese adult BMI categories: underweight (BMI = 18.5; BMI (centered) = -6.7), normal weight (BMI = 24; BMI (centered) = -1.2), and overweight (BMI = 28; BMI (centered) = 2.8).

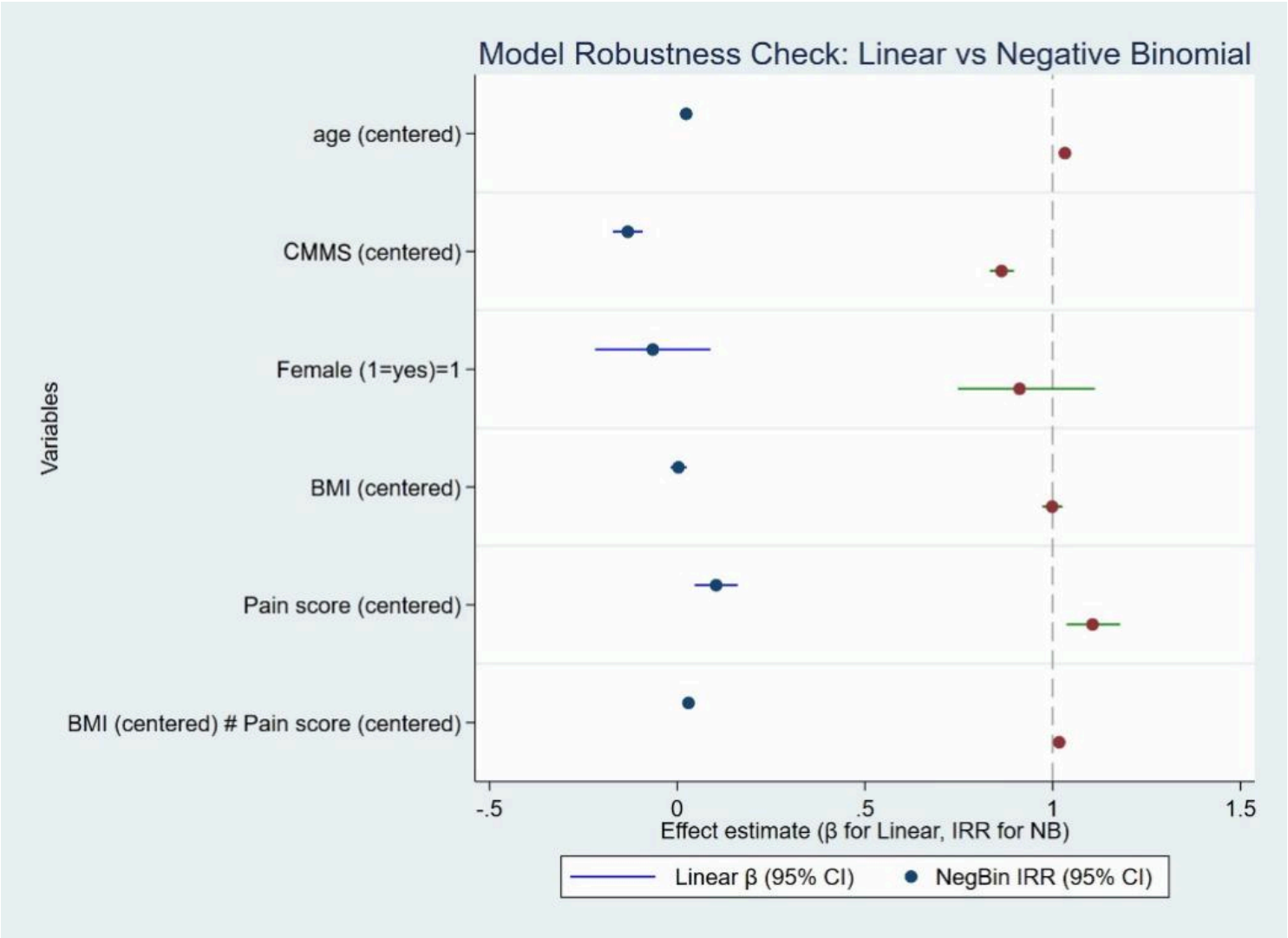


Figure 2

Robustness check of regression models

Robustness comparison between the linear and negative binomial regression models. Across all the key predictors, the direction and magnitude of the effect estimates were highly consistent between the two models. Age and pain remained positive predictors of frailty, whereas cognitive score showed a stable protective effect in both models. The BMI $\times$ pain interaction also showed the same positive trend across models. The overlap of confidence intervals and agreement in the effect direction indicate that the primary conclusions of this study are robust to the model specifications.