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Study on the current status and influencing factors of physical activity in pre-frail rural empty-nest older adults

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Abstract

Objective To evaluate the current status of physical activity and its influencing factors among pre-frail rural empty-nest older adults, and to provide targeted recommendations for improving the quality of life for rural empty-nest older adults.

Methods A purposive sampling method, considering convenience, was used to select participants. Between May and December 2023, a questionnaire survey was conducted among pre-frail rural empty-nest older adults in Chaoyang County, Liaoning Province. The survey included a demographic information form, a lifestyle behavior questionnaire, a nutrition risk assessment scale, and a physical activity scale for the older adults.

Results A total of 522 pre-frail older adults were included in this study. The median score for physical activity was 162.5 (109.0, 229.0), with walking (98.5%) and household physical activities (85.8%) being the predominant forms of activity. Logistic regression analysis revealed that the presence of hypertension ($OR = 1.537$), coronary heart disease ($OR = 1.490$), respiratory diseases ($OR = 1.534$), osteoarthritis ($OR = 1.726$), and malnutrition ($OR = 1.637$) were independent risk factors for low physical activity levels in pre-frail rural empty-nest older adults ($P < 0.05$).

Conclusion Physical activity levels among pre-frail rural empty-nest older adults are low, with walking and household activities being the primary forms of exercise. Community healthcare providers should enhance physical activity management for this population, conduct health education on chronic diseases, help foster healthy eating habits, and prevent the risk of malnutrition. These measures will help improve physical activity levels and potentially delay or even reverse the frailty state.

Clinical trial number Not applicable.

Keywords Physical activity, Pre-frailty, Rural empty-nest older adults, Influencing factors

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Introduction

Frailty is a clinical syndrome characterized by the decline of multiple organ systems, with a marked reduction in physiological reserves and impaired stress response. It is significantly associated with an increased risk of falls, disability, hospitalization, and death [1–2]. The widely used assessment tools include the Fried frailty phenotype (based on five criteria: unintentional weight loss, exhaustion, decreased grip strength, slow walking speed, and low physical activity) and the Frailty Index (FI, based on the cumulative proportion of health deficits) [1, 3]. According to the Fried criteria, 1–2 symptoms indicate pre-frailty, while 3 or more symptoms define frailty [1]. In the FI classification, an FI ≥ 0.25 is frailty, and an FI between 0.12 and 0.25 is pre-frailty [3–4].

The global prevalence of frailty among community-dwelling older adults varies between 4% and 59%, with higher rates in women and a significant increase with age [1]. As one of the fastest-aging countries, China faces a particularly prominent frailty issue. A nationwide cross-sectional study in 2023 ($n = 208{,}386$) reported that the frailty prevalence among individuals aged 60 and older in China was 9.5%, with pre-frailty at 46.1% [4]. However, a longitudinal study based on CHARLS data (2011–2015) found that frailty prevalence among Chinese older adults increased from 18.7 to 28.4% [5], indicating that the frailty problem may worsen with the intensification of aging.

The prevalence of frailty in rural older adults is significantly higher than that in urban areas. A 2023 survey in China showed that the frailty prevalence in rural areas was 10.3% (compared to 8.2% in urban areas), and pre-frailty was 48.7% (compared to 42.3% in urban areas) [4]. This disparity may be attributed to the lack of healthcare resources, insufficient chronic disease management, and lower economic levels in rural areas. Furthermore, the frailty risk for rural "empty-nest" older adults—living alone or with a spouse only, with all adult children residing outside the household for ≥ 6 months annually [6]—is further increased due to limited social engagement [3, 5].

The prevalence of chronic diseases, such as hypertension and arthritis, is higher among rural older adults, and protein deficiency is more common, which is closely related to pre-frailty [3, 5]. The higher physical labor demands in rural areas contribute to a higher incidence of degenerative joint diseases, accelerating the decline in walking speed and grip strength [1–2]. Rural "empty-nest" older adults are more likely to experience social isolation, with loneliness scores significantly higher than those in urban areas ($OR = 1.8$), and low social support is strongly associated with a reduced risk of pre-frailty ($OR = 0.65$) [2, 4]. The proportion of economically disadvantaged older adults in rural areas (32.5%) is twice that in urban areas, and the inconvenience of medical insurance reimbursement further limits their health management behaviors [3–4, 6]. In rural areas, daily physical activity mainly consists of agricultural labor; however, individuals in pre-frailty experience a significant reduction in physical activity due to functional decline, creating a "decreased activity - functional decline" vicious cycle [2–3]. Additionally, the lack of infrastructure (such as accessible facilities) in rural areas increases the risk of falls, and a history of falls is a key predictive factor for the progression of pre-frailty to frailty (HR = 2.1) [2, 5].

Although existing research has revealed urban-rural differences in frailty, most studies have focused on urban or mixed populations, and there is a lack of systematic analysis of pre-frailty in rural "empty-nest" older adults [3–4]. A 2023 meta-analysis that included 64 studies found that only 23% of frailty research in China involved rural areas, and many studies did not distinguish between "empty-nest" and non-empty-nest populations [3]. Furthermore, the role of physical activity as an intervenable factor in rural pre-frailty populations remains unclear. This study aims to evaluate the current status of physical activity and its influencing factors among pre-frail rural empty-nest older adults, and to provide targeted recommendations for improving the quality of life for this population.

Methods

Study design

This was a cross-sectional study conducted from May to December 2023. A purposive sampling method was used, taking convenience into account, to select rural empty-nest older adults in Chaoyang County, Liaoning Province.

Setting

The study was conducted in rural areas of Chaoyang County, Liaoning Province, China. Data collection occurred between May and December 2023. The study involved recruiting participants from this area, with recruitment taking place at local community centers and senior activity centers.

Participants

Eligibility Criteria: The inclusion criteria for participants were: Aged ≥ 60 years by May 2023. Rural household registration and a permanent resident (living for ≥ 6 months), Official rural household registration (hukou) according to the Chinese government's administrative classification system; Permanent residency in a rural area for ≥ 6 months, verified through self-reported residence records and cross-checked with local community registries. Rural areas were defined as townships or villages outside of city districts, consistent with the National Bureau of Statistics of China's criteria [7]. No children or children who are not living with them and visit less than once a week.

Ability to communicate normally and cooperate with the survey (assistance was provided for illiterate participants). Informed consent was obtained, and participation was voluntary. Living alone or only with a spouse. Diagnosed with pre-frailty according to the Fried frailty assessment criteria [8]. As detailed below: (1) Weight loss: a reduction in weight of more than 4.5 kg or 5% of body weight without an obvious cause in the past year; (2) Slower walking speed: the time taken to walk 4.57 m. For men with a height ≤ 173 cm, ≥ 7 s; for men with a height > 173 cm, ≥ 6 s; for women with a height ≤ 159 cm, ≥ 7 s; for women with a height > 159 cm, ≥ 6 s, indicating slower walking speed; (3) Grip strength reduction: measured by the dominant hand using a hand dynamometer (Model: EH101) while seated, arms naturally hanging down, palm facing inward, and the dial facing outward, ensuring no contact with the body or clothing. Each grip test was held for 3 to 5 s, and the reading was taken after stabilizing. The test was repeated three times with a 30-second interval, and the average value was analyzed. Grip strength decline was assessed considering body mass index (BMI) and gender; (4) Reduced physical activity: men with weekly energy expenditure < 382 kcal (approximately equivalent to 2.5 h of walking) or women with weekly energy expenditure < 270 kcal (approximately equivalent to 2 h of walking) were considered to have reduced physical activity; (5) Fatigue: feeling physically weak or lacking motivation to do anything for more than 3 days in the past week. Meeting 1 or 2 of these criteria was classified as "pre-frailty."

Exclusion Criteria: Older adults with severe organic diseases, such as malignant tumors or severe cardiovascular diseases. Older adults with a history or current mental health issues. Older adults living near children who can provide regular care.Non-cooperative participants or those with incomplete or poor-quality questionnaires. A total of 522 pre-frail rural empty-nest older adults were included in the study.

Variables

Outcome variables

Physical Activity: Assessed using the Physical Activity Scale for the Older Adults (PASE). The Chinese version of the PASE questionnaire, translated and validated by Yu Hongjun et al. [9], was used with permission from the original developers (Washburn et al. [10]). The scale consists of 10 items, covering leisure, household, and occupational physical activities. Leisure physical activities include six items: sedentary behavior, walking, light, moderate, vigorous intensity activities, and muscle exercises. Scores for all items, except sedentary behavior (which is not scored), are calculated using the formula: [(number of active days in the past week × average duration of daily activity) / 7 × weight]. Household physical activities include three items: light and heavy household chores, as well as other household tasks. Participants are assigned the corresponding score if they engage in these activities; if not, the score is 0. Occupational physical activities include one item, which pertains to paid labor, farming, or volunteer work. The score for this item is calculated using the formula: [(number of workdays in the past week × average daily work duration) / 7 × weight]. The total score of the scale is the sum of the scores for all items, with a range from 0 to 400 points. A higher score indicates a greater amount of physical activity.The total score from PASE was used to categorize participants into high (≥ 162.5 points) and low (< 162.5 points) physical activity groups [9].

Nutritional status

Evaluated using the Nutritional Risk Screening 2002 (NRS 2002) [11]. The scale includes three dimensions: age score (1 point is added if the age is greater than 70 years), nutrition score (ranging from 0 to 3 points), and disease score (ranging from 0 to 3 points). The total score ranges from 0 to 7 points. A score of ≥ 3 indicates a potential risk of malnutrition [12].

Exposure variables: sociodemographic characteristics

Age was categorized into two groups: 60–75 years and ≥ 75 years. Gender was classified into two groups: male and female. Body Mass Index (BMI) was classified into two groups: <24 and ≥ 24. Education level was segmented into three categories: elementary school and below, junior high school, and high school/junior college. Marital status was categorized into two groups: married and not married. Average monthly household income per capita was categorized into two groups: <5000 yuan and ≥ 5000 yuan. The income threshold of 5,000 yuan was selected based on: China's rural poverty alleviation benchmarks for 2018 [13], where 5,000 yuan per capita monthly income represents the economic vulnerability threshold in rural regions; Alignment with prior studies on geriatric populations to ensure comparability [14].

Health status

Self-reported conditions such as hypertension(no, yes), diabetes(no, yes), coronary heart disease(no, yes), respiratory diseases(no, yes), cerebrovascular diseases(no, yes), malignant tumors(no, yes), and osteoarthritis(no, yes).

Lifestyle behaviors

Smoking(non-smoker, smoking), alcohol consumption(do not drink alcohol, drinking), and sleep patterns(<6, 6–8, ≥ 8) [14].

Health status
Self-reported, verified with medical records when available.

Bias considerations
Efforts to minimize bias included the use of standardized questionnaires and the involvement of trained researchers to ensure consistency and accuracy in data collection. Additionally, participants were given clear instructions to avoid misinterpretation during the survey.

Study size
The sample size was calculated based on the number of independent variables in the study (25 variables). Considering a 20% rate of invalid questionnaires, the estimated minimum sample size was 150–300 [15]. Ultimately, 522 pre-frail rural empty-nest older adults were included, providing sufficient statistical power for analysis.

Data collection procedure
The data were collected on-site by trained researchers who explained the study's purpose to participants and obtained informed consent before administering the survey. Participants were assisted in completing the questionnaire, particularly illiterate individuals, using standardized guiding language. Incomplete questionnaires were considered invalid, and data were cross-checked for accuracy before being entered into the database.

Data analysis
Data analysis was conducted using SPSS version 26.0. Descriptive statistics were used for continuous data with a skewed distribution (median and interquartile range [M (P25, P75)]) and categorical data (frequencies and percentages). Group comparisons were performed using chi-square tests for categorical variables and the Mann-Whitney U test for continuous variables with non-normal distribution. Binary logistic regression was used to identify independent factors associated with lower physical activity levels in pre-frail rural empty-nest older adults. Statistical significance was set at $P<0.05$ for two-sided tests.

Ethical considerations
This research project was approved by the Ethics Committee of Jinzhou Medical University School of Medicine (Approval No.: JZMULL2022017). All participants provided verbal informed consent prior to participation, and the study was conducted in accordance with ethical standards for research involving human participants.

Results
Profile of participants
A total of 522 pre-frail rural empty-nest older adults were included in this study. The mean age was 71 (66, 76) years, with a mean BMI of 24.3 (23.1, 25.5) kg/m². Sociodemographic characteristics, health status, and lifestyle behaviors of the participants are summarized in Table 1. Income Level Criteria: Income was categorized based on the participants' monthly per capita household income. The two groups were: Low income: Monthly per capita income less than 5000 yuan. High income: Monthly per capita income equal to or greater than 5000 yuan.

Physical Activity Level Criteria: Physical activity levels were classified into two categories based on the participants' total physical activity scores and participation in different activity dimensions. The groups were as follows:

High activity level group: Participants who reported engaging in higher levels of physical activity, including regular participation in light, moderate, and heavy household activities, as well as occupational physical activity. The group also demonstrated a greater engagement in leisure activities such as walking and moderate-to-high intensity exercises.

Low activity level group: Participants who reported lower levels of physical activity, with limited engagement in leisure physical activity or high-intensity tasks, and who had lower participation in household and occupational activities.

Univariate analysis revealed significant differences between the high and low physical activity groups in terms of BMI, education level, alcohol consumption, average monthly household income, presence of hypertension, coronary heart disease, respiratory diseases, osteoarthritis, and nutritional status (Table 1).

Physical activity levels in pre-frail rural empty-nest older adults
The physical activity levels of the 522 pre-frail rural empty-nest older adults were generally low. The total physical activity score was [162.5 (109.0, 229.0)], with the following breakdown by activity dimension:

Leisure Physical Activity: The median score was [20.1 (12.1, 28.1)]. The most common activity was walking, with 515 participants (98.5%) engaging in walking. In the high-activity level group, 99.0% of participants engaged in walking, and 98.0% of participants in the low-activity level group did so. However, participation in higher-intensity activities was minimal, with only 31 participants (5.9%) engaging in high-intensity physical activity, 14 participants (2.5%) engaging in moderate-intensity activities, and 37 participants (6.9%) participating in light-intensity activities.

Table 1 Univariate analysis of physical activity levels in Pre-Frail rural Empty-Nest older adults (N, %)

Variable	Overall (*N* = 522) *n* (%)	High activity level group (*N* = 261) *n* (%)	Low activity level group (*N* = 261) *n* (%)	x^2 value	*P* value
Age (years)				1.046	0.306
60–75	349 (66.8)	169 (64.7)	180 (68.9)		
≥ 75	173 (33.2)	92 (35.3)	81 (31.1)		
Gender				0.380	0.538
Male	233 (44.7)	113 (43.2)	120 (46.0)		
Female	289 (55.3)	148 (56.8)	141 (54.0)		
BMI (kg/m^2)				4.745	0.029*
<24	192 (36.8)	84 (32.2)	108 (41.4)		
≥ 24	330 (63.2)	177 (67.8)	153 (58.6)		
Marital status				0.241	0.624
Married	379 (72.6)	192 (73.6)	187 (71.6)		
Not married	143 (27.4)	69 (26.4)	74 (28.4)		
Educational Level				26.324	0.000*
Elementary school and below	156 (29.9)	54 (20.6)	102 (39.1)		
Junior High School	260 (49.8)	157 (60.1)	103 (39.5)		
High School / Junior College	106 (20.3)	50 (19.3)	56 (21.4)		
Smoking status				0.492	0.483
Non-smoker	434 (83.1)	220 (84.3)	214 (81.9)		
Smoking	88 (16.8)	41 (15.7)	47 (18.1)		
Alcohol consumption				18.587	0.000*
Do not drink alcohol	183 (35.1)	68 (26.1)	115 (44.1)		
Drinking	339 (64.9)	193 (73.9)	146 (45.9)		
Average monthly household income per capita				5.770	0.016*
<5000	458 (87.8)	238 (91.2)	220 (84.3)		
≥ 5000	64 (12.2)	23 (8.8)	41 (15.7)		
Length of sleep at night (h)				1.149	0.563
<6	161 (30.8)	76 (29.1)	85 (32.5)		
6–8	156 (29.8)	83 (31.8)	73 (27.9)		
≥ 8	205 (39.4)	102 (39.1)	103 (39.6)		
High blood pressure				5.569	0.018*
No	192 (36.7)	83 (31.8)	109 (41.7)		
Yes	330 (63.3)	178 (68.2)	152 (48.3)		
Diabetes				1.181	0.277
No	194 (37.2)	103 (39.6)	91 (34.9)		
Yes	328 (62.8)	158 (60.4)	170 (65.1)		
Coronary heart disease				10.428	0.001*
No	204 (39.1)	84 (32.2)	120 (45.9)		
Yes	318 (60.9)	177 (67.8)	141 (54.1)		
Respiratory Diseases				9.875	0.002*
No	203 (38.9)	84 (32.2)	119 (45.6)		
Yes	319 (61.1)	177 (67.8)	142 (54.4)		
Cerebrovascular disease				4.601	0.032*
No	171 (32.8)	97 (37.1)	74 (28.4)		
Yes	351 (67.2)	164 (62.9)	187 (71.6)		
Malignant Tumor				2.778	0.096
No	491 (94.1)	250 (95.7)	241 (92.3)		
Yes	31 (5.9)	11 (4.3)	20 (7.7)		
Osteoarthritis				4.077	0.043*
No	113 (21.6)	66 (25.2)	47 (18.0)		
Yes	409 (78.4)	195 (74.8)	214 (82.0)		
Malnutrition				7.507	0.006*

Table 1 (continued)

Variable	Overall (*N* = 522) *n* (%)	High activity level group (*N* = 261) *n* (%)	Low activity level group (*N* = 261) *n* (%)	x^2value	*P* value
No	225 (43.1)	97 (37.1)	128 (49.0)		
Yes	297 (56.9)	164 (62.9)	133 (51.0)		

Note: * represents $P < 0.05$. For the univariate analysis in Table 1, the following criteria were used to distinguish the high and low physical activity levels:

BMI: Body Mass Index. Participants were divided into two categories based on their BMI– those with a BMI below 24 and those with a BMI of 24 or higher

Monthly per capita income: Categorized into two groups based on the monthly income threshold of 5000 yuan

Table 2 Current status of physical activity in Pre-Frail rural Empty-Nest older adults (N, %)

Dimension	Entry	Overall *n* (%)	High activity level group *n* (%)	Low activity level group *n* (%)
Leisurely Physical Activity	Sitting Activity	522 (100)	261 (100)	261 (100)
	Walking activity	515 (98.5)	258 (99.0)	257 (98.0)
	Light physical activity	37 (6.9)	28 (10.8)	9 (2.9)
	Moderate physical activity	14 (2.5)	11 (3.9)	3 (1.0)
	High Intensity Physical Activity	31 (5.9)	26 (9.8)	5 (2.0)
	Muscle building	3 (0.5)	3 (1.0)	0 (0.0)
Domestic Physical Activity	Light Household Activities	448 (85.8)	261 (100)	187 (71.6)
	Heavy Chore Activity	210 (40.2)	190 (72.5)	20 (7.8)
	Other Household Activities	451 (86.3)	261 (100)	190 (72.5)
Occupational physical activity	Occupational Physical Activity	298 (57.1%)	245 (93.8)	53 (20.3)

Domestic Physical Activity: The median score was [139.2 (58.6, 219.8)]. Most participants were involved in light household activities (85.8%) and other household activities (86.3%). However, 40.2% of participants engaged in heavy household tasks. In the high-activity group, all participants (100%) participated in light and other household tasks, and 72.5% engaged in heavy household activities. In contrast, the low-activity group had a significantly lower participation rate, with only 71.6% engaging in light household tasks and 7.8% participating in heavy household chores.

Occupational Physical Activity: The median score was [3.2 (2.6, 3.8)]. Overall, 57.1% of participants engaged in occupational physical activities. Notably, the high-activity level group showed significantly higher engagement in occupational activities (93.8%) compared to the low-activity level group (20.3%). (see Table 2).

Multifactorial analysis of factors affecting physical activity levels in pre-frail rural empty-nest older adults

A binary logistic regression analysis was conducted using the physical activity level of pre-frail rural empty-nest older adults as the dependent variable (with low physical activity assigned a value of 1 and high physical activity assigned a value of 0). The model was adjusted for potential confounding factors including age, gender, marital status, smoking, and sleep patterns. The factors with statistical significance from the univariate analysis were included as independent variables. The results indicated that factors such as the presence of hypertension(*OR*: 1.537; 95% *CI*: 1.010–2.340; $P = 0.044$), coronary heart disease(*OR*: 1.490; 95% *CI*: 1.001–2.218; $P = 0.049$), respiratory diseases(*OR*: 1.534 95% *CI*: 1.036–2.270; $P = 0.032$), osteoarthritis(*OR*: 1.726; 95% *CI*: 1.070–2.784; $P = 0.025$), and malnutrition(*OR*: 1.637; 95% *CI*: 1.111–2.413; $P = 0.013$) were independent factors influencing low physical activity levels in pre-frail rural empty-nest older adults (Table 3).

Discussion

Physical activity levels in pre-frail rural empty-nest older adults

The results of this study showed that the pre-frail rural empty-nest older adults exhibited higher levels of physical activity compared to older adults in previous studies [16], which categorized participants into high and low activity levels. In our study, the majority of participants were likely classified into higher activity levels due to their daily involvement in labor-intensive tasks such as farming and raising poultry. This is consistent with findings from other studies that have highlighted the elevated activity levels of rural older adults due to the nature of their daily lives, where physical labor plays an essential role in maintaining health [17]. For instance, research conducted by Wang Chenchen et al. and Lan Chongling et al. focused on general older adults living in community settings and reported lower physical activity scores, which may be attributed to urban environments where older adults often rely on assistance from their children or community services for daily tasks [18–19]. This discrepancy in activity levels could be explained by the

Table 3 Logistic regression analysis of physical activity levels in Pre-frail rural Empty-nest older adults ($n = 522$)

Independent variable	Assignment of values	B value	SE	Wald x^2 value	*P* value	OR value	95%CI
Constant		-0.478	0.890	0.289	0.591	0.620	
BMI	< 24 = 1,≥24 = 2	0.101	0.210	0.231	0.632	1.105	0.732 ~ 1.668
Education level	Elementary school and below = 1, junior high school = 2, high school/junior college = 3	0.250	0.210	1.417	0.234	1.284	0.852 ~ 1.933
Average monthly household income per capita	< 5000 yuan = 1, ≥5000 yuan = 2	0.180	0.240	0.562	0.453	1.197	0.755 ~ 1.880
Alcohol consumption	Do not drink alcohol = 1,drinking = 2	-0.150	0.210	0.510	0.481	0.860	0.587 ~ 1.265
Hypertension	No = 1, Yes = 2	0.430	0.214	4.019	0.044*	1.537	1.010 ~ 2.340
Coronary heart disease	No = 1, Yes = 2	0.399	0.203	3.860	0.049*	1.490	1.001 ~ 2.218
Respiratory disease	No = 1, Yes = 2	0.428	0.200	4.579	0.032*	1.534	1.036 ~ 2.270
Osteoarthritis	No = 1, Yes = 2	0.546	0.244	5.013	0.025*	1.726	1.070 ~ 2.784
Malnutrition	No = 1, Yes = 2	0.493	0.198	6.199	0.013*	1.637	1.111 ~ 2.413

Note: BMI: Body Mass Index. * represents $P < 0.05$. The model was adjusted for potential confounding factors including age, gender, marital status, smoking, and sleep patterns

differing living environments and the types of daily activities older adults engage in [20].

Additionally, pre-frail older adults, who are often more conscious of their declining health, may be more proactive in engaging in physical activities to prevent further frailty. Studies have shown that pre-frail individuals tend to exhibit stronger health awareness and self-regulation, which can translate into higher activity levels when compared to their frail or robust counterparts [21]. Therefore, when categorizing physical activity into high and low levels, it is important to consider not only the environment but also the individuals' health status, as these factors can significantly influence activity patterns [22].

The results of this study indicate that walking is the most common form of leisure activity among pre-frail rural empty-nest older adults. A total of 98.5% of participants reported engaging in walking, but the participation rate in high-intensity physical activities was very low Previous studies [23] have shown that walking, as a low-intensity activity, is widely favored by older adults, but the participation rate in moderate- and high-intensity activities is low, suggesting that the intensity of physical activity among pre-frail older adults may be insufficient to improve physical function.

Related research indicates that older adults need to engage in at least 100 MET-min of physical activity per day (equivalent to 40 min of low-intensity activity or 25 min of moderate-intensity activity) to significantly improve physical function [24]. However, the participants in this study primarily engaged in low-intensity walking, which may not meet the required exercise dose necessary to achieve significant functional improvements, indicating a severe lack of moderate- and high-intensity activities among pre-frail rural empty-nest older adults, far below the levels required for effective physical improvement.

Regarding household activities, participants showed a strong involvement in light physical tasks and other household chores, although fewer engaged in heavier tasks. The high-activity group demonstrated consistent participation in both light and heavy household activities. On the other hand, the low-activity group showed significantly lower engagement in heavy chores, with a lesser number taking part in lighter tasks as well. These findings align with previous research, which suggests that engaging in household labor significantly reduces the risk of frailty and all-cause mortality among older adults [25–26].

Furthermore, occupational physical activity plays a significant role in the physical activity levels of rural empty-nest older adults. Many participants engage in some form of occupational physical activity, with a higher proportion of individuals in the high-activity group involved in such activities. In rural areas, the living environment and economic pressures often necessitate older adults' continued involvement in agricultural work, which contributes substantially to their overall physical activity levels. This is in contrast to urban settings, where older adults may be less likely to engage in physical labor due to access to community services or assistance from family members, resulting in lower levels of occupational physical activity.

Factors influencing physical activity levels in pre-frail rural empty-nest older adults

The physical activity levels of pre-frail rural empty-nest older adults are influenced by a variety of chronic diseases and physiological pathophysiological factors.

Research indicates that independent risk factors such as hypertension, coronary heart disease, respiratory system diseases, osteoarthritis, and malnutrition significantly reduce the older adults's physical activity levels through mechanisms such as physiological limitations, symptom exacerbation, or psychological barriers [27, 28, 29]. In this section discusses the mechanisms of action of these risk factors and existing research evidence.

Hypertension affects the cardiovascular system over time, increasing the burden on the heart and reducing vascular elasticity, ultimately leading to insufficient blood flow and increased fatigue during exercise. Studies have shown that hypertensive patients, due to an imbalance in myocardial oxygen supply and demand, have significantly lower exercise tolerance compared to healthy individuals. Additionally, comorbidities (such as diabetes and arteriosclerosis) further limit their physical activity capacity [30]. A cohort study on older adults hypertensive patients revealed that the risk of cardiovascular events was 1.8 times higher in the low-activity group compared to the high-activity group, emphasizing the need for exercise interventions [31]. Moreover, cognitive decline in hypertensive individuals may be linked to microvascular damage in the central nervous system, which affects their willingness to engage in physical activity, further exacerbating their activity limitations [32].

Meta-analyses have shown that low-intensity aerobic exercise (e.g., 150 min of walking per week) can effectively reduce systolic blood pressure (with an average decrease of 10.8 mmHg) and diastolic blood pressure (with a decrease of 8.2 mmHg) in hypertensive patients, while being safe [33]. Personalized exercise programs combined with health education have been shown to improve patient adherence and reduce the risk of cardiovascular events [34]. Therefore, implementing targeted exercise interventions not only helps to improve blood pressure control in hypertensive patients but also enhances their quality of life and physical activity capacity.

Coronary artery disease (CAD) limits physical activity due to myocardial ischemia, leading to chest pain (angina) and shortness of breath during exercise. Coronary artery narrowing causes metabolic disturbances that lower the fatigue threshold of muscles, particularly during activities that demand higher oxygen consumption [35]. This phenomenon further exacerbates the physical activity limitations in CAD patients, making them more prone to symptom worsening during exercise. Psychological factors also play a significant role, as many patients avoid exercise due to "cardiac anxiety," fearing that physical activity might worsen their condition. A cross-sectional study found that 45% of CAD patients reduced their daily activities out of concern that exercise could exacerbate their condition [36].

However, cardiac rehabilitation programs, including psychological interventions and progressive aerobic training, have been shown to significantly improve both physical capacity and mental health. Exercise interventions combined with cognitive-behavioral therapy have been reported to increase the 6-minute walking distance by 23% and reduce anxiety scores by 40% in CAD patients [37]. Furthermore, cardiac rehabilitation typically includes both aerobic exercise and resistance training, which not only help improve exercise endurance but also alleviate angina symptoms, enhance overall quality of life, and reduce the risk of cardiovascular events [38–39]. Therefore, implementing personalized exercise interventions combined with psychological support is effective in enhancing both exercise capacity and cardiac health in CAD patients.

Respiratory diseases such as chronic obstructive pulmonary disease (COPD) cause impaired lung ventilation, leading to hypoxia during physical activity. This, in turn, creates a vicious cycle of "breathlessness - reduced activity - functional decline." Research has shown that COPD patients take only 60% of the daily steps compared to healthy age-matched individuals, and their step count correlates positively with forced expiratory volume in one second (FEV1) [40]. Further studies indicate that COPD patients often reduce physical activity to avoid breathlessness, which accelerates disease progression and functional decline.

To break this cycle, recent strategies emphasize combining respiratory rehabilitation training with low-intensity exercise to improve activity levels. A systematic review found that respiratory rehabilitation techniques (such as pursed-lip breathing and diaphragmatic exercises) combined with low-intensity exercises (such as Tai Chi) not only improved lung function in COPD patients but also significantly enhanced their physical endurance. Moreover, within six months, this approach reduced acute exacerbation rates by 32% [41]. Additionally, studies show that increasing moderate exercise helps improve cardiovascular function, reduces respiratory-related complications, and subsequently enhances quality of life and physical endurance in COPD patients [42]. These findings provide a basis for clinical treatment strategies, underscoring the importance of early intervention and ongoing exercise training.

In particular, in managing chronic diseases like COPD, incorporating moderate daily physical activity and personalized rehabilitation programs can effectively delay disease progression and reduce the incidence of hospitalizations and acute exacerbations. Therefore, integrating respiratory training with physical activity interventions has become a key component in COPD treatment.

Osteoarthritis (OA) is characterized by joint pain and stiffness, significantly affecting lower limb function, especially in older adults. Studies show that daily activity levels in patients with knee osteoarthritis decrease by up to 40%, and there is a negative correlation between pain intensity and activity levels [43]. Furthermore, the physical decline caused by OA prevents patients from engaging in routine activities, which exacerbates muscle atrophy and joint degeneration. Effective interventions include low-impact exercises, such as aquatic therapy and resistance training, which help alleviate joint load and enhance muscle strength and stability. Research has shown that a 12-week aquatic exercise intervention can significantly reduce pain by 35% and increase walking speed by 20%, demonstrating the positive functional effects of such activities [44–45]. These findings highlight the therapeutic potential of regular non-weight-bearing activities, such as swimming and cycling, which improve joint flexibility and reduce pain without exacerbating cartilage damage.

Malnutrition, particularly protein deficiency and vitamin D insufficiency, can indirectly impair physical activity capacity by leading to sarcopenia and reduced immune function. Studies have shown that inadequate protein intake (< 0.8 g/kg/d) is significantly associated with decreased grip strength and slower walking speed in older adults, while vitamin D deficiency accelerates bone mineral density loss and increases the risk of falls, further affecting mobility [46]. Interventions combining nutrition and exercise have demonstrated positive outcomes. For example, combining resistance training with the Mediterranean diet (rich in omega-3 fatty acids and antioxidants) can increase muscle mass by 5% and improve 6-minute walking distance by 15%, highlighting the importance of such integrated treatment plans in reversing physical frailty [47]. This approach underscores the importance of combining dietary improvements with physical rehabilitation in treating physical decline.

Comprehensive intervention strategies for pre-frail rural empty-nest older adults

Managing frailty requires a comprehensive, multidisciplinary approach that integrates physical, nutritional, and psychological interventions. Exercise prescriptions tailored to individual health conditions are essential; low-intensity aerobic exercises, such as walking or Tai Chi, combined with resistance training, have been shown to improve physical function and delay the onset of frailty [48]. Nutritional support is equally crucial, as research indicates that dietary interventions focusing on protein, calcium, and vitamin D supplementation can improve musculoskeletal health, slow age-related muscle loss, and ultimately enhance mobility and quality of life [49]. Psychological interventions, particularly cognitive-behavioral therapy (CBT) and group activities, play an important role in alleviating exercise-related anxiety and enhancing self-efficacy, helping older adults continue participating in physical activities [50]. Additionally, optimizing the management of chronic conditions such as hypertension and coronary artery disease through medication and lifestyle interventions can help reduce functional limitations and support greater independence in older adults [50]. Studies have shown that integrated intervention strategies combining exercise, nutrition, and psychological support can increase physical activity levels in older adults by 30-50%, delay the progression of frailty, and improve overall health status [49]. This holistic approach not only ensures higher quality of life and independence for older adults but also reduces the medical burden associated with frailty.

In conclusion, the physical activity of pre-frail rural empty-nest older adults is primarily composed of low-intensity activities such as walking and household tasks, with a notable lack of moderate- and high-intensity activities. This deficiency restricts the potential for improving physical function. Hypertension, coronary heart disease, respiratory diseases, osteoarthritis, and malnutrition are key risk factors that contribute to reduced physical activity levels. To address this, community healthcare providers should focus on promoting moderate- and high-intensity exercises, particularly resistance and muscle-strengthening activities. Personalized exercise plans that consider individual health conditions are crucial for enhancing physical activity. Encouraging continued participation in household labor as a supplement to physical activity is also beneficial for promoting overall health. By targeting these factors with integrated interventions—combining exercise, nutrition, and psychological support—healthcare providers can help delay the progression of frailty and improve the physical well-being of older adults.

Limitations

The study's focus on rural empty-nest older adults from Chaoyang County, Liaoning Province, may limit the generalizability of the findings. Differences in culture, economy, and healthcare conditions across regions could affect the health status of older adults. To enhance representativeness and external validity, future research should expand the sample size to include a broader range of regions, particularly rural areas with varying economic levels and living conditions.

The study used the Fried frailty assessment method to select pre-frail older adults. While this method is widely used, it may not comprehensively capture all aspects of frailty. Frailty can be reflected not only in physical declines, such as reduced mobility and strength, but also in social, cognitive, and psychological factors. Therefore, future studies could include a broader set of criteria to assess frailty, incorporating multiple dimensions of health. Moreover, the exclusion of older adults with severe organic diseases or mental health issues may have led to a sample that does not fully reflect the diversity of frailty experiences. This exclusion could limit the comprehensiveness of the findings and overlook the needs of individuals with more severe health conditions, which may differ from those classified as pre-frail.

This study relied primarily on surveys and self-reports, which may introduce biases such as participant subjectivity, recall bias, or misinterpretation of questions. To improve the accuracy of the data, future research could combine multiple data collection methods, such as cross-validating survey results with medical records or health assessments, and incorporating qualitative methods like interviews and observations. Additionally, some rural older adults, especially those in remote areas, may experience language barriers or cultural differences that affect their understanding and responses to the survey questions. Ensuring that interviewers are properly trained and using appropriate translation or clarification methods will help enhance the quality of the data.

Although the sample size was calculated based on the number of independent variables, the assumption of a 20% invalid questionnaire rate may be too high, particularly in smaller-scale studies, which could lead to an underestimation of the necessary sample size. In practice, factors such as low participant compliance or changes in research conditions may affect the sample quality. Therefore, sample size calculations should account for these real-world factors. Furthermore, while the study had a large sample size, the regional and demographic specificity of the sample may limit the external validity of the findings. Future studies should explicitly address the limitations of the sample and avoid overgeneralizing the results.

Another limitation of this study is the potential influence of confounding factors, which were not fully accounted for in the analysis. While several significant health-related factors were included as independent variables, other variables that could also affect physical activity levels, such as psychological factors, environmental influences, and socio-economic factors, were not adjusted for. The lack of control for these confounding variables may have introduced bias, affecting the interpretation of the relationships between the health conditions and physical activity levels. Future studies should aim to incorporate these additional confounding factors in their models to provide a more accurate and comprehensive understanding of the factors influencing physical activity in older adults.

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Author contributions
Conceived and designed the research: Z-q J. Wrote the paper: Z-q J. Analyzed the data: Z-q J, Q S, Z-x X, M-y Z, X-y Z, T L, S-x Z.Revised the paper: Z-q J, S-n S. All authors reviewed the manuscript.

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Data availability
The datasets used and analyzed during the current study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
This study was approved by the Medical Ethics Committee of Jinzhou Medical University (approval number JZMULL2022017), and written informed consent was obtained from all participants. All methods were performed by the Declaration of Helsinki.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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