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SIMPLE PHYSICAL ACTIVITY INDEX PREDICTS PROGNOSIS IN OLDER ADULTS: BEIJING LONGITUDINAL STUDY OF AGING

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Abstract: *Objective*: Frailty, which involves low physical activity (PA), is as a well-established factor of increased risk of hospitalization, disability, and mortality. To date, there are no specific tools to assess PA among Chinese elderly. As part of the Beijing Longitudinal Study of Aging (BLSA), we aimed to develop the BLSA Leisure-Time Physical Activity Questionnaire (BLSA-PAQ) and assess its prediction of mortality. *Design:* Longitudinal study. *Setting:* Community. *Participants:* 1810 Chinese older adults completed the BLSA-PAQ questionnaire. *Measurements:* BLSA-PAQ questionnaire containing four items: walking, outdoor chores, low-intensity exercise, and moderate-intensity exercise. Physical function was assessed through the balance test, chair-stand test, and the activities of daily living (ADL), and instrumental activities of daily living (IADL). Frailty was evaluated using a modified frailty phenotype and frailty index. *Results:* The following equation was obtained based on the 8-year mortality for the four BLSA-PAQ components: BLSA-PAQ index (BLSA-PAQ total score) = Walking score + Outdoor chores score + 2 × (low-intensity exercise score) + 3 × (moderate-intensity exercise score). The BLSA-PAQ index decreased with age, and was negatively related to modified frailty phenotype score and frailty index. Low PA and pre-low PA statuses were associated with poorer results in the balance and chair-stand tests, ADL dependency, IADL dependency, and frailty. After adjusting for age and gender, the 8-year mortality HRs were 1.453 (95% CI, 1.166-1.811) and 2.358 (95% CI, 1.856-2.995) for low PA and pre-low PA, respectively. Low PA defined by the BLSA-PAQ index was associated with frailty, disability, worse physical function, and higher mortality. *Conclusion:* The BLSA-PAQ seems to be a reliable tool to measure PA in Chinese older adults. Further studies are needed to confirm these findings and validate the use of the BLSA-PAQ for frailty assessments of older adults.

Key words: Physical activity, mortality, physical function, frailty, age.

Introduction

The increasing number of elderly persons in China poses a significant public health challenge. Frailty is one of the most significant clinical conditions affecting older adults, with an estimated prevalence of 7.0-18.6% in the elderly Chinese population according to our previous studies, i.e., the Beijing Longitudinal Study of Aging (BLSA) (1, 2), BLSA II (3), and China Comprehensive Geriatric Assessment Study (4), as well as other research (5); furthermore, frailty has been shown to increase the risk of mortality (1). Consequently, the clinical identification of frailty may play an important role in the development of preventive strategies against age-related conditions.

Frailty is a syndrome characterized by reduced homeostatic reserves and ability to cope with stressors (6). To transfer the theoretical concept of frailty into clinical practice, several operational definitions have been proposed (7). The best-known tool is the Fried phenotype model (8), which has been operationally defined by the presentation of three or more of the following features: low physical activity (PA), weight loss, fatigue, slow gait speed, and weakness. PA is a very challenging point in relation to the definition of phenotypic frailty (9) because it is affected by the different cultures and life styles of people. Despite the fact that frailty screening tools can effectively identify patients at highest risk for adverse outcomes, few if any specific PA questionnaires exist for Chinese older adults.

PA is particularly critical for elderly persons, with physical inactivity being the fourth leading risk factor contributing to death and burden of disease (10). Inadequate PA not only increases the risk of chronic diseases, but also progressively compromises the ability to live independently (11). Daily PA was associated with higher quality of life in pre-frail and frail community-dwelling older adults (12), even midlife PA was shown to have a strong protective effect in relation to later-life mortality (13–16), and higher midlife PA was strongly associated with less frailty in old age (17). A short questionnaire was validated using an accelerometer and showed adequate reliability with Spanish older adults (18). Subjective PA questionnaires are inexpensive, easy to administer to large groups, and allow both quantitative and qualitative data to be collected, representing the most convenient means of evaluating PA in epidemiological studies (19). Frailty is more strongly associated with self-reported functional decline than with performance decline in older adults (20), and self-

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reported physical function was found to predict postoperative complications slightly better than did the frailty phenotype in older persons in USA (21). We currently still lack valid methods to measure PA for frailty in China, which could predict adverse health outcomes that hamper well-being, especially when low PA is the main contributing factor of the frailty phenotype to disability (22). Moreover, most of this kind of instruments are designed and validated with European and USA populations, making their specific validation with Chinese elderly necessary. Thus, the purpose of the present study was to determine whether our self-developed PA questionnaire, the BLSA Leisure-Time Physical Activity Questionnaire (BLSA-PAQ), was associated with physical function and examine its prediction of mortality.

Methods

Participants

The study sample was derived from the BLSA. Complete details concerning the BLSA have been described elsewhere (23, 24). Briefly, a random selection method with clustering and stratification was used to conduct a cross-sectional survey in 2004 (1, 25). 1865 community-dwelling older adults were selected, of whom 1810 completed the BLSA-PAQ and were followed up for 8 years. Demographic variables including age, gender, and residential area were collected. This study was approved by the ethics committee of Xuanwu Hospital, Capital Medical University, and informed consent was obtained from the participants.

BLSA-PAQ

PA was assessed using the BLSA-PAQ, which contains the following four items: walking, outdoor chores, low-intensity exercise, and moderate-intensity exercise (Table 1). Low-intensity exercise involved Tai Chi, qigong, yoga, fencing, and martial arts, and moderate-intensity exercise included dancing, bowling, golf, swimming, tennis, soccer, basketball, pingpang, running, and climbing. A total of 20 minutes/week was equal to 1 time/week. The frequency of each component of the BLSA-PAQ was rated using four levels: never (score = 0), <1 time/week (score = 1), 1-3 times/week (score = 2), and ≥4 times/week (score = 3).

Evaluation of physical frailty

Physical frailty was assessed using the modified Fried frailty phenotype and frailty index (FI). The Frailty Screening Questionnaire (FSQ) with four self-reported components (slowness, weakness, inactivity, and exhaustion) based on modified Fried criteria was used to measure the frailty phenotype (unpublished). A score of 0 was considered robust; 1-2 was considered pre-frail; and ≥3 indicated frail. FI was measured using 68 parameters, of which details were published elsewhere (1, 4). Frailty was indicated by FI ≥0.25 (3, 26).

Table 1
BLSA Leisure-Time Physical Activity Questionnaire items

Item	Component	Definition
1	Walking	Walking for exercise
2	Outdoor chores	Garden
3	Low-intensity exercise	Tai Chi, qigong, yoga, fencing, and martial arts
4	Moderate-intensity exercise	Dancing, bowling, golf, swimming, tennis, soccer, basketball, pingpang, running, and climbing

Evaluation of physical performance

We assessed physical function by means of the balance test, chair-stand test, Activities of daily living (ADL), and instrumental activities of daily living (IADL). The balance test comprises four parts: standing unsupported for 10 seconds with the feet together; a semi-tandem stand; full-tandem stand; and standing unsupported for 10 seconds with the feet together and eyes closed. We considered that subjects who were unable to complete the four tests had failed the balance test. The chair-stand test was performed with the subject seated in a chair, with the feet flat on the floor and arms held flat against their side with the elbows at 90°. We considered that subjects who were unable to stand five times stand from the chair had failed the test. ADL and IADL were each assessed in terms of 14 items; the performance of each activity was rated as being performed independently (score of 1), partially dependently (score of 2), or completely dependently (score of 3). ADL consisted of eating, bathing, dressing, toileting, indoor walking, and getting in and out of bed. IADL consisted of shopping, phone calls, housekeeping, laundry, money management, medication, and transportation.

Statistical methods

Data analysis was performed using SPSS 11.5 (SPSS, Inc., Chicago, IL, USA). Chi-square tests were conducted for discrete variables, and analysis of variance was used to compare group means for continuous variables, with Tukey post hoc tests. Spearman correlation coefficients were calculated for the relationship of BLSA-PAQ score with age, FSQ score, and FI. A Cox proportional hazards model was used to evaluate the effect of covariates on mortality. We considered $p < 0.05$ (two-tailed) statistically significant.

Results

Demographic characteristics of baseline sample

A total of 1810 Beijing community-dwellers aged ≥60 years were included in this study in 2004. There were 871 (48.1%) men and 939 (51.9%) women; 967 (53.4%) lived in rural areas and 843 (46.6%) in urban areas; the age range was 60-100

Table 2
Predictive models of 8-year mortality of each component of BLSA-PAQ

Variables	Model 1			Model 2			Weights
	HR	95% CI	P value	HR	95% CI	P value	
Gender							/
Male	/			Ref			
Female	/			1.363	1.163-1.596	<0.001	
Age	/			1.088	1.077-1.100	<0.001	/
Walking							
Yes	Ref			Ref			
No	1.948	1.664-2.281	<0.001	1.596	1.357-1.877	<0.001	1
Outdoor chores							
Yes	Ref			Ref			
No	1.587	1.332-1.890	<0.001	1.252	1.049-1.496	0.013	1
Low-intensity exercise							
Yes	Ref			Ref			
No	2.513	1.684-3.748	<0.001	1.968	1.313-2.949	0.001	2
Moderate-intensity exercise							
Yes	Ref			Ref			
No	5.063	1.628-15.741	0.005	3.190	1.024-9.938	0.045	3

Model 1: Unadjusted Cox proportional hazard analysis; Model 2: Adjusted Cox proportional hazard analysis. Adjusted by age and sex; Abbreviations: HR, hazard ratio.

(74.51 ± 7.20) years. As for the BLSA-PAQ, the percentages of those answering "never" to walking, outdoor chores, low-intensity exercise, and moderate-intensity exercise were 31%, 64.9%, 91.7%, and 98%, respectively. The total number of deaths by 2012 was 632 (34.9%).

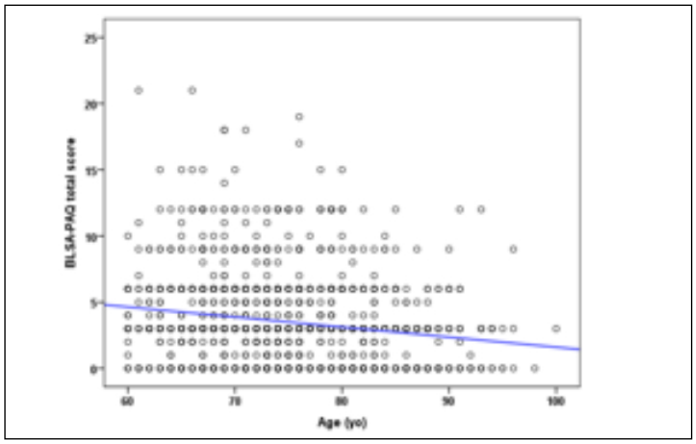
Calculation of BLSA-PAQ index

We used the Cox proportional hazard model to assess the predictive validity of each component of the BLSA-PAQ. Never engaging in walking for exercise, outdoor chores, low-intensity exercise, and moderate-intensity exercise significantly predicted 8-year mortality [hazard ratios (HRs, 95% CI): 1.948 (1.664-2.281), 1.587 (1.332-1.890), 2.513 (1.684-3.748), and 5.063 (1.628-15.741), respectively]. After adjusting for age and gender, the 8-year mortality HRs (95% CI) were 1.596 (1.357-1.877), 1.252 (1.049-1.496), 1.968 (1.313-2.949), and 3.190 (1.024-9.938), respectively. Among the BLSA-PAQ components, moderate-intensity exercise was the strongest predictor before and after adjustment but with a higher p-value (Table 2). Weights for combing the four components to generate a PA index, the BLSA-PAQ index, were obtained according to the HRs adjusting for age and gender (Table 2), and the following equation was obtained: BLSA-PAQ index (BLSA-PAQ total score) = Walking score + Outdoor chores score + 2 × (low-intensity exercise score) + 3 × (moderate-intensity exercise score).

BLSA-PAQ index was negatively associated with age and frailty

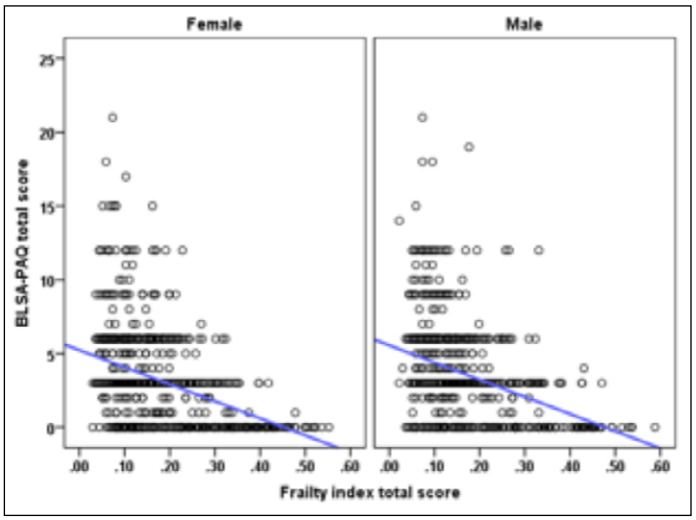
Figure 1 shows the relationship between BLSA-PAQ total score and age for all study participants; BLSA-PAQ total scores decreased with age (r = -0.190, p <0.001). The BLSA-PAQ total score was negatively associated with FI (r = -0.369, p <0.001) (Figure 2), and FSQ score (r = -0.457, p <0.001) (Figure 3), in males and females.

Figure 1
Correlation with BLSA-PAQ total score and age



Analysis of the correlation between BLSA-PAQ total score and age among the 1810 participants, analyzed by the Spearman rank correlation. BLSA-PAQ, Beijing Longitudinal Study of Aging leisure-Time Physical Activity Questionnaire.

Figure 2
Correlation with BLSA-PAQ total score and frailty index total score



Analysis of the correlation between correlation between BLSA-PAQ total score and FI total score in male and female, analyzed by the Spearman rank correlation. BLSA-PAQ, Beijing Longitudinal Study of Aging leisure-Time Physical Activity Questionnaire; FI, frailty index.

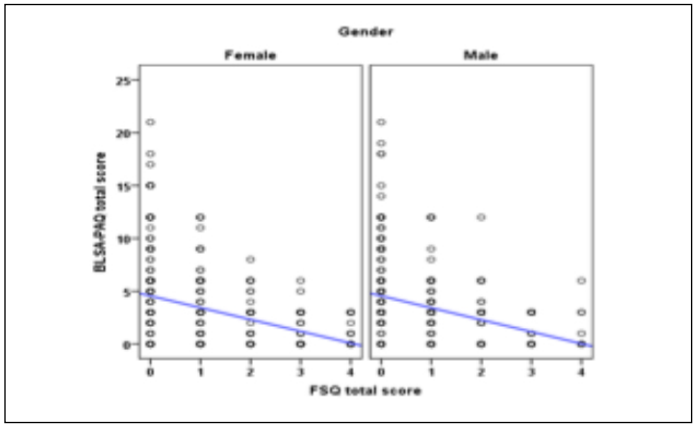
BLSA-PAQ index could predict 8-year mortality

We divided the study sample into three groups according to the higher and lower quartiles of the BLSA-PAQ index: low PA group (n = 394, 21.8%), pre-low PA group (n = 939, 51.9%), and normal group (n = 477, 26.4%). The 8-year mortality HRs were 1.307-2.026 and 2.406-3.837 for the low PA and pre-low PA groups, respectively (all p <0.001; Table 3, Model 1). After adjusting for age and gender, the 8-year mortality HRs were 1.166-1.811 and 1.856-2.995 for low PA and pre-low PA, respectively (all p <0.01; Table 3, Model 2). We further evaluated the mortality effect of the BLSA-PAQ index across different age strata. As indicated in Table 4, the predictive association of low PA with mortality was significant in urban and rural areas, and young and older age, for both genders (all p <0.01); while the predictive association of pre-low PA with mortality was significant only in older males (HR = 1.015-2.053) and rural females (HR = 1.260-3.417).

BLSA-PAQ index was associated with physical function

Compared with normal PA, low and pre-low PA statuses were associated with poorer results in the balance and chair-stand tests, ADL dependency, IADL dependency, and frailty. We found this was the case even after adjustment for gender (except for balance test failure in females) (Table 5).

Figure 3
Correlation with BLSA-PAQ total score and FSQ total score



Analysis of the correlation between correlation between BLSA-PAQ total score and FSQ total score in male and female, analyzed by the Spearman rank correlation. BLSA-PAQ, Beijing Longitudinal Study of Aging leisure-Time Physical Activity Questionnaire; FSQ, frailty screening questionnaire.

Table 3
Predictive models of 8-year mortality of BLSA-PAQ index

Variables	Model 1			Model 2		
	HR	95% CI	P value	HR	95% CI	P value
Gender						
Male	/			Ref		
Female	/			1.340	1.144-1.569	<0.001
Age	/			1.089	1.077-1.100	<0.001
PAQ 3 group						
Normal	Ref			Ref		
Pre-low PA	1.627	1.307-2.026	<0.001	1.453	1.166-1.811	0.001
Low PA	3.038	2.406-3.837	<0.001	2.358	1.856-2.995	<0.001

Model 1: Unadjusted Cox proportional hazard analysis; Model 2: Adjusted Cox proportional hazard analysis. Adjusted by age and sex; Abbreviations: PA, physical activity; HR, hazard ratio.

Table 4
Mortality effect of the BLSA-PAQ index across different gender strata

	Male		Female	
	HR	**95% CI**	**HR**	**95% CI**
Living area				
Urban				
Normal	Ref		Ref	
Pre-low PA	1.078	0.665-1.747	1.274	0.755-2.148
Low PA	3.006	1.752-5.159**	2.838	1.581-5.095**
Rural				
Normal	Ref			
Pre-low PA	1.371	0.958-1.963	2.075	1.260-3.417**
Low PA	1.939	1.307-2.876**	3.341	2.016-5.537**
Age (yo)				
60-74				
Normal	Ref		Ref	Ref
Pre-low PA	1.413	0.877-2.277	1.611	0.928-2.799
Low PA	2.339	1.350-4.055**	3.066	1.664-5.650**
75-100				
Normal	Ref			
Pre-low PA	1.444	1.015-2.053*	1.476	0.933-2.337
Low PA	2.657	1.807-3.907**	2.415	1.516-3.849**

*P<0.05, **P<0.01; Abbreviation: PA, physical activity; BLSA-PAQ, Beijing Longitudinal Study of Aging leisure-Time Physical Activity Questionnaire.

Discussion

This study revealed that low PA defined by BLSA-PAQ index was associated with frailty, disability, worse physical function, and higher risk of mortality, which is consistent with previous studies in other countries (27). PA is a major contributor to healthy aging (28), and increasing PA has a positive influence on health outcomes, such as reducing frailty, especially in patients at higher risk of disability (29), and lowering the risk of mortality (27). A meta-analysis showed that exercise is beneficial to improve walking speed, balance, and ADL performance in frail older adults (30).

Although moderate intensity exercise had the highest weight in our PA index equation, older adults spent limited time engaging in moderate-intensity exercise, whereas a considerable amount of time was spent in light activities (walking and outdoor chores). Low-intensity exercise such as Tai Chi, qigong, yoga, fencing, and martial arts had a higher weight than did light activities. Although PA decreases with age (31), maintenance of PA might be critical for preventing physical decline. Light activities require no specific skills and can be easily integrated into daily life among older adults. Our results emphasize the need for interventions aimed at stimulating healthy PA levels in older adults, especially low- or moderate-intensity exercise.

This study provides evidence that a self-reported questionnaire is a reliable method to assess PA. Previously, self-reported questionnaires were found to be well suited for large population-based samples but not appropriate for individual older adults (32). Another study showed that self-report questionnaires generally exhibited good test-retest reliability, but were not suitable for those elderly persons with eyesight, hearing, mood, or memory problems; moreover, an intermediate phenotype has been proposed to represent patients who meet the self-report-based but not the performance-based measurement (33–35). Furthermore, many individuals tend to overestimate their PA level (36), and the validity of a PA scale was found to differ by key socio-demographic characteristics among Danish adults (37). Moreover, the limitation of recall bias indicates that more large-scale population-based studies investigating PA objectively are needed to adequately inform public health policy (34).

While most previous studies recorded the exact time spent on PA, we did not collect this information, since it was unlikely for respondents to accurately recall and mentally calculate average durations of their PA. The overestimation of PA levels may lead to an underestimation of the benefits of PA among older adults (38). Our PA questionnaire included rough frequency categories, and we calculated a PA index according to the weighted scores of each component; thus, our method might have the advantage of minimizing the overestimation bias of self-reported PA. As an attempt to potentially integrate the BLSA-PAQ into the frailty construct, we examined the relationship between BLSA-PAQ and frailty scores, and our results revealed that the modified frailty phenotype score and frailty index were negatively correlated with the BLSA-PAQ index. As far as we know, there is limited comparable population-based information on the relationship between PA and frailty, and no studies assessing a weighted PA score could be found.

This study has several limitations. Firstly, an objective measure of PA using an accelerometer was not included, and the total volume of activity performed throughout the day was thus not measured. However, there are inconsistencies reported between accelerometer-based and self-report measures. It is worth noting that previous accelerometer-based studies with older adults reported much lower compliance with WHO recommendations regarding PA than did those using self-report measures (34). Further longitudinal studies with objective PA measures as well as reliability and validity studies need to be conducted to further validate our tool and confirm our findings. Secondly, we did not examine the correlation of PA with grip strength or walking speed. Nevertheless, we identified a correlation between PA and frailty, with PA being negatively associated with frailty phenotype and index, which provides strong evidence that the BLSA-PAQ might be used in the frailty construct. Thirdly, the dynamic characteristics of PA were not considered. Assessing PA levels and physical performance at several time points could provide more robust evidence on

Table 5
Characteristics of physical functions in different PA group according to BLSA-PAQ

	Normal, n (%)	Pre-low PA, n (%)	Low PA, n (%)	X^2	P
Balance test failure					
Total	42(9.9)	93(12.7)	31(17.2)	6.271	0.043
Male	14(6.2)	36(9.7)	14(16.1)	7.437	0.024
Female	28(14.3)	57(15.6)	17(18.3)	0.765	0.682
Chair stand test failure					
Total	50(10.6)	202(22.0)	171(49.1)	166.839	<0.001
Male	14(5.7)	89(19.7)	61(42.1)	76.726	<0.001
Female	36(16.0)	113(24.1)	110(54.2)	86.533	<0.001
ADL dependency					
Total	9(1.9)	72(7.7)	133(33.8)	242.286	<0.001
Male	5(2.0)	36(7.9)	58(34.7)	117.352	<0.001
Female	4(1.7)	36(7.5)	75(33.0)	124.984	<0.001
IADL dependency					
Total	102(21.4)	377(40.3)	265(67.4)	188.662	<0.001
Male	43(17.5)	155(34.0)	97(58.4)	74.097	<0.001
Female	59(25.7)	222(46.3)	168(74.0)	108.071	<0.001
Frailty by FI [a]					
Total	18(3.8)	106(11.4)	171(44.5)	291.548	<0.001
Male	12(4.9)	44(9.7)	72(43.9)	138.121	<0.001
Female	6(2.6)	62(13.0)	99(45.0)	152.634	<0.001
Frailty by FSQ [b]					
Total	2(0.4)	72(7.8)	120(36.0)	270.983	<0.001
Male	1(0.4)	26(5.8)	34(24.3)	78.489	<0.001
Female	1(0.4)	46(9.8)	86(44.6)	180.042	<0.001

a: Frailty defined by 68-item frailty index (FI); b: Frailty defined by modified Fried frailty phenotype – frailty screening questionnaire (FSQ); Abbreviations: PA, physical activity; ADL, activities of daily living; IADL, instrumental activities of Daily Living.

causal roles. Lastly, our study did not capture information on interventions that might lead to improvements in health status and could thus lead to an overestimation of the effect of PA on mortality.

Despite these limitations, this study has several important strengths. Firstly, our BLSA-PAQ tool, including information on PA type and frequency, is the only PA tool designed specifically for Chinese elderly, and the BLSA-PAQ index developed in this study provides an easy and reliable method for frailty phenotype assessment and exploration of the impact of PA on frailty and mortality in China. Secondly, the large sample size and high follow-up rates enhanced the generalizability of the results. Accurate assessment of PA levels is essential to identify those individuals who may benefit from an intervention, and misclassification can bias research results and conclusions. Our study is large-scale and population-based, thus decreasing bias compared to other previous studies with very small sample size. Thirdly, a major strength of our study was the inclusion of very old community-dwelling pre-frail and frail individuals, while previous studies on PA mostly included young adults, and specific cut-off values were needed for older adults (35). Our results provide a cut-off value with a large Chinese sample of elderly persons, and a weighted PA score is proposed for the first time. In addition, we adopted a standardized battery of physical performance tests, including balance and chair-stand tests, ADL, and IADL, with well-known predictive ability for adverse health outcomes in older adults.

Conclusions

This longitudinal study of Chinese community-dwelling older adults involving 8 years of follow-up indicated that the BLSA-PAQ had adequate reliability for assessing PA and predicting mortality. We provided evidence that shorter and easy-to-administer PA questionnaires, such as the BLSA-PAQ,

are suitable for large epidemiologic studies, and specifically for Chinese elderly populations. To the best of our knowledge, this is the first study to examine the role of PA in the prediction of mortality in Chinese older adults. Our study also indicates that increasing PA might be an important approach to reduce mortality among older persons. Further longitudinal studies including objective measures of PA are necessary to confirm these results.

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Conflict of interest: None.

Ethical standard: The present study followed the ethical guideline of the Declaration of Helsinki and was approved by the Ethics Committee.

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