Association Between Physical Activity and All-Cause Mortality in Chinese Middle-Aged and Older Adults: A Prospective Cohort Study Postprint

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Abstract

Background Physical inactivity is one of the most important public health problems of the 21st century. Studies have found an association between physical activity and mortality, and the impact of physical activity on mortality risk has attracted considerable attention in recent years. However, there have been few research reports on the relationship between physical activity and all-cause mortality risk in different populations. Objective To investigate the relationship between physical activity and all-cause mortality risk among middle-aged and elderly people (aged 45 years and above) in China. Methods Based on data from the China Health and Retirement Longitudinal Study (CHARLS) 2011-2018, 2,799 middle-aged and elderly individuals from the 2011 baseline population were extracted from CHARLS on September 10, 2022, as study subjects. Baseline data including demographic variables, lifestyle variables, and number of chronic diseases were collected. Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ): low-level physical activity [3,000 METs/week). The follow-up period was from 2011 to 2018, with data from 2013, 2015, and 2018 selected for tracking follow-up. The endpoint event was all-cause mortality. Based on the survival status of subjects, they were divided into a survival group (n=2,424) and an all-cause mortality group (n=375). Cox proportional hazards regression models were used to analyze the relationship between physical activity levels and all-cause mortality risk among middle-aged and elderly people, with sensitivity analysis and stratified analysis conducted. Results During the 7-year follow-up of 2,799 middle-aged and elderly individuals, there were 375 cases of all-cause mortality, with an incidence rate of 13.40%. Comparisons between the survival group and the all-cause mortality group showed statistically significant differences in physi-

cal activity level, gender, age, marital status, education level, ADL limitation status, BMI, smoking status, drinking status, and number of chronic diseases (P<0.05). After adjusting for confounding factors, multivariate Cox proportional hazards regression analysis results showed that, compared with low-level physical activity, the all-cause mortality risk was reduced by 43% [HR=0.57, 95%CI (0.44, 0.75), P<0.001] and 64% [HR=0.36, 95%CI (0.27, 0.48), P<0.001] for moderate and high-level physical activity groups, respectively. Two sensitivity analyses both showed that, compared with low-level physical activity, the all-cause mortality risk was reduced in moderate and high-level physical activity groups (P<0.001), indicating robust results. Stratified analysis results showed that moderate-level physical activity could reduce all-cause mortality risk by 50% [HR=0.50, 95%CI (0.33, 0.26), P<0.001] in the 60-74 age group and by 51% [HR=0.49, 95%CI (0.33, 0.73), P<0.001] in the normal BMI group; high-level physical activity could reduce all-cause mortality risk by 74% [HR=0.26, 95%CI (0.14, 0.47), P<0.001] and 65% [HR=0.35, 95%CI (0.24, 0.51), P<0.001] in the 45-59 and 60-74 age groups, respectively, and by 71% [HR=0.29, 95%CI (0.20, 0.43), P<0.001] and 64% [HR=0.36, 95%CI (0.22, 0.59), P<0.001] in normal BMI and overweight/obese groups, respectively. Conclusion Both moderate and high-level physical activity can reduce all-cause mortality risk among middle-aged and elderly people, with high-level physical activity showing more pronounced effects. From the perspective of reducing all-cause mortality risk, high-level physical activity is appropriate for the 45-59 age group and overweight/obese individuals; both moderate and high-level physical activity can benefit the 60-74 age group and those with normal BMI; for individuals aged $ $75 years and underweight individuals, there is insufficient evidence to form clear recommendations, and choices should be made based on individual specific circumstances.

Full Text

Abstract

Background: Insufficient physical activity represents one of the most critical public health challenges of the 21st century. While studies have established an association between physical activity and mortality, and the impact of physical activity on mortality risk has garnered substantial attention in recent years, few studies have specifically examined the relationship between physical activity and all-cause mortality risk across different populations.

Objective: To investigate the relationship between physical activity and all-cause mortality risk among middle-aged and elderly adults (aged 45 years and above) in China.

Methods: Based on data from the China Health and Retirement Longitudinal Study (CHARLS) spanning 2011–2018, we extracted 2,799 middle-aged and elderly adults from the 2011 baseline population on September 10, 2022. Baseline data including demographic variables, lifestyle factors, and number of

chronic diseases were collected. Physical activity levels were assessed using the International Physical Activity Questionnaire (IPAQ) and categorized as: low-level physical activity (<600 metabolic equivalents [METs]/week), moderate-level physical activity (600–3,000 METs/week), and high-level physical activity (>3,000 METs/week). Follow-up was conducted from 2011 to 2018 using data from 2013, 2015, and 2018, with all-cause death as the endpoint event. Participants were divided into a survival group (n=2,424) and an all-cause death group (n=375) based on their survival status. Cox proportional hazard regression models were employed to analyze the relationship between physical activity levels and all-cause mortality risk, with sensitivity and stratified analyses performed.

Results: During the 7-year follow-up period, 375 all-cause deaths occurred among the 2,799 participants, yielding an all-cause mortality incidence of 13.40%. Statistically significant differences between the survival and all-cause death groups were observed in physical activity level, gender, age, marital status, education level, activities of daily living (ADL) limitations, BMI, smoking status, alcohol consumption, and number of chronic diseases (P<0.05). After adjusting for confounding factors, multivariate Cox proportional hazard regression analysis revealed that, compared with low-level physical activity, moderate and high-level physical activity reduced all-cause mortality risk by 43% [HR=0.57, 95%CI (0.44, 0.75), P<0.001] and 64% [HR=0.36, 95%CI (0.27, 0.48), P<0.001], respectively. Both sensitivity analyses confirmed that moderate and high-level physical activity were associated with reduced all-cause mortality risk compared with low-level activity (P<0.001), demonstrating robust results. Stratified analysis showed that moderate-level physical activity reduced all-cause mortality risk by 50% [HR=0.50, 95%CI (0.33, 0.76), P<0.001] among individuals aged 60–74 years and by 51% [HR=0.49, 95%CI (0.33, 0.73), P<0.001] among those with normal BMI. High-level physical activity reduced all-cause mortality risk by 74% [HR=0.26, 95%CI (0.14, 0.47), P<0.001] and 65% [HR=0.35, 95%CI (0.24, 0.51), P<0.001] among individuals aged 45–59 and 60–74 years, respectively, and by 71% [HR=0.29, 95%CI (0.20, 0.43), P<0.001] and 64% [HR=0.36, 95%CI (0.22, 0.59), P<0.001] among those with normal BMI and overweight/obese individuals, respectively.

Conclusion: Both moderate and high-level physical activity can reduce all-cause mortality risk in middle-aged and elderly adults, with high-level activity demonstrating more pronounced effects. From the perspective of reducing all-cause mortality risk, high-level physical activity is particularly suitable for individuals aged 45–59 years and those who are overweight or obese. Individuals aged 60–74 years and those with normal BMI can benefit from either moderate or high-level physical activity. For individuals aged $ $75 years and those who are underweight, no definitive recommendations based on sufficient evidence have been established; these groups should make decisions based on their specific circumstances.

Keywords: Physical activity; All-cause death; Middle-aged and elderly people; CHARLS; Prospective cohort study

Introduction

Insufficient physical activity is one of the most important public health problems of the 21st century and has become the fourth leading risk factor for mortality globally. The World Health Organization estimates that more than 2 million deaths worldwide are attributable to physical inactivity each year. In 2021, China recorded 10.14 million deaths, an increase of 164,000 compared with 2020, imposing a severe socioeconomic burden on the nation. Chronic diseases represent the primary cause of death in China, and insufficient physical activity constitutes a significant contributing factor to chronic disease development, posing a serious threat to national health.

Physical activity is an independent factor affecting survival outcomes and can predict 15% of premature deaths. Cross-sectional studies have demonstrated that physical activity can reduce attributable mortality from ischemic stroke, ischemic heart disease, and diabetes while extending life expectancy. Longitudinal research has also identified an inverse relationship between physical activity and mortality risk, with completely inactive and insufficiently active individuals exhibiting significantly higher all-cause mortality than those who are sufficiently active. While these findings establish an association between physical activity and mortality, existing research has several limitations: (1) most studies focus on specific disease-mortality relationships rather than comprehensive all-cause mortality risk; (2) few prospective studies target middle-aged and elderly Chinese populations; and (3) physical activity level measurements rely solely on baseline assessments without considering potential changes over time. Additionally, Carlson et al. reported that the increased mortality risk due to physical inactivity is particularly pronounced among middle-aged and elderly individuals over 40 years old. Against this background, this study utilizes CHARLS data from 2011–2018 to explore the relationship between physical activity and all-cause mortality risk among Chinese middle-aged and elderly adults, providing evidence-based recommendations for physical activity levels in these populations.

Methods

Study Population

CHARLS is a nationally representative longitudinal survey initiated in 2011 that systematically collects high-quality microdata from Chinese households and individuals aged 45 years and older. The study was approved by the Peking University Ethics Committee (IRB00001052-11015), and all participants provided informed consent. On September 10, 2022, we extracted middle-aged and elderly adults from the 2011 CHARLS baseline population as study subjects. Inclusion criteria were: (1) age $ $45 years; and (2) no change in physical activity level from the 2011 baseline survey until death or the final follow-up survey. Exclusion criteria were: (1) missing physical activity information; (2) missing survival status information; and (3) missing data for $ $3 of 11 covariates. A

total of 2,799 participants were ultimately included.

Baseline Survey

Baseline data collection included: (1) demographic variables: gender, age, marital status, education level, and household registration type; (2) lifestyle variables: smoking, alcohol consumption, life satisfaction, BMI, and activities of daily living (ADL) limitations. BMI categories were defined as underweight (<18.5 kg/m^2), normal (18.5–23.9 kg/m^2), and overweight/obese ($ 24.0kg/m^{2}). ADL limitations were defined as difficulty performing any of six activities: eating, dressing, transferring between bed and chair, toileting, bathing, and continence control; and (3) number of chronic diseases, including hypertension, dyslipidemia, diabetes or hyperglycemia, cancer or malignant tumors, chronic lung disease, liver disease, heart disease, stroke, kidney disease, stomach or other digestive diseases, emotional and neurological or psychiatric problems, memory-related diseases, arthritis or rheumatism, and asthma. Participants with none of these conditions were classified as having no chronic disease, those with any one condition as having one chronic disease, and those with any two or more conditions as having two or more chronic diseases.

Physical Activity Assessment

Physical activity was assessed using the International Physical Activity Questionnaire (IPAQ), which measures the number of days per week and daily duration of activities lasting at least 10 minutes. Following the methodology of Qiao Yucheng for evaluating physical activity levels, metabolic equivalent (MET) values were assigned as follows: low-intensity activity=3.3 METs, moderate-intensity activity=4.0 METs, and high-intensity activity=8.0 METs. Weekly energy expenditure was calculated as: MET × daily activity duration (minutes) × weekly activity days (days). Based on IPAQ criteria, physical activity levels were categorized as: low-level (<600 METs/week), moderate-level (600–3,000 METs/week), and high-level (>3,000 METs/week). The IPAQ is a widely used instrument for assessing adult physical activity levels and has demonstrated good validity and reliability in Chinese empirical studies.

Follow-up, Endpoint Events, and Grouping

The follow-up period spanned 2011–2018, with tracking data from 2013, 2015, and 2018. The endpoint event was all-cause death. Outcome variables included survival status (all-cause death/survival) and survival time (measured in months). Participants were divided into a survival group and an all-cause death group based on survival status.

Statistical Analysis

Data analysis was performed using Stata 16.0 and SPSS 26.0 software. Non-normally distributed continuous variables were expressed as median (P25,

P75). Categorical variables were presented as frequencies and percentages, with between-group comparisons conducted using chi-square tests or chi-square trend tests. Cox proportional hazard regression models were used to calculate hazard ratios (HR) and 95% confidence intervals (95%CI) with months as the time unit, analyzing the relationship between physical activity levels and all-cause mortality risk. To adjust for confounding effects, three models were constructed: Model 1 adjusted for demographic variables; Model 2 adjusted for demographic and lifestyle variables; and Model 3 adjusted for demographic variables, lifestyle variables, and number of chronic diseases. Two sensitivity analyses were performed to verify result robustness. Multiplicative interaction analysis was used to examine interactions between covariates and physical activity on all-cause mortality outcomes, with stratified analysis conducted for covariates showing significant interactions. The significance level was set at α=0.05.

Results

Baseline Characteristics

Among the 2,799 participants (1,362 males and 1,437 females), the median age was 58.00 (52.00, 66.00) years for males and 57.00 (50.00, 65.00) years for females. During the 7-year follow-up period totaling 18,280 person-years (average 6.53 years per person), 375 all-cause deaths were reported, yielding a mortality incidence of 13.40%. Significant differences between the survival and all-cause death groups were observed in physical activity level, gender, age, marital status, education level, ADL limitations, BMI, smoking status, alcohol consumption, and number of chronic diseases (P<0.05). No significant differences were found in household registration type or life satisfaction (P>0.05) .

Multivariate Cox Proportional Hazard Regression Analysis of Physical Activity Effects on All-Cause Mortality

Using all-cause death as the dependent variable and physical activity level, gender, age, marital status, education level, household registration type, ADL limitations, BMI, smoking, alcohol consumption, life satisfaction, and number of chronic diseases as independent variables (see variable assignments in), multivariate Cox proportional hazard regression analysis revealed that, after adjusting for confounders, moderate-level physical activity reduced all-cause mortality risk by 43% [HR=0.57, 95%CI (0.44, 0.75), P<0.001] and high-level physical activity reduced risk by 64% [HR=0.36, 95%CI (0.27, 0.48), P<0.001] compared with low-level physical activity .

Sensitivity Analysis

Two sensitivity analyses were conducted: (1) excluding participants who died within the first two years of follow-up; and (2) excluding participants with cardiovascular/cerebrovascular diseases or cancer at baseline. Both analyses confirmed

that moderate and high-level physical activity were associated with reduced all-cause mortality risk compared with low-level activity (P<0.001), demonstrating robust findings .

Stratified Analysis

Multiplicative interaction analysis revealed significant interactions between age and physical activity level (P-interaction=0.36) and between BMI and physical activity level (P-interaction=0.49) on all-cause mortality outcomes. No significant interactions were found for gender, marital status, education level, smoking, alcohol consumption, ADL limitations, or number of chronic diseases (P-interaction>0.05). Stratified analysis by age and BMI showed that among individuals aged 45–59 years, high-level physical activity reduced all-cause mortality risk by 74% [HR=0.26, 95%CI (0.14, 0.47), P<0.001] compared with low-level activity. Among those aged 60–74 years, moderate and high-level physical activity reduced risk by 50% [HR=0.50, 95%CI (0.33, 0.76), P<0.001] and 65% [HR=0.35, 95%CI (0.24, 0.51), P<0.001], respectively. In individuals with normal BMI, moderate and high-level physical activity reduced all-cause mortality risk to 49% [HR=0.49, 95%CI (0.33, 0.73), P<0.001] and 29% [HR=0.29, 95%CI (0.20, 0.43), P<0.001] of the risk associated with low-level activity. Among overweight/obese individuals, high-level physical activity reduced risk to 36% [HR=0.36, 95%CI (0.22, 0.59), P<0.001] of that associated with low-level activity .

Discussion

Physical activity encompasses diverse forms and can be categorized from various perspectives: by time and space into leisure, occupational, transportation, and household activities; by energy metabolism characteristics into aerobic and anaerobic exercise; and by activity form into flexibility, resistance, and comprehensive exercises. Research has shown that higher levels of leisure-time physical activity are associated with lower all-cause mortality risk, and increased household physical activity also reduces all-cause mortality. Studies further indicate that higher physical activity levels at any intensity are associated with reduced all-cause mortality risk. The IPAQ is a comprehensive measurement tool based on intensity, frequency, and duration dimensions, demonstrating good reliability and validity for adult physical activity assessment. This study employed IPAQ as the measurement instrument and evaluation standard, providing an overall reflection of individual physical activity. Our findings demonstrate that moderate and high-level physical activity are protective factors against all-cause mortality in middle-aged and elderly adults, reducing mortality risk to varying degrees, consistent with the results of Bernabe-Ortiz et al.

Stratified analysis revealed that high-level physical activity significantly reduced all-cause mortality risk among individuals aged 60–74 years, while moderate-level activity significantly reduced risk among those aged 45–59 and 60–74 years. No association between physical activity level and all-cause mortality risk was

observed among individuals aged $ $75 years, possibly due to the small sample size in this age group, but more likely reflecting objective realities such as age-related muscle and calcium loss, declining physical function, and increased disease burden. Current research findings on the relationship between physical activity and mortality risk in older adults remain inconclusive. A prospective cohort study in the United States found that increased physical activity did not significantly reduce mortality risk among women aged $ $75 years, whereas another study demonstrated that the association between physical activity and reduced mortality risk was strongest among individuals aged $ $80 years, with older adults participating in physical activity $ $5 times per week gaining greater health benefits. These discrepancies may be attributed to the more complex health status of older populations, cumulative effects of other risk factors, and variations in physical activity definitions and measurement methods across studies.

This study also found that high-level physical activity significantly reduced all-cause mortality risk among individuals with normal, overweight, or obese BMI, consistent with Tarp et al.'s findings. Additionally, moderate-level physical activity significantly reduced mortality risk among those with normal BMI, but no association was observed between physical activity level and all-cause mortality among underweight individuals, possibly related to the higher prevalence of osteoporosis and anemia in this population.

This study has several innovative aspects. Based on CHARLS data, we employed a prospective cohort design to analyze the impact of different physical activity levels on all-cause mortality in middle-aged and elderly adults. During participant selection, we considered not only baseline physical activity levels but also incorporated follow-up data from 2013, 2015, and 2018 to ensure that each participant's physical activity remained consistent throughout the study period, avoiding confounding effects from activity level changes. However, limitations remain. Despite adjusting for multiple important confounders, we could not completely eliminate interference from unknown confounding factors. Physical activity measurement also represents a significant factor affecting results. In this study, physical activity information was self-reported through participant recall, introducing potential recall bias. Currently, heart rate monitoring or motion sensor-based measurements provide more objective data but require conversion to energy expenditure, and the quality of energy expenditure equations may increase measurement error risk. Additionally, the use of heart rate monitors or motion sensors limits large-scale population application. Future research should explore combined measurement approaches to enhance accuracy.

In conclusion, both moderate and high-level physical activity can reduce all-cause mortality risk in middle-aged and elderly adults, with high-level activity demonstrating more pronounced effects. From a mortality risk reduction perspective, high-level physical activity is particularly suitable for individuals aged 45–59 years and those who are overweight or obese. Individuals aged 60–74 years and those with normal BMI can benefit from either moderate or high-level physi-

cal activity. For individuals aged $ $75 years and those who are underweight, no definitive evidence-based recommendations have been established; these groups should make decisions based on their specific circumstances.

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Author Contributions

Chen Xi contributed to conceptualization, study design, statistical analysis, results interpretation, and manuscript writing. Zhang Juan contributed to conceptualization, study design, quality control, manuscript review, and overall responsibility for the work. Li Ling and Zhang Jiaqi performed data curation. Guo Hui, Wu Yaoli, and Wang Chaoqun contributed to manuscript revision.

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Note: Figure translations are in progress. See original paper for figures.