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The association between intensity-specific physical activity and the number of multiple chronic diseases among Chinese elderly: A study based on the China Health and Retirement Longitudinal study (CHARLS)

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A R T I C L E I N F O

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Number of multiple chronic diseases
Elderly
Propensity score matching

A B S T R A C T

Background: With ageing, the elderly are facing a complex situation where multiple chronic diseases coexist. This paper aims to investigate the effect of intensity-specific physical activity on the number of multiple chronic diseases in the elderly.
Methods: Our data came from wave 4 of the China Health and Retirement Longitudinal Survey (CHARLS), which involved 10,341 residents aged $\geq$ 60 years. The intensity-specific physical activity was divided into two categories: moderate-intensity physical activity (MPA) lasting $\geq$ 150 min/week and vigorous-intensity physical activity (VPA) lasting $\geq$ 75 min/week. Data on 14 types of chronic diseases were collected. Propensity score matching (PSM) with controlling nine confounding factors were used to analyse the effects of intensity-specific physical activity.
Results: Among 10,341 samples, 40.12% of the elderly often participated in MPA and 25.72% participated in VPA. The PSM results showed that performing 150 min/week of MPA leads to 0.0675($P<0.05$) fewer multiple chronic diseases than not achieving this standard, and VPA up to 75 min/week leads to 0.0785($P<0.05$) fewer multiple chronic disease than that does not meet this criterion. Additionally, VPA is more effective than MPA.
Conclusion: Both MPA of at least 150 min/week and VPA of at least 75 min/week can significantly reduce the number of multiple chronic diseases in elderly. Elderly people should increase their exercise intensity as much as possible while ensuring safety.

1. Introduction

China is one of the countries with the highest degree of aging in the world, with the largest number of aging people and the fastest rate of aging. According to the National Statistical Office, the number of elderly people aged 60 and above in China reached 280 million at the end of 2022, accounting for 19.8 % of the total population. Along with the ageing of the population, the elderly are confronting a complex situation in which multiple chronic disease threats coexist and various health-influencing factors intertwine, causing both individual and social problems (Gu, 2016). At the individual level, multiple chronic diseases greatly reduce the quality of patience life with an 1.55 %-4.02 % decrease (Navickas et al., 2016; Makovski et al., 2019). At the social level, multiple chronic diseases have become significant public issuses due to their increase of morbidity, which leads to climbing health care expenditures (Demirer et al., 2021).

Older people who regularly engage in physical activity training show a positive correlation with various socio-environmental aspects that influence their quality of life. These socio-environmental factors not only contribute to quality of life, but also play an important role in shaping lifestyles (Zapata-Lamana et al., 2021). Gender, education, functional skills, activity and leisure, and health are all quality-of-life factors that predict the level of physical activity training among older persons (Parra-Rizo et al., 2022).

Many studies have found exercise reduces chronic disease rates. Khurshid S et al. observed a strong link between physical activity and hundreds of diseases, including cardiac, digestive, endocrine/metabolic, and respiratory (Khurshid et al., 2022). However, there's debate over how much exercise is beneficial. Some scholars argued that even once a week of low-to-moderate-intensity physical activity was sufficient to

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reduce the risk of chronic disease (Marques et al., 2018), while others state higher levels (≥3,000 MET minutes/week) significantly lower the risk of various conditions (Kyu et al., 2016). A recent study concurs, finding a strong association between higher total physical activity and lower Type 2 diabetes risk(Luo et al., 2023). So that, WHO recommends adults 65 + engage in at least 150 min of moderate or 75 min of vigorous aerobic activity weekly to prevent multiple chronic diseases (World Health Organization, 2010).

Multiple chronic diseases are those in which a person has two or more diseases at the same time (Cromley et al., 2018). Compared to isolated single diseases, elderly people have a higher incidence of multiple chronic diseases (King et al., 2018). Multiple chronic diseases result in more severe health outcomes, greater economic expenditures and mental burdens (Hajat and Stein, 2018). Exercise therapy appears to be a safe and beneficial intervention for improving the physical and psychosocial health of people with Multiple chronic diseases (Huang et al., 2023). However, previous literatures mainly focused on the relationship between the amount of exercise and the risk of Multiple chronic diseases (Kyu et al., 2016; Luo et al., 2023), as well as the effectiveness of exercise in the treatment of Multiple chronic diseases (Schweda et al., 2022; Pasanen et al., 2017). Few literatures discussed the impact of exercise intensity on the number of multiple chronic diseases. In fact, healthcare expenditures greatly increase, sometimes exponentially, with each additional chronic condition (Hajat and Stein, 2018).

This study, based on the China Health and Retirement Longitudinal Study (CHARLS), aimed to find out the effect of intensity-specific physical activity on the number of multiple chronic diseases in the elderly, which will help to prevent, control and intervene in the occurrence of Multiple chronic diseases in a more targeted way.

2. Methods

2.1. Data

The data in this study was drawn from CHARLS, which is a national representative longitudinal survey of persons in China. The study was approved by the ethics committee of Peking University (IRB00001052–11015). CHARLS national baseline survey was conducted in 2011, covering 150 counties, 450 villages, approximately 17,000 people from 10,000 households. The respondent are 45 years of age or older with their spouses also included. CHARLS used a multistage, stratified, probability proportional to size (PPS) sampling method, and following up every 2 years from 2013 to 2018. The response rates of all samples were higher than 80 % in each wave (Zhao et al., 2014). The study will utilize CHARLS 2018 data. According to our research needs, we cleaned the data as follows.

Firstly, We matched and merged data from some modules in the CHARLS. Secondly, missing values are deleted. Thirdly, considering that disability can affect physical exercise, the physical disability samples were removed. Finally, since the target population is the elderly, samples under the age of 60 were moved. The final sample size for analysis is 10,341 (see Fig. 1).

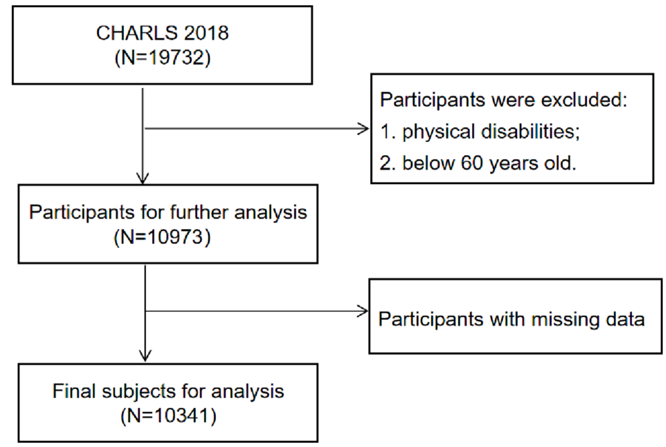

Fig. 1. Flow chart of this analysis based on CHARLS 2018.

2.2. Variable measurement

2.2.1. Dependent variable

CHARLS 2018 data asked about 14 types of chronic diseases diagnosed by doctors, including Hypertension, Dyslipidemia, Diabetes, Cancer or malignant tumor, Chronic lung diseases, Liver disease, Heart attack, Stroke, Kidney disease, Stomach or other digestive diseases, Emotional, nervous, or psychiatric problems, Memory-related disease (such as dementia, brain atrophy, and Parkinson's disease), Arthritis or rheumatism, Asthma. We calculated the total number of chronic diseases for each respondent, and defined them as number of chronic diseases, which is the dependent variable in our research.

2.2.2. Independent variable

According to the International Physical Activity Questionnaire - Short Form (Craig et al., 2003), the physical activity was divided into three intensity levels: vigorous, moderate and mild. We focused on the former two. Vigorous activities can cause shortness of breath, which included carrying heavy stuff, digging, hoeing, aerobic workout, bicycling at a fast speed, riding a cargo bike/motorcycle, etc. ; moderate activities can faster-than-usual breath, which included carrying light stuff, bicycling at a normal speed, mopping, Tai-Chi, and speed walking. Specifically, we calculated the number of minutes of exercise per week (minutes of exercise = days of exercise per week x duration of each exercise session) for each respondent. The independent variable was the Moderate-intensity physical activity(MPA), which was categorized as "1″ for elders with moderate-intensity exercise time ≥ 150 min/week and less than this time is "0". Another independent variable was the Vigorous-intensity physical activity(VPA), which was categorized as "1" for elders with vigorous-intensity exercise time ≥ 75 min/week and less than this time is "0".

2.2.3. Covariate

The potential factors between intensity-specific physical activity and number of chronic diseases were selected as covariates, including gender, age, residential area, education background, sleep duration per day, smoking, drinking, insurance, annual pension amount. Covariate measurements and attributes are shown in Table 1. Continuous variables were described by means and standard deviations, while categorical variables were described by frequencies and percentages.

2.3. Statistics analysis

All data statistical analysis was performed using STATA 17.0. We used logit regression to explore the relationship between physical activity at specific intensity and the number of chronic diseases. But regression only explained correlation, not causation. In addition, there might be selection bias when using regression. Therefore we choose propensity score matching (PSM) to solve this problem. PSM is based on Rubin causal model and Neyman-Rubin causal model (Rosenbaum et al., 1983), which aims at artificially matching a appropriate control group for the intervention group after adding covariates. The matching makes the sample distribution of the intervention and control groups close to random distribution, which reduces the effect of selection bias.

$$P(x_1, x_2 \cdots x_n) = Pr(D = 1 | x_1, x_2 \cdots x_n) \tag{1}$$

$$Y_{1,i}, Y_{0,1} \perp\!\!\!\perp x_1, x_2 \ldots x_n \tag{2}$$

Equation (1) explained the formula for calculating the propensity score. The propensity score P (x_1,x_2 …x_n) is the probability of

Table 1
Descriptive statistics of 10,341 Chinese older population from the CHARLS study in 2018.

Variable	Mean (SD) or frequency (%)
Gender	51.07
MaleFemale	
Age	69.22 (7.12)
Residential area	6.06
The center of city/town	75.40.27
Urban-Rural Integration Zone	
VillageSpecial area	
Education backgroundNo formal education	22.92
(illiterate)	21.54
Did not finish primary school	15.55
Sishu/Home school/Elementary school	5.58
Middle school	2.44
High school	0.770.72
Vocational school	
Two−/Three-Year College/Associate degreeFour-Year College/Bachelor's degree /Master's degree/Doctoral degree/Ph.D.	
Sleep duration per day	6.14(2/17)
Smoking	41.1954.78
Yes	
Replacing missing values with average valuesNo	
Drinking	6.7568.88
Drink more than once a month	
Drink but less than once a monthNone of these	
Insurance	2.89
YesNo	
Annual pension amount	10149.7(17047.27)

individuals choosing to receive the standard physical exercise treatment behavior (D = 1) conditional on the known factors $x_1, x_2 \ldots x_n$. Equation (2) explains the principle of propensity score matching. After controlling for factors ($x_1, x_2 \ldots x_n$), the assignment of the treatment behavior (D) could be viewed as random. Then we could the assignment of the behavior (D) on these factors ($x_1, x_2 \ldots x_n$) to construct the propensity score). And after controlling for the propensity score, the assignment of the processing behavior (D) can also be viewed as random. Based on the propensity score, we used three methods for matching to ensure robustness, including nearest neighbor matching with caliper, radius matching, and kernel matching.

$$ATE = E(Y_{1i} - Y_{0i})$$

$$ATT = E(y|t = 1) - E(y \mid t = 1)$$

$$ATU = E(y|t = 0) - E(y \mid t = 0) \quad (3)$$

Finally, we measured treatment effects based on Equation (3): Average treatment effect (ATE), Average treatment effect of the treated group (ATT), Average treatment effect of the untreated group (ATU), but focus primarily on ATE.

3. Results

3.1. Regression results

Before using PSM for causal inference, we first used linear regression to examine how different intensity of exercise affects the number of chronic diseases. Specifically, we took number of chronic diseases as the dependent variable. As for the independent variable, we only utilize moderate-intensity or vigorous-intensity physical activity to perform two seperate linear regressions. The results are as shown in Table 2. Participation in MPA was 40.12 % and in VPA was 25.72 %. Both MPA and VPA have a negative effect on the number of chronic diseases of eldly ($P < 0.01$). MPA reduces the number of chronic diseases by 0.067, and VPA reduces the number of chronic diseases by 0.137. However, this effect cannot be free from the endogeneity problem due to sample selectivity bias, and thus cannot be taken as a true representation of the impact of physical activity on the number of chronic diseases.

Table 2
Linear regression results between physical activity and number of chronic disease among 10,341 Chinese older population from the CHARLS study in 2018.

Independent variable	Dependent variable: *Number of chronic diseases*			
	E/CSample size	Coefficient	Std. err.	P
MPA	4,149/6,192	−0.067	0.021	0.001
VPA	2,660/7,681	−0.137	0.023	<0.001

Note: *E* experimental group; *C* control group.

Following previous research, we added covariates to the linear regression for deeper analysis, with results in Table 3. In the MPA regression, age, residential area, smoking, drinking, and sleep are significant. In the VPA regression, these variables are also significant. Hence, propensity score matching is necessary to control covariate effects.

3.2. Propensity score matching and balance test

We calculated propensity scores using logistic regression and then matched appropriate objects to the exercise group based on the propensity scores. Since there are multiple matching modalities for PSM, this study focused on three dominant matching modalities, nearest neighbor matching, radius matching, and kernel matching, to explore the effect of intensity-specific physical activity on the number of chronic diseases.

In order to ensure the quality of the matching and the reliability of the estimated results, it is necessary to verify the balance assumption. The most commonly used balance test index is the mean of deviation. Theoretically, mean of deviation after matching should be less than 10 %. Table 4 reported the balance test results of the characteristic variable matching between the intervention and the control groups, taking the nearest neighbour matching(k = 1) as an example. As can be seen from the Table 4, after matching, there is a substantial decrease in the mean of deviation of all covariates except the annual pension amount, which increases. However, the mean of deviation of all covariates are controlled within 5 %. T-test results indicated that no significant difference was observed between the two elderly sample groups after matching, indicating that the matching effect was good, the quality of matching is high, and the conditional independence assumption is satisfied.

3.3. Treatment effect

Four matching modalities are employed in this study: nearest neighbor matching (k = 1, k = 4), radius matching, and kernel matching. Resulting estimates are shown in Table 5. All results are obtained from 500 Bootstrap sample estimations.

The PSM results showed that the ATT value presents a negative and significant effect of MPA on the number of chronic diseases prevalence in all matching modalities. Specifically, the mean coefficient value of all 4 modalities is −0.0675 ($P<0.05$), suggesting 150 min of MPA weekly reduces diseases by 0.0675. VPA also shows a significant reduction, with a coefficient of −0.0785 ($P < 0.05$), meaning 75 min of VPA weekly leads to 0.0785 fewer diseases. VPA's impact exceeds that of MPA. Meanwhile, the value of ATE and ATU shows only subtle differences with ATT and are both statistical significant, indicating a relatively robust results.

4. Discussion

The elderly population is disproportionately affected by chronic diseases, with China alone having over 180 million elderly individuals suffering from these conditions. Notably, more than one-third of them

Table 3
Linear regression results between covariates and the number of chronic diseases among 10,341 Chinese older population from the CHARLS study in 2018.

	MPA			VPA		
	Coefficient	Std. err.	P-value	Coefficient	Std. err.	P-value
Gender	0.040	0.026	0.125	0.028	0.026	0.279
Age	0.003	0.002	0.025**	0.003	0.002	0.042**
Residential area	−0.055	0.017	0.001***	−0.047	0.017	0.006***
Education background	0.002	0.009	0.842	0.000	0.016	0.980
Smoking	−0.511	0.075	<0.001***	−0.510	0.075	<0.001***
Drinking	0.082	0.013	<0.001***	−0.081	0.013	<0.001***
Daily sleeping hours	−0.042	0.005	<0.001***	−0.042	0.005	<0.001***
Insurance	0.122	0.062	0.051	0.120	0.062	0.055
Annual pension amount	1.81e	9.20e	0.050	1.76e	9.12e	0.054
_cons	1.548	0.202	<0.001***	1.575	0.204	<0.001***

Note: ***p<0.01, **p<0.05, *p<0.1.

Table 4
Balance test results after PSM matching among 10,341 Chinese older population from the CHARLS study in 2018.

Variables	U/M	MPA		VPA	
		%bias	P-value	%bias	P-value
Gender	U	11.9	<0.001***	11.9	<0.001***
	M	0.9	0.692	0.9	0.692
Age	U	−41.0	<0.001***	−41.0	<0.001***
	M	1.3	0.501	1.3	0.501
Residential area	U	−3.1	0.128	−3.1	0.128
	M	−2.6	0.230	−2.6	0.230
Education level	U	7.7	<0.001***	7.7	<0.001***
	M	2.7	0.228	2.7	0.228
Smoking	U	4.4	0.031**	4.4	0.031**
	M	2.2	0.311	2.2	0.311
Drinking	U	−11.9	<0.001***	−11.9	<0.001***
	M	0.2	0.094	0.2	0.941
Daily sleeping hours	U	−4.0	0.049**	−4.0	0.049**
	M	−0.9	0.660	−0.9	0.660
Insurance	U	10.1	<0.001***	10.1	<0.001***
	M	1.3	0.482	1.3	0.482
Annual pension amount	U	−0.1	0.979	−0.1	0.979
	M	1.6	0.402	1.6	0.402

Note: *U* unmatched, *M* matched.
***p<0.01, **p<0.05, *p<0.1.

Table 5
Treatment effects of physical activity on the number of chronic diseases among 10,341 Chinese older population from the CHARLS study in 2018.

Matching modality	Treatment effect	MPA		VPA	
		coefficient	P-value	coefficient	P-value
Nearest neighbor matching (k=1)	ATT	−0.090	0.009***	−0.076	0.039**
	ATU	−0.072	0.026**	−0.089	0.014**
	ATE	−0.079	0.004**	−0.086	0.004***
Nearest neighbor matching (k = 4)	ATT	−0.063	0.025**	−0.077	0.010***
	ATU	−0.052	0.054*	−0.115	0.001***
	ATE	−0.057	0.018**	−0.105	<0.001***
Radius matching (0.01)	ATT	−0.064	0.024**	−0.077	0.014**
	ATU	−0.053	0.048**	−0.108	0.002***
	ATE	−0.057	0.015**	−0.100	0.001***
Kernel matching	ATT	−0.053	0.014**	0.084	0.001***
	ATU	−0.060	0.007***	0.104	<0.001***
	ATE	−0.057	0.007***	0.099	<0.001***

Note: ***p<0.01, **p<0.05, *p<0.1.

have two or more chronic diseases (Wang et al., 2019), highlighting the complex interplay between different illnesses. It is crucial to understand that multiple chronic diseases cannot be simply added together, as each condition can exacerbate the progression of the others, leading to a significantly higher medical burden (Vetrano et al., 2018). A 2015 survey conducted by the Centers for Medicare and Medicaid Services in the United States revealed that those with 2 to 3 chronic diseases had medical expenditures three times higher than those without multiple chronic diseases, while those with six or more chronic diseases had expenditures 17 times higher. Furthermore, patients with six or more chronic diseases had hospital readmission rates approximately three times higher than those without multiple chronic diseases (Centers for medicare and medicaid services, 2019).

Multiple chronic diseases are believed to be the result of complex interactions between various internal and external factors within a network system (Sturmberg et al., 2017). Given the intricate pathogenesis and diverse clinical manifestations of these diseases, it is evident that a single measure cannot effectively prevent or manage multiple chronic disease. Exercise, as a crucial intervention method for multiple chronic diseases, has gained increasing recognition for its significance and role in non-pharmacological clinical interventions.

This study utilized wave 4 data from CHARLS, a nationally representative sample of older Chinese individuals, to investigate the causal effects of intensity-specific physical activity on the number of multiple chronic diseases. To address potential biases stemming from non-randomized studies, we employed PSM methods and controlled for various confounding factors.

This study analyzed data from 10,341 individuals and discovered that exercise had a significant negative impact on the number of chronic diseases in elderly individuals, even after controlling for potential confounding factors. Specifically, those who met the exercise recommendation of 150 min/week of MPA had 0.0675 fewer chronic diseases than those who did not reach this level. Similarly, those who performed 75 min/week of VPA had 0.0785 fewer chronic diseases than those who did not. These findings were consistent with an English Longitudinal Study of Ageing (ELSA) study that assessed the association between five lifestyle factors and multimorbidity (≥2 chronic diseases) in UK adults over the age of 50. The study found that insufficient physical activity was associated with a 33 % increased risk of multimorbidity (Dhalwani et al., 2017).Another cross-sectional study based on data from the European Health Interview Survey in Spain also supported this view, finding that physical activity was inversely associated with multimorbidity in older men (Cimarras-Otal et al., 2014).

The consistent positive impact of exercise on multiple chronic diseases has been observed in current research (Dhalwani et al., 2017; Cimarras-Otal et al., 2014; Dhalwani et al., 2016; Ryan et al., 2018; Autenrieth et al., 2013). However, there are significant differences in the definitions of exercise intensity. Dhalwani NN et al. conducted a study using data from Wave 6 of the ELSA, which included 15,688 participants. They concluded that moderate-intensity exercise is most effective in reducing the prevalence of multimorbidity in individuals aged 50 and above. Moderate activities such as gardening, car cleaning, walking at a moderate pace, dancing, floor or stretching exercises were recommended to be performed once a week (Dhalwani et al., 2016). Another study by Dhalwani NN et al. analyzed data from waves 4, 5, and 6 of

ELSA. They found that physical inactivity increased the risk of multimorbidity by 33 % in individuals aged 50 and above. The criteria for insufficient physical activity were less than 30 min of moderate-intensity physical activity or less than 15 min of vigorous-intensity physical activity per week (Dhalwani et al., 2017). A negative dose–response relationship between physical activity levels and multiple diseases was also identified in the Irish Longitudinal Study of Ageing (TILDA), where exercise intensity was defined based on the International Physical Activity Questionnaire (IPAQ) (Ryan et al., 2018). Differences in exercise intensity definitions have led to varying results. For instance, while some studies suggest that VPA is more effective in reducing the number of multiple chronic diseases (Autenrieth et al., 2013), others believe that MPA is better (Dhalwani et al., 2016). Therefore, future research should focus on determining the minimum amount of exercise required to reduce chronic disease multimorbidity and the range of effective exercise levels.

5. Conclusion

In conclusion, our research findings have confirmed that engaging in 150 min of MPA per week or 75 min of VPA per week can significantly reduce the number of multiple chronic diseases in older adults. This provides a new approach to preventing, controlling and intervening in the development and progression of multiple chronic diseases, and will help to reduce the physical and financial burden on patients. Therefore, it is imperative to motivate and inspire senior citizens to participate in sports and increase their intensity of exercise as much as possible while prioritizing safety.

There are some limitations to this study: variables were derived from self-reports of the respondents and there may be some recall bias, such as the variable exercise duration. Future studies should focus on optimal exercise intensity, exercise type, and exercise duration with the aim of developing more precise and personalized exercise prescriptions for patients with multiple chronic diseases.

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CRediT authorship contribution statement

Kexin Ren: Funding acquisition, Conceptualization. **Yuan Tao:** Formal analysis, Data curation. **Meihong Wang:** Methodology.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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