Association between continuous exercise and cognitive function in Chinese elderly with chronic diseases: the mediating role of positive emotions

Keywords
positive emotions, Exercise, cognitive function, the elderly with chronic diseases

Abstract

Introduction
Exercise has been proven to have a positive effect on improving cognitive function. However, the specific mechanisms by which exercise affects cognitive function states remain unclear. We aimed to explore the association between continuous exercise and cognitive function in Chinese elderly□age≥65□with chronic diseases and the mediating role of positive emotions.

Material and methods
Data were obtained from 2018 waves of the Chinese Longitudinal Healthy Longevity Survey. We relied on the database entries for the types of chronic diseases to assess whether the samples had chronic diseases. We used logistic regression to verify correlations between exercise and cognition, and the Karlson-Holm-Breen Method (KHB) to verify the mediating role of positive emotions.

Results
3959 samples were included in this study, of which 36.37% were <75 years old, 35.87% were 75-84 years old, and 27.76% were ≥85 years old; 46.70% were females and 53.30% were males. Logistic regression results showed that continuous exercise was significantly associated with an increase in cognition (β=0.21,P=0.01). About different domains of cognition, logistic regression results indicated that continuous exercise and non-continuous exercise are significantly associated with the growth of positive emotion (β=0.57,P□0.001; β=0.85,P□0.001). The results of regression and KHB methods indicated that positive emotions fully mediated the effects of continuous exercise on cognition, and partially mediated the effects of exercise on orientation.

Conclusions
Exercise could improve levels of orientation of cognition of Chinese elderly with chronic diseases, and positive emotions mediated this effect. Only continuous exercise that produced positive emotions could have an impact on cognition ability.

Association between continuous exercise and cognitive function in Chinese elderly with chronic diseases: the mediating role of positive emotions

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Abstract

Introduction Exercise has been proven to have a positive effect on improving cognitive function. However, the specific mechanisms by which exercise affects cognitive function states remain unclear. We aimed to explore the association between continuous exercise and cognitive function in Chinese elderly（age≥65）with chronic diseases and the mediating role of positive emotions.

Material and methods Data were obtained from 2018 waves of the Chinese Longitudinal Healthy Longevity Survey ~~(CLHLS)~~. We relied on the database entries for the types of chronic diseases to assess whether the samples had chronic diseases. ~~The dependent variable was cognition, and the independent variable was exercise.~~ We used logistic regression ~~and linear regression~~ to verify correlations between exercise and cognition, and ~~used stepwise regression and~~ the Karlson-Holm-Breen Method (KHB) to verify the mediating role of positive emotions.

Results 3959 samples were included in this study, of which 36.37% were <75 years old, 35.87% were 75-84 years old, and 27.76% were ≥85 years old; 46.70% were females and 53.30% were males. Logistic regression results showed that continuous exercise was significantly associated with an increase in ~~overall~~ cognition (β=0.21,P=0.01). About different domains of cognition, logistic regression results indicated that continuous exercise and non-continuous exercise are significantly associated with the growth of positive emotion (β=0.57,P＜0.001; β=0.85,P＜0.001). ~~continuous exercise was significantly associated with improvements in orientation (β=0.43,P<0.001) and language (β=0.03,P=0.02), and non-continuous exercise was also significantly associated with the improvement of orientation (β=0.44,P<0.001).~~ The results of regression and KHB methods indicated that positive emotions fully mediated the effects of continuous exercise on ~~overall~~ cognition ~~and language~~, and partially mediated

the effects of exercise on orientation.

Conclusions ~~Continuous~~ Exercise could improve levels of orientation ~~and language~~ of cognition of Chinese elderly with chronic diseases, and positive emotions mediated this effect. Only continuous exercise that produced positive emotions could have an impact on cognition ~~and language~~ ability. ~~The elderly with chronic diseases should be encouraged to improve cognition through continuous exercise. It is noteworthy that it is important to generate and maintain positive emotions through exercise to ensure this effect is realized.~~

Keywords Exercise, cognitive function, positive emotions, the elderly with chronic diseases

Introduction

Dementia is gradually becoming a major health hazard for the world's elderly, and studies showed that the degree of aging and the economic impact of dementia in China are higher than the global average [1]. ~~According to the Chinese Guideline Recommendations for Early Prevention Strategies of Alzheimer's Disease, there will be 21.6 million dementia patients in China by 2030 if it is not effectively prevented and controlled, which will not only greatly increase the cost of health care and social services, but also have a serious impact on China's socioeconomic development.~~ Dementia is associated with pathological changes in the brain that are often irreversible [2], and cognitive impairment is an important manifestation of dementia [3]. Studies showed that there are about 38.77 million patients with mild cognitive impairment (MCI) in China, with a prevalence rate of 15.54% and about 15.07 million dementia patients, with an overall prevalence rate of 6.04% [4]. ~~As a predementia syndrome, mild cognitive impairment occured in the transitional stage between normal cognitive aging and dementia 5. Cognitive decline in older adults negatively affects their quality of life and imposes a heavy burden on~~

their families and society, and this burden is exacerbated by cognitive decline in older adults with chronic diseases. Cognitive impairment in the elderly is becoming an important public health issue in China.

As a predementia syndrome, mild cognitive impairment occurred in the transitional stage between normal cognitive aging and dementia [5], Therefore, early intervention in cognitive decline in older adults is important. Physical exercise as a non-pharmacological intervention to improve cognition in older adults has gradually received widespread attention [6]. Physical exercise could help to maintain and develop physical fitness [7], and lack of physical exercise would harm the elderly cognitive ability and increase the risk of dementia. [2]. One study found that exercise have an independent influence on the development of cognitive decline and that reduces exercise accelerates cortical apoptosis, which in turn reduces an individual's learning and memory functions and increases the incidence of cognitive decline. On the contrary, participation in physical exercise may improve cognitive level of older adults. As early as 2004, it was reported that regular physical exercise can slow cognitive decline and prevent dementia [8]. The results of many studies showed that exercise interventions can lead to improvements in overall cognitive function in older adults [9,10]. A reticulated meta-analysis comparing the intervention effects of aerobic, resistance, multifunctional, and physical-mental exercise on cognitive function in older adults with subjective memory complaints found that different modalities of exercise have significant improvement effects on cognitive function. Results from previous intervention studies also confirmed that physical exercise significantly improves cardiorespiratory fitness in older adults and that higher cardiorespiratory fitness can reduce the rate of cognitive decline [11,12,13].

Depressed emotions and cognitive impairment are important factors that reduced quality of life [14],

and physical exercise had a positive effect on mood while improving cognitive function. Older people's participation in outdoor activities could effectively help them alleviate negative emotions [15]. Some scholars pointed out that square dance exercise, as a kind of activity beneficial to physical and mental health, could significantly improve the positive emotions of middle-aged and elderly people [6,16]. Exercise could also be used as a complementary therapy for depression [17], and previous findings suggested that both short-term and long-term exercise interventions may be beneficial for improving depressive symptoms, and that the longer the duration of exercise, the better the mood improvement [14].

Some studies also showed that mood has an important effect on cognitive function. It was showed that depressed mood has a negative effect on cognitive function [18], and that centenarians with better cognitive performance are more likely to have a positive mental status, whereas centenarians with a negative mental status may have underlying cognitive decline [19].

~~Existing studies found that exercise is an effective intervention to improve cognitive function in older adults, mainly analyzed the effects of exercise on cognitive function in older adults from the perspective of whether it is lacking or not, whether it is regular or not, and the mode of exercise, etc., and there has not yet been an in-depth analysis of whether continuous exercise affects the occurrence of the effects.~~ Existing studies have not yet been an in-depth analysis of whether continuous exercise affects the occurrence of the effects. Cognitive decline, as one of the prevalent health concerns in the elderly population, is closely associated to the emergence and aggravation of chronic diseases, and unhealthy lifestyle factors can accelerate the cognitive decline which is relevant to chronic diseases [2]. Can individuals mitigate their cognitive decline during the chronic disease state of old age through sustained exercise? Do the effects on different categories of cognitive function differ? Meanwhile, existing studies

have also found that exercise is helpful in improving mood, and negative mood has a negative impact on cognitive function, so does exercise improve cognitive function by generating positive emotions? ~~This study aimed to explore the relationship between exercise persistence and cognitive function in the elderly with chronic diseases and whether positive emotions mediate this relationship.~~

Summarizing the above issues, The aim of this study was to investigate the relationship between exercise and cognitive function and the mediating role of positive emotions in Chinese older adults with chronic diseases when they never exercise, exercise non-continuously, and exercise continuously, and to analyze each of the five dimensions of cognitive function, orientation, registration, attention and calculation , recall, language abilities, in order to provide a reference basis for the development of targeted interventions on cognitive function.

Materials and methods

Study sample

This dataset is from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS). CLHLS is a large-scale longitudinal survey program for Chinese seniors aged 65 and older. The database uses a multistage stratified sampling method, and the survey consists of seven parts covering a wide range of aspects, including basic information on the elderly, family information, living habits, health status, and socioeconomic status. Since the baseline survey in 1998, six follow-up surveys have been conducted, covering 23 provincial administrative units across the country, with the total population of the regions covered accounting for about 85% of the country's total population. In each research province, half of the cities/counties were randomly selected for the survey to ensure the representativeness of the sample and the quality of the data. The CLHLS database was established at the initiative of the Gerontology

Research Center of the Chinese Academy of Social Sciences. The survey is conducted in the form of face-to-face interviews, in which trained enumerators interview respondents directly. The enumerators receive professional training before the interview to ensure that they accurately understand the content of the questionnaire and can explain the questions to the respondents in an appropriate manner. During the survey, there is a specialized supervisory team responsible for checking the quality of the enumerators' work. They will randomly check a portion of the interview records to ensure that respondents understand the purpose of the questions and that their answers are accurate. The CLHLS study was approved by the Biomedical Ethics Committee of Peking University (IRB00001052-13074).

Regarding chronic diseases, chronic diseases are often referred to as Non-communicable Diseases (NCDs), and other relevant organizations, such as the World Health Organization (WTO), have emphasized in their definitions of chronic diseases that they are characterized by their long-term persistence, slow progression, and persistent impacts on the health of individuals and society. Common chronic diseases include cardiovascular and cerebrovascular diseases (e.g. hypertension, coronary heart disease, etc.), cancer, diabetes mellitus, rheumatoid arthritis, tuberculosis, hepatitis, chronic nephritis, and mammary gland hyperplasia. We regarded respondents who reported that they suffered from one or more of the chronic diseases in the questionnaire as chronic disease patients.

Since the CLHLS survey was for older adults aged 65 and older, we used 65 as the threshold. After removing missing values from the 2018 CLHLS, a total of 3959 participants aged 65 years and older were included in this study, and Fig.1 shows the data inclusion process.

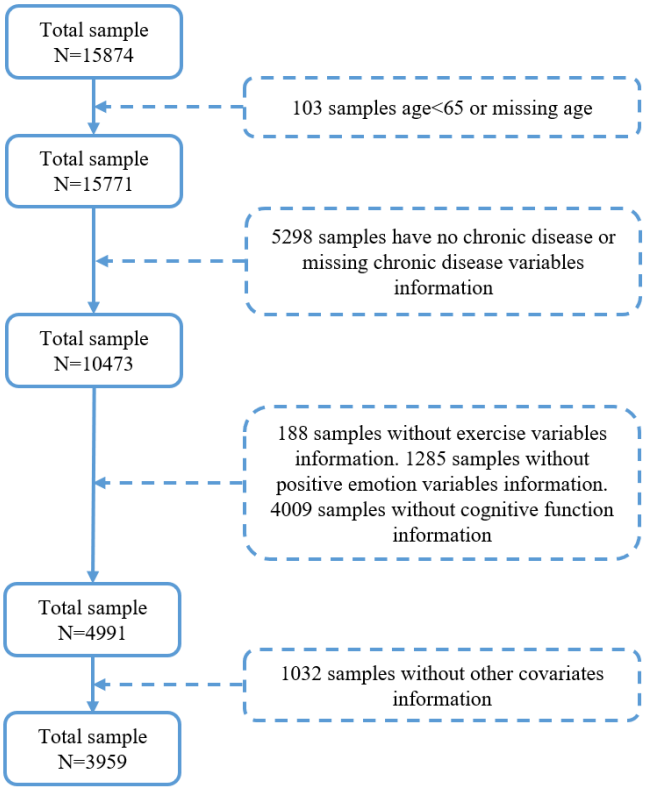

Fig. 1 Sample selection process

Variable

Cognition

The dependent variable in this study was cognition in the elderly with chronic diseases, and we set the cognition as a dichotomous variable according to the CLHLS questionnaire. The cognitive function portion of the questionnaire was measured using the Mini-Mental State Examination (MMSE), which was developed by Folstein et al [20] and translated and revised by Lige et al [21]. ~~The MMSE consists of 5 dimensions and 24 items, including orientation (6), registration (3), attention and calculation (6), recall (3), and language (6).~~ The scale was modified and designed to fit the Chinese cultural context, with a total score ranging from 0 to 30, with higher scores indicating improved cognitive performance. ~~We wanted to test whether continuous exercise had an effect on cognitive function, so overall~~ Cognitive function was categorized using median scores, with scores greater than or equal to 29 considered higher

cognitive levels=1 and scores less than 29 considered lower cognitive levels=0. Due to the skew distribution of cognitive scores in the CLHLS database, the choice was made to dichotomize cognition into two groups, high and low cognitive levels, using the median. It has been shown that the median split method is reasonable in dealing with skew distribution data when there is no collinearity in the independent variables [22]. We subsequently explored the effect of exercise on the cognitive level of each dimension using continuous variables for each dimension and taking the scores of each dimension. The Cronbach's alpha value of the MMSE after removing missing values was 0.69.

Orientation

In the CLHLS questionnaire, the score of orientation ranges from 0 to 12 points measures include six questions, such as specific time, month, date of Mid-Autumn Festival, season, name of place, and name of foods. The first five questions are worth one point for each correct answer, the sixth question is worth 1-6 points depending on the number of answers for up to seven foods, and 7 points for seven and more foods, with the score range of, with higher scores indicating better orientation ability. Orientation was categorized based on the median score, with a score equal to 12 considered as indicating a higher level and assigned a value of 1, while a score below 12 was considered as indicating a lower level and assigned a value of 0.

Registration

Questions measuring reflexes included "Repeat the names of three items in order," with one point awarded for correctly answering one item in order. The score of registration ranges from 0 to 3, and higher scores representing better registration. Registration was categorized based on the median score, with a score equal to 3 considered as indicating a higher level and assigned a value of 1, while a score

below 3 was considered as indicating a lower level and assigned a value of 0.

Attention and calculation

~~The questions measuring attention and calculation consisted of five price calculation questions and one graph imitation question, with one point awarded for each correct answer and~~ The score of attention and calculation ranges from 0 to 6. Higher scores represented better attention and calculation. Attention and calculation was categorized based on the median score, with a score equal to 6 considered as indicating a higher level and assigned a value of 1, while a score below 6 was considered as indicating a lower level and assigned a value of 0.

Recall

Recall ~~was measured by the question "Name three items that have been asked to be repeated before," with one point awarded for each correct answer and the~~ score ranges from 0 to 3, with higher scores suggesting better recall. Recall was categorized based on the median score, with a score equal to 3 considered as indicating a higher level and assigned a value of 1, while a score below 3 was considered as indicating a lower level and assigned a value of 0.

Language

~~Questions measuring language include asking the respondent to name the two items the interviewer is referring to, to repeat the sentence spoken by the interviewer, and to pick up, fold, and put down the paper as needed, with one point awarded for each correct performance, for a total~~ Language score ranges from 0 to 6. Higher scores indicated better language abilities. Language was categorized based on the median score, with a score equal to 6 considered as indicating a higher level and assigned a value of 1, while a score below 6 was considered as indicating a lower level and assigned a value of 0.

Exercise

The independent variable in this study was exercise, which in the CLHLS questionnaire refers to purposeful fitness activities ~~such as walking, playing ball, running, and qigong.~~ In the questionnaire, participants were asked "Do you do exercises regularly at present?" and "Did you do exercises regularly in the past?" The options included "yes" and "no". Participants were categorized into two groups based on their responses; if participants answered "no" to both questions, they were considered to have never exercised, and if participants answered "yes" to one question and "no" to the other, they were considered to exercise non-continuously, and if participants answered "yes" to both questions, they were considered exercisers continuously.

Positive emotion

The mediating variable in this study was positive emotion, which are good emotional states such as positivity, pleasantness, happiness, satisfaction, confidence, and calmness that people feel and are subjectively experienced [6]. The questionnaire asked participants four questions related to positive emotions. ~~These included "Do you always look on the bright side of things no matter what happens to you?" "Do you like to keep your belongings neat and clean? " "Do you feel energized?" "Can you make your own decisions concerning your personal affairs?" four questions.~~ The options for each question are categorized as "always", "often", "sometimes", "rarely" and "never". We reverse score them, never is 1, always is 5, and the total score of positive emotions ranges from 4 to 20, with higher scores indicating more positive emotions.

Covariates

The covariates in this study include demographic characteristics, physical health status and economic

status. Demographic characteristics included age, gender, marital status, place of residence, education, and cohabitation. ~~Age was categorized as 65-74 years = 1, 75-84 years = 2, and ≥85 years = 3; gender was categorized as male = 1 and female = 0; marital status was categorized as having no spouse=0, having a spouse=1.~~ Type of residence was categorized according to the CLHLS questionnaire options as city = 1, town = 2, and rural = 3, and education was categorized as illiterate = 0 and non-illiterate = 1. ~~Co-residence was categorized according to CLHLS questionnaire options as living with household member=1, alone=2, in a nursing home=3.~~ Physical health status includes sleep duration, smoking and drinking status, hearing status, and activities of daily living (ADL). According to the Action for a Healthy China (2019-2030), more than 7 hours of sleep at night is defined as enough sleep, while less than 7 hours of sleep is defined as non-enough sleep [23]. In the questionnaire, we used the questions "Do you currently smoke?", "Did you smoke in the past? ", "Do you currently drink alcohol? "," Did you drink alcohol in the past? " to assess the history of smoking and drinking. ~~We assessed current smoking and drinking status as dichotomous variables, with "yes" and "no" representing current smoking and drinking, respectively.~~ Recent studies have shown that older adults with hearing impairment require more cognitive resources to support hearing function, resulting in increased cognitive load, which in turn leads to less cognitive resources being allocated to higher-order memory processes and accelerated cognitive decline [24]. Therefore, this study included hearing status as a covariate, using the question "Do you have any difficulty with your hearing?" to assess whether older adults have hearing difficulties. This study also included ADL as a health-related covariate. In the CLHLS database. ~~six indicators measuring ADL include bathing, dressing, toileting, indoor activities, bowel control, and eating.~~ ADLs were considered a dichotomous variable. If difficulty was reported on either question, the reporter would

be considered to have difficulty with ADLs [25]. ~~Therefore, we coded respondents with difficulty with ADLs as 0 and respondents without difficulty with ADLs as 1.~~ Studies have showed that people with higher socioeconomic status (SES) have better health outcomes [26,27], and the CLHLS questionnaire question on SES was " How do you rate your economic status compared with others in your local area? ", and was categorized as poor ~~= 1~~, average~~= 2,~~ and rich ~~= 3~~. Table S1 showed the assignment of the variables.

Statistical Analysis

We described the basic characteristics of participants using the mean ± standard deviation for continuous variables that follow a normal distribution (Figure 1). For the categorical variable, we used proportions to describe. In addition, we will examine the relationship between exercise, positive emotion, and cognition and its dimensions according to Baron and Kenny's stepwise test [28]. Thus, the propagation of the mediating effect will be tested by estimating the following three regression processes.: (1) First, we used simple linear regression to regress the independent variable, exercise (X), on the mediating variable, positive emotion (M) to verify whether it is relevant. (Fig. 2, path a). (2) We used binary logistic regression to perform regression between the independent variable, exercise, and the dependent variable, cognitive function (Y), to test for correlation (Fig. 2, path c). (3) We used binary logistic regression to perform regression of both the independent variable, exercise, and the mediating variable, positive emotion, on the dependent variable, cognitive function, to verify the correlation between the mediating variable and the dependent variable and to test whether the mediating variable attenuates the influence of the independent variable on the dependent variable (Fig. 2, path b and path c'). c is the total effect of independent variable X on dependent variable Y, a is the effect of independent

variable X on mediator variable M; b is the effect of mediator variable M on dependent variable Y after controlling for the effect of independent variable X; and c is the direct effect of independent variable X on dependent variable Y after controlling for the effect of mediator variable M [29]. After these regressions, if the final effect of the independent variable on the dependent variable remains significant, it is considered partially mediated, while if the final effect of the independent variable on the dependent variable is no longer significant, it is considered fully mediated. In addition, following the three steps above, we used binary logistic regression to regress exercise on each of the five dimensions of cognition and further explored and tested the mediating role of positive emotions among them. Regarding the test of mediating effects, we will use the KHB method. We processed and analyzed the data using stata17.0 from StataCorp LLC (4905 Lakeway Drive, College Station, TX77845, USA).

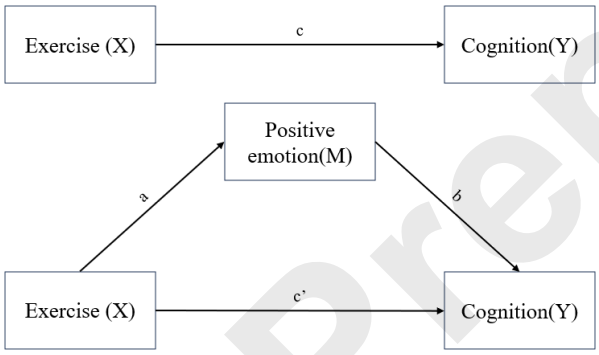

Fig.2 Research Pathway Hypothesis

Results

Descriptive statistical analysis

According to the results of descriptive statistics, the number of people with lower level of cognitive function was 36.88% of the total sample, and the number of people with higher level of cognitive function was 63.12% of the total sample. Men made up 53.3% of the sample, most of them lived in towns or rural areas (64.38%), most of the participants were educated (74.69%), and a higher number of

them had a spouse (59.13%). The vast majority of participants lived with their families (81.51%), had no history of smoking, (63.80%), no history of drinking (69.36%), and no limitations in ADL (89.54%). Most had enough sleep (61.91%) and no hearing impairment (75.17%). The majority of participants had an average level of local wealth (68.20%). In addition, individuals with higher orientation accounted for 75.20% of the total sample, while those with higher registration represented 93.84%. Additionally, 60.92% of participants demonstrated higher attention and calculation abilities, 79.04% exhibited higher recall ability, and 94.27% showed higher language ability. ~~the mean of orientation was 11.42 (±1.31), the mean of registration was 2.90 (±0.44), the mean of attention and calculation was 5.31 (±1.23), the mean of recall was 2.63 (±0.81), the mean of language was 5.92 (±0.41), and~~ The mean of positive emotion was 15.42 (±2.32) points. There were 1827(46.15%) who never exercised and 2,132 (53.86%) who exercised, with 17.18% of the total sample exercising non-continuously and 36.68% exercising continuously. Table S2 shows the characteristics of samples.

Regression of cognitive function

Firstly, we tested the independent variables for the presence of multicollinearity. Normally, VIF < 10 indicates the absence of multicollinearity. Table S3 shows that the VIF values of each variable are less than 10, indicating the absence of multicollinearity. For continuous variables that followed a normal distribution, we applied analysis of variance (ANOVA), whereas for categorical variables, we utilized the chi-square test to further screen the covariates (S4,S5,S6). Covariates that showed no significant results in the analysis of variance (ANOVA) or chi-square test were excluded from the regression models.

Table I shows the results of the regressions for exercise and positive emotion. Based on the regression

results, we can find that continuous exercise and non-continuous exercise are significantly associated with the growth of positive emotion (β=0.57,P＜0.001; β=0.85,P＜0.001). Table II shows the results of the regressions for exercise and cognition. ~~Model 1 measured the association between exercise and positive emotion, model 2 measured the association between exercise, demographic characteristics and cognition, model 3 included all control variables and model 4 included positive emotion.~~ Based on the regression results, we can find that continuous exercise is significantly correlated with the increase in the level of cognitive function (β=0.21,P=0.01), while non-continuous exercise has no significant correlation with changes in the level of cognitive function. In Table III, we found that the correlation between continuous exercise and cognitive function was no longer significant (β=0.13,P=0.11) after the inclusion of positive emotion, suggesting that positive emotions may have a fully mediated effect (Fig. 3). In addition, we found that being male, having a spouse, being illiterate, and not having impaired ADLs were significantly associated with better levels of cognitive function, whereas being older, living in a town or rural, living in a nursing home, and having hearing impairment were risk factors for cognitive decline.

Table I Regression results for exercise and positive emotions

Variable	β	SE	P	95%CI		R^2
				Lower	Upper	
Exercise						
Non-continuous	0.556	0.102	0.000	0.357	0.756	
Continuous	0.848	0.083	0.000	0.685	1.010	
Residence						
Town	-0.174	0.094	0.064	-0.357	0.010	
Rural	-0.067	0.091	0.461	-0.245	0.111	
Education(Non-illiterate)	0.124	0.086	0.149	-0.044	0.291	0.082
Co-residence						
Alone	0.248	0.100	0.013	0.053	0.444	
In a nursing home	0.011	0.201	0.955	-0.382	0.404	
Drink status(Yes)	0.134	0.078	0.086	-0.019	0.286	
Sleep time(Enough sleep)	0.497	0.073	0.000	0.353	0.641	
ADL(Non-impaired)	0.358	0.121	0.003	0.121	0.596	
Hearing status(Yes)	-0.129	0.084	0.124	-0.293	0.0353	

Economic status					
Average	0.625	0.132	0.000	0.366	0.884
Rich	1.265	0.147	0.000	0.977	1.553
Constant	13.599	0.193	0.000	13.220	13.978
N	3959	3959	3959	3959	3959

Exercise: Never=1,Non-continuous=2,Continuous=3; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; Sleep time: Non-enough sleep=0, Enough sleep=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1; Economic status: Poor=1,Average=2,Rich=3

Table II Regression results for exercise and cognition

Variable	β	SE	P	95%CI	
				Lower	Upper
Exercise					
Non-continuous	0.114	0.100	0.254	-0.081	0.310
Continuous	0.211	0.082	0.010	0.050	0.372
Age					
75~84	-0.485	0.088	0.000	-0.657	-0.313
⩾85	-0.964	0.106	0.000	-1.172	-0.755
Gender(Male)	0.171	0.084	0.043	0.006	0.336
Marital status(Have a spouse)	0.321	0.088	0.000	0.148	0.494
Residence					
Town	-0.235	0.094	0.013	-0.419	-0.050
Rural	-0.358	0.091	0.000	-0.537	-0.179
Education(Non-illiterate)	0.564	0.086	0.000	0.396	0.732
Co-residence					
Alone	-0.025	0.106	0.817	-0.233	0.184
In a nursing home	-0.556	0.194	0.004	-0.936	-0.176
Drink status(Yes)	-0.057	0.085	0.503	-0.224	0.110
ADL(Non-impaired)	0.506	0.119	0.000	0.272	0.741
Hearing status(Yes)	-0.316	0.084	0.000	-0.480	-0.152
Constant	0.097	0.175	0.578	-0.245	0.439
N	3959	3959	3959	3959	3959

Exercise: Never=1,Non-continuous=2,Continuous=3; Age: <75=1,75~84=2,≥85=3; Gender: Female=0,Male=1; Marital status: Have no spouse=0,Have a spouse=1; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1

Table III Regression results for exercise, positive emotions and cognition

Variable	β	SE	P	95%CI	
				Lower	Upper
Exercise					
Non-continuous	0.067	0.101	0.505	-0.130	0.264
Continuous	0.133	0.084	0.112	-0.031	0.297
Positive emotion	0.086	0.016	0.000	0.056	0.117
Age					

75~84	-0.477	0.088	0.000	-0.650	-0.305
⩾85	-0.963	0.107	0.000	-1.172	-0.754
Gender(Male)	0.191	0.085	0.024	0.025	0.357
Marital status(Have a spouse)	0.344	0.089	0.000	0.170	0.518
Residence					
Town	-0.213	0.094	0.024	-0.398	-0.028
Rural	-0.346	0.092	0.000	-0.526	-0.167
Education(Non-illiterate)	0.545	0.086	0.000	0.376	0.714
Co-residence					
Alone	-0.029	0.107	0.787	-0.238	0.180
In a nursing home	-0.555	0.195	0.004	-0.937	-0.173
Drink status(Yes)	-0.083	0.086	0.333	-0.251	0.085
ADL(Non-impaired)	0.479	0.120	0.000	0.245	0.714
Hearing status(Yes)	-0.309	0.084	0.000	-0.473	-0.144
Constant	-1.182	0.290	0.000	-1.751	-0.613
N	3959	3959	3959	3959	3959

Exercise: Never=1,Non-continuous=2,Continuous=3; Age: <75=1,75~84=2,≥85=3; Gender: Female=0,Male=1; Marital status: Have no spouse=0,Have a spouse=1; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1

Regression of each dimensions of cognitive function

Table S7~11 shows the results of the regression of exercise with the indicators of the five modules measuring cognition. ~~Model 5 measures the correlation between exercise and orientation, model 6 measures the correlation between exercise and registration, model 7 measures the correlation between exercise and attention and calculation, model 8 measures the association between exercise and recall, and model 9 measures the association between exercise and language abilities.~~ From Table S7 we can find that exercise with different persistence is significantly associated with improvement in orientation (β =0.44,P<0.001; β =0.43,P<0.001). Table S9 and S10 shows a significant correlation between non-continuous exercise and decrease in attention and calculation and recall ability (β =-0.21,P=0.04; β =-0.22,P=0.04). ~~model 9 shows a significant correlation between continuous exercise and language abilities were significantly correlated.~~ And all three states of exercise have no significant correlation with changes in registration and language abilities (S8, S11). At the same time, we can find significant correlations between ~~having a spouse, being non-illiterate, and~~ having unimpaired ADL with the

improvement of all aspects of ability. On the contrary, being older and having a hearing impairment had a very significant correlation with a decline in all aspects of abilities.

Table S12~S14 shows the regression results after including positive emotion, and compared with Table S7, we can find that in Table S12, the effect of continuous and non-continuous exercise on orientation was attenuated (β =0.37,P=0.001; β =0.31,P=0.001), suggesting that there may be a partially mediated effect of positive emotion (Fig. 4, Fig. 5). In Table S13, the correlation between positive emotion and attention and calculation was not significant (β =0.01,P=0.49), and in Table S14, the correlation between positive emotion and recall was not significant (β =0.01,P=0.76), suggesting that positive emotions may not have mediating effects. ~~In Model 14, compared to Model 9, it can be seen that the effect of continuous exercise on language is no longer significant, indicating that there may be a fully mediated effect of positive emotions (Fig. 6).~~

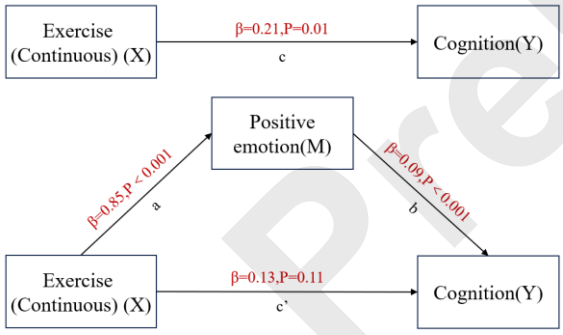

Fig.3 Positive emotion mediates relationship between continuous exercise and cognition

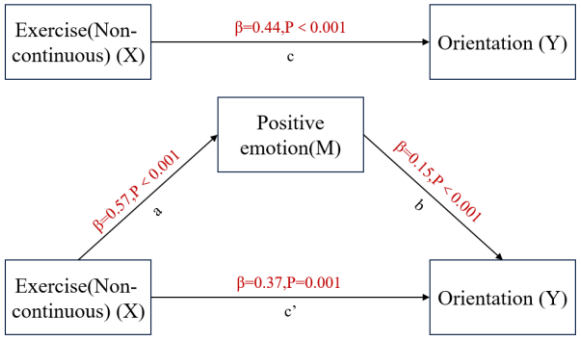

Fig.4 Positive emotion mediates relationship between non-continuous exercise and orientation

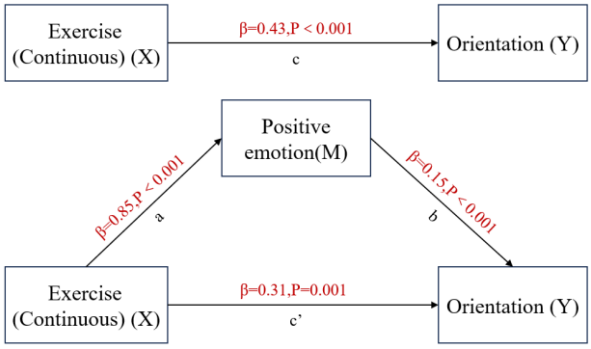

Fig.5 Positive emotion mediates relationship between continuous exercise and orientation

Test of moderating effect

We re-tested the mediating effect of positive emotions using the KHB method to confirm its accuracy. The results in Table XV show that the mediating effects of positive emotions on cognitive function and orientation are significant, and that positive emotions have a full mediating effect on cognitive function ~~and language~~, and a partial mediating effect on orientation ability.

Table IV KHB test for positive emotion

Effect	β	SE	P	95%CI		Mediation (%)
				Lower	Upper	
Exercise(Continuous)—Positive emotion—Cognition						
Total effect	0.213	0.082	0.010	0.052	0.374	
Direct effect	0.131	0.083	0.117	-0.033	0.294	
Indirect effect	0.082	0.019	0.000	0.045	0.119	38.54
Exercise(Non-continuous)—Positive emotion—Orientation						
Total effect	0.441	0.112	0.000	0.221	0.661	
Direct effect	0.363	0.113	0.001	0.142	0.583	
Indirect effect	0.079	0.021	0.000	0.038	0.120	17.85
Exercise(Continuous)—Positive emotion—Orientation						
Total effect	0.426	0.091	0.000	0.248	0.605	
Direct effect	0.303	0.092	0.001	0.122	0.483	
Indirect effect	0.124	0.024	0.000	0.077	0.171	28.99

Heterogeneity analysis

Our regression results showed that non-continuous exercise would be significantly associated with attention and calculation and recall decline, which is a thought-provoking finding, and given that

attention and calculation and recall are related to age, the present study attempted to explore this further by analyzing heterogeneity by grouping participants by age. The results showed (S15) that non-continuous exercise was highly significantly correlated with attention and calculation decline only for participants aged 75~84 years. ~~whereas non-continuous exercise had no significant effect on recall change for participants aged 75-84 years as well as ≥85 years.~~ This suggests that this negative association was only seen in the 75~84 year-old sample. Table S16 shows that non-continuous exercise was highly significantly correlated with recall decline only for participants aged 65~74 years, suggesting this negative association was only seen in the 65~74 year-old sample.

Discussion

This study used binary logistic regression to explore the impact of continuous exercise on cognitive function among elderly Chinese individuals with chronic diseases, while also investigating the mediating role of positive emotions. Continuous exercise was positively correlated with cognitive function in elderly individuals with chronic diseases, and positive emotions exhibited a fully mediating effect. From the perspective of various dimensions of cognitive function, both non-continuous and continuous exercise were positively associated with improvements in orientation. Positive emotions demonstrated a partially mediating effect in the relationship between different levels of exercise adherence and orientation.

Consistent with the findings of previous research，education is an protective factor for decline in cognitive function in older age [30]. Higher educational attainment may enhance cognitive reserve, enabling individuals to better counteract progressive brain changes associated with aging and neurodegenerative diseases. Consequently, they may exhibit greater resilience against the onset of

Alzheimer's disease (AD) and other dementias or experience mitigated symptom severity [31]. Our study also found that men were significantly associated with better levels of cognitive function. This is supported by some researchers who found that women with amnestic MCI had a greater rate of cognitive change and atrophy than men over a 1-year period [32], and women decline to AD at a faster rate compared to men [33].

According to our findings, continuous exercise has a positive effect on cognition in the elderly with chronic disease. This is consistent with previous findings, and one explanation is that the improvement in cognitive performance with physical exercise may be related to changes in neurovascular and molecular cascades [34], and that physical exercise promotes the release of neurotrophic factors, such as pituitary neurotrophic factor [35,36] and insulin growth factor [37,38], which cross the blood-brain barrier and induce synaptic plasticity and neurogenesis, thereby improving cognitive performance [34,39,40]. At the same time, physical exercise modulates resting activation and connectivity in the prefrontal cortex associated with cognition in healthy older adults [41,42,43,44]. Physical exercise may also indirectly improve cognitive performance by improving health and reducing chronic diseases that affect neurocognitive function [45]. While most scholars have explored the impact of exercise on cognition from the aspect of frequency or intensity of exercise, we further found the importance of continuous exercise on cognitive function, and this result suggested that only continuous exercise can have an improvement in cognitive function in the elderly with chronic diseases, and that the use of exercise as an intervention to slow cognitive decline needs to be strengthened in terms of its persistence.

Looking at the dimensions of cognitive function, we found significant positive correlations between continuous and non-continuous exercise on orientation.~~, and only continuous exercise had significant~~

positive effects on language. Previous studies have shown that exercise has a significant effect on executive function [14]., while physical exercise tends to have a beneficial effect on verbal fluency in the elderly with mild cognitive impairment, and exercise can increase local cerebral blood flow triggered by the activation of neuronal cells in the cerebral cortex, which may improve verbal fluency and language processing in older adults. In addition, exercise activities usually require older adults to work in pairs, which can increase the frequency of verbal communication among older adults and improve their language comprehension skills when engaging in multi-participant exercise activities. Our study also found that continuous exercise is a prerequisite for its effectiveness. Our study discovered that non-continuous exercise among elderly individuals aged 75 to 84 with chronic diseases may contribute to a decline in attention and calculation abilities. Meanwhile, non-continuous exercise among elderly individuals aged 65 to 74 with chronic diseases may contribute to a decline in recall ability. Within these age groups, the majority of participants who were non-continuous exercise specifically reported currently exercising but not having exercised in the past. We think the possible reason was that these aging groups perceived a decline in their attention, calculation and memory ability and therefore increased their exercise frequency and intensity in the recent past.

The mediating effect is the effect of the independent variable (X) on the dependent variable (Y) by influencing the mediating variable (M). In simple terms, the mediating variable explains the mechanism by which X affects Y, and it reveals the specific path by which X affects Y [29]. Baron and Kenny argued that full mediation is the strongest evidence for the existence of mediation effects [28]. Our study found that positive emotions played a full mediating role of the association between continuous exercise and cognitive function. It indicated that the cognitive benefits of continuous exercise must be mediated

through the pathway of enhancing positive emotions. Physical exercise increases the release of hindbrain-derived neurotrophic factors (BDNF), which can produce more positive emotions. BDNF is a protein synthesized in the brain that plays an important role in mood regulation. Regular aerobic exercise can promote the gene expression of BDNF and increase the amount of BDNF protein in the brain, which in turn regulates mood [46]. Other secretions such as dopamine and serotonin are also produced after physical exercise, which can also increase the production of positive emotions [47,48]. Some studies have shown that older adults with higher positive emotions are more able to efficiently regulate brain circuits when facing difficulties and setbacks, thus maintaining homeostasis within the organism and mitigating the negative effects of adverse events; as well as slowing the loss of neuronal function and structure and reducing pathological damage, thus preventing cognitive dysfunction [49]. Therefore, exercise can increase positive emotions and thus improve cognitive levels. And this fully mediated effect also implies to us that older adults with chronic diseases should produce a positive attitude and optimistic mood during exercise, so that they are more likely to improve cognitive function through continuous exercise. Our study also confirmed that continuous exercise can have a positive effect on orientation abilities to some extent through positive emotions. ~~whereas for positive effects on language, exercise must produce positive emotions to have an improving effect.~~

There are some limitations of this study: (1) There are many factors that affect cognitive decline in older adults, and this study did not cover all of them; (2) Although this study used large samples of data from reliable databases, the deletion of missing data may still affect the results. (3) The measures of exercise and positive emotion were derived from self-reports, and the classification of exercise persistence did not have a specific time criterion, which may have introduced bias in the data collection

process. (4) This was a cross-sectional study, so no causal information can be provided. (5) This study only focused on Chinese older adults with chronic diseases, and it is not yet known whether the findings of the study are applicable to populations with other social characteristics. Further research is needed. (6) A limited number of independent variables and covariates were included in this study, and further research is needed to determine whether other factors have an impact on cognitive function in Chinese elderly with chronic diseases. Despite these limitations, our study has a number of strengths. The data for this study were obtained from Chinese population survey database, which provided rich data for exploring the relationship between variables. Meanwhile, the use of a nationally representative community elderly database could make our results to be generalized to Chinese elderly with chronic diseases, which is important for guiding the prevention and control of cognitive impairment in Chinese elderly with chronic diseases. This study used positive emotion as a mediating variable, providing additional evidence to verify that positive emotions can mediate the relationship between exercise and cognition. This study takes the elderly with chronic diseases as the research object, and the research results have significant implications for the management of chronic diseases and health-related quality of life in older adults.

Conclusions

In conclusion, our findings suggested that continuous exercise was significantly associated with improved cognitive levels, and positive emotions fully mediated the effect of continuous exercise on cognition. Meanwhile, continuous exercise was significantly associated with improvements in orientation in the elderly with chronic disease. This suggested that cognitive function in the elderly with chronic diseases can be intervened with continuous exercise and that we can encourage individuals to

engage in early continuous exercise, thereby slowing the deterioration of cognition in the elderly with chronic diseases, especially in language abilities, which is a key competency for improving the quality of life of them. Meanwhile, the fully mediated effect of positive emotions also suggests the importance of generating a positive and optimistic mindset when engaging in continuous exercise, and that enjoyable exercise is an effective intervention.

Acknowledgments

We thank the Chinese Longitudinal Healthy Longevity Survey (CLHLS) team and volunteers for collecting and sharing data. We would like to thank all participants of the National School of Development workshop at Peking University and for their efforts in the Chinese Longitudinal Healthy Longevity Survey (CLHLS) of 2018. We also thank National Natural Science Foundation of China (72074125) and Social Science Foundation of Jiangsu Province.

Conflict of interest

The authors declare no conflict of interest.

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Graphical Abstract

Logistic regression results showed that continuous exercise was significantly associated with an increase in cognition (β=0.21,P=0.01). About different domains of cognition, logistic regression results indicated that continuous exercise and non-continuous exercise are significantly associated with the growth of positive emotion (β=0.57,P < 0.001; β=0.85,P < 0.001). The results of regression and KHB methods indicated that positive emotions fully mediated the effects of continuous exercise on cognition (β=0.13,P=0.11), and partially mediated the effects of exercise on orientation (β=0.31,P=0.001).

Exercise could improve levels of orientation of cognition of Chinese elderly with chronic diseases, and positive emotions mediated this effect. Only continuous exercise that produced positive emotions could have an impact on cognition ability. The elderly with chronic diseases should be encouraged to improve cognition through continuous exercise. It is noteworthy that it is important to generate and maintain positive emotions through exercise to ensure this effect is realized.

Table I Regression results for exercise and positive emotions

Variable	β	SE	P	95%CI		R^2
				Lower	Upper	
Exercise						
Non-continuous	0.556	0.102	0.000	0.357	0.756	
Continuous	0.848	0.083	0.000	0.685	1.010	
Residence						
Town	-0.174	0.094	0.064	-0.357	0.010	
Rural	-0.067	0.091	0.461	-0.245	0.111	
Education(Non-illiterate)	0.124	0.086	0.149	-0.044	0.291	
Co-residence						
Alone	0.248	0.100	0.013	0.053	0.444	
In a nursing home	0.011	0.201	0.955	-0.382	0.404	0.082
Drink status(Yes)	0.134	0.078	0.086	-0.019	0.286	
Sleep time(Enough sleep)	0.497	0.073	0.000	0.353	0.641	
ADL(Non-impaired)	0.358	0.121	0.003	0.121	0.596	
Hearing status(Yes)	-0.129	0.084	0.124	-0.293	0.0353	
Economic status						
Average	0.625	0.132	0.000	0.366	0.884	
Rich	1.265	0.147	0.000	0.977	1.553	
Constant	13.599	0.193	0.000	13.220	13.978	
N	3959	3959	3959	3959	3959	

Exercise: Never=1,Non-continuous=2,Continuous=3; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; Sleep time: Non-enough sleep=0, Enough sleep=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1; Economic status: Poor=1,Average=2,Rich=3

Table II Regression results for exercise and cognition

Variable	β	SE	P	95%CI	
				Lower	Upper
Exercise					
Non-continuous	0.114	0.100	0.254	-0.081	0.310
Continuous	0.211	0.082	0.010	0.050	0.372
Age					
75~84	-0.485	0.088	0.000	-0.657	-0.313
⩾85	-0.964	0.106	0.000	-1.172	-0.755
Gender(Male)	0.171	0.084	0.043	0.006	0.336
Marital status(Have a spouse)	0.321	0.088	0.000	0.148	0.494
Residence					

Town	-0.235	0.094	0.013	-0.419	-0.050
Rural	-0.358	0.091	0.000	-0.537	-0.179
Education(Non-illiterate)	0.564	0.086	0.000	0.396	0.732
Co-residence					
Alone	-0.025	0.106	0.817	-0.233	0.184
In a nursing home	-0.556	0.194	0.004	-0.936	-0.176
Drink status(Yes)	-0.057	0.085	0.503	-0.224	0.110
ADL(Non-impaired)	0.506	0.119	0.000	0.272	0.741
Hearing status(Yes)	-0.316	0.084	0.000	-0.480	-0.152
Constant	0.097	0.175	0.578	-0.245	0.439
N	3959	3959	3959	3959	3959

Exercise: Never=1,Non-continuous=2,Continuous=3; Age: <75=1,75~84=2,≥85=3; Gender: Female=0,Male=1; Marital status: Have no spouse=0,Have a spouse=1; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1

Table III Regression results for exercise, positive emotions and cognition

Variable	β	SE	P	95%CI	
				Lower	Upper
Exercise					
Non-continuous	0.067	0.101	0.505	-0.130	0.264
Continuous	0.133	0.084	0.112	-0.031	0.297
Positive emotion	0.086	0.016	0.000	0.056	0.117
Age					
75~84	-0.477	0.088	0.000	-0.650	-0.305
⩾85	-0.963	0.107	0.000	-1.172	-0.754
Gender(Male)	0.191	0.085	0.024	0.025	0.357
Marital status(Have a spouse)	0.344	0.089	0.000	0.170	0.518
Residence					
Town	-0.213	0.094	0.024	-0.398	-0.028
Rural	-0.346	0.092	0.000	-0.526	-0.167
Education(Non-illiterate)	0.545	0.086	0.000	0.376	0.714
Co-residence					
Alone	-0.029	0.107	0.787	-0.238	0.180
In a nursing home	-0.555	0.195	0.004	-0.937	-0.173
Drink status(Yes)	-0.083	0.086	0.333	-0.251	0.085
ADL(Non-impaired)	0.479	0.120	0.000	0.245	0.714
Hearing status(Yes)	-0.309	0.084	0.000	-0.473	-0.144
Constant	-1.182	0.290	0.000	-1.751	-0.613
N	3959	3959	3959	3959	3959

Exercise: Never=1,Non-continuous=2,Continuous=3; Age: <75=1,75~84=2,≥85=3; Gender:

Female=0,Male=1; Marital status: Have no spouse=0,Have a spouse=1; Residence: City=1,Town=2,Rural=3; Education: Illiterate=0, Non-illiterate=1; Co-residence: With household member=1, Alone=2, In a nursing home=3; Drink status: No=0,Yes=1; ADL: Impaired=0, Non-impaired=1; Hearing status: No=0,Yes=1

Table IV KHB test for positive emotion

Effect	β	SE	P	95%CI		Mediation (%)
				Lower	Upper	
Exercise(Continuous)—Positive emotion—Cognition						
Total effect	0.213	0.082	0.010	0.052	0.374	
Direct effect	0.131	0.083	0.117	-0.033	0.294	
Indirect effect	0.082	0.019	0.000	0.045	0.119	38.54
Exercise(Non-continuous)—Positive emotion—Orientation						
Total effect	0.441	0.112	0.000	0.221	0.661	
Direct effect	0.363	0.113	0.001	0.142	0.583	
Indirect effect	0.079	0.021	0.000	0.038	0.120	17.85
Exercise(Continuous)—Positive emotion—Orientation						
Total effect	0.426	0.091	0.000	0.248	0.605	
Direct effect	0.303	0.092	0.001	0.122	0.483	
Indirect effect	0.124	0.024	0.000	0.077	0.171	28.99

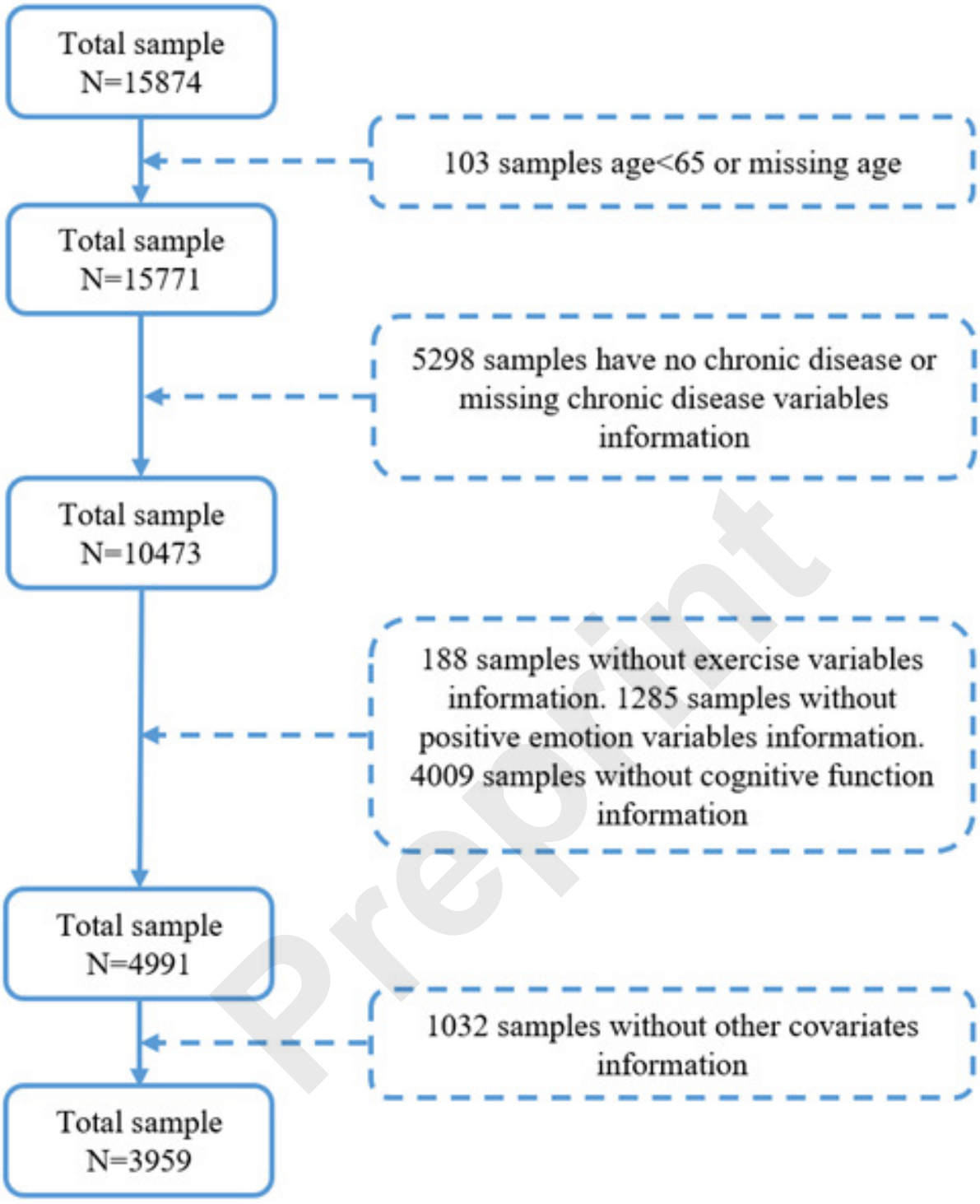

Fig.1 Sample selection process

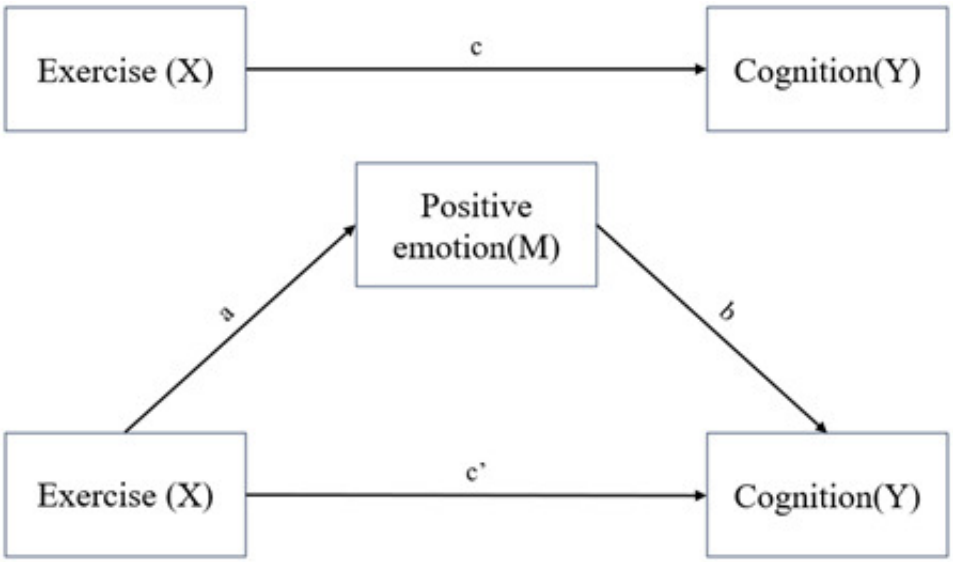

Fig.2 Research Pathway Hypothesis

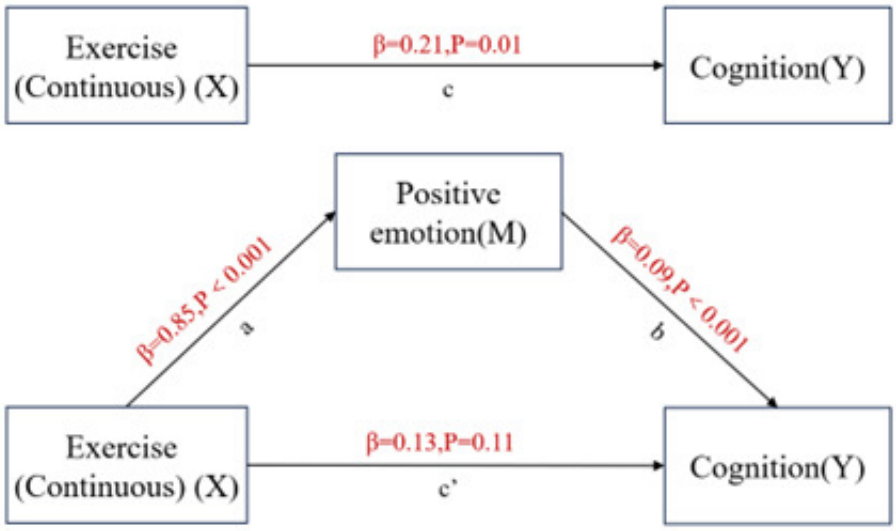

Fig.3 Positive emotion mediates relationship between continuous exercise and cognition

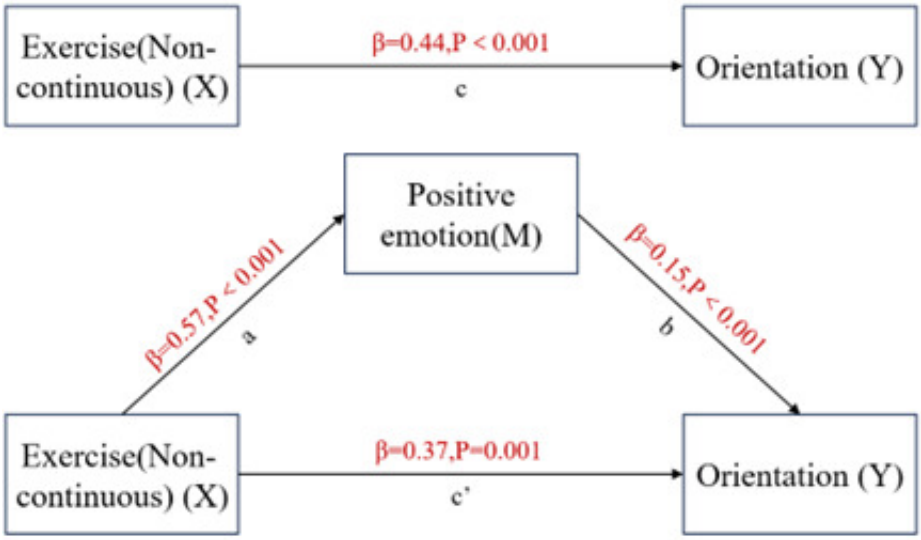

Fig.4 Positive emotion mediates relationship between non-continuous exercise and orientation

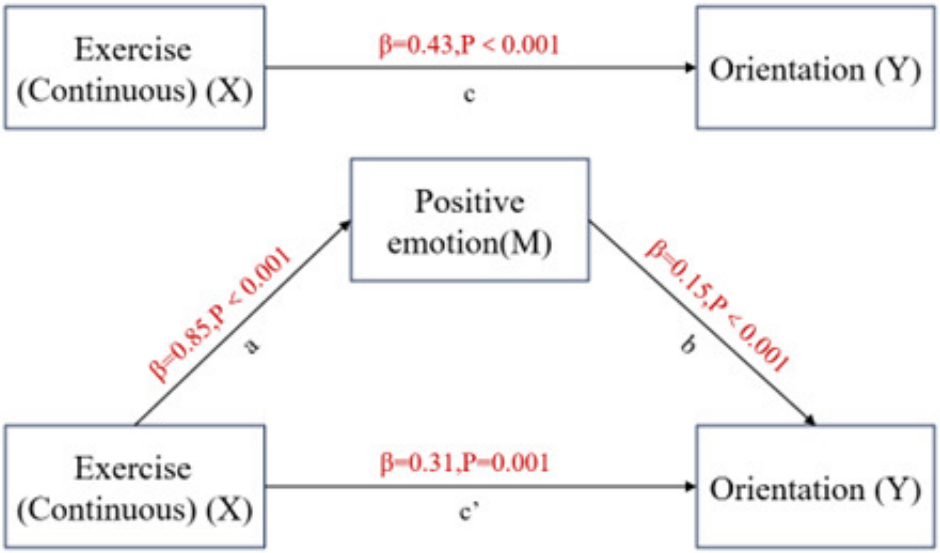

Fig.5 Positive emotion mediates relationship between continuous exercise and orientation