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Relationship between leisure activity and depression in Chinese older adults: chain mediating effect of diet and cognition

Yan Cui[1], Ying Duan[1], Jing Du[1], Ling Yang[1], Xi Tian[1] and Huaqing Liu[1*]

Abstract

Background Leisure activity was associated with depression in older adults. However, the specific processes by which diet and cognition mediate the role of leisure activities and depression remain uncertain. The study aims to investigate the relationship between leisure activity and depression in older people and the underlying mechanisms involved, while constructing a comprehensive model that links these variables.

Methods Data came from the 2018 Chinese Longitudinal Healthy Longevity Survey. Mini-Mental State Examination and CES-D-10 were used to assess cognition and depression, respectively. PROCESS macro was employed to assess the mediation effects of diet and cognition on the relationship between leisure activity and depression.

Results Leisure activity was negatively associated with depression, with 35.90% of the total effect mediated through dietary diversity and cognitive function, of which 1.28% was from the chain-mediated effect of dietary diversity and cognition. In addition, 20.94% of the total effect mediated through a plant-based diet and cognitive function, of which 0.43% was from the chain-mediated effect of plant-based diet and cognition.

Conclusions Leisure activities are linked to depression, with diet and cognition acting as chain-mediating factors. Public health experts recommend that older adults engage in leisure activities, ensure a broad spectrum of dietary intake, and prioritize the augmentation of plant-based diets as preventative strategies against depression.

Keywords Depression, Cognitive function, Leisure activity, Plant-based diet, Dietary diversity

Introduction

Depression is a psychiatric condition characterized by persistent feelings of sadness and diminished interest [1], making it the leading cause of disability worldwide [2]. As people age, they experience changes in social and family responsibilities due to retirement, shifts in leisure activities, and widowhood. These changes can result in heightened negative emotions and an elevated risk of depression [3]. Recent research indicates that over 35% of older people in China show signs of depression [4], which can lead to a significant health and economic burden for society and families [5]. Therefore, it is necessary to conduct a comprehensive study of the mechanisms that contribute to depression in the older population.

Recently, there has been a growing emphasis on identifying protective factors against depression in older people due to the severity of its consequences and the challenges of effective treatment [6, 7]. Leisure activities are pastimes that individuals participate in during their free time [8], encompassing non-exercise leisure

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activities (e.g., reading, and watching television, mahjong or card games), and exercise leisure activities (e.g., tai chi, square dancing, and garden work) [9]. These activities are classified as lifestyle behaviours that are modifiable and are notably prevalent among older people in China, especially among retirees [10]. Both reading and card games have been found to foster a sense of fulfilment and enhance mental health [11], while engaging in exercise-type activities can improve older people's physical fitness and increase their sense of well-being [12]. Although leisure activities play a pivotal role in the health of older individuals, access to such activities is not universally equal [13]. The persistent urban-rural dichotomy in China has contributed to disparities in economic development between these regions [14]. Consequently, there are marked differences in the extent of leisure activities between China's rural and urban populations, with older residents in urban areas typically engaging in more diverse and abundant leisure activities compared to their rural counterparts [13]. Leisure activity is widely recognized as an effective strategy for preventing depression in older people [15]. Studies on leisure activities among older adults suggest that a decrease in participation may be associated with an increased susceptibility to depression [3]. However, the precise mechanism through which leisure activity influences depression remains elusive.

Engaging in leisure activities and maintaining a healthy diet are fundamental components of one's lifestyle, with these behaviours typically exhibiting stability. A recent observational study has demonstrated a strong correlation between frequent engagement in leisure activities and adherence to a healthy diet [16]. Engaging in nonexercise leisure activities can improve the psychological and sensory well-being of older individuals [17]. Furthermore, reading and watching television programmes can provide individuals with additional knowledge and skills in health management [18], potentially motivating them to make healthier dietary choices. On the other hand, engaging in exercise leisure activities can enhance physical activity levels in older individuals. Previous research has shown that increased levels of exercise are associated with a more comprehensive understanding of the nutritional value of food [19] and a more balanced diet [20]. Dietary diversity refers to the intake of a variety of foods, with better dietary diversity indicating more adequate nutrient intake [21]. Plant-based diets, characterized by a predominant intake of plant foods with minimal or no animal foods, are of interest due to their potential health and longevity benefits [22]. Dietary diversity is associated with a wide range of nutrients from different food sources, but plant-based diets are characterized by the benefits of plant foods and thus represent an important aspect of dietary diversity that may improve health outcomes [21]. A study by Poorrezaeian and Chen found

that individuals who adhere to healthy diets, such as those characterized by dietary diversity and plant-based diets, are less likely to experience depression [23, 24]. Therefore, dietary diversity and plant-based diets may act as mediators between leisure activity and depression.

Cognitive function is the brain's ability to perform complex mental processes such as perception, attention, memory, language, thought, and awareness [25]. Cognitive function often declines with age and plays a crucial role in older adults' health [26]; having less cognitive reserve may increase the risk of future depression [27]. A decrease in cognitive abilities can lead to various negative emotional states, which increases the risk of developing depressive disorders [28]. Engaging in leisure activities can slow down cognitive decline in older adults [29, 30], reading can enhance cognitive reserve [31], and physical inactivity is a risk factor for cognitive impairment in older adults [32]. Depression is associated with cognitive function, but the mechanisms by which leisure activity affects depression through cognitive function are unclear. Examining cognitive function as a mediating mechanism to understand how leisure activity affects depression in older adults can provide a deeper understanding of the relationship between leisure activity and depression. In addition, higher dietary diversity and adherence to a plant-based diet have been associated with a lower likelihood of experiencing a decline in cognitive function [33, 34]. Dietary fibre-rich whole grains may improve gut health [35], thereby improving cognitive function in older adults [36]. A healthy diet may reduce the risk of late-life depression by improving cognitive function [37]. Therefore, the combined effect of dietary diversity or a plant-based diet and cognitive function may have a chain-mediated effect on the relationship between leisure activity and depression.

Previous studies have suggested a link between leisure activity and depression, yet the precise mechanisms underlying this association remain unclear. It is possible that leisure activities promote healthy dietary habits and cognitive functioning, which in turn may alleviate depressive symptoms [16, 28]. This study sought to examine three primary hypotheses: (1) whether diet serves as a potential mediator in the relationship between leisure activity and depression, (2) whether cognitive function acts as a potential mediator in the relationship between leisure activity and depression, and (3) whether both diet and cognitive function serially mediate the relationship between leisure activity and depression.

Materials and methods
Participants
The data for the study were collected from the 2018 Chinese Longitudinal Healthy Longevity Survey (CLHLS). The primary purpose of the CLHLS was to research the

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social environment, nutrition, and health conditions of individuals in China who were 65 years of age or older. Participants were selected from 23 Chinese provinces using a multistage whole-group selection method. Data collection involved face-to-face interviews. Additional details regarding the CLHLS are provided in the literature [38]. Written agreements were obtained from all participants, and the CLHLS program received approval from the Ethics Committee of Peking University. Of the 15,874 participants initially included in the study, 5,816 were excluded due to not meeting the inclusion criteria (≥65 years old and no missing data), including 103 participants aged <65 years old, 398 participants without information on leisure activity, 446 participants without information on dietary diversity, 196 participants without information on plant-based diet, 2,989 participants without information on depression, and 1,684 participants without information on cognitive function. In total, 10,058 participants aged 65 years and older were included in the present study (Fig. 1). Participants excluded were more likely to be female, to have other marital status, not to be economically independent, not to be educated, and

not to exercise (Table S1). Furthermore, the study did not employ the use of proxy respondents, as the assessment of depressive symptoms and cognitive functioning were required to be self-reported by the participants.

Assessment of depression

The evaluation of depression was conducted using the 10-item Centre for Epidemiologic Studies Depression Scale (CES-D-10) [39]. Participants were asked to choose the response that best matched their experience in the past seven days. Each item was accompanied by four response options, with values ranging from 0 (less than one day) to 3 (five to seven days). The total scores on this scale ranged from 0 to 30, with higher scores indicating a greater level of depression. The scientific validity of the CES-D-10 was previously substantiated [40].

Assessment of leisure activity

The leisure activity index was computed based on engagement in various activities, including completing exercise leisure activities (e.g., garden work, tai chi, keeping chickens or pets, and square dancing) and non-exercise leisure
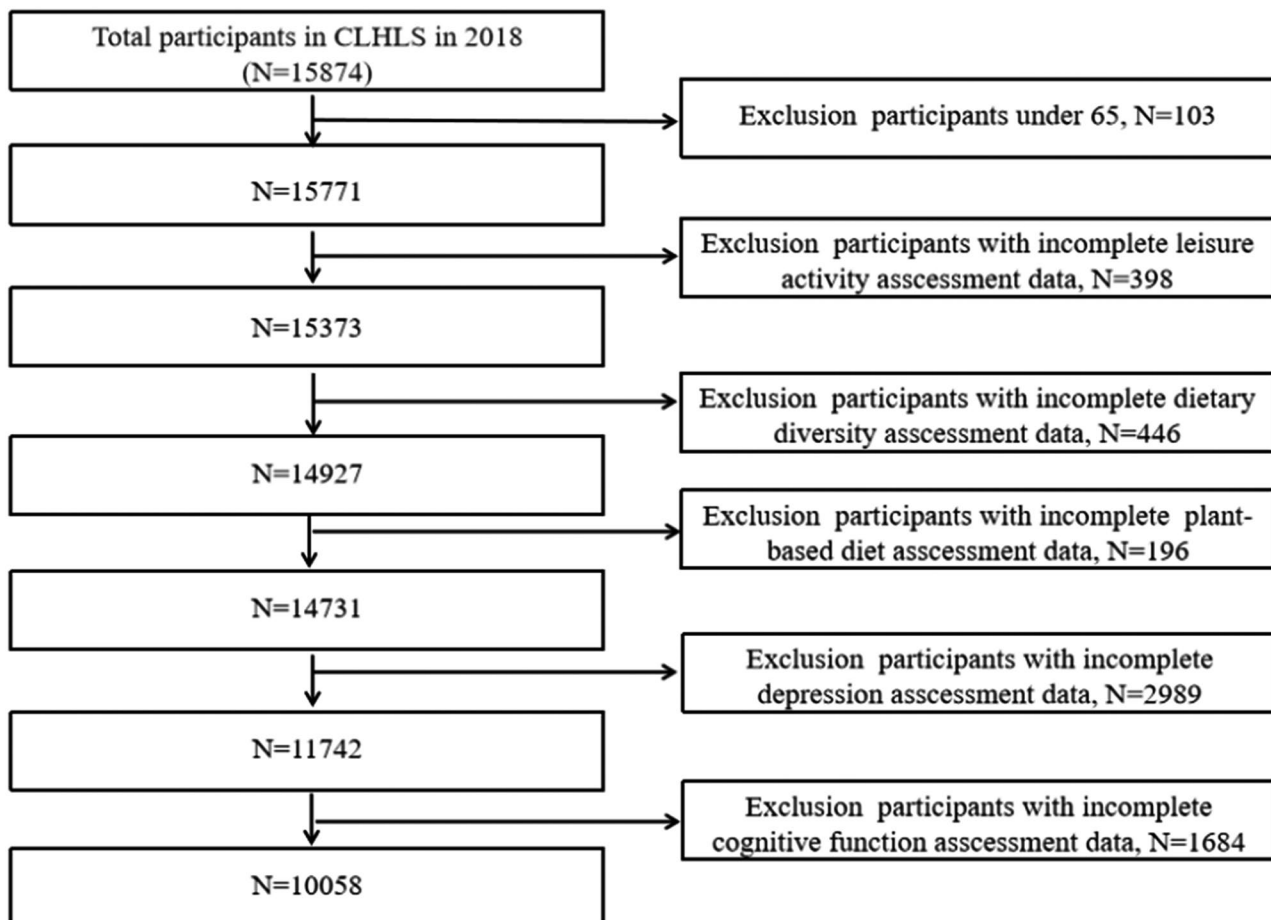

Fig. 1 Flowchart for screening participants

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activities(e.g., mahjong or card games, reading, watching television, and participating in social activities) [9]. The individual was asked what leisure activities to engage in. Each item is given one of three response options: 1= "Almost every day", 2= "Sometimes" and 3= "Never" [41]. The range of the leisure activity index is from 8 to 24, with higher values indicating more engagement.

Assessment of dietary diversity scores (DDS)
The food intake frequency data from the CLHLS served as an indicator of the participants' intake of various food groups. To evaluate the adequacy and healthiness of the participants' food consumption, the DDS questionnaire employed in this study primarily comprised healthy food items. In addition, because nearly every Chinese person consumes grains and oil daily, these foot items were excluded from the DDS calculation [42]. Ultimately, the DDS questionnaire included fresh vegetables, fruits, mushrooms or algae, bean products, nut products, tea, garlic, milk products, meat, fish, and eggs. The DDS was calculated based on the frequency of consumption of these 11 foods, with total scores ranging from 0 to 11 [43]. A higher DDS score indicated a more diverse diet. This scoring system was previously scientifically validated [44].

Assessment of plant-based diet index (PDI)
The study employed a simplified questionnaire regarding food consumption frequency to evaluate participants' dietary intake concerning the types of foods they consumed and the frequency with which the foods were consumed. The validity of this method was previously demonstrated [45]. The present study evaluated 16 food groups, categorized into two types based on their contributions to health: plant foods (i.e., vegetables, whole grains, fruits, legumes, nuts, preserved vegetables, tea, garlic, vegetable oils, sugar, and refined grains,) and animal foods (i.e., meats, animal fats, eggs, milk, and fish) [46, 47]. By the methodology established in earlier surveys [48, 49], the PDI was calculated using self-reported food intake. Each food item received a score ranging from 1 to 5, with positive scores assigned to plant-based foods and negative scores assigned to animal-based foods. The cumulative PDI score ranged from 16 to 80, with a higher score indicating greater consumption of plant-based foods.

Assessment of cognitive function
The cognitive function was evaluated by administering the Chinese version of the Mini-Mental State Examination (MMSE), which has been validated for its reliability. The MMSE is a 24-item test that evaluates cognitive functioning across several domains, including orientation (5 items), reactivity (1 item), transient memory (3 items),

attention and calculation (5 items), delayed memory (3 items), language (6 items), and visual and spatial abilities (1 item). The Reactive Ability component is assessed using a food naming task, where subjects are asked to name as many foods as possible within one minute. Each correctly identified food item is worth one point, with a maximum score of seven points. For the remaining 23 items, each correct response is worth one point, and incorrect responses are not scored. The total scores on this scale ranged from 0 to 30, with lower scores on this scale indicating lower levels of cognitive ability [50]. Before this, the validity and reliability of the MMSE were confirmed [51].

Covariates
To enhance the reliability of the study results, we controlled for several confounding factors. These factors included age, sex, marital status, body mass index (BMI), presence of chronic diseases, financial independence, education, place of residence, smoking habit, drinking habit, and exercise status. Financial independence was defined as having a source of income through work or retirement payments [43]. Chronic disease status was determined based on whether an individual had diabetes, hypertension, heart or lung disease [43].

Statistical analyses
The data analysis was performed using SPSS, version 24.0. The presentation of quantitative data involves the use of means and standard deviations (M±SD), whereas categorical variables is typically displayed in the form of frequencies or percentages. Spearman correlation analysis was employed to explore the correlations among leisure activity, DDS, PDI, cognitive function, and depression. Linear regression was used to explore the relationship between leisure activities, diet (DDS or PDI), cognitive functioning alone with depression. The PROCESS macro (Model 6) [52] was employed to assess the chain mediation effects. The chain-mediated roles of diet (DDS or PDI) and cognition in leisure activities and depression were explored using the bootstrapping method. Furthermore, we incorporated DDS, PDI, and cognition into a comprehensive chain-mediated model to systematically examine the three chain-mediated effects linking leisure activity with depression. In addition, we used subgroup analyses to explore urban-rural differences in the chain-mediated effects of diet and cognition on the depression for leisure activity. The present study determined that a mediation effect could be considered significant if the sample size was 5000 and the 95% confidence interval did not include zero. A p-value below 0.05 was considered to indicate statistical significance.

Table 1 Characteristics of participants (*N* = 10,058)

Variable	*N*	Percentage (%)
Age (years, mean ± SD)	10,058	82.36 ± 10.71
Sex		
Male	4752	47.2
Female	5306	52.8
Place of residence		
Rural	7627	75.8
Urban	2431	24.2
Marital status		
Presently married and cohabiting with their spouse	4716	47.3
Other	5254	52.7
Education (years)		
0	4238	42.6
≥ 1	5714	57.4
Financially independent		
No	5987	61.3
Yes	3784	38.7
Smoking status		
No	8299	83.2
Yes	1679	16.8
Drinking status		
No	8335	83.9
Yes	1596	16.1
Exercise status		
No	6318	63.5
Yes	3628	36.5
BMI (body mass index, kg/m^2)		
Underweight (< 18.5)	1309	13.44
Normal (18.5–23.9)	5038	51.74
Overweight (24-27.9)	2543	26.11
Obese (≥ 28)	848	8.71
Chronic disease		
No	3373	36.3
Yes	5929	63.7
Leisure activity (mean ± SD)	10,058	11.26 ± 2.41
DDS (mean ± SD)	10,058	5.80 ± 1.88
PDI (mean ± SD)	10,058	48.23 ± 5.42
Cognitive function (mean ± SD)	10,058	26.18 ± 5.11
Depression (mean ± SD)	10,058	7.23 ± 4.38

Note: DDS: dietary diversity scores; PDI: plant-based diet index

Table 2 Correlation analysis between leisure activity, DDS, PDI, cognitive function, and depression

Variables	Leisure activity	DDS	PDI	Cognition function	Depression
Leisure activity	1				
DDS	0.369***	1			
PDI	0.192***	0.358***	1		
Cognitive function	0.424***	0.254***	0.160***	1	
Depression	-0.225***	-0.218***	-0.151***	-0.199***	1

***$P < 0.001$

abnormal BMI (48.3%), and 63.7% had chronic diseases. The average leisure activity score was 11.26 ± 2.41 points, the average DDS score was 5.80 ± 1.88 points, the average PDI score was 48.23 ± 5.42 points, the average cognitive function score was 26.18 ± 5.11 points, and the average depression score was 7.23 ± 4.38 points.

Table 2 presents the correlations among leisure activity, DDS, PDI, cognitive function, and depression. The correlation analysis revealed that leisure activity, DDS, PDI, and cognitive function exhibited a significant negative correlation with depression ($P < 0.001$). Moreover, leisure activity showed significant positive correlations with DDS, PDI, and cognitive function ($P < 0.001$). Furthermore, cognitive function exhibited positive correlations with DDS and the PDI ($P < 0.001$). Notably, all these variables were significantly correlated, necessitating further tests to explore potential mediating effects. Moreover, leisure activity, DDS, PDI and cognitive function was associated with depression after adjusting sex, marital status, BMI, chronic diseases, financial independence, education, place of residence, smoking, drinking, and exercise status (shown in Table 3).

Table 4 presents the results concerning the mediating effects of diet (DDS or PDI) and cognitive function on the relationship between leisure activity and depression. The coefficients and significance of each path were depicted in Fig. 2. As depicted in Fig. 2A, leisure activity had a direct effect on depression, with an effect value of -0.150, which accounted for 64.10% of the total effect. Furthermore, leisure activity affected depression through three indirect paths, with a total effect of -0.084, representing 35.90% of the overall effect. First, leisure activity influenced depression through DDS, with a mediating effect value of -0.053, accounting for 22.64% of the total effect. Second, leisure activity influenced depression through cognitive function, with a mediating effect value of -0.028, accounting for 11.97% of the total effect. Third, leisure activity influenced depression through DDS and cognitive function sequentially, with a mediating effect value of -0.003, accounting for 1.28% of the total effect. The relationship between leisure activity and depression was chain-mediated by DDS and cognitive function. As

Results

The characteristics of the study participants are displayed in Table 1. The average age of the participants was 82.4 ± 10.7 years. Regarding sex, of the respondents, 4,752 (47.2%) were men, and 5,306 (52.8%) were women. In addition, 75.8% resided in a town or rural area, 47.3% were married, 42.6% had an education level of ≥ 1 year, and 38.7% were financially independent. Most of the included older adults were non-smokers (83.2%), were non-drinkers (83.9%), and did not engage in exercise (63.5%). Approximately half of the older adults had an

Table 3 Association of leisure activity, diet and cognitive function with depression

Characteristic	R	R²	F	β	t	P
Leisure activity	0.289	0.083	63.256	-0.230	-10.155	<0.001
DDS	0.304	0.092	70.655	-0.380	-13.620	<0.001
PDI	0.285	0.081	61.431	-0.079	-9.099	<0.001
Cognitive function	0.294	0.086	65.686	-0.126	-11.410	<0.001

Adjusted sex, marital status, BMI, chronic diseases, financial independence, education, place of residence, smoking, drinking, and exercise status

Table 4 Chain mediating effects of diet (DDS or PDI) and cognitive function on the relationship between leisure activity and depression

Pathway	Effect	SE	95%CI	Proportion (%)
Pathway A				
Leisure activity→DDS→Depression	0.164*-0.321=-0.053	0.006	(-0.065, -0.042)	22.64
Leisure activity→Cognitive function→Depression	0.266*-0.105=-0.028	0.004	(-0.036, -0.020)	11.97
Leisure activity→DDS→Cognitive function→Depression	0.164*0.151*-0.105=-0.003	0.001	(-0.004, -0.002)	1.28
Total indirect effects	-0.084	0.007	(-0.098, -0.070)	35.9
Direct effect	-0.150	0.023	(-0.195, -0.105)	64.10
Total effect	-0.234	0.023	(-0.278, -0.189)	100
Pathway B				
Leisure activity→PDI→Depression	0.236*-0.070=-0.017	0.003	(-0.022, -0.011)	7.26
Leisure activity→Cognitive function→Depression	0.285*-0.110=-0.031	0.004	(-0.040, -0.024)	13.25
Leisure activity→PDI→Cognitive function→Depression	0.236*0.024*-0.110=-0.001	0.000	(-0.001, 0.000)	0.43
Total indirect effect	-0.049	0.005	(-0.059, -0.039)	20.94
Direct effect	-0.185	0.023	(-0.230, -0.140)	79.06
Total effect	-0.234	0.023	(-0.278, -0.189)	100

Note: Pathway A: Chain mediating effects of DDS and cognitive function on the relationship between leisure activity and depression; Pathway B: Chain mediating effects of PDI and cognitive function on the relationship between leisure activity and depression. Adjusted sex, marital status, BMI, chronic diseases, financial independence, education, place of residence, smoking, drinking, and exercise status. * *P*<0.05
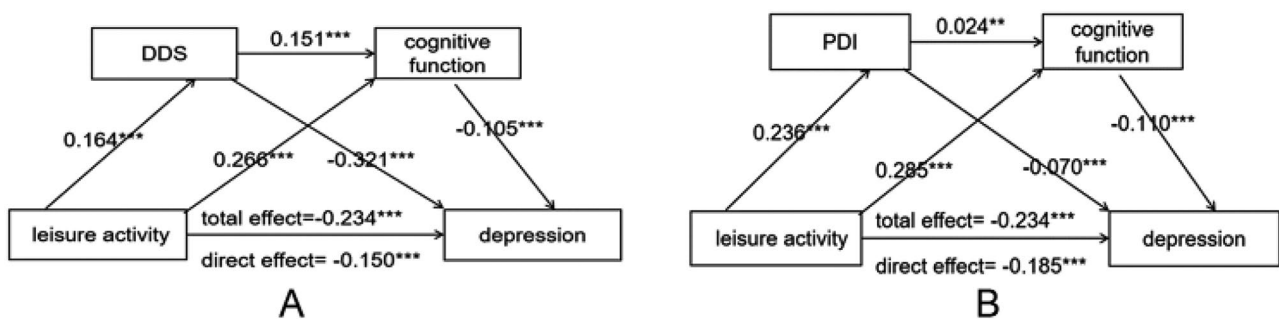

Fig. 2 Chain mediating effects of diet (A: DDS; B: PDI) and cognitive function on the relationship between leisure activity and depression. Note: ***P*<0.001

depicted in Fig. 2B, leisure activity affected depression through three indirect paths, with a total effect of -0.049, representing 20.94% of the overall effect. First, leisure activity affected depression through PDI, with a mediating effect value of -0.017, accounting for 7.26% of the total effect. Second, leisure activity influenced depression through cognitive function, with a mediating effect value of -0.031, accounting for 13.25% of the total effect. Third, leisure activity influenced depression through PDI and cognitive function sequentially, with a mediating effect value of -0.001, accounting for 0.43% of the total effect.

A further stratified analysis of the chain mediation effect was conducted, distinguishing between urban and rural areas. As presented in Table S2 and Fig. 3,

the findings suggested that the chain mediation effect observed in rural older adults paralleled that seen in their urban counterparts. However, it was noted that leisure activities had a significant direct impact on depression only within the rural context, not in the urban setting.

To further examine the chain mediation effects of diet and cognition in the relationship between leisure activity and depression, we constructed a unified model including three mediators, i.e., DDS, PDI and cognitive function. As depicted in Table 5; Fig. 4, leisure activity exerted an influence on depression, with a total indirect effect of 37.58%. This was comprised of 17.64% attributable to DDS, 11.90% to cognitive function, 4.40% to PDI, and 2.56% to DDS via PDI.
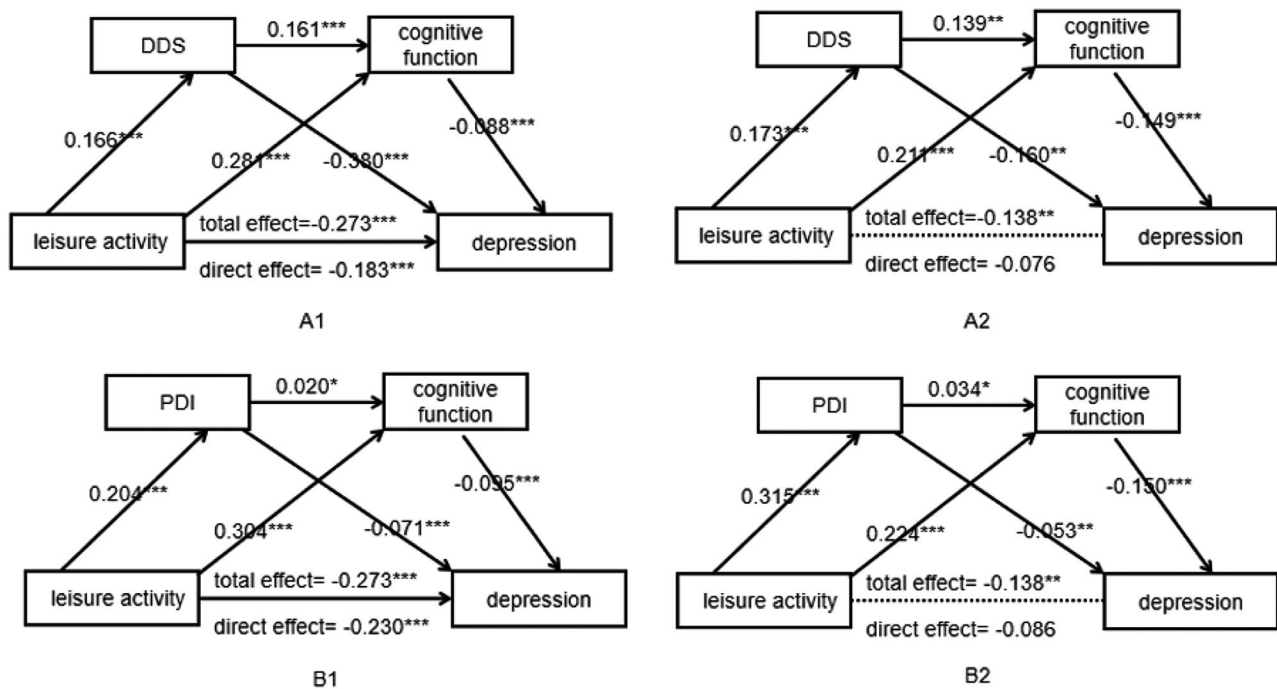
Fig. 3 Chain mediating effects of diet (A: DDS / B: PDI) and cognitive function on the relationship between leisure activity and depression. Rural = 1; Urban = 2. Note: ***$P < 0.001$

Table 5 Chain mediating effects of PDI, DDS and cognitive function on the relationship between leisure activity and depression

Pathway	Effect	SE	95%CI	Proportion (%)
Leisure activity→PDI→Depression	0.2319*-0.0441=-0.0102	0.0025	(-0.0154,-0.0057)	4.40
Leisure activity→DDS→Depression	0.1474*-0.2756=-0.0406	0.0052	(-0.0510,-0.0305)	17.64
Leisure activity→Cognitive function→Depression	0.2625*-0.1044=-0.0274	0.0040	(-0.0358,-0.0199)	11.9
Leisure activity→PDI→DDS→Depression	0.2319*0.0919*-0.2756=-0.0059	0.0010	(-0.0080,-0.0040)	2.56
Leisure activity→PDI→Cognitive function→Depression	0.2319*0.0110*-0.1044=-0.0003	0.0002	(-0.0007,0.0002)	/
Leisure activity→DDS→Cognitive function→Depression	0.1474*0.1397*-0.1044=-0.0021	0.0005	(-0.0033,-0.0011)	0.91
Leisure activity→PDI→DDS→ Cognitive function→Depression	0.2319*0.0919*0.1397*-0.1044=-0.0003	0.0001	(-0.0005,-0.0002)	0.13
Total indirect effects	-0.0865	0.0073	(-0.1012,-0.0728)	37.58
Direct effect	-0.1437	0.0231	(-0.1888,-0.0985)	62.42
Total effect	-0.2302	0.0227	(-0.2750,-0.1860)	100

Note: Adjusted sex, marital status, BMI, chronic diseases, financial independence, education, place of residence, smoking, drinking, and exercise status. * $P < 0.05$
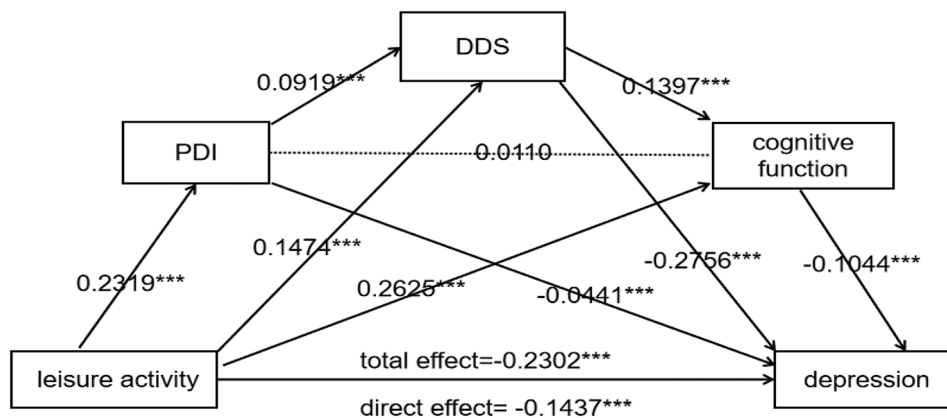

Fig. 4 Chain mediating effects of PDI, DDS and cognitive function on the relationship between leisure activity and depression. Note: ***$P < 0.001$

Discussion

The current study aimed to examine the potential impact of diet and cognition on the relationship between leisure activity and depression. The chain mediation analysis revealed a significant sequence of influences connecting diet and cognition. These discoveries have the potential to offer an understanding of the intricate relationship between leisure activity and depression, which has significant implications for clinical management and future studies. In addition, this could potentially heighten the awareness of public health professionals regarding the involvement of family members and community resources to bolster leisure engagement and dietary quality among older people.

Consistent with a study conducted in American [53], our findings indicate a correlation between leisure activity and depression among older people in China. Similarly, a study involving middle-aged and older adults in India showed that higher engagement in leisure activities was negatively associated with depression [54]. Participating in leisure activities may contribute to increased social support and happiness of older individuals, thereby potentially leading to improved mental health [55]. Therefore, older individuals who participated in high levels of leisure activity were less likely to experience depression [56]. However, the rapid urbanization and societal changes in China have resulted in a significant reduction of green spaces within cities [57], prompting an increased preference for indoor living among older people. Additionally, market reforms have fostered a trend towards personalized social life, leading to a sense of estrangement within neighbourhoods [58]. These factors collectively contribute to a sedentary and solitary lifestyle among older people. Studies indicate that between 1998 and 2018, there was a gradual decline in the participation of China's older population in leisure activities [59]. Therefore, greater attention should be paid to leisure activity as a means of preventing depression in older populations. Local authorities and community service centres can promote the mental well-being of older people by establishing and maintaining activity centres tailored for them to providing a diverse range of leisure activities, including reading, gardening and square-dancing classes.

Using a chain mediation model, this study revealed a possible mechanism underlying the relationship between leisure activity and depression in the aging population of China. That is, engaging in leisure activity can influence dietary diversity and adherence to a plant-based diet and can thereby influence depression. This is consistent with the findings of a study on older Japanese people, which revealed that frequent engagement in leisure activity was linked to a healthier diet [60]. Inadequate dietary intake of essential vitamins such as B6 and B12 was previously linked to reduced synthesis of brain mono-amines, which can lead to depression [61]. Individuals with a diverse diet are likely to obtain a wide range of essential nutrients, and therefore, such a diet can reduce the likelihood of experiencing depression [62]. In addition, individuals with depression tend to exhibit lower antioxidant levels and higher oxidative stress levels than those without depression [63, 64]. Plant-based foods contain a wide range of antioxidants, such as vitamins C and E [24], that are crucial for reducing oxidative stress and, consequently, preventing depression [65]. Ensuring dietary diversity and adopting a plant-based diet are recommended dietary measures that may help prevent the occurrence of depressive symptoms. Our study revealed that engaging in leisure activity enhances cognitive function and thereby alleviates depression. Engaging in leisure activity was previously demonstrated to prevent degenerative changes in the entorhinal cortex, thus contributing to the prevention of cognitive deficits [30] and, consequently, alleviating depressive symptoms [66]. Enriching leisure activities for older individuals can lead to improved cognitive function and enhanced mental health. It is advisable for geriatric healthcare professionals to prioritize initiatives that encourage older population to augment their involvement in leisure activities, adhere to a nutritious diet, and enhance cognitive function. Such strategies may potentially mitigate the risk of depression among older individuals.

Additionally, this study identified a chain mediating relationship between leisure activity and depression, with diet (DDS or PDI) as well as cognitive function acting as intermediaries in this chain. This suggests that engaging in leisure activity may contribute to higher levels of diet (DDS or PDI) or cognitive function, which subsequently leads to improved depression. The level of leisure activity is directly linked to healthy dietary habits, which can lead to elevated cognitive function and diminished depression levels. Several studies have demonstrated a positive association between DDS or PDI scores and cognitive function in Chinese older individuals [67, 68]. In addition, a cohort study showed that a high level of dietary diversity was associated with a low risk of dementia in middle-aged and older Japanese women [69]. Liu et al. found that adherence to a plant-based diet was associated with a decreased cognitive risk in older African American adults [34]. Highly diverse and plant-based diets serve as rich sources of anti-inflammatory nutrients, and therefore, such diets can reduce central nervous system inflammation [70, 71], ultimately influencing cognition [72]. Participation in leisure activities among older people has been shown to promote socialization [73], thereby encouraging them to share healthy meals and nutritional information. Furthermore, long-term engagement in leisure activities may contribute to individuals adopting healthier lifestyles, which in turn may lead

to better eating habits [20]. Healthy eating behaviours such as consuming a diverse diet and adopting a plant-based diet can enhance diet quality and nutritional status, thereby preventing cognitive impairment [45, 67]. A diet that is balanced in composition is advantageous for sustaining consistent blood glucose levels, which are crucial for optimal brain function [74]. People with low cognitive function have poorer attention and memory, making them more susceptible to depression than the general population [75]. A robust memory is associated with increased self-confidence and self-efficacy in older adults, which can reduce the risk of depressive symptoms [76]. Improved cognitive abilities encourage older adults to participate in social activities [77], thereby reducing feelings of isolation and depression. Thus, DDS and the PDI as well as cognitive function exert chain-mediated effects on the association between leisure activity and depression. Maintaining high levels of leisure activity, adopting a healthy diet, and enhancing cognitive function collectively exert multiple effects on depression among older adults. Consequently, public health professionals are encouraged to advocate for leisure activities and healthy dietary habits, emphasizing their potential benefits in enhancing cognitive function and mitigating the risk of depression.

Moreover, rural-urban differences were observed in the mediating mechanisms of leisure activities on depression. The findings suggest that diet and cognition fully mediate the relationship between leisure activity and depression among urban older adults, while the direct effect of leisure activity on depression is also significant among rural older adults. One possible explanation for this difference is that rural older adults in China are more likely to be depressed than their urban counterparts [78], which may strengthen the association between leisure activity and depression among rural older adults. Furthermore, urban older individuals have greater access to medical resources to enhance their mental health [79], which may reduce the impact of leisure activities on them. Public health professionals should prioritize leisure activities and healthy eating among rural older adults as strategies to improve their mental health.

The findings indicated that in the newly constructed chain mediated model of diet (DDS and PDI) and cognition, the chain-mediated effect of PDI and cognition was no longer statistically significant, while the chain-mediated effects of PDI, DDS and cognition remained significant. This suggests that the chain mediating effect of diet and cognition is mainly dependent on DDS rather than PDI. Although there is a positive correlation between plant-based diets and cognitive function [34], this dietary pattern is not widely adopted by Chinese older adults [80], which may hinder the observed association between plant-based diets and cognitive function. In addition,

older adults who participate in high levels of sports and leisure activities may consume more energy, which may affect their dietary choices [20], prompting them to prefer a variety of food groups rather than only plant-based foods. Studies have shown that the consumption of animal foods, such as fish, can also promote cognitive and general health improvements in older adults [81]. Therefore, some older adults actively incorporate animal foods into their diets with the aim of improving their overall health and well-being. A plant-based diet includes a variety of plant-based food groups [82], and promoting the consumption of different types of vegetables and fruits can help to adopt a varied diet, which may improve cognitive function in older adults. The Korean aging study showed that older adults adhering to a plant-based diet demonstrated superior swallowing abilities [83], which allows them to consume a wider range of foods, thereby facilitating the acquisition of more comprehensive nutrition and enhancing older adults' self-confidence and mental health. Public health workers can advocate for cognitive improvement in depression by encouraging older adults to engage in leisure activities and adopt healthy eating habits, especially dietary variety.

The exploration of the chain-mediated effects of diet and cognition on leisure activity and depression yields promising implications for enhancing mental health among older adults. This study posits that diet and cognition serve as chain mediators in the relationship between leisure activity and depression in this demographic. More specifically, heightened levels of leisure activity foster healthy eating habits and bolster cognitive function, subsequently mitigating depressive symptoms. Interventions targeting leisure activity, diet, and cognition hold potential for effectively ameliorating depressive symptoms in older adults. Such an integrated intervention strategy not only addresses the depressive symptoms directly but also considers the foundational lifestyle and cognitive determinants, offering a more holistic approach to enhancing the mental well-being of older adults. In essence, understanding the chain-mediated effects of diet and cognition in the context of leisure activity and depression provides both a robust theoretical foundation and practical insights for mental health interventions, underscoring the significance of comprehensive, multifaceted interventions. Public health professionals can thus craft expansive intervention programs that amalgamate leisure activity, dietary guidance, and cognitive training, thereby establishing a multidimensional support framework to bolster mental health in older adults. For instance, community initiatives that merge education on healthy eating with cognitive training can be instrumental in reducing depression among older adults.

This study was the first to use a large data-set to examine the potential mechanisms that govern the relationship

between leisure activity and depression in older Chinese people. However, the study has some limitations. First, the cross-sectional design of the research prevented the assessment of the causality between variables. In addition, previous research has suggested that depressive symptoms could adversely affect cognitive functioning, thereby constraining dietary choices and engagement in leisure activities [77, 84]. Therefore, we cannot conclusively determine the chronological order of leisure activity, diet, cognitive function, and depression. Future investigations could benefit from adopting longitudinal study designs and implementing behavioural interventions focused on leisure activity and depression. Second, although the CES-D-10 has been validated in population studies, it is not a clinical diagnostic tool for depression. Third, while leisure activity can influence depression through diet and cognition, it also has the potential to enhance mental health by improving physical fitness and fostering social relationships. Consequently, the chain-mediated effects of diet and cognition in relation to leisure activities and depression might be somewhat exaggerated. Future research should explore other factors beyond diet and cognition that mediate the relationship between leisure activities and depression. Despite the potentially minimal chain-mediated effects of diet and cognition, these factors may still significantly influence depression in older adults. This population is at a heightened risk for depression due to physical changes, social isolation, or loss of family and friends. Therefore, the chain-mediated effects of diet and cognition on leisure activity and its subsequent impact on depression could be particularly relevant in the older population. Fourth, data on leisure activity, diet, cognition, and depression relied on a self-report questionnaire, which may introduce self-report bias. In addition, all participants included in this study were from China. Previous studies have shown that due to China's unique socio-cultural context, Chinese older adults exhibit unique leisure activities [85] and dietary habits [86]. Consequently, the generalizability of our findings warrants verification across different cultural and ethnic groups to ascertain potential heterogeneity. Lastly, our study cannot avoid possible sample selection bias, which could potentially affect the robustness of our findings.

Conclusion

Engaging in leisure activity is significantly associated with depression among older individuals. Moreover, diet and cognitive function exert a chain-mediating effect on this association. The study findings provide novel evidence that enhances the understanding of the interconnected roles of leisure activity, diet, and cognition in influencing depression among older individuals. Public health workers can encourage older people to engage in some leisure activities, keep high dietary diversity, and enhance plant-based diets for the prevention and improvement of depression.

Declarations

Ethics approval and consent to participate
Ethical approval was obtained from the Peking University Research Ethics Committee (IRB00001052-13074), and informed consent was obtained when the CLHLS was administered. The research was performed in accordance with the Declaration of Helsinki.

Consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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