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The relationship between physical activity and diabetes in middle-aged and elderly people

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Abstract

To investigate the association between diabetes symptoms and physical activity (PA) levels among middle-aged and older Chinese adults. Data for this study were obtained from 2018 Charles data. *Z* test, logistic regression analysis, and linear hierarchical regression analysis were performed in 5352 individuals aged ≥50 years with complete information. In terms of diabetes, 6.8% of the middle-aged and elderly people with diabetes were detected, and 93.2% of the middle-aged and elderly people without diabetes symptoms. The proportion of middle-aged and elderly people with high PA levels was 50.5%, and the proportion of middle-aged and elderly people with low PA was 49.5%. There was a significant positive correlation between low PA and diabetes ($P < .05$). After adjusting demographic characteristics (gender, registered permanent residence type, education level, age, widowhood) and health status characteristics (poor mood, asthma, hyperlipidemia, disability, memory disease, self-assessment of health status, hypertension, smoking, stroke, depression), there was still a statistical significance between PA level and diabetes ($P < .05$). The risk of diabetes of middle-aged and elderly people in China increases with age, while the risk of diabetes of middle-aged and elderly people with low level of PA is higher. The risk of diabetes is high among middle-aged and elderly people who are old, have poor self-evaluation health, suffer from hyperlipidemia, memory disease, and asthma. The middle-aged and old people should increase their PA levels to prevent and improve diabetes.

Abbreviations: CHARLS = China Health and Retirement Longitudinal Study, CI = confidence interval, IPAQ = International Physical Activity Questionnaire, OR = odds ratio, PA = physical activity.

Keywords: diabetes, middle-aged and elderly, physical activity, relationship

1. Introduction

The prevalence of diabetes is rising due to the aging population, unbalanced eating habits, increased high obesity rates, and low levels of physical activity (PA).[1] The increase in the number of elderly people suffering from diabetes is regarded as one of the problems facing healthy aging.[2] The World Health Organization predicts that by 2030, the population of diabetes will reach 522 million, of which the elderly aged ≥60 account for half of the total number of diabetes.[3] The main health feature of diabetes patients is persistent hyperglycemia caused by insufficient insulin secretion.[4] Defects in mitochondrial metabolism in islet A cells may contribute to dysregulated glucagon secretion in type 2 diabetes.[5] Newman–Watts, the small-world feedforward neural network, has been found to be effective in the diagnosis of diabetes.[6] Persistent hyperglycemia will damage different organs and systems of the body.[7] For example, the incidence of lower limb amputation, myocardial infarction, visual impairment, and renal failure in patients with diabetes is higher than that in normal people. Physical dysfunction, decreased physical control ability, falls, urinary incontinence, pain, depression, and dementia are also very common among the elderly with diabetes.[8] These complications will cause the elderly to be weak, even disabled, and reduce the quality of life of the elderly, which will cause a great burden on families and society suffering from diabetes.[9,10] A large amount of literature has confirmed that regular PA is considered one of the best ways to prevent and treat type 2 diabetes.[11–13] Insulin secretion insufficiency of elderly diabetes patients is significantly related to body composition, obesity, and lack of PA, and PA can significantly improve the above problems.[14,15] Research shows that [16,17] PA is negatively related to the risk of diabetes, but the number of research evidence about PA and the risk of diabetes is limited, and the scientific quality of each research is uneven, so it is necessary to further explore the relationship between PA and the risk of diabetes. Therefore, the purpose of

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this study is to explore the correlation between the risk of diabetes and PA in middle-aged and elderly people in China and to provide a new basis for the study of PA in the prevention and treatment of diabetes in middle-aged and elderly people.

2. Methods

2.1. Participants and data

A significant multidisciplinary survey study called China Health and Retirement Longitudinal Study (CHARLS) is being carried out at Peking University in China.[18] For the analysis of China's population aging and to advance interdisciplinary aging research, the aim of the study is to collect data on demographic characteristics, physical and mental health, personal and family economic status, medical services, and insurance of middle-aged and elderly people in China who are ≥45 years of age. The multi-stage probability scale proportional sampling approach is used by CHARLS, and it involves sampling at 2 different levels: county (district), village (resident), home, and person. Data from CHARLS 2018 were utilized in our analysis. The CHARLS database at Peking University in China houses all the data that was gathered during CHARLS. All information is available at http://charls.pku.edu.cn. The study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of College of Sports Science, Shenyang Normal University (protocol code 049, protocol approved on July 30, 2022).

2.2. Variables

2.2.1. Demographic, chronic disease, and mental health variables. Gender (male or female), age (50–59, 60–69, 70–79, 80–89, and ≥90), household registration type (urban or rural), education levels (below high school or high school above), and widower status are among the demographic factors. Chronic disease variables included arthritis (yes or no), hypertension (yes or no), disability (yes or no), asthma (yes or no), self-rated health (good or bad), memory disorders (yes or no), stroke (yes or no), and hyperlipidemia (yes or no). Mental health variables included bad mood (yes or no) and depression (yes or no).

2.2.2. Physical activities. According to the questionnaire poll, lugging heavy things, excavating, farming, and other physically labor-intensive occupations are common among middle-aged and older persons. A few examples of low-intensity physical activities are sweeping the floor, performing Taijiquan, strolling, entertainment, and mahjong. The number of days and the length of the participants' daily activities for each PA lasting at least 10 minutes were then assessed. Each PA's length is classified as follows: 0.5 hours, >0.5 hours but 2 hours, >2 hours but 4 hours, and >4 hours. The PA level was calculated using the International Physical Activity Questionnaire (IPAQ), and IPAQ has good reliability and validity.[19,20] Total PA per week was calculated by metabolic equivalent × h/wk and divided into 2 groups: ≥23 metabolic equivalent of energy/h/wk-1 (high PA) or <23 metabolic equivalent of energy/h/wk-1 (low PA).

2.2.3. Diabetes. Information about whether participants have diabetes was obtained by means of self-reports of participants.

2.3. Statistical analysis

First, all listed variables are statistically described. Multivariate logistic regression was used to analyze the risk factors of diabetes and PA. In order to evaluate the correlation between PA and the possibility of diabetes, a multi-level linear regression analysis was conducted with diabetes as the dependent variable and PA level as the independent variable to determine the relationship between PA and the possibility of diabetes. *P* values of PA and diabetes were obtained in model 1. Model 2 predicts demographic variables (registered residence status, education level, gender, age, and widowhood) based on model 1. Model 3 predicts chronic diseases and mental health variables (arthritis, bad mood, hypertension, disability, asthma, self-rated health, memory disease, stroke, hyperlipidemia, depression) according to model 2. For all statistical analyses, *P* values <.05 were considered statistically significant. All statistical analyses were performed using IBM SPSS Statistics 27.0 (IBM SPSS Inc., Chicago, IL).

3. Results

3.1. Demographic characteristic

Demographic characteristics, health status characteristics, lifestyle characteristics of middle-aged and elderly participants, and the selection process of participants were described in Table 1 and Figure 1. In this study, there were 5352 middle-aged and elderly people >50 years old were included. Among them, there were 2595 men (49.4%) and 2657 women (50.6%). There was no significant difference in the gender of the participants (P = .342). In terms of the symptoms of the disease, 6.8% of the middle-aged people had the disease, and 93.2% of the middle-aged people had no symptoms of the disease. The number of middle-aged people with high physical strength was 50.5%, and the number of middle-aged people with low physical strength was 49.5%. There was no significant difference in their physical strength (P = .449). The ages of 50 to 59, 60 to 69, 70 to 79, 80 to 89, ≥90 were 5.3% (276), 17.6% (5.3%), 276 (17.6%), 276 (5.3%), 276 (276), 17.6% (276), 276 (17.6%), 276 (276), 17.6% (276), 276 (17.6%), 17.6% (276), 17.6% (276), 17.6% (276), 276 (17.6%), 17.6% (17.6%), 5.3% (276), 276 (276), etc. In terms of household registration type, the rural household registration was 78% (4099 people), and the urban household registration was 22% (1153 people). In terms of education, there were 18.5% (971) high school students and above, and 81.5% (4281) middle school students and below. A total of 11.9% of the participants were widowed (625), and 88.1% were not widowed (4627). The number of participants with good health was 24.4% (1282), and the number of ones with bad health was 75.6% (3970). The number of disabled participants was 3.6% (189), and the number of people without disabilities was 96.4% (5063). In terms of chronic diseases, 12.8% (671) of the participants had high blood fat, 12% (631) of the participants had high blood pressure, 6.2% of the participants had stroke, 326 of the participants had asthma, 1.8% of the participants had asthma, and 326 of the participants had joints inflammation. 26.2% of the participants had the habit of smoking (1391), 2.5% of them had memory disease (132), and 34.9% of them had depression (1835). Except for sex and PA, the Z test results of all the other variables were significantly different (P < .05) (Fig. 1 and Table 1).

3.2. Analysis of influencing factors of diabetes

The influencing factors of diabetes in middle-aged and elderly participants were analyzed in Table 2. Age, widowhood, self-evaluation of health status, hypertension, hyperlipidemia, memory disease, arthritis, asthma, depression, and PA were statistically significant (P < .05). With the increase of age, the risk of diabetes in middle-aged and elderly people is higher, odds ratio (OR) = 2.480 (95% confidence interval [CI] = 1.253–4.908). Compared with the widowed participants, the widowed participants had a higher risk of diabetes (OR = 1.421) (95% CI = 1.207–1.818). In terms of health status, the middle-aged and elderly people with worse self-evaluation health status were more likely to suffer from diabetes OR = –0.506 (95% CI =

Table 1

Characteristics of middle-aged and elderly participants of the CHARLS in 2018.

		Number of participants	%	Z	P
Gender	Male	2595	49.4%		
	Female	2657	50.6%	.950	.342
Age (yr)	50–59	276	5.3%		
	60–69	924	17.6%		
	70–79	2126	40.5%		
	80–89	1605	30.6%		
	≥90	321	6.1%	−63.692	.000
Location of residence	City	1153	22.0%		
	Rural	4099	78.0%	40.776	.000
Degree of education	Junior high school and below	4281	81.5%		
	High school and above	971	18.5%	−45.872	.000
Widowed	Yes	625	11.9%		
	No	4627	88.1%	55.401	.000
Self-rated health status	Good	1282	24.4%		
	Bad	3970	75.6%	37.223	.000
Physical disability	Yes	189	3.6%		
	No	5063	96.4%	67.410	.000
Hypertension	Yes	631	12.0%		
	No	4621	88.0%	55.236	.000
Hyperlipemia	Yes	671	12.8%		
	No	4581	87.2%	54.024	.000
Stroke	Yes	326	6.2%		
	No	4926	93.8%	63.526	.000
Bad mood	Yes	54	1.0%		
	No	5198	99.0%	71.100	.000
Memory disease	Yes	132	2.5%		
	No	5120	97.5%	68.951	.000
Arthritis	Yes	371	7.1%		
	No	4881	92.9%	62.350	.000
Asthma	Yes	94	1.8%		
	No	5158	98.2%	69.977	.000
Smoke	Yes	1391	26.5%		
	No	3861	73.5%	34.084	.000
Depression	Yes	1835	34.9%		
	No	3417	65.1%	21.855	.000
Diabetes	Yes	359	6.8%		
	No	4893	93.2%	62.728	.000
Physical activity level	High	2651	50.5%		
	Low	2601	49.5%	−.757	.449

0.386–0.904). Middle-aged and elderly participants with hypertension OR = 1.683(95% CI = 1.243–2.280), hyperlipidemia OR = 4.226 (95% CI = 3.237–5.517), memory diseases OR = 1.860 (95% CI = 1.105–3.133), asthma OR = 2.263 (95% CI = 1.201–4.264), arthritis OR = 1.716 (95% CI = 1.659–1.978), depression OR = 1.530 (95% CI = 1.322–1.918) and low PA levels OR = 0.042 (95% CI = 0.025–0.070) were at higher risk of diabetes (Table 2).

3.3. Analysis of influencing factors of PA

The influencing factors of PA in middle-aged and elderly participants are analyzed in Table 3. Age, degree of education, disability, hypertension, diabetes, stroke, bad mood, memory disorders, arthritis, smoking, walking 1 km ability, and depression were significantly correlated with PA level ($P < .05$). With the increase of age, the level of PA of participants became lower OR = 0.710 (95% CI = 0.542–0.929). Low education level is negatively correlated with high PA OR = 0.847 (95% CI = 0.721–0.995). Physical disability was positively related to low PA OR = 0.501 (95% CI = 0.351–0.716). Participants suffering from hypertension OR = 0.861 (95% CI = 0.705–1.050), diabetes OR = 0.042 (95% CI = 0.025–0.071), stroke OR = 0.445 (95% CI = 0.332–0.595), bad mood OR = 0.442 (95% CI = 0.226–0.867), memory disease OR = 0.587 (95% CI = 0.369–0.934), and depression OR = 0.186 (95% CI = 0.162–0.214) were negatively correlated with high PA. The amount of PA of the participants with smoking habits OR = 1.332 (95% CI = 1.153–1.538) was significantly higher than that of the participants without smoking habits (Table 3).

3.4. Linear hierarchical regression model of diabetes and PA level of participants

The linear hierarchical regression between participants' diabetes and PA levels was analyzed in Table 4. Model 1 demonstrates that there is a statistically significant relationship (P 0.05) between PA level and diabetes. The results of Model 2 are likewise statistically significant (P 0.05), and it modifies demographic characteristic factors (gender, household registration type, education level, age, widowhood) depending on PA levels. The results remained statistically significant (P 0.05) when Model 3 adjusted the health status characteristics based on model 2 (bad mood, asthma, hyperlipidemia, disability, memory disease, self-assessment of health status, hypertension, smoking, stroke, depression) (Table 4).

4. Discussion

In this study, logistic regression model and linear hierarchical regression model were used to statistically analyze the collected data, and it was determined that there was a significant

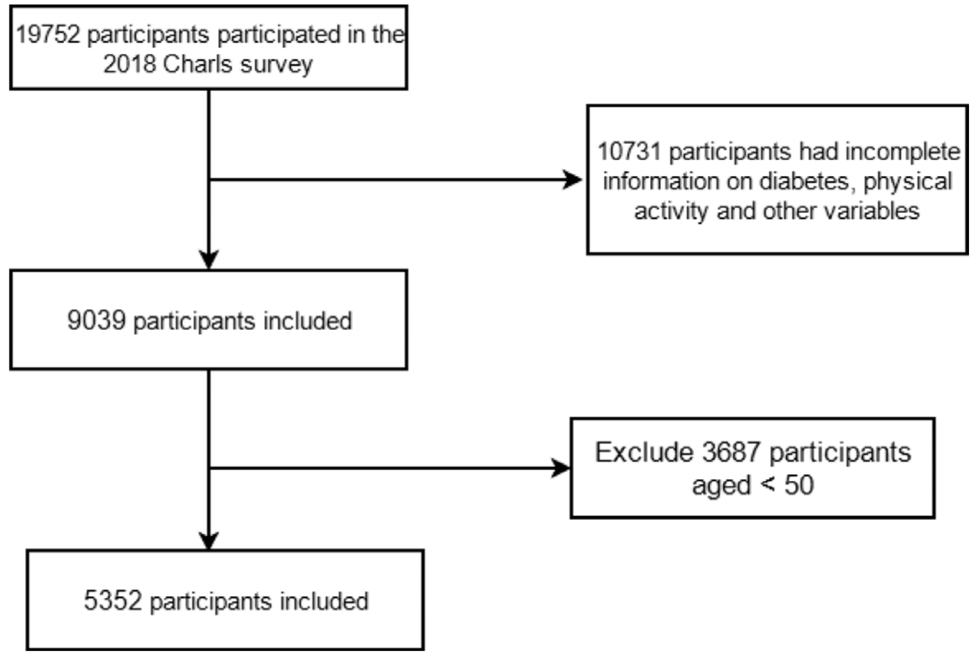

Figure 1. A total of 19,752 participants participated in the 2018 China Health and Retirement Longitudinal Study (CHARLS), and 10,731 people were excluded because of incomplete information on diabetes, physical activity and other variables, with 9039 remaining. 3687 people were excluded from 9039 because they were <50 years old. Finally, the remaining 5352 participants were included in the study.

Table 2

Analysis of influencing factors of diabetes.

	Diabetes	B	SE	Wald	*P*	OR	95% CI Lower	95% CI Upper
Yes	Gender	.130	.124	1.087	.297	1.139	.892	1.453
	Age	.908	.348	6.793	**.009**	2.480	1.253	4.908
	Location of residence	.093	.166	.316	.574	1.098	.793	1.521
	Degree of education	−.027	.157	.031	.861	.973	.715	1.323
	Widowed	.324	.086	3.971	**.000**	1.421	1.207	1.818
	Self-rated health status	−.682	.175	15.123	**.000**	.506	.359	.713
	Physical disability	.195	.265	.542	.461	1.215	.723	2.041
	Hypertension	.521	.155	11.332	**.001**	1.683	1.243	2.280
	Hyperlipemia	1.441	.136	112.231	**.000**	4.226	3.237	5.517
	Stroke	.026	.201	.016	.898	1.026	.692	1.522
	Poor mood	−.462	.558	.687	.407	.630	.211	1.880
	Memory disorders	.621	.266	5.448	**.020**	1.860	1.105	3.133
	Arthritis	.923	1.491	11.933	**.000**	1.716	1.659	1.978
	Asthma	.817	.323	6.388	**.011**	2.263	1.201	4.264
	Smoke	.004	.146	.001	.980	1.004	.755	1.335
	Depressive symptoms	.446	.313	5.502	**.001**	1.530	1.322	1.918
	Physical activity level	−3.176	.263	145.581	**.000**	.042	.025	.070

CI = confidence interval, OR = odds ratio.

correlation between diabetes and PA in middle-aged and elderly people ($P < .05$). After adjusting demographic characteristics (gender, registered permanent residence type, education level, age, widowhood) and health status characteristics (poor mood, asthma, hyperlipidemia, disability, memory disease, self-assessment of health status, hypertension, smoking, stroke, depression), there was still statistical significance ($P < .05$). Our research results show that in terms of diabetes, 6.8% of the middle-aged and elderly people >50 years old with diabetes were detected, and 93.2% of the middle-aged and elderly people without diabetes symptoms. The proportion of middle-aged and elderly people >50 years old with high PA is 50.5%, and the proportion of middle-aged and elderly people with low PA is 49.5%. There is a significant positive correlation between low PA and diabetes ($P < .05$), which indicates that middle-aged and elderly people should increase PA to reduce the risk of diabetes. This result is supported by a previous study conducted by Iijima K et al.[21] They investigated whether there was metabolic syndrome in elderly Japanese patients with type 2 diabetes and analyzed the correlation between PA and clinical parameters. A total of 846 Japanese elderly people (408 men and 438 women, with an average age of 68.7 years) participated in the study. Their PA level was assessed through the Beck questionnaire. The results show that lower PA and excessive calorie intake are significantly related to the prevalence of metabolic syndrome in elderly patients with type 2 diabetes. In our work on prevention

Table 3

Influencing factors of physical activity among middle-aged and elderly participants in CHARLS in 2018.

	Physical activity level	B	SE	Wald	*P*	OR	95% CI Lower	95% CI Upper
High	Gender	–.114	.065	3.081	.079	.892	.785	1.013
	Age	–.343	.137	6.216	**.013**	.710	.542	.929
	Location of residence	–.021	.083	.062	.803	.980	.833	1.152
	Degree of education	–.166	.082	4.062	**.044**	.847	.721	.995
	Widowed	–.088	.102	.744	.388	.916	.751	1.118
	Self-rated health status	.078	.074	1.135	.287	1.082	.936	1.249
	Physical disability	–.691	.182	14.390	**.000**	.501	.351	.716
	Hypertension	–1.150	.101	2.191	**.011**	.861	.705	1.050
	Hyperlipemia	–.007	.102	.005	.944	.993	.813	1.212
	Diabetes	–3.162	.263	144.996	**.000**	.042	.025	.071
	Stroke	–.810	.149	29.641	**.000**	.445	.332	.595
	Poor mood	–.816	.344	5.635	**.018**	.442	.226	.867
	Memory disorders	–.532	.237	5.045	**.025**	.587	.369	.934
	Arthritis	.326	.122	7.142	**.008**	1.385	1.091	1.758
	Asthma	.048	.245	.038	.845	1.049	.649	1.695
	Smoke	.286	.073	15.200	**.000**	1.332	1.153	1.538
	Depressive symptoms	–1.681	.072	546.334	**.000**	.186	.162	.214

CI = confidence interval, OR = odds ratio.

Table 4

Linear hierarchical regression model of diabetes and physical activity level of participants.

Model	*R*	R^2	Adjusted R^2	Variation statistics: R^2 variation	*F* variation	*P*
1	.234*	.055	.054	.012	303.646	**.000**
2	.240†	.057	.056	.003	3.124	**.000**
3	.323‡	.104	.101	.047	21.070	**.000**

* Predicted variable: physical activity. † Predicted variables: physical activity, gender, household registration type, education level, age, widowhood. ‡ Predicted variables: physical activity, household registration type, education level, gender, age, widowhood, arthritis, poor mood, asthma, hyperlipidemia, disability, memory disease, self-assessment of health, hypertension, smoking, stroke, depression.

and treatment of type 2 diabetes and metabolic syndrome in the elderly, it is not recommended to use multiple drugs directly for prevention and treatment. The elderly should be encouraged to participate in more physical activities. Physical exercise helps prevent the metabolic syndrome in the elderly and reduces the risk of type 2 diabetes. Saadeddine D et al[22] collected data on the lack of links between PA and health outcomes in developing countries. They conducted a cross-sectional survey to study the relationship between the PA level of middle-aged and elderly people in community housing in Lebanon and skeletal muscle reduction, cardiovascular risk factors (dyslipidemia, type 2 diabetes, and cardiovascular disease), and quality of life. In this cross-sectional observational study, data on physical composition, PA level, and quality of life of 243 elderly people in Lebanese communities were obtained. The research results show that the proportion of Lebanese elderly >60 years old lacking PA is very high; a high level of PA is significantly associated with a lower risk of skeletal muscle decline, a lower risk of type 2 diabetes, and a good quality of life. The study highlighted the strategic importance of increasing PA among older people in developing countries. This is consistent with the conclusion of this study. This study also believes that high levels of PA can reduce the risk of diabetes in the elderly. PA is important for the prevention and treatment of diabetes in the elderly. People should strengthen their physical exercise, improve their health, and reduce the risk of chronic diseases.

Chang CH et al[23] evaluated the correlation between daily PA and diabetes control in adults <65 years old and elderly >65 years old with type 2 diabetes. A total of 206 young (≤65 years old) and older (>65 years old) adults participated in the prospective study. Their daily sports activities were assessed by the international sports activity questionnaire. The results showed that the average glycosylated hemoglobin level of the participants was 7.8%, and 95.9% of the participants had poor control of diabetes. More moderate to high-intensity daily PA per week was significantly associated with participants' reduced risk of diabetes. Moderate daily PA significantly reduces the risk of diabetes. Health workers must encourage type 2 diabetes patients to carry out appropriate daily physical activities to improve the control of diabetes. Negera GZ et al[24] assessed the prevalence and predictors of non-adherence to diet and PA recommendations in patients with type 2 diabetes. In 2019, they conducted a cross-sectional study involving 322 patients with type 2 diabetes. Data on sociodemographic, psychosocial, and clinical characteristics were collected through face-to-face interviews with structured and pretest questionnaires. Logistic regression was used to determine the predictors of non-adherence to diet and PA. The results show that the rate of type 2 diabetes patients who do not adhere to healthy diets and PA recommendations is very high. It is suggested that type 2 diabetes patients should take healthy diets and more physical exercise to treat and control diabetes. However, special attention should be paid to the formulation of exercise prescriptions for the elderly with diabetes, and the formulation of exercise prescription content suitable for exercise intensity in combination with the health status of the elderly with diabetes. Such exercise prescriptions are scientific, safe and effective.

The existing evidence shows that PA can improve the metabolic function of glucose, increase the peripheral sensitivity to insulin, and improve body shape to prevent and control the development of diabetes. PA can prevent and control diabetes by directly improving glucose metabolism. Tan S et al[3] found that the elderly patients with type 2 diabetes for a long time can benefit from the 6-month composite program of aerobic and resistance training, their glucose metabolism function has been improved, and their body's ability to control blood sugar and exercise ability has been increased. Kumar KV et al[25] in order to understand the effect of yoga on some biochemical parameters of elderly subjects with long-term type 2 diabetes. Sixty elderly people with type 2 diabetes were recruited and randomly assigned to the control group (education group) and yoga group. The control group received advice and leaflets on general healthy lifestyle and exercise every month. The yoga group conducts personalized yoga asanas and pranayama 6 days a week for 12 weeks. After 12 weeks of intervention, the researchers analyzed the biochemical parameters before and after the experiment group and the control group. The results showed that compared with the control group of elderly people with type 2 diabetes, the yoga group of elderly people with type 2 diabetes had significantly improved the levels of glycosylated hemoglobin, fasting blood glucose, and blood lipids. It was concluded that yoga could improve the symptoms of diabetes in elderly subjects by improving glucose metabolism. Physical exercise delayed the occurrence of insulin resistance or reversed the occurrence of insulin resistance. O'Leary et al[26] evaluated the effects of exercise training on glucose metabolism, abdominal obesity, and adipocytokines in obese elderly people. The results showed that the decrease of visceral fat after aerobic exercise training could improve glucose metabolism and was related to the reversal of insulin resistance in elderly obese men and women. Heijden GJVD et al[27] explored the effects of physical exercise on insulin resistance and fat accumulation in viscera, liver, and muscle cells. The study concluded that, without losing weight, 12 weeks of aerobic exercise can reduce fat content in viscera, liver, and muscle cells of sedentary Hispanic adolescents, and reduce insulin resistance. Gert Jan et al[28] explored the effects of controlled aerobic exercise programs on insulin sensitivity and glucose metabolism in the liver of sedentary lean and obese Hispanic adolescents. They concluded that aerobic exercise program is an effective strategy to improve insulin sensitivity and glucose metabolism in the liver of lean and obese sedentary adolescents. Research shows that [29] the risk of diabetes in the elderly with high body mass index and waist-hip index is significantly higher than that in the elderly with normal body mass index and waist-hip index. Sada Y et al[30] evaluated the correlation between obesity-related factors (including total abdominal visceral fat volume and intrahepatic lipid) and clinical markers of insulin resistance and then evaluated the impact of weight loss on these factors and markers. X-ray absorption method was used to measure body fat, proton magnetic resonance spectroscopy was used to evaluate liver fat, and total abdominal computed tomography scanning was used to determine the total abdominal subcutaneous fat volume and total abdominal visceral fat volume. A total of 7 subjects received a diet and exercise plan and checked these indicators again after 5% weight loss. The results showed that total abdominal subcutaneous fat volume, total abdominal visceral fat volume, and intrahepatic fat were independent, and intrahepatic fat was significantly correlated with the clinical marker index of insulin resistance in obese patients. Weight loss can improve the clinical marker index of insulin resistance and reduce the number of subjects with metabolic syndrome. Intrahepatic lipid is an excellent marker of insulin resistance, and PA can reduce the risk of diabetes by improving body composition. Resistance exercise and aerobic exercise for 8 to 12 weeks can improve body mass index, abdominal sebum thickness, visceral fat, and waist-hip ratio of obese patients.[31] It is worth noting that the overweight or obese patients with diabetes who insist on exercise can not only increase lean weight and reduce fat deposition but also better control the development of type 2 diabetes and reduce the risk of diabetes.[32] Therefore, diabetes patients can better control blood sugar through active physical exercise, and people without diabetes can also carry out physical exercise to prevent the occurrence of diabetes. The above research found that PA can improve the metabolic function of glucose, increase the peripheral sensitivity to insulin and improve body shape to prevent and control the development of diabetes, which later provided an important reference for the prevention and treatment of diabetes.

The results of our model also quantify the impact of demographic characteristic variables on the relationship between PA and diabetes. The results showed that the risk of diabetes in middle-aged and elderly people was higher with the increase in age. This is consistent with the previous research of Yamasaki S et al,[33] who analyzed the relationship between body shape, daily PA, cardiovascular risk factors, and disease complications of diabetes patients. Of 6800 randomly selected men, 1731 agreed to be the subjects of the study. The subjects were divided into 2 groups according to age (middle-aged group: 40–60 years old, elderly group: >60 years old). The results showed that the PA of the elderly group with diabetes was significantly less than that of the elderly without diabetes and the middle-aged group; the prevalence of coronary heart disease in the elderly group with diabetes was significantly higher than that in the elderly without diabetes and the middle-aged group. In addition, the incidence rate of hypercholesterolemia in elderly patients with diabetes was significantly higher than that in younger diabetes patients and non-diabetes patients. The study concluded that the elderly affected the relationship between daily PA, cardiovascular risk factors, and disease complications in diabetes patients. This study found that widowhood is one of the risk factors for middle-aged and elderly people to suffer from diabetes. Ding D et al[34] investigated and analyzed the correlation between marital status (widowhood and divorce) and health status of 33,184 middle-aged and elderly people aged ≥45 in Australia. Health status variables include lifestyle (smoking, drinking, diet, and PA), psychological outcomes (pain, anxiety, and depression), overall health, and quality of life. The results of social demographic characteristics and health status variables were adjusted by logistic regression. The results showed that marital status was positively correlated with smoking, poor health, poor quality of life, high psychological pressure, anxiety, and depression. This shows that poor marital status can be harmful to health. This study found that poor health will increase the risk of diabetes, while widowhood will lead to poor health in middle-aged and elderly people, which may be the reason why widowhood will increase the risk of diabetes.

The results of this study found that the health status of middle-aged and elderly people would affect the relationship between PA and diabetes. We found that middle-aged and elderly people with poor health, hypertension, hyperlipidemia, arthritis, asthma, and depression are more likely to suffer from diabetes. This study found that participants with cardiovascular diseases and respiratory diseases are more likely to develop diabetes, which is consistent with the research conclusion of FmA et al[35] They recruited 3096 adults aged ≤30 from a rural area in Bangladesh. The data collected included 2 blood pressure measurements, fasting blood glucose, and sociodemographic and anthropometric measurements. Logistic regression technology is used for data analysis. The study found that older men and women, higher waist circumference, hypertension, and women's lack of PA were significantly related to diabetes. Vassconcelos JP et al[36] evaluated the relationship between chronic disease and PA in patients with type 2 diabetes. In this 2-year follow-up study, 145 patients with an average age of 55 years participated in the study. At baseline, the severity of chronic disease complications was assessed by the Charlson Comorbidity Index, depressive symptoms were assessed by the Beck Depression Inventory-II, sleep quality was assessed by the Pittsburgh Sleep Quality Index, daytime sleepiness was assessed by the Epworth Sleepiness Scale, and PA was assessed by the IPAQ. Logistic regression analysis shows that hypertension and lower PA status are risk factors for increasing diabetes, and higher PA status is positively related to reducing the hospitalization rate of patients with type 2 diabetes, which proves that physical exercise is not only an important strategy to reduce medical care costs but also an important strategy to improve the hospitalization burden of patients.

In addition, the results of this study show that middle-aged and elderly people with depressive symptoms and poor mood have a higher risk of diabetes. This result is partially consistent with the previous study by Khajebishak Y et al,[37] who explored the potential relationship between depression, diabetes knowledge, and self-care management and the quality of life of diabetes patients. This analytical cross-sectional study was conducted in Iran from 2015 to 2017, and 309 diabetes patients participated in the study. The relationship between the above factors and the quality of life of diabetes patients was determined using simple and multiple regression models by assessing the quality of life and depression through questionnaires and evaluating knowledge and self-care management through the Health Belief Model Questionnaire. The results showed that the score of "complications of diabetes" in men was significantly higher than that in women. There was a significant relationship between depression, self-care management, and diet and the quality of life of diabetes patients. The conclusion is that the knowledge and physical and mental health of diabetes patients are poor, and there is a close relationship between health-related factors and quality of life. Therefore, it is suggested to carry out community-based health promotion plans to improve the physical and mental health status and overall life satisfaction of diabetes patients. O'Donovan[38] et al evaluated the impact of diabetes and frailty on self-rated health, depressive symptoms, and quality of life. The data collected from the European Health, Aging, and Retirement Survey were participants ≥50 years old. The survey included diabetes (self-report), weakness, low self-evaluation of health, depression, and low quality of life. Logistic regression analysis was used to analyze the relationship between diabetes and frailty on self-rated health, depressive symptoms, and quality of life. The results showed that older, male and infirm participants were more likely to suffer from diabetes. Age, gender, diabetes, and frailty were all significantly and independently associated with low self-evaluation of health status, depression, and low quality of life. Participants with diabetes and frailty reported more of the worst self-rated health, the most depressive symptoms, and the lowest quality of life outcomes.

5. Conclusion and limitations

The condition of diabetes in middle-aged and elderly people is closely related to the level of PA, but the research on PA and diabetes in middle-aged and elderly people in China is in its infancy. In this study, there is no significant gender difference in diabetes among the middle-aged and elderly. The risk of diabetes among the middle-aged and elderly who participate in high PA is significantly lower than that of the middle-aged and elderly who participate in low PA. At the same time, middle-aged and elderly people with advanced age, poor self-evaluation health, hyperlipidemia, hypertension, and asthma are more likely to suffer from diabetes. This study helps to better understand the relationship between diabetes symptoms and PA in middle-aged and elderly people and provides a new basis for formulating scientific and effective exercise prescriptions to prevent and treat diabetes symptoms in middle-aged and elderly people.

Some limitations have also affected our research. First, this study only revealed the relationship between PA and hypertension but did not specifically distinguish between type 1 diabetes and type 2 diabetes. It is necessary to analyze the relationship between PA and type 1 diabetes and type 2 diabetes in future research. Second, we found that PA can improve the metabolic function of glucose, increase the peripheral sensitivity to insulin, and improve body shape, so as to prevent and control the development of diabetes. It is necessary to further explore whether there is information about other potential mechanisms of PA affecting diabetes. Thirdly, we have proved that there is a correlation between the level of sports activities of the middle-aged and elderly people in China and diabetes. We need to expand the sample size of the survey and further explore the relationship between sports activities and diabetes in China to determine the validity of the conclusions of this study, because there may be ethnic and regional differences in the correlation between sports activities and diabetes.

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