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ORIGINAL RESEARCH

Associations Between Physical Activity and Preserved Ratio Impaired Spirometry: A Cross-Sectional NHANES Study

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Background: Preserved ratio impaired spirometry (PRISm) is considered to be one of the early chronic obstructive pulmonary disease states, and there are few studies on PRISm prevention. We aimed to evaluate the relationship between physical activity and the risk of PRISm.

Methods: A cross-sectional study was conducted using data from US adults who participated in the National Health and Nutrition Examination Survey (NHANES) between 2007 and 2012. We examined the association between physical activity and PRISm using multivariable logistic regression models and a restricted cubic spline (RCS) model.

Results: Compared to the normal and chronic obstructive pulmonary disease (COPD) groups, the PRISm group had lower levels of physical activity (3537.2 MET-min/week in the normal group vs 3452.1 MET-min/week in the COPD group vs 2841.5 MET-min/week in the PRISm group). Adjusted multivariable regression models revealed that greater physical activity dose (more than 4800 MET-min/week) was associated with lower odds of PRISm (adjusted odds ratio [aOR] = 0.77, 95% confidence interval [95% CI] = 0.61–0.98; $P = 0.031$). The RCS curve revealed that there was a significant nonlinear negative dose–response relationship between the level of physical activity and the risk of PRISm ($P_{\text{non-linearity}}<0.05$). In the population with a body mass index (BMI) ≥25 kg/m^2, the higher physical activity dose was associated with a significantly lower risk of PRISm (OR = 0.51, 95% CI: 0.46–0.82).

Conclusion: A greater total physical activity level was associated with a lower risk of PRISm in US adults, especially in populations with a BMI ≥ 25 kg/m^2. These findings emphasize that a physically active lifestyle may be a potential precaution against PRISm.

Keywords: physical activity, preserved ratio impaired spirometry, lung function, National Health and Nutrition Survey

Background

Preserved ratio impaired spirometry (PRISm) is defined as normal 1-second rate (FEV1/FVC ≥70% after inhalation of bronchodilator), but impaired lung ventilation (FEV1 <80% predicted).[1] It is a type of airflow limitation characterized by nonobstructive lung function abnormalities often accompanied by structural changes in the lungs (such as emphysema) and/or physiological abnormalities.[1] PRISm is widely present in middle-aged and elderly individuals, with an estimated prevalence of 4.7–25.2%.[2,3] The risk of COPD, cardiovascular-related death, and all-cause death was significantly greater in the PRISm population than in the population with normal lung function.[4,5] PRISm is considered to be one of the disease states associated with early COPD.[6–8] Although PRISms have received increasing attention, the development mechanism, longitudinal change trajectory and treatment management of PRISm have not yet been fully characterized.

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Given the significant impact of COPD on the health and economy of the population, early identification of PRISm and appropriate interventions are highly important for the prevention of COPD.

Physical activity is characterized as the movement of the body that involves the action of skeletal muscles and leads to an increase in energy expenditure beyond resting levels.[9,10] Prospective observational studies have shown that regular physical activity is associated with a reduced risk of various disease outcomes (including cardiovascular disease, stroke, diabetes, obesity, early death, some cancers, and depression).[9,11] Results from longitudinal studies indicated that individuals with higher levels of physical activity exhibited a more gradual decline in lung function.[12,13] In addition, previous studies have indicated that actively participating in physical exercise may also play a crucial role in the prognosis of PRISm.[14,15] However, whether the risks of PRISm can be reduced with different physical activity levels is less certain. Therefore, we used nationally representative data to explore the relationship between physical activity and PRISm.

Materials and Methods

Study Design and Population

The NHANES (National Health and Nutrition Examination Survey) is an ongoing cross-sectional program conducted by the National Center for Health Statistics (NCHS) of the Centers for Disease Control and Prevention. It aims to investigate various aspects of the public's health-related behaviors, socioeconomic status, nutritional status, and physical examination results in US civilian and noninstitutionalized population. The NHANES protocols were approved by the institutional review boards of the CDC and NCHS, and all participants provided their informed permission. The following website provided information on NHANES protocols, methods, and IRB approval: https://www.cdc.gov/nchs/nhanes/index.htm. Data from the NHANES 2007–2008, 2009–2010 and 2011–2012 cycles were enrolled in our analysis. Participants under 20 years of age were the first to be excluded (n = 12729), followed by those who were missing information, including FEV1 value or FVC value as well as data of physical activity (n = 4326).

Assessment of Spirometry

Lung function test followed the recommendations of the American Thoracic Society. Participants in the NHANES from 2007 to 2012, aged 6 to 79 years, were invited to participate in spirometry. A more comprehensive description of inclusion and exclusion criteria was provided by the NHANES protocol(https://www.cdc.gov/nchs/data/nhanes/nhanes_11_12/spirometry_procedures_manual.pdf). Lung function categories were defined using postbronchodilator spirometry as follows: PRISm ($FEV_1/FVC \geq 0.7$ and $FEV_1 < 80\%$ predicted), COPD ($FEV_1/FVC < 0.7$), and normal ($FEV_1/FVC \geq 0.7$).

Assessment of Physical Activity

The Global Physical Activity Questionnaire (GPAQ) was used to gather data on the weekly physical activity of the respondents at the individual level.[16] The weekly metabolic equivalent (MET) was calculated based on the suggested MET scores provided by the NHANES. A MET of 8 points was assigned to vigorous work activity and vigorous recreational activity, while a score of 4 points was assigned to moderate work activity, moderate recreational activity, walking, and bicycling. These METs were used to determine the weekly physical activity level of the respondents.[10] Physical activity (MET-min/week)=High-intensity work (minutes)* days * 8 +moderate-intensity work (minutes) * days * 4+walking/cycling for transportation (minutes) * days * 4+vigorous recreational activity (minutes) * days * 8+moderate recreational activity (minutes) * days * 4

Then, physical activity was categorized by quartiles of the METs (Quartile 1: 0–120 MET-min/week; Quartile 2: 120–1200 MET-min/week; Quartile 3: 1200–4080 MET-min/week; Quartile 4: ≥4080 MET-min/week).

Assessment of Covariates

The following information was collected using a household-structured questionnaire: gender (male, female), age (<65, ≥65 years), education level (less than 11th grade, high school graduate, some college, college graduate, or above), marital

status (married, widowed, divorced, separated, never married, living with partner), race (Mexican American, other Hispanic, Non-Hispanic, White Non-Hispanic Black, other race). Poverty Impact Ratio (PIR) was used as the main measure of socioeconomic status, calculated by dividing the participant's reported family income by the federal poverty threshold for that year. A ratio of 1 indicates a family at the poverty level. BMI was determined as weight (kg) divided by height squared (kg/m^2). Participants were defined as hypertensive based on self-reported medical diagnosis, antihypertensive medicine usage, or a high blood pressure measurement value (systolic blood pressure 140 mm Hg and/or diastolic blood pressure 90 mm Hg). Participants were classified as having diabetes if they met any of the following criteria: self-report of diagnosis by a healthcare professional, use of insulin or diabetic medication, or elevated fasting glucose or HbA1c levels. Cardiovascular disease (CVD) diagnosis was based on participants' self-reported physician diagnoses during interviews using a standardized questionnaire. Participants were asked if a doctor or health expert had ever told them they had conditions like heart failure, coronary heart disease, angina, myocardial infarction, or stroke. A "yes" response to any question indicated CVD.

Statistical Analysis

The data were classified into continuous and categorical variables. Categorical variables were expressed as proportions (%), whereas continuous variables were characterized by either the mean (standard deviation, SD) or the median (interquartile range, IQR), depending on their distribution. To assess differences across groups, analysis of variance (ANOVA) was employed for normally distributed data, Kruskal–Wallis tests for data with skewed distributions, and chi-square tests for categorical variables. We applied multivariable logistic regression models to investigate the associations of physical activity with PRISm and COPD. With PRISm as the outcome, and physical activity as the exposure, two models were constructed to verify the correlation between physical activity and PRISm and to perform trend analysis. Model 1 of the PRISm is a crude model, and Model 2 of the PRISm adjusts for BMI, race, education, marital status, poverty impact ratio (PIR), smoking status, alcohol consumption, diabetes status, hypertension status, CVD status, total cholesterol (TC), and high-density lipoprotein (HDL) levels. With COPD as the outcome, and physical activity as the exposure, divided by quartile, two models were constructed to verify the correlation between physical activity and COPD and to perform trend analysis. Model 1 of COPD was a rough model, and Model 2 of COPD adjusted sex, age, BMI, race, education, marital status, smoking status, alcohol consumption, diabetes status, hypertension status, and CVD status. And subgroup analysis of the participants was carried out based on sex (female/male) and BMI (18.5–25/ ≥25 kg/m^2). Weighted analysis is crucial for NHANES data results.[17] Different sample weights, such as interview weight, Mobile Examination Center (MEC) exam weight, and subsample weights, were available in the dataset. The correct weight selection depended on the variables used in the analysis. All weights used in the study were obtained from Demographic Data. NHANES (2007–2012) combined three survey cycles, with data weighted according to NHANES guidelines for analysts.

The analyses were performed using R version 4.3.0, and a significance level of $P < 0.05$ was considered statistically significant for differences.

Results

In the 2007–2008, 2009–2010, and 2011–2012 NHANES cycles, 17,713 individuals aged ≥20 years were surveyed. A total of 13,387 individuals (mean age 44.93 ± 0.36 years, 49.46% male) with valid lung function and physical activity data were included in the final study (Figure 1). According to the lung function reports, the individuals were divided into three groups: 659 (4.9%) individuals with PRISm, 1,801 (13.5%) individuals with COPD, and 10,927 (81.6%) individuals in the normal group (Table 1). Compared to those in the normal group, the PRISm group had a higher proportion of people in over 65 years old (9.0% vs 24.0%). Compared to the normal and COPD groups, the PRISm group had a higher proportion of males (46.3% in normal group vs 61.0% in COPD group vs 85.9% in PRISm group, $P < 0.001$) and a higher mean BMI (28.81 in normal group vs 27.67 in COPD group vs 31.60 in PRISm group, $P < 0.001$). Interestingly, 532 (81.2%) of individuals with PRISm had BMI ≥25 kg/m^2. PRISm was more common in Non-Hispanic White and Non-Hispanic Black populations making up 133 (37.0%) and 376 (45.3%) of 659 individuals, respectively. We also found that the PRISm group had a higher proportion of previous or current smoking (52.0% vs 40.4%), diabetes

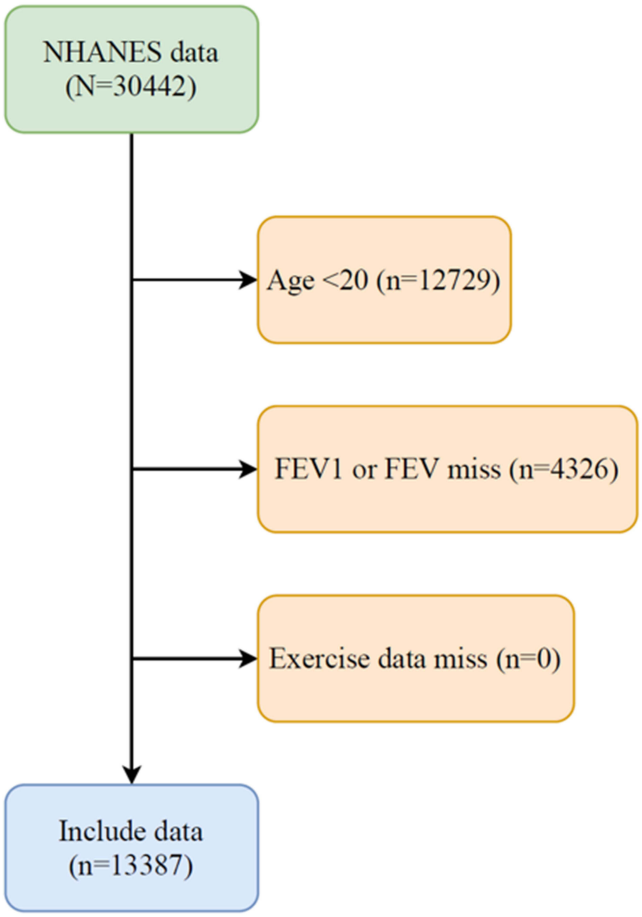

Figure 1 Participant flow diagram.
Abbreviations: NHANES, National Health and Nutrition Examination Survey. FEV1, forced expiratory volume in 1s; FVC, Forced vital capacity.

(33.7% vs 8.9%) and had hypertension (52.0% vs 40.4%) than normal group. However, lower levels of education (37.8% in normal individuals vs 44.2% in COPD individuals vs.52.2% in PRISm) and lower levels of physical activity (3537.2 in normal group vs 2841.5 in COPD group vs 3452.1 in PRISm group) were more common in the PRISm group than the normal and COPD group (Table 1).

Univariate logistic regression analysis revealed that female (OR = 0.14, 95% CI: 0.11–0.18), higher levels of education (some college [OR = 0.50, 95% CI: 0.40–0.63], college graduate or above [OR = 0.38, 95% CI: 0.28–0.51], lower levels of PIR (OR = 0.84, 95% CI: 0.79–0.90), alcohol (OR = 0.69, 95% CI: 0.52–0.91), and lower levels of TC (OR = 0.14, 95% CI: 0.11–0.18) and HDL (OR = 0.29, 95% CI: 0.21–0.40) were associated with a lower risk of PRISm. However, being over 65 years of age (OR = 3.20, 95% CI: 2.51–4.07), having BMI ≥25 kg/m2 (OR = 1.97, 95% CI: 1.59–2.44), being Non-Hispanic White (OR = 1.54, 95% CI: 1.03–2.31) or Non-Hispanic Black (OR = 11.76, 95% CI: 8.60–16.09), smoking previously (OR = 1.59, 95% CI: 1.20–2.10), smoking currently (OR = 1.61, 95% CI: 1.18–2.21), diabetes (OR = 5.24, 95% CI: 4.07–6.73), hypertension (OR = 2.81, 95% CI: 2.26–3.50), and CVD (OR = 6.14, 95% CI: 4.66–8.09) were associated with a higher risk of PRISm (Table 2).

Then, the unadjusted results suggested that, the physical activity levels of Q3 (OR = 0.59, 95% CI: 0.43–0.80) and Q4 (OR = 0.50, 95% CI: 0.38–0.64) populations had lower the risk of PRSIm, and the trend was statistically significant ($P < 0.001$). After adjusting for BMI, race, education, marital, PIR, smoke, alcohol, diabetes, hypertension, CVD, TC, and HDL levels, it was found that only the physical activity level of Q4 population with Q1 as reference had a lower risk of PRISm (aOR =0.0.76, 95% CI: 0.67–0.86), and this trend was statistically significant ($P = 0.004$). No statistical association was found between physical activity and COPD in adjusted model 2 (Table 3). Furthermore, the RCS

Table 1 Characteristics of Study Participants, NHANES 2007–2012

Variable	Total (n=13387)	Group			Statistic	*P*
		Normal (n=10927)	PRISm (n=659)	COPD (n=1801)		
Gender, n (%)					χ^2=340.754	**<0.001**
Male	6679 (49.46)	4973 (46.33)	559 (85.85)	1147 (61.00)		
Female	6708 (50.54)	5954 (53.67)	100 (14.15)	654 (39.00)		
Age, Mean (S.E)	44.93 (0.36)	42.84 (0.35)	52.11 (0.95)	56.06 (0.49)	F=393.740	**<0.001**
Age, n (%)					χ^2=664.457	**<0.001**
<65	11,126 (87.79)	9568 (91.02)	467 (76.03)	1091 (70.66)		
≥65	2261 (12.21)	1359 (8.98)	192 (23.97)	710 (29.34)		
BMI, Mean (S.E)	28.73 (0.10)	28.81 (0.12)	31.60 (0.38)	27.67 (0.16)	F=45.789	**<0.001**
BMI, n (%)					χ^2=50.495	**<0.001**
<18.5	187 (1.46)	135 (1.37)	10 (1.50)	42 (1.96)		
18.5–25	3717 (29.58)	3001 (29.25)	117 (17.33)	599 (34.03)		
≥25	9483 (68.97)	7791 (69.38)	532 (81.16)	1160 (64.01)		
Race, n (%)					χ^2=683.959	**<0.001**
Mexican American	2119 (8.39)	1943 (9.49)	40 (3.42)	136 (2.72)		
Other Hispanic	1437 (5.55)	1279 (6.15)	35 (3.37)	123 (2.39)		
Non-Hispanic White	5715 (67.91)	4502 (66.55)	133 (36.97)	1080 (82.33)		
Non-Hispanic Black	2932 (11.28)	2195 (10.68)	376 (45.29)	361 (8.04)		
Other Race※	1184 (6.88)	1008 (7.13)	75 (10.94)	101 (4.51)		
Education, n (%)					χ^2=70.583	**<0.001**
Less than 11th grade	3403 (16.83)	2674 (16.13)	206 (28.16)	523 (18.76)		
High school graduate	3047 (22.29)	2417 (21.71)	165 (23.99)	465 (25.43)		
Some college	3903 (31.25)	3268 (31.69)	177 (27.60)	458 (29.29)		
College graduate or above	3034 (29.64)	2568 (30.47)	111 (20.25)	355 (26.52)		
Marital, n (%)					χ^2=278.104	**<0.001**
Married	6936 (55.88)	5575 (54.91)	340 (52.73)	1021 (62.40)		
Widowed	681 (3.38)	460 (2.66)	46 (7.00)	175 (6.97)		
Divorced	1487 (10.53)	1143 (10.16)	78 (10.90)	266 (12.70)		
Separated	469 (2.29)	393 (2.34)	23 (2.97)	53 (1.87)		
Never married	2691 (19.77)	2406 (21.71)	125 (19.04)	160 (8.21)		
Living with partner	1123 (8.14)	950 (8.22)	47 (7.36)	126 (7.85)		
PIR, Mean (S.E)	3.03 (0.05)	3.03 (0.05)	2.55 (0.08)	3.12 (0.07)	F=18.152	**<0.001**
Smoke, n (%)					χ^2=610.524	**<0.001**
None	7327 (55.04)	6489 (59.58)	309 (47.95)	529 (29.09)		
Previous	3013 (23.29)	2201 (21.22)	188 (27.11)	624 (35.01)		
Current	3047 (21.67)	2237 (19.20)	162 (24.94)	648 (35.89)		
Alcohol, n (%)					χ^2=54.775	**<0.001**
No	9953 (70.89)	8182 (71.74)	516 (78.61)	1255 (64.21)		
Yes	3434 (29.11)	2745 (28.26)	143 (21.39)	546 (35.79)		
Diabetes, n (%)					χ^2=273.899	**<0.001**
No	11474 (89.77)	9583 (91.15)	427 (66.30)	1464 (86.16)		
Yes	1913 (10.23)	1344 (8.85)	232 (33.70)	337 (13.84)		
Hypertension, n (%)					χ^2=300.207	**<0.001**
No	8418 (67.44)	7278 (70.54)	280 (46.00)	860 (53.12)		
Yes	4969 (32.56)	3649 (29.46)	379 (54.00)	941 (46.88)		
CVD					χ^2=374.818	**<0.001**
No	12414 (94.38)	1522 (87.48)	10,367 (96.01)	525 (79.68)		
Yes	973 (5.62)	279 (12.52)	560 (3.99)	134 (20.32)		
TC, Mean (S.E)	5.09 (0.01)	5.09 (0.02)	4.88 (0.05)	5.15 (0.04)	F=10.343	**<0.001**
HDL, Mean (S.E)	1.36 (0.01)	1.37 (0.01)	1.20 (0.02)	1.38 (0.02)	F=45.412	**<0.001**
Physical activities, Mean (S.E)	3505.93 (101.95)	3537.15 (113.64)	2841.52 (270.35)	3452.07 (244.87)	F=4.443	**0.017**

Notes: ※ including race of multi-racial and Non-Hispanic White. Data in bold indicates statistical difference (*P* <0.05).

Abbreviations: PRISm, Preserved ratio impaired spirometry; COPD, Chronic obstructive pulmonary disease; BMI, Body Mass Index; PIR, Poverty Impact Ratio; CVD, Cardiovascular Disease; TC, Total cholesterol; HDL, High-density lipoprotein; S.E, Standard Error.

Table 2 Univariate Logistic Regression of PRISm and COPD

Variables	PRISm		COPD	
	OR (95% CI)	***P***	**OR (95% CI)**	***P***
Gender				
Male	1.00 (Reference)		1.00 (Reference)	
Female	0.14 (0.11–0.18)	**<0.001**	0.55 (0.46–0.66)	**<0.001**
Age				
<65	1.00 (Reference)		1.00 (Reference)	
≥65	3.20 (2.51–4.07)	**<0.001**	4.21 (3.66–4.85)	**<0.001**
BMI				
<18.5	1.85 (0.89–3.83)	0.104	1.23 (0.73–2.06)	0.443
18.5–25	1.00 (Reference)		1.00 (Reference)	
≥25	1.97 (1.59–2.44)	**<0.001**	0.79 (0.68–0.93)	**0.006**
Race				
Mexican American	1.00 (Reference)		1.00 (Reference)	
Other Hispanic	1.52 (0.95–2.44)	0.089	1.35 (0.96–1.90)	0.086
Non-Hispanic White	1.54 (1.03–2.31)	**0.042**	4.31 (3.63–5.12)	**<0.001**
Non-Hispanic Black	11.76 (8.60–16.09)	**<0.001**	2.62 (2.09–3.29)	**<0.001**
Other Race	4.25 (2.81–6.42)	**<0.001**	2.20 (1.47–3.29)	**<0.001**
Education				
Less than 11th grade	1.00 (Reference)		1.00 (Reference)	
High school graduate	0.63 (0.51–0.79)	**<0.001**	1.01 (0.84–1.21)	0.938
Some college	0.50 (0.40–0.63)	**<0.001**	0.79 (0.63–1.00)	0.051
College graduate or above	0.38 (0.28–0.51)	**<0.001**	0.75 (0.63–0.89)	**0.002**
Marital				
Married	1.00 (Reference)		1.00 (Reference)	
Widowed	2.74 (1.69–4.42)	**<0.001**	2.30 (1.83–2.90)	**<0.001**
Divorced	1.12 (0.78–1.60)	0.551	1.10 (0.91–1.33)	0.321
Separated	1.32 (0.83–2.10)	0.246	0.70 (0.49–1.00)	0.053
Never married	0.91 (0.68–1.23)	0.551	0.33 (0.26–0.42)	**<0.001**
Living with partner	0.93 (0.63–1.39)	0.732	0.84 (0.65–1.09)	0.191
PIR	0.84 (0.79–0.90)	**<0.001**	1.03 (0.99–1.08)	0.169
Smoke				
None	1.00 (Reference)		1.00 (Reference)	
Previous	1.59 (1.20–2.10)	**0.002**	3.38 (2.81–4.07)	**<0.001**
Current	1.61 (1.18–2.21)	**0.004**	3.83 (3.20–4.58)	**<0.001**
Alcohol				
No	1.00 (Reference)		1.00 (Reference)	
Yes	0.69 (0.52–0.91)	**0.011**	1.41 (1.23–1.63)	**<0.001**
Diabetes				
No	1.00 (Reference)		1.00 (Reference)	
Yes	5.24 (4.07–6.73)	**<0.001**	1.66 (1.41–1.95)	**<0.001**
Hypertension				
No	1.00 (Reference)		1.00 (Reference)	
Yes	2.81 (2.26–3.50)	**<0.001**	2.11 (1.81–2.46)	**<0.001**
CVD				
No	1.00 (Reference)		1.00 (Reference)	
Yes	6.14 (4.66–8.09)	**<0.001**	3.45 (2.88–4.13)	**<0.001**
TC	0.81 (0.73–0.91)	**<0.001**	1.06 (0.99–1.13)	0.125
HDL	0.29 (0.21–0.40)	**<0.001**	1.10 (0.92–1.31)	0.316

Note: Data in bold indicates statistical difference (*P* <0.05).

Abbreviations: PRISm, Preserved ratio impaired spirometry; COPD, Chronic obstructive pulmonary disease; BMI, Body Mass Index; CVD, Cardiovascular Disease; TC, Total cholesterol; HDL, High-density lipoprotein; OR, Odds ratio; 95% CI, 95% confidence interval.

Table 3 Association of Physical Activity Levels with the Risk of PRISm and COPD

Variables	Model 1		Model 2	
	OR (95% CI)	*P*	OR (95% CI)	*P*
PRISm				
Physical activity, MET-min/week				
Q1 (0–120)	1.00 (Reference)		1.00 (Reference)	
Q2 (120–1200)	1.32 (0.41–4.22)	0.644	1.09 (0.37–3.20)	0.879
Q3 (1200–4080)	0.59 (0.43–0.80)	**0.001**	0.76 (0.56–1.05)	0.108
Q4 (≥ 4080)	0.50 (0.38–0.64)	**<0.001**	0.67 (0.52–0.86)	**0.004**
Trend		**<0.001**		**0.004**
COPD				
Physical activity, MET-min/week				
Q1 (0–120)	1.00 (Reference)		1.00 (Reference)	
Q2 (120–1200)	0.82 (0.71–0.95)	**0.012**	0.91 (0.76–1.08)	0.298
Q3 (1200–4080)	0.80 (0.66–0.98)	**0.033**	1.01 (0.80–1.27)	0.906
Q4 (≥ 4080)	0.81 (0.66–0.99)	**0.042**	0.99 (0.79–1.23)	0.902
Trend		0.054		0.876

Notes: Data in bold indicates statistical difference (P <0.05). Model 1: Crude model. ^{PRISm} Model 2: adjust BMI, Race, Education, Marital, PIR, Smoke, Alcohol, Diabetes, Hypertension, CVD, TC, and HDL. ^{COPD} Model 2: adjust Gender, Age, BMI, Race, Education, Marital, Smoke, Alcohol, Diabetes, CVD, and Hypertension.

Abbreviations: PRISm, Preserved ratio impaired spirometry; COPD, Chronic obstructive pulmonary disease; CVD, Cardiovascular Disease; OR, Odds Ratio; 95% CI: 95% Confidence Interval.

model revealed a significant nonlinear negative dose–response relationship between the level of physical activity and the risk of PRISm ($P_{\text{non-linearity}} < 0.05$) (Figure 2).

Finally, we conducted the association between physical activity levels and risk of PRISm after sex and BMI stratification. Compared to the physical activity level of Q1 population, the physical activity levels of Q4 had a lower risk of PRISm in both males and females (OR = 0.61, 95% CI: 0.46–0.82, P = 0.003), and the trend tests were both statistically significant (P = 0.002) (Figure 3A). In the BMI stratification, those with BMIs ≥25 kg/m^2 had significantly greater levels of physical activity and a lower risk of PRISm (OR_{Q4} = 0.51, 95% CI: 0.46–0.82), and the trend was statistically significant (P = 0.002) (Figure 3B).

Discussion

To our knowledge, this is the first report about relationship between different physical activity levels and the risk of PRISm. In this national representative study, the lower risk of PRISm was associated with greater physical activity, especially in populations with a BMI ≥25 kg/m^2. There was a significant nonlinear negative dose–response relationship between the level of physical activity and the risk of PRISm. These findings have important implications for public health.

The prevalence of PRISm in our study was lower than that in most previous studies.[3,18–21] The prevalence of PRISm varies widely among studies. For instance, the PERSIAN study in Iran reported a prevalence rate of 25.2% for PRISm,[3] the BOLD study reported a prevalence rate of 14.2% in individuals aged 40 and above,[18] the OCEAN study in Japan found a prevalence rate of 16.7%,[19] the Health and Nutrition Survey in South Korea showed a rate of 8.9%,[20] and the overall age-standardized prevalence of PRISm recently investigated in China was 5.5% (95% CI: 4.3–6.9).[6] On the one

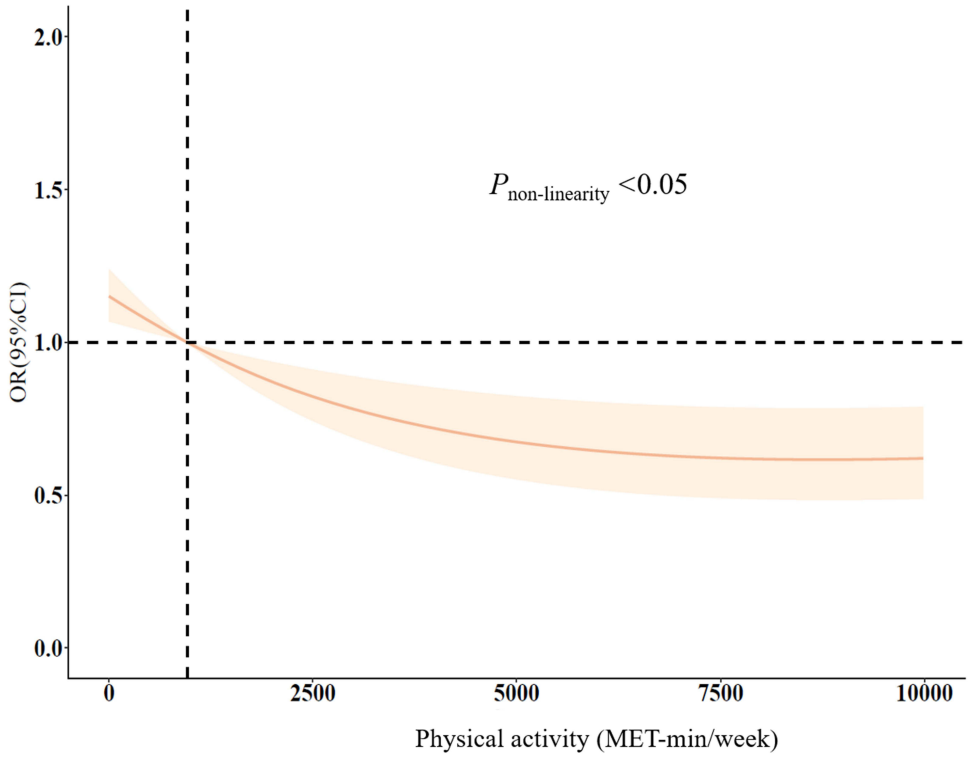

Figure 2 The odds ratio of physical activity with PRISm.
Abbreviations: OR, Odds ratio; 95% CI, 95% confidence interval; PRISm, Preserved ratio impaired spirometry.

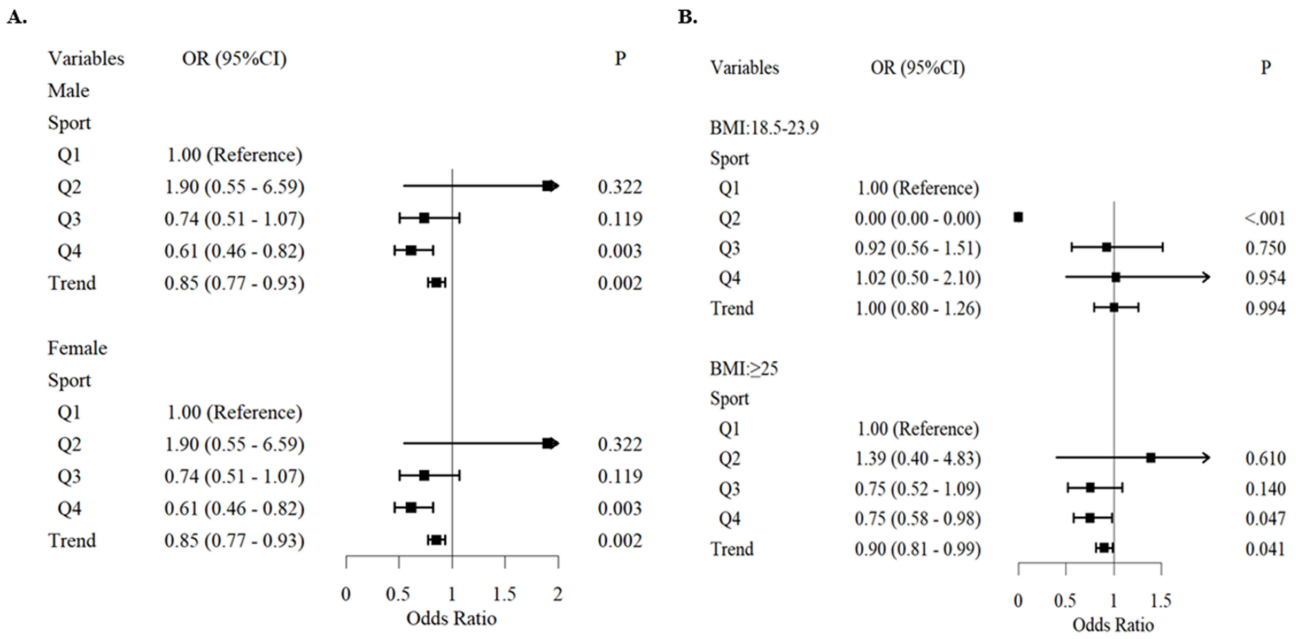

Figure 3 The association between physical activity levels and risk of PRISm after sex and BMI stratification. (**A**) Forest plot of sex stratification; (**B**) Forest plot of BMI stratification.
Abbreviations: OR, Odds ratio; 95% CI, 95% confidence interval; BMI, Body Mass Index; Preserved ratio impaired spirometry.

hand, the differences in disease rates may be related to factors such as sex, race, geographical location, smoking status, high-risk factors, and the use of different reference values. On the other hand, there is no consensus on whether pre- or post-bronchodilator lung function is used to diagnose PRISm.[22] The use of pre-bronchodilator lung function will cause some overdiagnosis compared with post-bronchodilator lung function. However, some studies have shown that the use of

pre- or post-bronchodilator lung function has no significant effect on long-term mortality risk or patient prognosis.[23] In our study, post-diastolic pulmonary function was used to diagnose PRISm, consistent with the GOLD 2023 guidelines.[24]

The prevention and control of PRISm depend on the identification and discovery of high-risk factors. Both the PRISm and COPD groups demonstrated a higher proportion of males, an elevated mean age, and a greater prevalence of former and current smokers. In contrast, the COPD group and the normal group showed more similar in terms of BMI, poverty-PIR, TC, and physical activity in our study. And the PRISm group had the greatest BMI among three group. According to the adjusted multiple logistic regression, being over 65 years of age, having a BMI ≥25 kg/m^2, being a Non-Hispanic White or Non-Hispanic Black race, smoking previously or currently smoking, diabetes, and hypertension may be adverse factors for PRISm. These results were consistent with those of previous studies.[19,25–29] Compared with the normal group, the PRISm group had increased dyspnea symptoms, greater dyspnea scores (Modified Medical Research Council, mMRC),[30] fewer 6-minute walks,[30,31] greater levels of emphysema, and greater increases in bronchial wall thickness.[32] In addition, PRISm was associated with more diseases, such as hypertension and diabetes, hypercholesterolemia, obesity, stroke, ischemic heart disease, chronic kidney disease, thyroid disease, osteoarthritis, and physical frailty.[20,27,33] Therefore, for patients with lung-function suggestive of PRISm, clinicians should not only pay attention to the corresponding clinical features in terms of respiratory symptoms, imaging, and exercise capacity but also strengthen the follow-up of patients with accompanying diseases to alleviate the disease burden.

The longitudinal development of PRISm mainly includes three different trajectories: continuous PRISm, transition to normal lung function, and progression to COPD.[7,8,34] Studies have shown that the PRISm population has a significantly greater risk of cardiovascular-related mortality and all-cause mortality than individuals with normal lung function.[35] Furthermore, compared with that of COPD patients, the risk of all-cause death in PRISm patients was between GOLD 1 and GOLD 2.[5] Although GOLD 2023 recommends the treatment of PRISm,[24] there is still a lack of research on the management and treatment of this disease.[36] These exciting results showed that greater physical activity was associated with a lower risk of PRISm, especially in individuals with a BMI ≥25 kg/m^2 in our study. A cohort study revealed that young and middle-aged individuals with PRISm and middle-aged individuals with normal lung function who progressed to middle-aged individuals with PRISm had a significantly greater risk of death due to lung disease and heart disease than did young and middle-aged individuals with normal lung function.[15] In addition, it was also found that individuals who were diagnosed with PRISm but who recovered to normal lung function among middle-aged individuals had no significant increase in the risk of death due to lung or heart disease,[15] highlighting the necessity and importance of early detection and intervention of PRISm. Unfortunately, our findings suggested that the physical activity in the PRISm group was significantly lower than that in the normal group and COPD group. PRISm may prevent individuals from participating in physical activity. Nevertheless, the risk of PRISm was reduced when the physical activity increased. This finding emphasize that physically active lifestyle may be a potential precaution against PRISm. A prospective study in Taiwan suggested that physical activity was associated with a two-third reduction of excess mortality from all cause and from CVD.[37] Therefore, it is time to call on individuals with PRISm to increase physical activity and further explore the effect of the physical activity in PRISm.

This study has several limitations. First, this study is retrospective and therefore susceptible to the inherent issues of retrospective studies. Our results should be viewed with caution because cross-sectional observational studies cannot be used to determine causality or directionality. Second, participants may underreport or overreport how often they participate in physical activity on the NHANES questionnaire, leading to information bias. Last, due to the relatively small sample sizes, we could not explore the association of physical activity with PRISm in population with a BMI <18.5 kg/m^2. Although the previous study has suggested that low or high BMI is a risk factor for PRIMs, prospective studies are still lacking.

Conclusion

In summary, our study demonstrated that higher levels of physical activity were associated with a lower risk of PRISm, especially in populations with a BMI ≥25 kg/m^2. There was a significant nonlinear negative dose–response relationship between the level of physical activity and the risk of PRISm. Regular physical activity may be a potential precaution

against PRISm, the optimal level of activity is likely to vary based on individual circumstances. Further prospective studies are needed to clarify these associations and their causal relationship.

Role of the Funding Source

The sponsor had no role in the study design, data collection, data analysis, data interpretation, or writing of the report.

Abbreviation

PRISm, Preserved ratio impaired spirometry; COPD, Chronic obstructive pulmonary disease; RCS, Restricted cubic spline; NHANES, National Health and Nutrition Examination Survey; FEV1, Forced expiratory volume in 1s; FVC, Forced vital capacity; 95% CI, 95% Confidence interval; OR, Odds ratio; BMI, Body Mass Index; IRB, Institutional Review Board; MET, metabolic equivalent; S.E, Standard Error; ANOVA, Analysis of variance; PIR, Poverty Impact Ratio; TC, Total cholesterol; HDL, High-density lipoprotein; mMRC, Modified Medical Research Council; LLN, Lower limit of normal; MEC, Mobile Examination Center; NCHS, National Center for Health Statistics; CVD, Cardiovascular Disease.

Data Sharing Statement

Publicly available datasets were analyzed in this study. These data can be found at: https://wwwn.cdc.gov/nchs/nhanes/Default.aspx.

Ethical Approval

The National Center for Health Statistics and Ethics Review Board approved the protocol for NHANES, and all participants provided written informed consent. As the NHANES database is available to the public, the IRB of the study hospital (The Second Affiliated Hospital of Zhejiang University School of Medicine) waived both IRB review and informed consent by the participants for the present study.

Author Contributions

All authors made a significant contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; have agreed on the journal to which the article has been submitted; and agree to be accountable for all aspects of the work.

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Disclosure

The authors declare no competing interests.

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