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Original Research

Benefits of movement-based Behaviors on improving erectile function in American men: a nationwide survey study

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Abstract

Background: Erectile dysfunction (ED) is a prevalent condition with significant psychological and physiological impacts. Recently, a new concept called movement-based behaviors (MBB) has been proposed, which includes four types of PA: vigorous PA (VPA), moderate-intensity PA (MPA), walking/cycling, and muscle-strengthening activities (MSA), and uses an MBB index (range 0–4) to estimate the combined effects of these activities on health outcomes.
Aim: This study aims to evaluate the relationship between different types of physical activities (PA) and ED using the MBB index in a nationally representative sample of U.S. men.
Methods: We analyzed data from the National Health and Nutrition Examination Survey (NHANES) 2001-2004, including 3435 male participants. Multivariate logistic regressions were performed to explore the associations, supplemented with subgroup analysis and sensitivity analysis.
Outcomes: The assessment of PA in this study is based on four self-reported questions from the NHANES Mobile Examination Center interview, including VPA, MPA, walking/cycling, and MSA. The MBB index, ranging from 0 to 4, was used to assess combined PA types. ED was evaluated using a single-question self-assessment.
Results: Higher MBB index values were associated with lower ED risk. Participants with an MBB index of 2 had a significantly lower risk of ED in Model 3 (OR = 0.65, 95% CI: 0.43-0.97, P = 0.04). Those with an MBB index of 3 or 4 had the lowest risk of ED across all models, with OR_Model1 = 0.29 (95% CI: 0.21-0.40, P < 0.0001), OR_Model2 = 0.52 (95% CI: 0.37-0.73, P < 0.001), and OR_Model3 = 0.61 (95% CI: 0.41-0.90, P = 0.02). However, this relationship was not significant in subgroups with severe ED or comorbid conditions.
Clinical Implications: Our findings can provide clinicians with guidance to help patients personalize their selection of different exercise combinations.
Strengths and Limitations: We explored the impact of different exercise combinations on reducing ED risk and innovatively proposed the MBB index for a comprehensive assessment of exercise benefits, supported by a large sample size and multivariable adjustments. However, the limitations of cross-sectional design and recall bias cannot be overlooked.
Conclusion: The MBB index effectively demonstrates that combined PA can reduce ED risk, supporting tailored exercise recommendations for patients.

Keywords: erectile dysfunction; physical activity; MBB index; NHANES; exercise and health.

Introduction

Erectile dysfunction (ED) is a very common and distressing condition that prevents men from achieving or maintaining an erection sufficient for satisfactory vaginal intercourse.[1] A statistical survey highlights that the prevalence of ED in adult men aged 20 years and older in the United States is nearly 19%, and this rate increases with age.[2,3] It is projected that by 2025, nearly 322 million men worldwide will experience ED, with up to 30 million occurred in the U.S. alone.[4] In fact, ED extends beyond its physiological impact; it often brings about profound emotional and psychological effects, impacting self-esteem, marital relationships, and sexual satisfaction, ultimately leading to a decrease in overall quality of life.[5,6] More importantly, ED is now recognized as a warning sign for future cardiovascular events due to the anatomical and functional similarities between penile and coronary vasculature.[7,8] Therefore, global public health systems have identified it as a critical health issue that urgently needs to be addressed.[9] This has motivated ongoing research to identify potential modifiable interventions that can improve erectile function and reduce the risk of ED.

Currently, the most commonly used treatment for ED is first-line therapy with phosphodiesterase type 5 inhibitors, which, however, can lead to various degrees of adverse

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complications.[10,11] In contrast, lifestyle interventions are more acceptable to affected individuals and can offer comparable therapeutic effects, making them a more appealing option.[12,13] Diet and physical activities (PA) are the most commonly recommended lifestyle modifications in public health to prevent or intervene in various chronic non-neoplastic diseases, and ED is no exception. Several studies have preliminarily indicated that PA can effectively reduce the risk of ED and improve erectile function in men.[14-16] Vignera et al. found that 150 minutes of aerobic exercise per week, without any other pharmacological interventions, significantly improved erectile function and penile arterial blood flow parameters in patients with ED.[17] Furthermore, a recent NHANES-based study concluded that engaging in recreational or vigorous PA (VPA) on a monthly basis could reduce the risk of ED, whereas walking, bicycling, and muscle-strengthening activities (MSA) did not.[18] However, it must be recognized that these studies almost exclusively explore the impact of a single type or intensity of PA on ED risk without considering their combined effects, which does not reflect real-world scenarios. More importantly, these findings seemingly suggest that only specific PA regimens can reduce ED risk, which is a highly limited perspective. Therefore, exploring the combined effects of different types of PA on reducing ED risk is highly valuable, providing more precise PA recommendations for ED patients with varying characteristics.

Recently, a new concept called movement-based behaviors (MBB) has been proposed, which includes four types of PA: VPA, moderate-intensity PA (MPA), walking/cycling, and MSA, and uses an MBB index (range 0–4) to estimate the combined effects of these activities on health outcomes.[19] To date, there are almost no studies investigating the combined effects of these four types of PA on improving erectile function, specifically selecting which could benefit in reducing the risk of ED. Therefore, to address this gap in knowledge, this study uses extensive data from a nationally representative sample of adult U.S men from the National Health and Nutrition Examination Survey (NHANES) 2001–2004.

Materials and methods

Data source and study population

NHANES is a biennial national cross-sectional survey project in the U.S. since 1999, designed to collect extensive nutritional and health information from the U.S. population to aid in public health management and policy-making. The survey uses a multistage, probability sampling method to obtain a representative sample of the non-institutionalized U.S. population, with data collection conducted by trained professionals through questionnaires and physical examinations. All study protocols are approved by the Ethics Review Board of the National Center for Health Statistics, and written informed consent is obtained from all participants. Currently, all data are publicly accessible to global researchers through the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm).

Our sample selection is based on the NHANES cycles from 2001 to 2004, as only these cycles include assessments of male erectile function. A total of 21 161 participants were initially considered. First, we excluded 10 860 female participants. Subsequently, we applied the following exclusion criteria: (1) ED data: excluded 6185 male participants without ED data; (2) PA Data: excluded 188 participants with difficulty walking, 202 participants unable to engage in PA, and three participants lacking PA data; (3) Covariates Data: excluded 204 participants without poverty income ratio (PIR) data and 67 participants without body mass index (BMI) data, and 17 participants missing other covariate data. After applying these criteria, a total of 3435 participants were included in the final analysis. The detailed flowchart of participant inclusion is shown in Figure 1.

Physical activities assessments

The assessment of PA in this study is based on four self-reported questions from the NHANES Mobile Examination Center interview, including VPA, MPA, walking/cycling, and MSA.[19] VPA: Participants were asked, "Over the past 30 days, have you engaged in any vigorous-intensity activities for at least 10 minutes that caused heavy sweating or a large increase in breathing or heart rate?". MPA: Participants were asked, "Over the past 30 days, have you engaged in any moderate-intensity activities for at least 10 minutes that caused light sweating or a slight to moderate increase in breathing or heart rate?". Walking/Cycling for Transportation: Participants were asked, "Over the past 30 days, have you walked or bicycled as part of getting to and from work, school, or to do errands?". MSA: Participants were asked, "Over the past 30 days, did you do any physical activities specifically designed to strengthen your muscles, such as lifting weights, push-ups, or sit-ups?". Due to the exclusion of participants with missing data or those unable to engage in these PA, all responses to these questions are binary (yes/no). Thus, the MBB index refers to the sum of individual participants' involvement in these activities, ranging from 0 to 4.

Erectile dysfunction assessment

The assessment of ED in this study was conducted using a single question derived from the Massachusetts Male Aging Study[20]: "Many men experience problems with sexual intercourse. How would you describe your ability to get and keep an erection sufficient for satisfactory intercourse?". The response options included: (1) Always able or almost always able to get and keep an erection; (2) Usually able to get and keep an erection; (3) Sometimes able to get and keep an erection; and (4) Never able to get and keep an erection. Based on previous literature,[21] in our study, participants who answered "Always able or almost always able" or "Usually able to get and keep an erection" were classified as not having ED. In contrast, those who answered "Sometimes able to" or "Never able to get and keep an erection" were diagnosed with ED. It is important to note that for sensitivity analysis, we adjusted the ED diagnostic criteria based on other studies.[22,23] This included a stricter definition, where only participants who answered "Never able to get and keep an erection" were diagnosed with ED, and a broader definition, where participants who answered "Usually able to," "Sometimes able to," or "Never able to get and keep an erection" were all diagnosed with ED.

Potential covariates assessment

Based on previous research, we included several potential covariates that might influence the relationship between PA and ED. These covariates include age, categorized into two groups (< 40 years and ≥ 40 years), and BMI, classified into three categories (< 25 kg/m^2, 25-30 kg/m^2, and ≥ 30 kg/m^2).

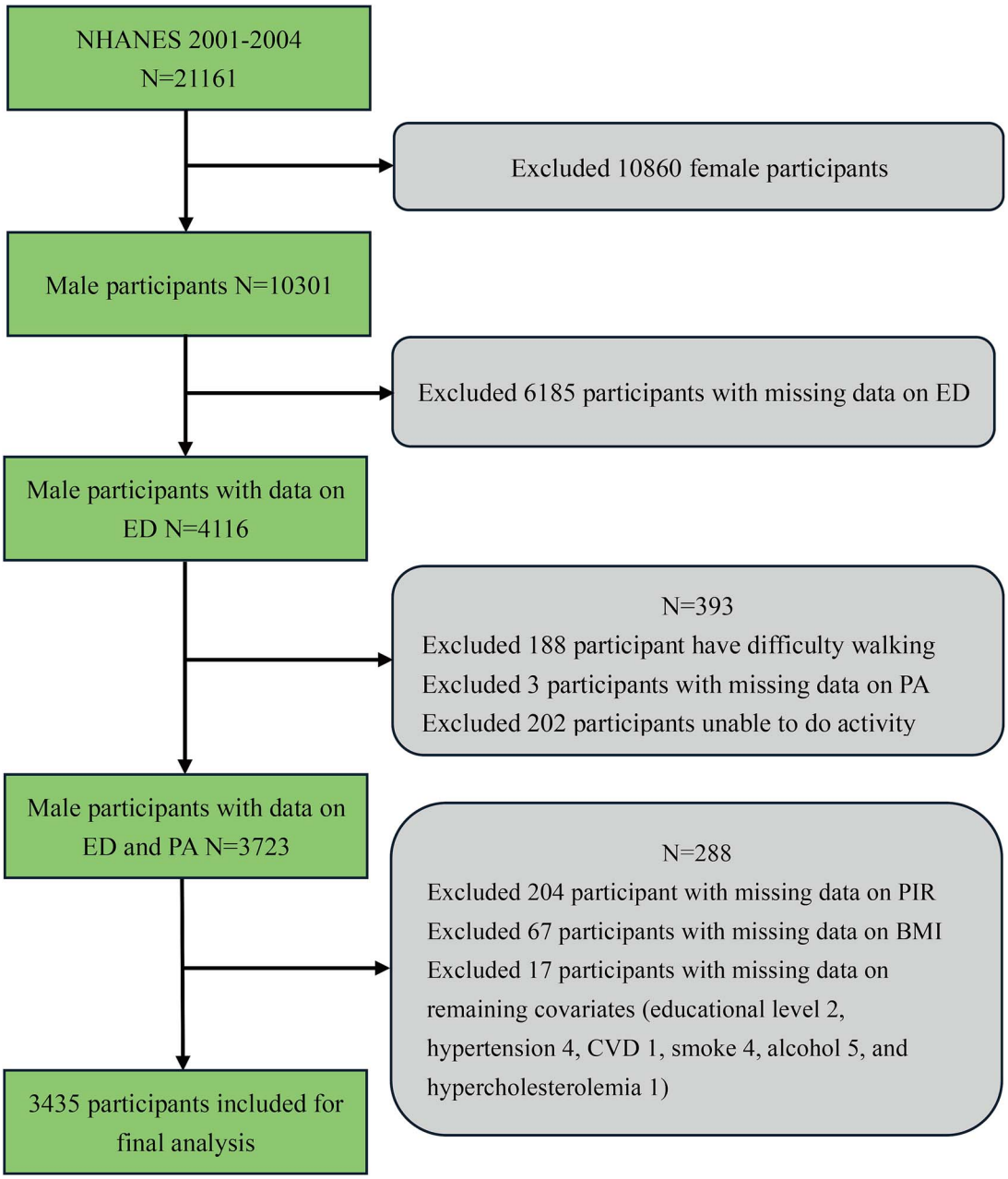

Figure 1. Flowchart of participant selection from the NHANES 2001-2004 dataset. NHANES: National Health and nutrition examination survey, ED: Erectile dysfunction, PA: Physical activity, BMI: Body mass index, PIR: Poverty to income ratio, CVD: Cardiovascular disease.

Ethnicity was considered with the following groups: Mexican American, Non-Hispanic White, Non-Hispanic Black, Other Hispanic, and Others. Education level was divided into less than high school, completed high school, or more than high school. Marital status was categorized as living alone or married/living with a partner. PIR was grouped into three categories (< 1.3, 1.3-3.5, and > 3.5). Additionally, lifestyle factors such as alcohol use and smoking status were included, with smoking status categorized as never, former, or current. Clinical factors such as the presence of diabetes mellitus (DM), hypertension, cardiovascular disease (CVD), and hypercholesterolemia were also considered.

Specifically, alcohol use was defined as consuming more than 12 drinks in the past year. Smoking status was categorized based on lifetime cigarette consumption and current smoking status: never smokers (<100 cigarettes), former smokers (≥100 cigarettes but not currently smoking), and current smokers (≥00 cigarettes and currently smoking). DM was diagnosed based on a history of diagnosis, use of insulin or oral hypoglycemic medications, or a fasting glucose level of ≥200 mg/dL. Hypertension was defined by a history of diagnosis, use of antihypertensive medications, or blood pressure readings ≥140/90 mmHg. Hypercholesterolemia was diagnosed based on a history of diagnosis, use of lipid-lowering medications, or a total cholesterol level ≥ 240 mg/dL. The diagnosis of CVD relied on a self-reported history of congestive heart failure, coronary heart disease, angina, or heart attack.

Statistical analysis

Based on the NHANES sampling methodology, we used sampling weights, strata, and primary sampling units to obtain reliable national estimates. The characteristics of the population were presented as weighted means ± standard errors for continuous variables and as weighted percentages for categorical variables. Weighted linear regression and chi-square tests were used to compare the characteristics of ED and non-ED participants for continuous and categorical variables, respectively. Multivariable logistic regression was employed to evaluate the relationship between PA and the risk of ED. This analysis included both individual PA components and a combined MBB index as independent variables. Individual PA components were treated as binary variables, while the MBB index was treated as an ordinal categorical variable (with 0 as the reference category) to assess potential trends in the association. To account for the influence of potential covariates, we developed three models. The Model 1 included only the exposure variables. The Model 2 adjusted for age, ethnicity, marital status, education, and PIR. The Model 3 further adjusted for BMI, smoking status, alcohol use, and history of hypertension, hypercholesterolemia, DM, and CVD.

To enhance the robustness of our results, we further conducted subgroup analyses and sensitivity analyses. The subgroup analyses explored the relationship between the MBB index and ED across different subgroups, including age, BMI, smoking status, DM, hypertension, hypercholesterolemia, and CVD. Each subgroup analysis adjusted for all variables in Model 3, except for the grouping variable. For the sensitivity analyses, we redefined ED based on broader and stricter criteria as outlined in the ED assessment section, while including the MBB index as the exposure variable. Statistical significance was set at a two-sided p-value of less than 0.05. EmpowerStats (http://www.empowerstats.com, X&Y Solutions, Inc.) and the statistical software package R (http://www.R-project.org; The R Foundation) were used for all statistical analyses in this study.

Results

Baseline characteristics of the population by ED status

Out of 3435 participants, 904 were classified as having ED (26.32%). The detailed baseline and PA characteristics of the study population, stratified by ED status, are presented in Table 1. Compared to non-ED participants, those in the ED group were older, with a mean age of 60.39 years versus 40.92 years ($P < 0.0001$). They also had a higher BMI and lower education levels. A higher proportion of ED participants were married or living with a partner, and they had lower PIR. Additionally, the ED group had a higher prevalence of comorbid conditions, such as DM, CVD, hypertension, and hypercholesterolemia. PA levels, including VA, MA, MSA, and walking or bicycling, were significantly lower in the ED group. The MBB index, reflecting PA levels, indicated a higher proportion of ED participants with lower scores ($P < 0.0001$).

Logistic regression analysis results of PA and ED

The regression analysis results for individual PA and ED are shown in Table 2. For VA, participants who engaged in VA had a significantly lower risk of ED across all models, with OR_Model1 = 0.33 (95% CI: 0.27-0.41, $P < 0.0001$), OR_Model2 = 0.48 (95%CI: 0.38-0.60, $P < 0.0001$), and OR_Model3 = 0.57 (95% CI: 0.44-0.73, $P < 0.001$). MA was associated with a reduced risk of ED in Model 1 (OR = 0.73, 95%CI: 0.60-0.90, P = 0.004), but this association was not significant in Models 2 (OR = 0.93, 95% CI: 0.75-1.17, P = 0.53) and 3 (OR = 0.93, 95% CI: 0.74-1.18, P = 0.53). MSA showed a significant reduction in ED risk in all models, with OR_Model1 = 0.45 (95% CI: 0.36-0.55, $P < 0.0001$), OR_Model2 = 0.66 (95% CI: 0.52-0.85, P = 0.003), and OR_Model3 = 0.69 (95% CI: 0.52-0.92, P = 0.02). Walking or bicycling also showed a significant reduction in ED risk in Model 1 (OR = 0.63, 95% CI: 0.49-0.82, P = 0.001) and Model 2 (OR = 0.73, 95% CI: 0.56-0.94, P = 0.02), but the association was marginally non-significant in Model 3 (OR = 0.79, 95% CI: 0.61-1.02, P = 0.07). The association between the MBB index and ED was also evaluated, with 0 MBB index as the reference. Participants with an MBB index of 2 had a significantly lower risk of ED in Model 3 (OR = 0.65, 95% CI: 0.43-0.97, P = 0.04). Those with an MBB index of 3 or 4 had the lowest risk of ED across all models, with OR_Model1 = 0.29 (95% CI: 0.21-0.40, $P < 0.0001$), OR_Model2 = 0.52 (95% CI: 0.37-0.73, $P < 0.001$), and OR_Model3 = 0.61 (95% CI: 0.41-0.90, P = 0.02). The trend analysis indicated a significant trend across all models ($P < 0.0001$ in Models 1 and 2, P = 0.003 in Model 3), suggesting that higher levels of PA, as reflected by the MBB index, are associated with a progressively lower risk of ED. All the results of Model 3 are illustrated in Figure 2.

Subgroup and sensitivity analyses of MBB index and ED

Subgroup analyses revealed significant associations between the MBB index and ED in several groups (Table 3). Participants aged ≥40 years with an MBB index of 2 or 3/4 had lower risks of ED (OR: 0.61, 95% CI: 0.41-0.93 and OR: 0.58, 95% CI: 0.36-0.92, respectively, P for trend = 0.002). Non-DM participants with an MBB index of 3/4 showed a lower risk of ED (OR: 0.63, 95% CI: 0.40-1.01, P for trend = 0.01). Participants without CVD and with an MBB index of 3/4 had reduced ED risks (OR: 0.62, 95% CI: 0.42-0.92, P for trend = 0.01). Hypertensive participants with an MBB index of 3/4 had a significantly lower risk of ED (OR: 0.41, 95% CI: 0.22-0.75, p for trend = 0.002). Lastly, participants without hypercholesterolemia and with an MBB index of 3/4 had reduced ED risks (OR: 0.58, 95% CI: 0.36-0.94, p for trend = 0.003). The results indicate that higher PA levels, as measured by the MBB index, are associated with lower risks of ED across various subgroups.

The sensitivity analyses with different ED diagnostic criteria are presented in Table 4. Using a stricter definition of ED, the association between the MBB index and ED was less pronounced. For an MBB index of 2, the odds ratio (OR) in Model 1 was 0.53 (95% CI: 0.33–0.86, P = 0.01), but this association was not significant in Model 3 (OR: 0.90, 95% CI: 0.51–1.60, P = 0.69). Similarly, for an MBB index of 3 or 4, the OR in Model 1 was 0.27 (95% CI: 0.16-0.45, $P < 0.0001$), but it was not significant in Model 3 (OR: 0.70, 95% CI: 0.35-1.40, P = 0.27). Using a more lenient definition of ED, the association between the MBB index and ED remained

Table 1. Baseline characteristics of the study population stratified by ED status, weighted.

Characteristics	Total	Non-ED	ED	P value
Number, n	3435	2531	904	
Age, year	44.36 ± 0.40	40.92 ± 0.34	60.39 ± 0.61	< 0.0001
BMI, kg/m^2	27.97 ± 0.11	27.78 ± 0.11	28.86 ± 0.29	0.001
Age, %				< 0.0001
< 40y	41.78	48.36	11.08	
≥ 40y	58.22	51.64	88.92	
BMI, %				< 0.001
< 25 kg/m^2	30.25	31.43	24.74	
≥ 25 kg/m^2 and < 30 kg/m^2	41.21	41.26	41.00	
≥ 30 kg/m^2	28.54	27.32	34.26	
Race, %				0.07
Mexican American	8.24	8.39	7.53	
Non-Hispanic White	73.16	72.78	74.92	
Non-Hispanic Black	10.18	10.39	9.18	
Other Hispanic	4.40	4.08	5.86	
Other races	4.03	4.36	2.51	
Educational level, %				< 0.0001
Below high school	16.86	14.32	28.69	
High school	26.90	27.63	23.50	
Above high school	56.24	58.05	47.81	
Marital status, %				< 0.0001
Living alone	29.79	31.41	22.26	
Married or living with a partner	70.21	68.59	77.74	
PIR, %				< 0.001
PIR ≤ 1.3	16.35	15.94	18.22	
1.3 < PIR ≤ 3.5	35.80	34.52	41.74	
PIR > 3.5	47.86	49.54	40.04	
Alcohol intake, %				< 0.0001
No	22.60	20.22	33.73	
Yes	77.40	79.78	66.27	
Smoking, %				< 0.0001
Never	43.03	45.44	31.80	
Former	28.68	24.95	46.05	
Now	28.29	29.61	22.15	
Vigorous activity (VA), %				< 0.0001
No	58.74	54.55	78.30	
Yes	41.26	45.45	21.70	
Moderate activity (MA), %				0.004
No	42.83	41.48	49.14	
Yes	57.17	58.52	50.86	
Muscle Strengthening Activities (MSA), %				< 0.0001
No	67.93	65.18	80.73	
Yes	32.07	34.82	19.27	
Walked or bicycled, %				< 0.001
No	74.83	73.42	81.40	
Yes	25.17	26.58	18.60	
History of DM, %				< 0.0001
No	90.45	94.15	73.22	
Yes	9.55	5.85	26.78	
History of CVD, %				< 0.0001
No	92.11	95.20	77.69	
Yes	7.89	4.80	22.31	
History of Hypertension, %				< 0.0001
No	66.90	72.02	43.03	
Yes	33.10	27.98	56.97	
History of Hypercholesterolemia %				< 0.0001
No	29.56	31.67	19.73	
Yes	70.44	68.33	80.27	
MBB Index, %				< 0.0001
0	22.31	20.32	31.59	
1	29.23	27.16	38.90	
2	24.88	26.38	17.89	
3	17.63	19.10	10.74	
4	5.95	7.04	0.88	

Abbreviations: BMI: body mass index PIR: poverty to income ratio VA: vigorous activity MA: moderate activity MSA: muscle strengthening activities DM: diabetes mellitus CVD: cardiovascular disease MBB: multi-behavioral balance index **Statistical Methods:** Continuous variables are presented as weighted means ± standard errors and compared using weighted linear regression. Categorical variables are presented as weighted percentages and compared using chi-square tests.

Table 2. Logistic regression analysis of PA and the risk of ED, weighted.

	Model 1		Model 2		Model 3	
	OR (95%CI)	P value	OR (95%CI)	P value	OR (95%CI)	P value
VA						
No	Reference	—	Reference	—	Reference	—
Yes	0.33(0.27,0.41)	<0.0001	0.48(0.38, 0.60)	<0.0001	0.57(0.44,0.73)	<0.001
MA						
No	Reference	—	Reference	—	Reference	—
Yes	0.73(0.60,0.90)	0.004	0.93(0.75, 1.17)	0.53	0.93(0.74,1.18)	0.53
MSA						
No	Reference	—	Reference	—	Reference	—
Yes	0.45(0.36,0.55)	<0.0001	0.66(0.52, 0.85)	0.003	0.69(0.52,0.92)	0.02
Walked or bicycled						
No	Reference	—	Reference	—	Reference	—
Yes	0.63(0.49,0.82)	0.001	0.73(0.56, 0.94)	0.02	0.79(0.61,1.02)	0.07
MBB index						
0	Reference	—	Reference	—	Reference	—
1	0.92(0.71,1.19)	0.52	1.07(0.80, 1.44)	0.61	1.12(0.81,1.54)	0.44
2	0.44(0.32,0.60)	<0.0001	0.61(0.42, 0.88)	0.01	0.65(0.43,0.97)	0.04
3&4	0.29(0.21,0.40)	<0.0001	0.52(0.37, 0.73)	<0.001	0.61(0.41,0.90)	0.02
P for trend	<0.0001		<0.0001		0.003	

Abbreviations: VA: vigorous activity MA: moderate activity MSA: muscle strengthening activities MBB: multi-behavioral balance index BMI: body mass index PIR: poverty to income ratio DM: diabetes mellitus CVD: cardiovascular disease OR: odds ratio CI: confidence interval **Statistical Methods:** Model 1 includes only the exposure variables. Model 2 adjusts for age, ethnicity, marital status, education level, and PIR. Model 3 further adjusts for BMI, smoking status, alcohol intake, and history of DM, CVD, hypertension, and hypercholesterolemia.

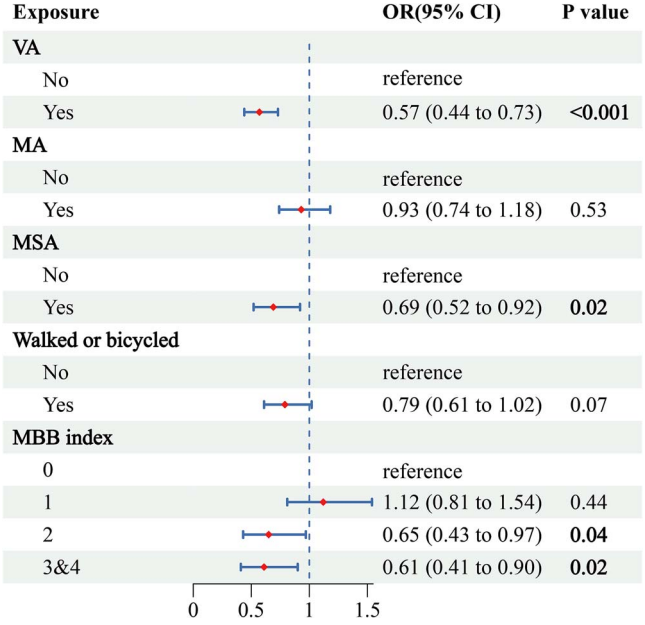

Figure 2. Logistic regression analysis of the association between various types of PA and the risk of ED in Model 3, weighted. Adjustments in Model 3 include age, ethnicity, marital status, education level, PIR, BMI, smoking status, alcohol intake, and history of DM, CVD, hypertension, and hypercholesterolemia. VA: Vigorous activity, MA: Moderate activity, MSA: Muscle strengthening activities, MBB: Multi-Behavioral balance index, BMI: Body mass index, PIR: Poverty to income ratio, DM: Diabetes mellitus, CVD: Cardiovascular disease, OR: Odds ratio, CI: Confidence interval.

significant across all models. For an MBB index of 2, the OR in Model 3 was 0.70 (95% CI: 0.51-0.98, P = 0.04). For an MBB index of 3 or 4, the OR in Model 3 was 0.62 (95% CI: 0.44-0.88, P = 0.01). These results indicate that while PA improves mild to moderate ED, it may not be sufficient to reduce the risk of severe ED.

Discussion

To our knowledge, this is the first study to use the MBB index to explore the combined effect of PA on ED using a nationally representative sample of U.S. men. Our results indicate that an increased MBB index is associated with a lower risk of ED. However, this relationship becomes insignificant in subgroups with high BMI, current smokers, and those with comorbid DM, hypertension, or hypercholesterolemia. Furthermore, when a stricter definition of ED is applied, the association between the MBB index and ED also loses significance. This suggests that while the MBB index is a beneficial option for improving erectile function in patients with mild to moderate ED, it may not provide clinically meaningful improvement for those with severe ED when used alone.

Sedentary behavior is currently recognized as an important risk factor for ED. A study on patients with type 2 DM found that prolonged sedentary behavior (at least 9 hours per day) was closely associated with the risk of severe ED, with an OR of 1.84 (95% CI: 1.06-3.33).[24] Moreover, a recent Mendelian randomization study also demonstrated a significant association between prolonged sedentary behavior and the risk of ED (OR = 3.57; 95%CI = 1.78–7.16; $P < 0.001$).[25] These findings naturally shift the focus of clinical prevention of ED towards PA. Multiple studies have confirmed that exercise can reduce the risk of ED, leading to recommendations for increased physical activity as a preventive measure. A recent meta-analysis further demonstrated that aerobic exercise can improve the IIEF-EF scores in patients with mild, moderate, and severe ED.[26] In our study, we used the MBB index to represent the cumulative effect of various PA. A high MBB index indicates a high level of PA, which is associated with a reduced risk of ED. These results collectively suggest that PA is beneficial for reducing the risk of ED and is advantageous for lowering the future incidence of ED.

When examining the relationship between individual types of PA and ED, our study found that not all types of PA are associated with a reduced risk of ED. VA significantly

Table 3. Subgroup analyses of MBB index and ED risk, weighted.

Subgroup	MBB index				P for trend	P for interaction
	0	1	2	3&4		
Age, %						0.26
< 40y	Reference	0.80(0.36, 1.76)	0.77(0.30, 1.97)	0.66(0.25, 1.74)	0.39	
≥ 40y	Reference	1.18(0.87,1.59)	0.61(0.41,0.93)	0.58(0.36,0.92)	0.002	
BMI, %						0.22
< 25 kg/m^2	Reference	0.81(0.44, 1.49)	0.46(0.22, 0.98)	0.37(0.18, 0.76)	0.01	
≥ 25 kg/m^2 and < 30 kg/m^2	Reference	1.07(0.68,1.69)	0.56(0.36,0.88)	0.60(0.35,1.03)	0.01	
≥ 30 kg/m^2	Reference	1.45(0.83, 2.52)	0.88(0.48, 1.63)	0.84(0.38, 1.89)	0.40	
Smoking, %						0.07
Never	Reference	2.73(1.59, 4.67)	1.04(0.48, 2.22)	1.11(0.57, 2.16)	0.28	
Former	Reference	0.67(0.44, 1.03)	0.53(0.29, 0.97)	0.48(0.25, 0.92)	0.01	
Now	Reference	1.04(0.59,1.84)	0.66(0.30,1.45)	0.55(0.23,1.35)	0.15	
History of DM, %						0.87
No	Reference	1.21(0.79,1.85)	0.69(0.42,1.13)	0.63(0.40,1.01)	0.01	
Yes	Reference	0.91(0.47, 1.76)	0.53(0.21, 1.35)	0.69(0.27, 1.80)	0.09	
History of CVD, %						0.18
No	Reference	1.05(0.76,1.46)	0.67(0.45,1.01)	0.62(0.42,0.92)	0.01	
Yes	Reference	1.86(0.75, 4.63)	0.52(0.20, 1.35)	0.52(0.21, 1.31)	0.04	
History of Hypertension, %						0.06
No	Reference	0.92(0.55,1.55)	0.54(0.30,0.96)	0.41(0.22,0.75)	0.002	
Yes	Reference	1.41(0.94, 2.12)	0.71(0.41, 1.24)	0.92(0.52, 1.64)	0.23	
History of Hypercholesterolemia %						0.94
No	Reference	1.13(0.79,1.61)	0.66(0.43,1.01)	0.58(0.36,0.94)	0.003	
Yes	Reference	1.12(0.59, 2.13)	0.61(0.24, 1.57)	0.67(0.28, 1.64)	0.21	

Abbreviations: BMI: body mass index PIR: poverty to income ratio DM: diabetes mellitus CVD: cardiovascular disease MBB: multi-behavioral balance index OR: odds ratio CI: confidence interval **Statistical Methods:** Subgroup analyses adjusted for all variables in Model 3 except the grouping variable itself, including age, ethnicity, marital status, education level, PIR, BMI, smoking status, alcohol intake, and history of DM, CVD, hypertension, and hypercholesterolemia.

Table 4. Sensitivity analysis of the association between MBB index and ED risk, weighted.

	Model 1		Model 2		Model 3	
	OR (95%CI)	P value	OR (95%CI)	P value	OR (95%CI)	P value
Sensitivity analysis_1st						
MBB index						
0	Reference	—	Reference	—	Reference	—
1	0.96(0.64,1.42)	0.82	1.13(0.73, 1.74)	0.56	1.20(0.75,1.93)	0.41
2	0.53(0.33,0.86)	0.01	0.82(0.47, 1.43)	0.46	0.90(0.51,1.60)	0.69
3&4	0.27(0.16,0.45)	<0.0001	0.58(0.32, 1.04)	0.07	0.70(0.35,1.40)	0.27
P for trend	<0.0001		0.071		0.235	
Sensitivity analysis_2nd						
MBB index						
0	Reference	—	Reference	—	Reference	—
1	0.83(0.65,1.05)	0.12	0.94(0.73,1.23)	0.66	0.98(0.75,1.27)	0.84
2	0.50(0.39,0.64)	<0.0001	0.65(0.48,0.88)	0.01	0.70(0.51,0.98)	0.04
3&4	0.34(0.26,0.44)	<0.0001	0.53(0.39,0.71)	<0.001	0.62(0.44,0.88)	0.01
P for trend	<0.0001		<0.0001		0.005	

Abbreviations: MBB: multi-behavioral balance index BMI: body mass index PIR: poverty to income ratio DM: diabetes mellitus CVD: cardiovascular disease OR: odds ratio CI: confidence interval **Statistical Methods:** 1st Sensitivity Analysis: This analysis uses a stricter definition of ED, examining the risk reduction associated with the MBB index. 2nd Sensitivity Analysis: This analysis employs a more lenient definition of ED, assessing the risk reduction associated with the MBB index. Model 1 includes only the exposure variables. Model 2 adjusts for age, ethnicity, marital status, education level, and PIR. Model 3 further adjusts for BMI, smoking status, alcohol intake, and history of DM, CVD, hypertension, and hypercholesterolemia.

reduced the risk of ED with an OR of 0.57 (95% CI: 0.44 to 0.73, $P < 0.001$), which is consistent with previous research. A large-scale population-based study indicated that high-intensity PA effectively reduces the risk of ED, reporting an OR of 0.50 (95% CI: 0.29 to 0.86, $P = 0.045$).[27] In addition, we found that MSA also reduce the risk of ED, with an OR of 0.69 (95% CI: 0.52 to 0.92, $P = 0.02$). However, we did not find a significant association between MA and ED risk. This finding contradicts previous studies where MVPA was shown to reduce the risk of ED.[28] We believe this discrepancy may be due to the potential underestimation of ED incidence when diagnosed based on a single PA type, leading to a negative result. Currently, the relationship between cycling and ED remains inconsistent. A large meta-analysis that synthesized six studies found that cyclists had significantly higher odds of having ED (OR: 2.00, 95% CI: 1.57 to 2.55).[29] The study suggested that prolonged cycling might place pressure on the perineal region, potentially damaging the perineal nerves and arteries, leading to ED.[30] However, other studies have indicated that cycling, like other forms of intense exercise, can reduce the risk of ED.[31] In our study, we did not find a significant relationship between cycling and ED. This may

be due to our combination of walking and cycling into a single category, which could have diluted the specific impact of cycling on ED. These inconsistent results highlight the need for further research to clarify the relationship between cycling and ED. Overall, our study provides a clearer understanding of how different types of PA are associated with ED risk, which can help patients make informed choices and assist physicians in making personalized exercise recommendations. Future studies should focus on refining the diagnostic criteria and exploring the effects of different types of PA on ED to provide more definitive conclusions.

In our sensitivity analysis, when we included a stricter definition of ED, referred to as severe ED, a high MBB index no longer reduced the risk of ED. This indicates that for severe ED, PA alone may not mitigate the risk. A review also pointed out that in populations with concurrent low testosterone levels, exercise can improve erectile function but requires adjunctive pharmacological intervention for better therapeutic outcomes.[14] Thus, the clinical advantages of PA for ED are not limited to enhancing erectile function but also extend to augmenting the efficacy of pharmacotherapy. These findings underscore the importance of a multifaceted treatment approach for severe ED, integrating PA with medical treatments to achieve optimal results. This holistic strategy ensures that patients benefit from the synergistic effects of lifestyle modifications and pharmacotherapy, thereby improving overall treatment outcomes for ED.

When considering the mechanisms by which PA reduces the risk of ED, PA can directly reduce systemic inflammation and improve endothelial cell function, which are crucial factors in promoting erections.[32,33] Additionally, exercise improves metabolic health.[34] Our study shows that even if VA cannot be performed, combining other types of PA is still significant for enhancing erectile function. This finding can help physicians make precise clinical decisions for patients, providing them with tailored exercise recommendations to maximize the benefits of PA.

Current guidelines for patients with ED often recommend aerobic exercise and moderate-to-vigorous intensity PA.[16] However, not all patients are free from exercise contraindications, particularly those with CVD.[14] Our study suggests that it is not only vigorous intensity exercise that can reduce the risk of ED. When the combined exercise modes result in an MBB index of 2 or higher, the risk of ED can also be reduced. This finding provides practical clinical value. Urologists and andrologists can recommend combined exercise modes based on a patient's exercise risk assessment to maximize the benefits of PA. However, our subgroup and sensitivity analyses also indicate that for patients with severe ED or those with comorbid hyperlipidemia, CVD, or other conditions causing significant penile vascular damage, PA alone may not achieve clinical benefits.[35,36] In such cases, additional pharmacological interventions are necessary to provide the best outcomes for these patients.

This study is the first to systematically evaluate the relationship between PA and the risk of ED using the MBB index with a representative sample of the U.S. population. The use of NHANES data ensures the quality and comprehensiveness of the sample, enhancing the robustness and reliability of our findings through complicated statistical methods. However, every study has limitations that need to be acknowledged. Firstly, the assessment of PA and ED in our study was based on self-reported questionnaires, which are subject to recall bias and social desirability bias. Secondly, the cross-sectional design of our study limits our ability to infer causality between PA and ED. Thirdly, although we included as many covariates as possible, certain factors such as medication history and psychological status could not be included in the analysis due to database limitations. Therefore, future studies with more complex designs and larger sample sizes are necessary to confirm our results and expand the precise clinical application of PA in the prevention and management of ED.

Conclusion

Our study indicates that not all individual PA can reduce the risk of ED; only VA and MSA are effective. However, a higher MBB index, reflecting a combination of various PA types, is beneficial for maintaining erectile function. These findings suggest that patients can reduce their risk of ED and improve their erectile function by choosing a combination of different PA modes tailored to their circumstances. Nonetheless, more rigorously designed studies with larger sample sizes are necessary in the future to validate our conclusions.

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Author contributions

YM Chen: Conceptualization, Methodology, Investigation, Data curation, Writing—original draft, Writing—review & editing. QF Zhuang: Data curation, Writing—review & editing. W Xia: Conceptualization, Data curation, Writing—review & editing. NY Shao: Conceptualization, Methodology, Supervision, Writing—review & editing. BZ: Conceptualization, Methodology, Supervision, Writing—review & editing. XL Feng: Conceptualization, Methodology, Investigation, Supervision, Writing—review & editing.

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Conflicts of interest

The authors reported no potential conflicts of interest.

Data Availability

The study data are available on the NHANES website (https://www.cdc.gov/nchs/nhanes/index.htm). More detailed analysis data and corresponding R code can be provided upon reasonable request by contacting the corresponding author.

Ethical statement

The NHANES protocols underwent review and approval by the National Center for Health Statistics institutional review board (NCHS IRB/ERB Protocol No. #98-12). All participants provided written

informed consent at the time of participation. Ethical review and approval for this study were waived, as secondary analysis did not necessitate additional institutional review board approval.

References

1. Nih consensus conference. Impotence. Nih consensus development panel on impotence. *JAMA*. 1993;**270**(1):83-90. https://doi.org/10.1001/jama.270.1.83
2. Saigal CS, Wessells H, Pace J, Schonlau M, Wilt TJ, Urologic Diseases in America Project. Predictors and prevalence of erectile dysfunction in a racially diverse population. *Arch Intern Med*. 2006;**166**(2):207-212. https://doi.org/10.1001/archinte.166.2.207
3. Johannes CB, Araujo AB, Feldman HA, Derby CA, Kleinman KP, McKinlay JB. Incidence of erectile dysfunction in men 40 to 69 years old: longitudinal results from the Massachusetts male aging study. *J Urol*. 2000;**163**(2):460-463. https://doi.org/10.1016/S0022-5347(05)67900-1
4. Ayta IA, McKinlay JB, Krane RJ. The likely worldwide increase in erectile dysfunction between 1995 and 2025 and some possible policy consequences. *BJU Int*. 1999;**84**(1):50-56. https://doi.org/10.1046/j.1464-410x.1999.00142.x
5. Capogrosso P, Montorsi F. Men's health and quality of life. *Curr Opin Urol*. 2016;**26**(2):121-122. https://doi.org/10.1097/MOU.0000000000000267
6. Yafi FA, Jenkins L, Albersen M, *et al*. Erectile dysfunction. *Nat Rev Dis Primers*. 2016;**2**:16003. Epub 20160204. https://doi.org/10.1038/nrdp.2016.3
7. Solomon H, Man JW, Jackson G. Erectile dysfunction and the cardiovascular patient: endothelial dysfunction is the common denominator. *Heart*. 2003;**89**(3):251-253. https://doi.org/10.1136/heart.89.3.251
8. Gandaglia G, Briganti A, Jackson G, *et al*. A systematic review of the association between erectile dysfunction and cardiovascular disease. *Eur Urol*. 2014;**65**(5):968-978. Epub 20130823. https://doi.org/10.1016/j.eururo.2013.08.023
9. Youcheng L, Xun W, Zhufeng C. Association between nonalcoholic fatty liver disease and erectile dysfunction among American adults from the National Health and nutrition examination survey: a cross-sectional study. *Int J Impot Res*. 2024. https://doi.org/10.1038/s41443-024-00914-6
10. Ventimiglia E, Capogrosso P, Montorsi F, Salonia A. The safety of phosphodiesterase type 5 inhibitors for erectile dysfunction. *Expert Opin Drug Saf*. 2016;**15**(2):141-152. Epub 20160109. https://doi.org/10.1517/14740338.2016.1131818
11. Scaglione F, Donde S, Hassan TA, Jannini EA. Phosphodiesterase type 5 inhibitors for the treatment of erectile dysfunction: pharmacology and clinical impact of the sildenafil citrate Orodispersible tablet formulation. *Clin Ther*. 2017;**39**(2):370-377. Epub 20170128. https://doi.org/10.1016/j.clinthera.2017.01.001
12. Kirby M. The circle of lifestyle and erectile dysfunction. *Sex Med Rev*. 2015;**3**(3):169-182. Epub 20151008. https://doi.org/10.1002/smrj.52
13. Ostfeld RJ, Allen KE, Aspry K, *et al*. Vasculogenic erectile dysfunction: the impact of diet and lifestyle. *Am J Med*. 2021;**134**(3):310-316. Epub 20201120. https://doi.org/10.1016/j.amjmed.2020.09.033
14. La Vignera S, Condorelli R, Vicari E, D'Agata R, Calogero AE. Physical activity and erectile dysfunction in middle-aged men. *J Androl*. 2012;**33**(2):154-161. Epub 20110519. https://doi.org/10.2164/jandrol.111.013649
15. Silva AB, Sousa N, Azevedo LF, Martins C. Physical activity and exercise for erectile dysfunction: systematic review and meta-analysis. *Br J Sports Med*. 2017;**51**(19):1419-1424. Epub 20161005. https://doi.org/10.1136/bjsports-2016-096418
16. Duca Y, Calogero AE, Cannarella R, *et al*. Erectile dysfunction, physical activity and physical exercise: recommendations for clinical practice. *Andrologia*. 2019;**51**(5):e13264. Epub 20190315. https://doi.org/10.1111/and.13264
17. La Vignera S, Condorelli R, Vicari E, D'Agata R, Calogero A. Aerobic physical activity improves endothelial function in the middle-aged patients with erectile dysfunction. *Aging Male*. 2011;**14**(4):265-272. Epub 20110208. https://doi.org/10.3109/13685538.2010.544344
18. Zhou H, Xu M, Xu Z, *et al*. The Association of Various Physical Activities with erectile dysfunction: Nhanes 2001-2004. *Sex Med*. 2023;**11**(3):qfad036. Epub 2023/07/28. https://doi.org/10.1093/sexmed/qfad036
19. Loprinzi PD, Loenneke JP, Blackburn EH. Movement-based Behaviors and leukocyte telomere length among us adults. *Med Sci Sports Exerc*. 2015;**47**(11):2347-2352. https://doi.org/10.1249/mss.0000000000000695
20. Derby CA, Araujo AB, Johannes CB, Feldman HA, McKinlay JB. Measurement of erectile dysfunction in population-based studies: the use of a single question self-assessment in the Massachusetts male aging study. *Int J Impot Res*. 2000;**12**(4):197-204. https://doi.org/10.1038/sj.ijir.3900542
21. Yan Y, Zhou L, La R, *et al*. Is erectile dysfunction associated with osteoarthritis and rheumatoid arthritis? Insights from a population-based study. *Sex Med*. 2024;**12**(3):qfae028. Epub 20240602. https://doi.org/10.1093/sexmed/qfae028
22. Li L, Yao H, Dai W, *et al*. A higher Tyg index is related with a higher prevalence of erectile dysfunction in males between the ages 20-70 in the United States, according to a cross-sectional research. *Front Endocrinol (Lausanne)*. 2022;**13**:988257. https://doi.org/10.3389/fendo.2022.988257
23. Wu X, Zhang Y, Jiang H, Zhang X. Monocyte-to-high-density lipoprotein cholesterol ratio and the risk of erectile dysfunction: a study from Nhanes 2001-2004. *Sex Med*. 2024;**12**(2):qfae025. https://doi.org/10.1093/sexmed/qfae025
24. Furukawa S, Sakai T, Niiya T, *et al*. Self-reported sitting time and prevalence of erectile dysfunction in Japanese patients with type 2 diabetes mellitus: the Dogo study. *J Diabetes Complicat*. 2017;**31**(1):53-57. Epub 20161018. https://doi.org/10.1016/j.jdiacomp.2016.10.011
25. Huangfu Z, Gan X, Yang Y, *et al*. A Mendelian randomization study on causal effects of leisure sedentary behavior on the risk of erectile dysfunction. *Andrology*. 2024;**12**(8):1841-1850. https://doi.org/10.1111/andr.13611
26. Khera M, Bhattacharyya S, Miller LE. Effect of aerobic exercise on erectile function: systematic review and meta-analysis of randomized controlled trials. *J Sex Med*. 2023;**20**(12):1369-1375. https://doi.org/10.1093/jsxmed/qdad130
27. Ettala OO, Syvänen KT, Korhonen PE, *et al*. High-intensity physical activity, stable relationship, and high education level associate with decreasing risk of erectile dysfunction in 1,000 apparently healthy cardiovascular risk subjects. *J Sex Med*. 2014;**11**(9):2277-2284. Epub 20140609. https://doi.org/10.1111/jsm.12618
28. Loprinzi PD, Edwards M. Association between objectively measured physical activity and erectile dysfunction among a nationally representative sample of American men. *J Sex Med*. 2015;**12**(9):1862-1864. Epub 20150831. https://doi.org/10.1111/jsm.12977
29. Gan ZS, Ehlers ME, Lin FC, Wright ST, Figler BD, Coward RM. Systematic review and meta-analysis of cycling and erectile dysfunction. *Sex Med Rev*. 2021;**9**(2):304-311. Epub 20200306. https://doi.org/10.1016/j.sxmr.2020.01.002
30. Baran C, Mitchell GC, Hellstrom WJG. Cycling-related sexual dysfunction in men and women: a review. *Sex Med Rev*. 2014;**2**(3-4):93-101. Epub 20151019. https://doi.org/10.1002/smrj.32
31. Sommer F, Goldstein I, Korda JB. Bicycle riding and erectile dysfunction: a review. *J Sex Med*. 2010;**7**(7):2346-2358. Epub 20100119. https://doi.org/10.1111/j.1743-6109.2009.01664.x
32. Pohjantähti-Maaroos H, Palomäki A, Hartikainen J. Erectile dysfunction, physical activity and metabolic syndrome: differences in markers of atherosclerosis. *BMC Cardiovasc Disord*. 2011;**11**: 36. Epub 20110627. https://doi.org/10.1186/1471-2261-11-36

33. Leoni LA, Fukushima AR, Rocha LY, Maifrino LB, Rodrigues B. Physical activity on endothelial and erectile dysfunction: a literature review. *Aging Male*. 2014;**17**(3):125-130. Epub 20140604. https://doi.org/10.3109/13685538.2014.923836
34. Maiorino MI, Bellastella G, Esposito K. Lifestyle modifications and erectile dysfunction: what can Be expected? *Asian J Androl*. 2015;**17**(1):5-10. https://doi.org/10.4103/1008-682x.137687
35. Allen MS. Physical activity as an adjunct treatment for erectile dysfunction. *Nat Rev Urol*. 2019;**16**(9):553-562. Epub 20190625. https://doi.org/10.1038/s41585-019-0210-6
36. Maio G, Saraeb S, Marchiori A. Physical activity and Pde5 inhibitors in the treatment of erectile dysfunction: results of a randomized controlled study. *J Sex Med*. 2010;**7**(6):2201-2208. Epub 20100330. https://doi.org/10.1111/j.1743-6109.2010.01783.x

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