Preventive Medicine Reports 10 (2018) 299–303

Contents lists available at ScienceDirect

Preventive Medicine Reports

journal homepage: www.elsevier.com/locate/pmedr

Anaerobic muscle strengthening physical activity and depression severity among USA adults

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ARTICLE INFO

Keywords:
Physical activity
Depression
Anaerobic muscle strengthening activity
Aerobic activity
PHQ depressive symptoms

ABSTRACT

We investigated the association between depression and anaerobic physical activity (while controlling aerobic physical activity), using a nationally representative sample of USA adults (n = 7354) who participated in the cross sectional National Health and Nutrition Examination Survey (NHANES, 1999–2006). We defined depression using the validated "Patient Health Questionnaire" (PHQ_9) scale of 0–27 as $PHQ_9 \geq 10$. Severity of depression was classified by clinically established PHQ_9 levels: mild (5–9), dysthymic (10–14), moderate (15–19), and major depression ($\geq$20). We used logistic regression to estimate adjusted odds ratios of depression associated with distinct types of activity (only aerobic, only anaerobic, combined regime). We used multinomial logistic regression to examine associations of anaerobic activity with various severity levels of depression (mild, dysthymic, moderate, and major depression) with adjustment for aerobic activity.

Women had higher prevalence of depression than men (8.4% versus 5.7%), whereas anaerobic muscle strengthening activity was more common in men than women (35% versus 24%). *Adjusting for aerobic activity*, anaerobic activity was inversely associated with depression ($PHQ_9 \geq 10$) in women under 50 (OR = 0.57; 95%CI = 0.41–0.81), all women (OR = 0.59; 0.43–0.80), men under 50 (OR = 0.85; 0.58–1.2), and all men (OR = 0.72; 0.51–1.01). Anaerobic activity was inversely associated with severity level of depressive symptoms in women and men. The combined regimen of anaerobic muscle strengthening activity and meeting the Physical Activity Guideline for America (PAGA) was related to the lowest odds ratio of depression in women (OR = 0.50; 95%CI = 0.33–0.75) and men (OR = 0.39; 95%CI = 0.23–0.62). Independent of aerobic physical activity, anaerobic muscle strengthening activity is significantly and inversely associated with depression among USA adults.

1. Introduction

Aerobic physical activity has been known to be inversely associated with depression (Kremer et al., 2014). Studies using aerobic accelerometer data show that even moderate level of aerobic activity was inversely linked to depression (Janney et al., 2014).

Although the anti-depressive benefits associated with aerobic activity have been observed in prior large scale epidemiological studies (Vallance et al., 2011), the independent association between *anaerobic muscle strengthening activity* and depression (while adjusting for aerobic activity) has not yet been systematically investigated. Prior studies of National Health and Nutrition Examination Survey (NHANES) data have examined "anaerobic muscle strengthening activity" in association with other outcomes such as youth obesity (Ervin et al., 2014), diabetes (Cheng et al., 2007), and all-cause mortality (Zhao et al., 2014). While a recent study identified the anti-depressive benefits of anaerobic resistance exercise among "wheelchair-bound older adults with dementia" (Chen et al., 2017), aerobic physical activity was not controlled during the investigation. The lack of research on the anti-depressive benefits associated with anaerobic physical activity (independent of aerobic activity) is a major gap in the literature.

The current study quantifies the independent relationship between anaerobic muscle strengthening activity and depression, while controlling for aerobic physical activity, using data from a nationally representative sample of USA adults who participated in NHANES during 1999–2006. Men and women were examined separately since their patterns of depression and physical activity differ.

2. Methods

Data were ascertained from four sequential biennial surveys of USA adults conducted as a part of the National Health and Nutrition Evaluation Survey (NHANES, 1999–2006). In each NHANES biennial survey, the samples of participants were representative of the civilian,

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https://doi.org/10.1016/j.pmedr.2018.03.005
Received 16 September 2017; Received in revised form 1 February 2018; Accepted 9 March 2018
Available online 14 March 2018

Table 1
Descriptive statistics (counts, percentages; means, confidence intervals) for all adults ≥ 18 years old: NHANES 1999–2006.

Characteristics	Women (n = 3935)		Men (n = 3419)		Total (n = 7354)	
Age (years)[a]	#	%	#	%	#	%
< 30	1569	(39.9%)	1179	(34.5%)	2748	(37.4%)
30 to < 40	1069	(27.1%)	902	(26.4%)	1971	(26.8%)
40 + plus	1297	(33.0%)	1338	(39.1%)	2635	(35.8%)
BMI (kg/(m^2))						
Obese (BMI ≥ 30)	1388	(35.3%)	979	(28.6%)	2367	(35.2%)
Ethnicity						
Non-Hispanic White	1829	(46.5%)	1612	(47.1%)	3441	(46.8%)
African American	870	(22.1%)	789	(23.1%)	1659	(22.6%)
Other	1236	(31.4%)	1018	(29.8%)	2254	(30.6%)
Medical conditions						
Arthritis	707	(18%)	514	(15%)	1221	(16.6%)
Cancer	215	(5.5%)	157	(4.6%)	372	(5.1%)
Cardiovascular diseases	206	(5.2%)	267	(7.8%)	473	(6.4%)
No major disease	2807	(71.3%)	2481	(72.6%)	5288	(71.9%)
Anaerobic activity						
Yes	978	(24.8%)	1208	(35.3%)	2186	(29.7%)
No	2957	(75.2%)	2211	(64.7%)	5168	(70.3%)
	Mean	95% CI	Mean	95% CI	Mean	95% CI
CRP (mg/dL)[b]	0.56	(0.53, 0.58)	0.35	(0.32, 0.37)	0.46	(0.44, 0.48)
Aerobic Activity (kcal/kg/month)[b]	63.3	(59, 67)	105.2	(98, 112)	82.8	(78.7, 86.7)
Depression severity (PHQ_9 Scores)						
0 to 4 none	3120	(79.4%)	2903	(85%)	6023	(81.9%)
5 to 9 mild	485	(12.3%)	320	(9.4%)	805	(10.9%)
10 to 14 dysthymia	226	(5.7%)	139	(4%)	365	(5%)
15+ moderate/major	104	(2.6%)	57	(1.6%)	161	(2.2%)
Dichotomized depression ($PHQ_9 \geq 10$)						
Depressed ($PHQ_9 \geq 10$)	330	(8.4%)	196	(5.7%)	526	(7.2%)
No Depr ($PHQ_9 < 10$)	3605	(91.6%)	3223	(94.3%)	6828	(92.8%)

[a] Counts and percentages (# and %).
[b] Mean and 95% confidence interval (CI) are given for aerobic energy expenditure and CRP.

non-institutionalized United States of America (US or USA) population. Since there were low numbers of individuals with severe depression (particularly in men), we pooled data from sequential surveys to achieve increased statistical stability and power. As justification, we noted that over time, the prevalence of depression hovered slightly under 10% and the prevalence of anaerobic muscle strengthening physical activity within the past month remained around 30%. For our analyses, we pooled data from the four successive surveys resulting in samples of 3935 women and 3419 men ranging in age from 18 to 85 years. In these analyses, incorporation of weights based on oversampling of ethnic minorities had little effect on the gender specific estimates from our analysis of the pooled data. The samples included only participants with valid non-missing data. To comply with ethical guidelines of human studies, all participants provided their written informed consents. Since NHANES sample data are de-identified and in the public domain, the study was exempt from the review process of the Institutional Review Board.

During 1999–2004, depression was evaluated by trained personnel during interviews in mobile examination centers using the World Health Organization Composite International Diagnostic Interview (CIQD https://wwwn.cdc.gov/Nchs/Nhanes/1999-2000/CIQMDEP.htm). In 2005–2006, participants reported depressive symptoms using the validated "Patient Health Questionnaire" (PHQ9 https://wwwn.cdc.gov/Nchs/Nhanes/2005-2006/DPQ_D.htm) instrument. On the PHQ9 scale from 0 to 27, established clinical cut-points published by Kroenke were used to define the severity level of depression (Kroenke et al., 2001): non-depressed (0–4), mild depression (5–9), dysthymia or chronic depressive disorder (10–14), moderate or moderately-severe depression (15–19), and major depression (20–27). For statistical analyses, it was necessary to combine the earlier depression data (1999–2004) with subsequent depression data (2005–2006). Hence, in the multinomial logistic models using the Kroenke's stratification, the CIQD interview data were translated to the same scale as the PHQ_9 data, by mapping corresponding items of these two instruments. Regarding the two different measurements of depressive symptoms, the CIQD and PHQ depression queries are quite similar, e.g., "lack energy or feel tired" by WHO CIQD005 and "feeling tired or having little energy" by PHQ090. In binary logistic models, depression was defined as a PHQ_9 score of 10 or more.

Anaerobic *muscle strengthening activity* is a categorical variable and it is defined by NHANES as 'activity using equipment that primarily involves upper body movement, and activity that strengthens muscle', including push-ups, bench-press, sit-ups, weight-lifting activity (Matthew, 2005). Participants reported whether they performed 'any physical activity designed to strengthen muscles such as weight-lifting, push-ups or sit-ups, over the past 30 days.'

Total aerobic activity is a continuous variable. The participants reported whether they walked or biked or completed any aerobic activity over the past thirty days. For each specific aerobic activity performed, its corresponding frequency, duration, and intensity were used to compute the aerobic energy expenditure per kilogram of body weight per month. Total aerobic energy expenditure for each participant was computed as the summation of energy expenditures across all reported aerobic activities. The 2008 Physical Activity Guidelines for Americans (PAGA) published by the U.S. Department of Health and Human Services were used to identify adults who met or exceeded the recommended level of aerobic activity (150 min per week of moderate intensity activity or 75 min per week of vigorous activity or equivalent combinations of moderate and rigorous activity).

Binary logistic regression was used to estimate adjusted odds ratios (OR with 95% confidence intervals) of depression (within the past two weeks) associated with anaerobic activity (within the past month), while controlling for a continuous measurement of aerobic physical activity (energy expenditure). Other covariates include age, body mass index (BMI), ethnicity as defined by NHANES, inflammation biomarker C-reactive protein (CRP) and medical conditions such as cardiovascular

disease (CVD), cancer, and osteoarthritis. "Latex-enhanced nephelometry" quantified the CRP level of blood specimens. Trained health professionals collected body measurement data and BMI data.

In separate analyses, Multinomial logistic regression was used to compute the adjusted odds ratios of anaerobic activity associated with the four levels of depression (mild, dysthymic, moderate, major depression). Due to the role of menopause in depression, the age of 50 was used in subgroup analyses because 50 is the average age of menopause. Separate estimates were obtained for men and women of all ages and those younger than 50 years of age. Adjusted odds ratios were estimated for the combined regimen of both anaerobic activity and meeting/exceeding aerobic PAGA guidelines.

3. Results

Characteristics of the NHANES samples of 3935 women and 3419 men are shown in Table 1. While age and ethnicity distributions (as defined by NHANES) were similar for men and women, more women were deemed obese than men (35.3% versus 28.6%, $p < 0.01$) and women had significantly higher average serum CRP than men (0.56 versus 0.35 mg/dL, t-test $p < 0.01$).

Fewer women reported anaerobic muscle strengthening activity than men (24.8% versus 35.3%; $p < 0.01$) whereas women had a higher prevalence of depression (8.4% versus 5.7% with PHQ9 ≥ 10, $p < 0.01$). Across all clinical severity levels of depression, women had significantly more mild depression, dysthymia and moderate or major depression (12.3%, 5.7%, and 2.6%) than men (9.4%, 4%, and 1.6%) (χ^2, $p < 0.001$).

We observed inverse associations of depression and anaerobic activity for men and women (Table 2). Notably, anaerobic activity was inversely associated with depression in women under 50 years old (OR = 0.57; 95%CI = 0.41–0.81) and men (OR = 0.85; 95% CI = 0.58–1.2) after controlling for aerobic activity. Similarly, the antidepressive benefit of anaerobic activity in all women (OR = 0.59; 95% CI = 0.43–0.8) and all men (OR = 0.72; 95% CI = 0.51–1.01) were independent of aerobic activity.

There was a significant inverse dose response between anaerobic activity and increasing severity of depression (trend test $p < 0.01$) (Table 3). As the severity level of depression worsened (from mild, dysthymic, moderate, to major depression), the odds ratios of anaerobic physical activity declined among women and men. Due to the low number of men with depression, men with $PHQ_9 \geq 10$ were merged in the analysis. Other covariates adjusted were CRP, age, BMI, ethnicity, cardiovascular disease, cancer, and arthritis. Crude models and age-only adjustment models produced similar results as the fully adjusted models shown in the tables.

The combined regimen of anaerobic muscle strengthening activity and meeting/exceeding the aerobic PAGA guidelines produced the lowest odds ratios of depression in all age and sex groups (Table 4). For example, the odds ratio of depression for the combined regimen of aerobic and anaerobic activity was 0.50 for women and 0.39 for men.

4. Discussion

Past studies provided the impetus for our current investigation into whether muscle strengthening activity, a primary mode of anaerobic activity, is inversely associated with depression, independent of aerobic physical activity. Previous trials, systematic reviews and meta-analyses provide consistent evidence that aerobic activity improved the status of depressed patients.

Results of the current study are the first to demonstrate independent inverse associations between anaerobic activity and depression in nationally representative samples of US men and women. The observed effects of anaerobic activity were consistent in both women and men. The odds ratios of depression associated with anaerobic muscle strengthening activity declined significantly, as the severity level of depression worsens. Notably, the regimen of anaerobic activity combined with aerobic activity meeting PAGA guidelines yielded favorable odds ratios of depression (0.50 for women and 0.39 for men).

Certain study limitations should be acknowledged. First, the cross-sectional nature of NHANES data makes it difficult to unveil the sequence of events; therefore, we can only confirm the presence of a significant inverse association between anaerobic exercise and depression and cannot determine whether anaerobic exercise reduced depression or vice versa. This secondary analysis of cross sectional data confirmed association but not causality.

Another limitation is the self-reported nature of physical activity data and the possibility of social desirability bias, e.g., the tendency of survey respondents to answer questions in a manner that will be viewed favorably by members of society. Nevertheless, participants had no apparent reasons or strong motives to misrepresent physical activity levels during the confidential data collection process. Prior published studies examining physical activity and depression utilized self-reported NHANES aerobic activity data (Mezuk et al., 2013; Hume et al., 2011). Strength of the investigation is that the findings pertain to most USA adults since NHANES is a nationally representative sample of the civilian non-institutionalized USA adult population.

In conclusion, we observed that anaerobic muscle strengthening activity was inversely and significantly associated with depression in US men and women participating in NHANES during 1999–2006. Based on these promising findings, there may be added benefit to incorporating "anaerobic muscle strengthening activity" into many popular aerobic fitness programs. Further cohort or time-to-event studies are needed to confirm a causal relationship and the biological basis of the current findings.

Funding details

The authors have no funding sources for this study.

Disclosure statement

The authors have no "financial interest or benefit that has arisen from the direct applications of your research." The authors have no

Table 2
Crude and adjusted odds ratios (OR) for anaerobic muscle strengthening activity and depression (PHQ9 ≥ 10) in adult men and women, NHANES 1999–2006.

Dichotomized Depression (PHQ ≥ 10)	Anaerobic activity	# non-depressed	# depressed	[a]OR	[a]OR 95% CI	Crude OR
Women < 50 age (n = 3014)	No MSA	2008	219	0.57	(0.41, 0.81)	0.59
	Yes MSA	739	48			
All women (n = 3935)	No MSA	2683	274	0.59	(0.43, 0.80)	0.59
	Yes MSA	922	56			
Men < 50 age (n = 2445)	No MSA	1368	90	0.85	(0.58, 1.2)	0.79
	Yes MSA	938	49			
All men (n = 3419)	No MSA	2071	140	0.72	(0.51, 1.01)	0.72
	Yes MSA	1152	56			

[a] Adjusted by multivariate binomial logistic regression for aerobic activity, CRP, age, BMI, ethnicity, and co-morbidity (CVD, cancer, arthritis).

Table 3
Crude and adjusted odds ratios (OR) for anaerobic activity and severity levels of depression, NHANES 1999–2006.[a]

Women	Women Aged < 50 (n = 3014)					All women ≥18 years (n = 3935)				
	No MSA	MSA	Crude odds ratio	Adjusted OR	95%CI	No MSA	MSA	Crude odds ratio	Adjusted OR	95%CI
None	1758	660	1	1	Reference	2302	818	1	1	Reference
Mild	239	90	1.00	0.99	(0.8, 1.2)	368	117	0.89	0.95	(0.7, 1.2)
Dysthymia	152	35	0.61	0.62	(0.4, 0.9)	187	39	0.59	0.59	(0.4, 0.8)
Moderate	54	14	0.70	0.56	(0.28, 1.1)	68	17	0.70	0.63	(0.3, 1.1)
Major	11	1	0.24	0.26	(0.03, 2.1)	17	2	0.33	0.43	(0.1, 1.9)

Men	Men aged < 50 (n = 2445)					All men ≥18 years (n = 3419)				
	No MSA	MSA	Crude odds ratio	Adjusted OR	95%CI	No MSA	MSA	Crude odds ratio	Adjusted OR	95%CI
None	1226	859	1	1	Reference	1843	1060	1	1	Reference
Mild	126	95	1.08	0.97	(0.7, 1.3)	208	112	0.94	0.88	(0.6, 1.1)
[b]Depressed	90	49	0.78	0.86	(0.5, 1.2)	140	56	0.70	0.69	(0.4, 0.9)

[a] Adjusted by multivariate multinomial logistic regression for aerobic activity, CRP, age, BMI, ethnicity, and co-morbidity (CVD, cancer, arthritis).
[b] For statistical stability of sub cell counts, the category of "Depressed" men, combine dysthymia, moderate, and major depression.

Table 4
Crude and adjusted odds ratios[a] for depression (PHQ9 ≥ 10) by activity type[b] in adults, NHANES 1999–2006.

Types of exercise	Non-depressed	Depressed ($PHQ_9 \geq 10$)	Odds ratio (OR)	95% CI	Crude odds ratio
All women (n = 3935)					
Reference	2221	242	1		1
Aerobic exercise only	449	30	0.63	(0.43, 0.93)	0.61
Muscle strengthening only	429	30	0.67	(0.44, 0.99)	0.64
Combined regimen	506	28	0.50	(0.33, 0.75)	0.51
All men (n = 3419)					
Reference	1564	124	1		1
Aerobic exercise only	487	16	0.39	(0.22, 0.66)	0.41
Muscle strengthening only	490	33	0.80	(0.53, 1.19)	0.85
Combined regimen	682	23	0.39	(0.23, 0.62)	0.43
Women ≤ 50 years (n = 3014)					
Reference	1502	186	1		1
Aerobic exercise only	495	31	0.54	(0.36, 0.79)	0.51
Muscle strengthening only	249	18	0.57	(0.34, 0.96)	0.58
Combined regimen	501	32	0.52	(0.35, 0.77)	0.52
Men ≤ 50 years (n = 2445)					
Reference	1031	75	1		1
Aerobic exercise only	321	15	0.64	(0.35, 1.1)	0.64
Muscle strengthening only	417	25	0.83	(0.52, 1.3)	0.82
Combined regimen	537	24	0.61	(0.37, 1.01)	0.61

[a] Odds ratios were adjusted for age, BMI, ethnicity, comorbidity (CVD, cancer, arthritis). Non-depressed individuals had PHQ9 < 10. Adjusted by multivariate binomial logistic regression for age, BMI, ethnicity, comorbidity (CVD, cancer, arthritis).
[b] Adults were partitioned into 4 groups of activity types. The group of "aerobic activity only" included all adults who met or exceeded the PAGA guideline for aerobic activity. The reference group included individuals who did not perform muscle strengthening activity and did not meet the PAGA guidelines for aerobic activity.

conflicts of interest for this study.

Acknowledgments

The authors thank the Centers for Disease Control and Prevention and the National Health and Nutrition Examination Survey for providing the data in the public domain. 'The results of the study are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation. Results of the present study do not constitute endorsement by ACSM.'

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