Exercise and Mental Illness: Results From the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC)

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ABSTRACT

Background: Regular exercise is thought to be associated with low rates of mental illness, but this association has been inadequately studied. The purpose of this study was to test the hypotheses that the recommended amount of self-reported vigorous exercise would be cross-sectionally associated with reduced prevalence and incidence of various *DSM-IV* psychiatric disorders, as well as increased rates of remission.

Method: Data were collected from 2001 to 2005 as part of the National Epidemiologic Survey on Alcohol and Related Conditions (NESARC), a 2-wave face-to-face survey conducted by the National Institute on Alcohol Abuse and Alcoholism. For this study, the sample consisted of 23,505 nondisabled adults aged between 18 and 65 years.

Results: Individuals who engaged in vigorous exercise at Wave 2 were significantly more likely than were nonexercisers to be diagnosed with a current psychiatric disorder (adjusted odds ratio [AOR] = 1.22, 95% CI, 1.12–1.34 for the nationally recommended amount vs no exercise), significantly less likely to attain remission from a psychiatric disorder between waves (AOR = 0.77, 95% CI, 0.65–0.91), and significantly more likely to relapse or be newly diagnosed with a psychiatric disorder between waves (AOR = 1.15, 95% CI, 1.02–1.30). Alcohol dependence and bipolar II disorder were the disorders most strongly associated with exercise.

Conclusions: This investigation suggests that the pursuit of vigorous exercise is associated with a vulnerability to mental illness. This surprising finding may be due to reward-related factors that influence both exercise engagement and the expression of certain psychiatric disorders. Prospective trials will be helpful in further clarifying the associations between exercise and mental illness, as the relationships between the 2 are more complex than previously believed.

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Physical exercise is associated with many health benefits.[1] Aerobic exercise has demonstrated beneficial effects on obesity,[2] cardiovascular disease,[3] type 2 diabetes,[4] and certain cancers,[5] and many reviews and meta-analyses have been published on the therapeutic effect of exercise on depressive symptoms, cognitive functioning, and anxiety.[6,7] Additionally, the reinforcing effects of exercise via activation of dopaminergic reward circuits suggest that exercise, as part of a treatment strategy, may compete with substance use.[8]

Exercise is also thought to protect against mental illness by promoting neural plasticity and improving brain health.[9,10] There has been only 1 study in adults (aged 15 to 54 years), however, examining the associations between physical activity and a broad range of psychiatric diagnoses, including substance use disorders (SUDs). This study reported that physical activity was associated with a reduced prevalence of depression and anxiety disorders but with no effect on SUD prevalence.[11] Moreover, while longitudinal data are available for adolescents and young adults,[12] there have been no investigations in adults into the associations between exercise and remission and incidence rates of psychiatric disorders.

The National Epidemiologic Survey on Alcohol and Related Conditions (NESARC)[13] offers a unique opportunity to examine the associations between exercise and mental illness in adults, because it characterized a large, representative sample of the US adult population with respect to various psychiatric disorders, followed them longitudinally, and contained information about frequency and duration of exercise. Here, we report the cross-sectional associations between vigorous aerobic exercise and the prevalence, remission, and incidence of psychiatric disorders. This expands on the previous epidemiologic investigation by focusing on well-characterized adults (aged 18 to 65 years); by containing data on remission, relapse, and incidence of psychiatric disorders; and by employing a valid and reliable measure of exercise engagement predicated on American College of Sports Medicine (ACSM) guidelines.[14,15] We hypothesized that vigorous exercise would be cross-sectionally associated with reduced prevalence and incidence of psychiatric disorders as well as greater likelihood of remission.

METHOD

Sample

The 2001–2002 NESARC (Wave 1), and the 2004–2005 follow-up (Wave 2), is a nationally representative sample of the adult population of the United States conducted by the US Census Bureau, under the direction of the National Institute on Alcoholism and Alcohol Abuse, as described in detail elsewhere.[13] Consistent with the target population of ACSM exercise guidelines,[15] which are intended for nondisabled adults aged between 18 and 65 years, we excluded individuals older than 65 years and/or those with a temporary (any time over 12 months) or permanent (persistent over 12 months) physical disability. Beginning with a sample size of 43,093 individuals, we obtained a sample size of 35,916 after excluding those over

65 years and accounting for those lost to follow-up and a final sample size of 23,505 after additionally excluding those with any disability. All individuals in the sample were assessed at both waves.

Diagnostic Assessment

There were 2 waves of assessments, Wave 1 in 2001–2002 and Wave 2 in 2004–2005. Information pertaining to psychiatric diagnosis and sociodemographic factors was obtained by self-report at both waves, while information pertaining to frequency and duration of vigorous aerobic exercise over the past 12 months was available at Wave 2 only.

All psychiatric diagnoses were made according to *DSM-IV* criteria using the Alcohol Use Disorder and Associated Disabilities Interview Schedule-*DSM-IV* version (AUDADIS-IV), a valid and reliable fully structured diagnostic interview designed for use by professional interviewers who are not clinicians. Disorders were considered current if they occurred in the 12 months preceding the interview or lifetime if they were in remission for that period. The test-retest reliability and validity of AUDADIS-IV measures of *DSM-IV* disorders are adequate, as detailed elsewhere.[16,17]

Assessment of Physical Exercise

Engagement in vigorous aerobic exercise over the preceding 12 months was assessed at Wave 2 using queries from the short-form International Physical Activity Questionnaire, which has been validated in several countries, including the United States.[14] The first question asked participants to assess the frequency over a typical 7-day period with which they engaged in vigorous physical activity, during leisure time or at work, that caused heavy sweating and large increases in heart or breathing rates. The second question asked participants to quantify the duration of each episode of vigorous activity. The queries excluded exercise of light or moderate intensity, for which the ACSM has issued different recommendations.[15] Approximating ACSM recommendations for vigorous exercise,[15] exercise engagement was classified categorically: (1) *public health dose* individuals engaged in the full amount of vigorous activity recommended by the ACSM (20 minutes or more at least 3 days a week), (2) *some exercise* individuals engaged in some vigorous activity for 20 minutes or more on less than 3 days a week, and (3) *no exercise* individuals were those who did not engage in any vigorous activity.

Statistical Analysis

Weighted percentages and means were computed to derive sociodemographic and clinical characteristics of respondents based on level of exercise participation: public health dose, some exercise, and no exercise. Logistic regressions were conducted to adjust the odds ratios (AORs) for sociodemographic variables that were significantly different between individuals based on exercise class. Prevalence, remission, relapse, and incidence of psychiatric disorders were compared in 2 sets: public health dose versus no exercise, and some exercise versus no exercise. Standard errors and 95% confidence intervals (CIs) for all analyses were estimated using software for Survey Data Analysis[18] to adjust for the design effects of the NESARC. We considered AORs significant whose CIs did not cross 1 (P value < .05).

Clinical Points

- While prescribed exercise may be helpful in managing symptoms of anxiety and depression, engagement in vigorous exercise was not associated in this cross-sectional analysis with lower rates of major depressive disorder or the anxiety disorders, indicating a more complex role of exercise in regard to these disorders than previously believed.
- Engagement in vigorous exercise was positively associated with the incidence of bipolar disorders and substance use disorders. This association suggests that the reward-related vulnerabilities associated with these disorders, including sensation seeking and reward dependence, may also influence the pursuit of rewarding activities such as vigorous exercise.
- Individuals with substance use disorders may have an increased affinity for the reinforcing effects of vigorous exercise, indicating that exercise might serve as a competing reward in addiction treatment.

RESULTS

Sociodemographic Characteristics

Table 1 presents the sociodemographic characteristics of the 3 groups, as well as the 2 sets of comparisons. The 2 comparisons yielded similar results. When compared to the no exercise group, public health dose individuals were more likely to be male (AOR = 2.15, 95% CI, 1.97–2.35), in a higher income bracket (AOR = 2.58, 95% CI, 2.20–3.04 for > US $70,000/year), and never married (AOR = 1.38, 95% CI, 1.24–1.52). Public health dose individuals were significantly less likely to be black (AOR = 0.65, 95% CI, 0.58–0.73), Asian (AOR = 0.48, 95% CI, 0.38–0.60), or Hispanic (AOR = 0.51, 95% CI, 0.44–0.58); to be foreign-born (AOR = 0.44, 95% CI, 0.38–0.51); to be older than 30 years (AOR = 0.70, 95% CI, 0.62–0.78 for those between 30–44 years); to be unemployed (AOR = 0.62, 95% CI, 0.56–0.68); to be widowed or divorced (AOR = 0.80, 95% CI, 0.72–0.88); and to have only a high school education (AOR = 0.69, 95% CI, 0.63–0.75) or less (AOR = 0.47, 95% CI, 0.41–0.55).

Prior 12-Month Psychiatric Diagnoses at Wave 2

Table 2 presents prevalence at Wave 2 of current (12-month) psychiatric diagnoses in the 3 groups, as well as 2 sets of comparisons. Compared to the no exercise group, the public health dose group was significantly more likely to be diagnosed with any Axis I disorder (AOR = 1.22, 95% CI, 1.12–1.34). The specific disorders accounting for this association were alcohol dependence (AOR = 1.35, 95% CI, 1.12–1.66), nicotine dependence (AOR = 1.13, 95% CI, 1.00–1.29),

Table 1. Sociodemographic Characteristics of the 3 Exercise Groups (N = 23,505) and Comparisons[a]

	Public Health Dose (n = 8,871; % = 37.74)		Some Exercise (n = 7,683; % = 32.69)		No Exercise (n = 6,951; % = 29.57)		Public Health Dose vs No Exercise (ref)			Some Exercise vs No Exercise (ref)		
Characteristic	%	SEM	%	SEM	%	SEM	OR	CI		OR	CI	
Sex												
Male	57.79	0.68	47.99	0.76	38.90	0.80	2.15	1.97	2.35	1.45	1.32	1.59
Female (ref)	42.21	0.68	52.01	0.76	61.10	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Race/ethnicity												
White (ref)	70.72	1.50	72.75	1.47	58.38	2.41	1.00	1.00	1.00	1.00	1.00	1.00
Black	11.02	0.71	10.02	0.72	14.01	0.92	0.65	0.58	0.73	0.57	0.51	0.64
Native American	2.70	0.31	1.35	0.18	1.90	0.26	1.17	0.88	1.57	0.57	0.39	0.83
Asian	3.87	0.49	4.85	0.63	6.67	0.81	0.48	0.38	0.60	0.58	0.46	0.74
Hispanic	11.69	1.18	11.03	1.00	19.05	2.19	0.51	0.44	0.58	0.46	0.40	0.54
Nativity												
US-born (ref)	87.52	1.19	87.55	1.17	75.49	2.39	1.00	1.00	1.00	1.00	1.00	1.00
Foreign-born	12.48	1.19	12.45	1.17	24.51	2.39	0.44	0.38	0.51	0.44	0.38	0.50
Age, y												
18–29 (ref)	24.51	0.63	22.33	0.61	15.72	0.56	1.00	1.00	1.00	1.00	1.00	1.00
30–44	39.56	0.57	38.55	0.60	36.42	0.85	0.70	0.62	0.78	0.74	0.67	0.83
45–64	35.93	0.59	39.11	0.71	47.86	0.90	0.48	0.43	0.54	0.57	0.51	0.64
Education												
< High school	9.82	0.47	6.90	0.43	16.93	1.05	0.47	0.41	0.55	0.29	0.25	0.34
High school	25.75	0.69	20.46	0.66	30.48	0.91	0.69	0.63	0.75	0.49	0.44	0.53
College (ref)	64.43	0.83	72.65	0.74	52.59	0.99	1.00	1.00	1.00	1.00	1.00	1.00
Individual income, US $												
0–19,000 (ref)	33.11	0.73	32.36	0.74	44.28	0.92	1.00	1.00	1.00	1.00	1.00	1.00
20,000–34,000	24.20	0.61	22.76	0.68	25.43	0.80	1.27	1.14	1.43	1.22	1.10	1.36
35,000–69,000	28.90	0.64	29.63	0.65	23.15	0.70	1.67	1.50	1.86	1.75	1.58	1.94
> 70,000	13.80	0.69	15.25	0.73	7.14	0.52	2.58	2.20	3.04	2.92	2.48	3.44
Employment status												
Employed (ref)	82.82	0.54	82.48	0.57	74.83	0.65	1.00	1.00	1.00	1.00	1.00	1.00
Unemployed	17.18	0.54	17.52	0.57	25.17	0.65	0.62	0.56	0.68	0.63	0.57	0.70
Marital status												
Married (ref)	64.61	0.63	67.66	0.85	66.78	0.80	1.00	1.00	1.00	1.00	1.00	1.00
Widowed/divorced	12.15	0.40	11.17	0.38	15.79	0.49	0.80	0.72	0.88	0.70	0.63	0.78
Never married	23.23	0.64	21.17	0.80	17.43	0.69	1.38	1.24	1.52	1.20	1.08	1.33

[a]Shaded areas represent associations in which the CI does not cross 1.
Abbreviations: OR = odds ratio, ref = reference.

and bipolar II disorder (AOR = 2.29, 95% CI, 1.39–3.76). Compared to the no exercise group, the some exercise group was also significantly more likely to be diagnosed with alcohol abuse (AOR = 1.16, 95% CI, 1.01–1.42), as well as less likely to be diagnosed with dysthymia (AOR = 0.49, 95% CI, 0.29–0.83).

Remission of a Current Wave 1 Diagnosis at Wave 2

Table 3 presents rates of remission at Wave 2 of a Wave 1 active diagnosis for the 3 groups as well as comparisons. Compared to the no exercise group, the public health dose group was significantly less likely to be in remission from any Axis I disorder (AOR = 0.77, 95% CI, 0.65–0.91). The only associations that reached statistical significance were with nicotine dependence (AOR = 0.78, 95% CI, 0.60–1.00) and any anxiety disorder (AOR = 0.75, 95% CI, 0.58–0.97).

Sustained Remission of Lifetime Wave 1 Diagnoses at Wave 2

Table 4 demonstrates rates of sustained remission of lifetime Wave 1 diagnoses at Wave 2. Compared to the no exercise group, the public health dose group but not the some exercise group was significantly less likely to be in remission from any Axis I disorder (AOR = 0.85, 95% CI, 0.75–0.95) and specifically any substance use disorder (AOR = 0.86, 95% CI, 0.75–0.99). The only specific association that reached statistical significance was with nicotine dependence (AOR = 0.80, 95% CI, 0.65–0.98).

New Incidence and Relapse at Wave 2

Table 5 presents the 12-month incidence of psychiatric disorders at Wave 2 in individuals without current symptoms (lifetime disorder and no disorder) at Wave 1. Incidence and relapse were significantly more likely in the public health dose group, compared to no exercise, for any Axis I disorder (AOR = 1.15, 95% CI, 1.02–1.30). Alcohol dependence (AOR = 1.43, 95% CI, 1.12–1.84) and bipolar II disorder (AOR = 2.29, 95% CI, 1.31–4.02) were the specific disorders accounting for this association. Compared to the no exercise group, the some exercise group was significantly more likely to also have new onset or relapse of alcohol abuse (AOR = 1.28, 95% CI, 1.05–1.56) and of bipolar I disorder (AOR = 1.43, 95% CI, 1.00–2.05), but not of bipolar II disorder, and significantly less likely to have dysthymia (AOR = 0.51, 95% CI, 0.28–0.90).

DISCUSSION

Contrary to expectations, we found that engagement in vigorous exercise was positively associated with the incidence

Table 2. Prevalence of Psychiatric Disorders in the 3 Exercise Groups at Wave 2 (N = 23,505) and Comparisons[a,b]

	Public Health Dose (n = 8,871; % = 37.74)		Some Exercise (n = 7,683; % = 32.69)		No Exercise (n = 6,951; % = 29.57)		Public Health Dose vs No Exercise (ref)			Some Exercise vs No Exercise (ref)		
Disorder	%	SEM	%	SEM	%	SEM	AOR[b]	CI		AOR[b]	CI	
Any Axis I disorder	37.57	0.83	36.21	0.76	31.68	0.95	1.22	1.12	1.34	1.24	1.13	1.35
Any substance use disorder	25.68	0.77	23.69	0.68	18.95	0.80	1.16	1.08	1.33	1.26	1.14	1.42
Alcohol abuse	7.52	0.36	6.82	0.37	4.25	0.33	1.17	0.99	1.38	1.16	1.01	1.42
Alcohol dependence	6.12	0.33	5.23	0.32	3.45	0.26	1.35	1.12	1.66	1.38	1.12	1.69
Drug abuse	2.19	0.19	2.02	0.19	1.46	0.23	0.99	0.68	1.44	1.14	0.78	1.66
Drug dependence	1.01	0.16	0.84	0.13	0.58	0.12	1.51	0.89	2.56	1.58	0.93	2.70
Nicotine dependence	15.34	0.64	14.63	0.59	12.99	0.66	1.13	1.00	1.29	1.23	1.08	1.37
Any depressive disorder	5.27	0.32	5.84	0.32	6.21	0.37	0.96	0.81	1.15	1.01	0.84	1.18
Major depressive disorder	5.04	0.29	5.71	0.32	5.87	0.36	0.96	0.82	1.15	1.03	0.86	1.24
Dysthymia	0.69	0.13	0.36	0.07	0.89	0.13	0.94	0.61	1.49	0.49	0.29	0.83
Any bipolar disorder	4.13	0.28	3.53	0.25	3.08	0.27	1.48	1.18	1.86	1.33	1.05	1.69
Bipolar I	2.88	0.22	2.63	0.23	2.48	0.25	1.27	0.97	1.65	1.23	0.92	1.65
Bipolar II	1.25	0.15	0.86	0.13	0.58	0.09	2.29	1.39	3.76	1.74	1.06	2.72
Any anxiety disorder	12.23	0.48	12.81	0.48	12.04	0.53	1.13	0.99	1.29	1.14	1.00	1.33
Panic disorder	2.35	0.21	2.51	0.21	2.28	0.21	1.14	0.86	1.51	1.19	0.93	1.53
Social phobia	2.21	0.19	2.83	0.25	2.31	0.22	0.98	0.76	1.27	1.29	0.98	1.69
Specific phobia	7.22	0.39	7.89	0.41	7.45	0.43	1.11	0.94	1.29	1.15	0.98	1.35
Generalized anxiety disorder	3.4	0.28	3.57	0.28	3.42	0.31	1.16	0.91	1.51	1.15	0.87	1.51

[a]Shaded areas represent associations in which the CI does not cross 1.
[b]Adjusted for significant sociodemographic variables: sex, race, nativity, age, education, individual income, employment status, and marital status.
Abbreviation: AOR = adjusted odds ratio, ref = reference.

Table 3. Remission at Wave 2 of a Wave 1 Current Diagnosis in the 3 Exercise Groups (N = 23,505) and Comparisons[a,b]

	Public Health Dose (n = 8, 871; % = 37.74)		Some Exercise (n = 7,683; % = 32.69)		No Exercise (n = 6,951; % = 29.57)		Public Health Dose vs No Exercise (ref)			Some Exercise vs No Exercise (ref)		
Disorder	%	SEM	%	SEM	%	SEM	AOR[b]	CI		AOR[b]	CI	
Any Axis I disorder	36.33	1.11	39.20	1.21	41.59	1.47	0.77	0.65	0.91	0.83	0.70	0.98
Any substance use disorder	37.01	1.37	37.40	1.58	38.66	1.79	0.89	0.72	1.10	0.85	0.69	1.06
Alcohol abuse	69.46	2.22	71.87	2.40	67.17	3.62	1.14	0.75	1.73	1.31	0.87	1.99
Alcohol dependence	66.87	2.65	65.42	3.27	62.62	4.45	1.11	0.71	1.76	0.92	0.57	1.48
Drug abuse	74.99	3.86	72.15	4.60	67.86	7.16	1.32	0.56	3.13	1.05	0.43	2.54
Drug dependence	79.12	7.97	76.52	7.93	83.50	6.05	0.66	0.15	2.88	0.35	0.07	1.69
Nicotine dependence	38.25	1.88	36.99	2.09	41.49	2.22	0.78	0.60	1.00	0.74	0.57	0.97
Any depressive disorder	80.64	2.18	76.14	2.31	71.67	2.84	1.42	0.96	2.11	1.19	0.80	1.78
Major depressive disorder	80.68	2.26	76.44	2.39	73.47	2.94	1.30	0.85	1.97	1.11	0.73	1.69
Dysthymia	95.62	3.26	95.96	2.29	89.67	3.32	2.39	0.49	11.55	2.46	0.45	13.48
Any bipolar disorder	64.69	3.65	65.14	3.79	60.39	4.88	0.89	0.52	1.55	0.96	0.55	1.65
Bipolar I	63.78	4.18	66.89	4.37	55.46	5.73	0.99	0.53	1.85	1.09	0.57	2.11
Bipolar II	72.98	6.52	69.15	7.38	85.62	5.52	0.41	0.10	1.71	0.40	0.12	1.32
Any Anxiety disorder	64.30	1.94	67.03	1.83	68.76	1.86	0.75	0.58	0.97	0.86	0.67	1.10
Panic disorder	82.48	3.49	82.29	3.19	81.73	3.14	1.12	0.57	2.20	1.02	0.53	1.94
Social phobia	80.75	3.17	73.53	3.78	80.53	2.89	1.01	0.55	1.84	0.69	0.39	1.23
Specific phobia	74.06	2.36	75.30	2.15	77.83	1.99	0.77	0.54	1.09	0.87	0.63	1.21
Generalized anxiety disorder	79.42	4.30	78.75	4.06	80.35	4.08	0.83	0.37	1.87	0.69	0.31	1.51

[a]Shaded areas represent associations in which the CI does not cross 1.
[b]Adjusted for significant sociodemographic variables: sex, race, nativity, age, education, individual income, employment status, and marital status.
Abbreviation: AOR = adjusted odds ratio, ref = reference.

and prevalence of certain psychiatric disorders, most strongly bipolar II disorder and alcohol dependence. Although there was an expected inverse association with dysthymia for the some exercise group, this was surprisingly not observed with major depressive disorder (MDD) or the anxiety disorders. We examine each of these unexpected results in turn. In addition, we consider hypotheses by which we may begin to understand these novel findings.

It is important to note, first, that this is the only survey to our knowledge validly investigating associations between self-reported exercise and psychiatric disorders in a large, representative sample of US adults. Previous epidemiologic studies have been smaller or focused on particular subgroups and have generally investigated associations between exercise and certain symptoms, such as anxiety and mood symptoms, rather than assessing for disorders.[19–21] A single study, discussed earlier, examined the cross-sectional associations between physical activity and psychiatric disorders, including SUDs, in a US sample of individuals aged between 15 and 54 years,[11] but its limitations have already been mentioned. Thus, although there is consistent evidence that exercise, particularly in subclinical cases, is associated with reduced

Table 4. Remission at Wave 2 of a Wave 1 Lifetime Diagnosis in the 3 Exercise Groups (N = 23,505) and Comparisons[a,b]

	Public Health Dose (n = 8,871; % = 37.74)		Some Exercise (n = 7,683; % = 32.69)		No Exercise (n = 6,951; % = 29.57)		Public Health Dose vs No Exercise (ref)			Some Exercise vs No Exercise (ref)		
Disorder	%	SEM	%	SEM	%	SEM	AOR[b]	CI		AOR[b]	CI	
Any Axis I disorder	48.98	0.97	52.26	1.00	52.47	1.14	0.85	0.75	0.95	0.92	0.81	1.04
Any substance use disorder	57.04	1.03	60.26	1.18	61.28	1.19	0.86	0.75	0.99	0.88	0.76	1.01
Alcohol abuse	85.86	0.96	87.54	0.95	88.94	1.20	0.96	0.71	1.29	1.00	0.72	1.40
Alcohol dependence	82.40	1.27	82.10	1.41	84.71	1.71	0.93	0.66	1.29	0.78	0.56	1.09
Drug abuse	90.61	1.12	90.98	1.11	91.70	1.48	0.98	0.59	1.60	0.84	0.52	1.38
Drug dependence	92.05	2.48	92.71	2.11	92.09	2.83	0.68	0.32	1.46	0.62	0.26	1.46
Nicotine dependence	49.38	1.64	51.85	1.66	53.26	1.88	0.80	0.65	0.98	0.83	0.67	1.03
Any depressive disorder	84.01	1.42	83.00	1.34	81.28	1.57	1.11	0.84	1.48	1.11	0.84	1.48
Major depressive disorder	84.04	1.46	83.18	1.36	82.32	1.51	1.04	0.77	1.40	1.06	0.79	1.42
Dysthymia	96.99	1.47	95.41	1.44	93.61	1.67	1.77	0.53	5.93	1.22	0.47	3.13
Any bipolar disorder	69.44	2.67	68.56	2.82	70.09	3.57	0.78	0.50	1.21	0.77	0.49	1.23
Bipolar I	70.19	3.13	69.84	3.27	68.25	4.26	0.82	0.49	1.38	0.85	0.49	1.48
Bipolar II	74.34	4.89	74.07	4.79	82.86	4.41	0.59	0.24	1.44	0.52	0.21	1.26
Any anxiety disorder	69.23	1.54	71.30	1.37	71.34	1.39	0.83	0.67	1.02	0.94	0.77	1.14
Panic disorder	84.36	2.26	89.66	1.66	86.79	1.96	0.85	0.50	1.43	1.31	0.77	2.20
Social phobia	84.38	2.07	80.39	2.61	83.04	2.26	1.03	0.62	1.73	0.84	0.52	1.36
Specific phobia	76.56	1.93	76.40	1.72	77.69	1.76	0.87	0.64	1.19	0.91	0.69	1.20
Generalized anxiety disorder	84.62	2.74	85.32	2.25	83.58	2.86	1.00	0.55	1.82	1.02	0.57	1.84

[a]Shaded areas represent associations in which the CI does not cross 1.
[b]Adjusted for significant sociodemographic variables: sex, race, nativity, age, education, individual income, employment status, and marital status.
Abbreviation: AOR = adjusted odds ratio, ref = reference.

Table 5. Incidence of Psychiatric Disorders at Wave 2 in the 3 Exercise Groups (N = 23,505) and Comparisons[a,b]

	Public Health Dose (n = 8,871; % = 37.74)		Some Exercise (n = 7,683; % = 32.69)		No Exercise (n = 6,951; % = 29.57)		Public Health Dose vs No Exercise (ref)			Some Exercise vs No Exercise (ref)		
Disorder	%	SEM	%	SEM	%	SEM	AOR[b]	CI		AOR[b]	CI	
Any Axis I disorder	24.43	0.76	24.28	0.83	21.15	0.88	1.15	1.02	1.30	1.22	1.07	1.38
Any substance use disorder	14.75	0.58	13.57	0.57	10.72	0.65	1.16	1.00	1.35	1.22	1.05	1.42
Alcohol abuse	5.90	0.34	5.49	0.33	3.22	0.28	1.21	0.99	1.48	1.28	1.05	1.56
Alcohol dependence	4.60	0.30	3.90	0.29	2.46	0.22	1.43	1.12	1.84	1.42	1.10	1.83
Drug abuse	1.66	0.16	1.54	0.16	1.11	0.20	1.05	0.70	1.59	1.17	0.76	1.80
Drug dependence	0.86	0.14	0.74	0.12	0.50	0.12	1.49	0.78	2.88	1.61	0.87	2.96
Nicotine dependence	7.97	0.43	7.22	0.43	6.93	0.47	1.08	0.89	1.30	1.12	0.94	1.34
Any depressive disorder	4.55	0.31	4.69	0.28	4.75	0.31	1.08	0.89	1.31	1.06	0.88	1.28
Major depressive disorder	4.36	0.28	4.63	0.28	4.63	0.31	1.05	0.86	1.28	1.06	0.87	1.29
Dysthymia	0.65	0.12	0.33	0.07	0.75	0.12	1.03	0.63	1.69	0.51	0.28	0.90
Any bipolar disorder	3.10	0.24	2.69	0.22	2.17	0.22	1.60	1.23	2.08	1.47	1.10	1.95
Bipolar I	2.08	0.20	2.06	0.21	1.64	0.19	1.35	0.98	1.87	1.43	1.00	2.05
Bipolar II	1.03	0.13	0.67	0.11	0.53	0.10	2.29	1.31	4.02	1.55	0.90	2.66
Any anxiety disorder	9.27	0.44	10.20	0.48	9.64	0.52	1.06	0.91	1.24	1.12	0.95	1.33
Panic disorder	2.05	0.20	2.19	0.21	1.93	0.20	1.19	0.87	1.63	1.23	0.93	1.63
Social phobia	1.77	0.17	2.15	0.22	1.75	0.18	1.04	0.78	1.38	1.28	0.95	1.72
Specific phobia	5.75	0.35	6.52	0.39	6.33	0.39	1.05	0.88	1.25	1.14	0.94	1.40
Generalized anxiety disorder	3.07	0.24	3.23	0.26	3.09	0.28	1.15	0.89	1.49	1.13	0.85	1.49

[a]Shaded areas represent associations in which the CI does not cross 1.
[b]Adjusted for significant sociodemographic variables: sex, race, nativity, age, education, individual income, employment status, and marital status.
Abbreviation: AOR = adjusted odds ratio, ref = reference.

symptoms of anxiety or depression, exercise had not been adequately investigated in regard to its associations with the prevalence, incidence, or remission of affective and anxiety disorders. Of note, the only disorder inversely associated with any level of vigorous exercise in our sample was dysthymia, a milder and more chronic form of depression than is MDD. These novel findings suggest that the complex relationship between exercise and depressive and anxiety disorders deserves further study.

Perhaps most striking is the positive association we observed between exercise and certain psychiatric disorders. A review of the literature, however, indicates that these findings have some precedent, particularly in studies with adolescents and young adults. While this is far from being a uniform finding, several studies have found that exercising youth are more likely to engage in problematic alcohol use.[22–24] This association was also found in a recent nationwide survey of adults.[25] A prospective study of European adolescents and young adults (aged 14 to 24 years), on the other hand, found that exercise was associated at follow-up with a significantly reduced incidence of SUDs, including alcohol use disorders.[12] Importantly, it also found that the

incidence of bipolar disorders among youth who exercise was significantly elevated.

As such, the present findings, although challenging some prevailing notions regarding exercise and mental health, are neither isolated nor anomalous. Moreover, recent research provides a valuable framework by which to understand these findings without deviating from current psychiatric concepts and without recourse to directional causal interpretations (exercise causes mental illness, for example, or mental illness leads to compensatory, possibly therapeutic behaviors such as exercise) requiring the sort of data unavailable in this nonprospective analysis.

One way to understand these results is to posit a shared diathesis by which individuals who elect to exercise vigorously[26] may also be more vulnerable to certain psychiatric disorders, such as SUDs and the bipolar disorders, than are those who do not. Such shared vulnerability might arise, as recently suggested in an animal study linking increased physical activity to dopamine dysregulation,[27] from differences in reward-related neurocircuitry. Physical activity, particularly when vigorous, serves as a reward by activating the same neurobiological reward systems that substance use or other rewards do.[8,28,29] Our findings can therefore be interpreted to suggest that individuals with SUDs and the bipolar disorders have an increased affinity for exercise, perhaps because of its reward-related reinforcing effects.

An increased affinity for rewards, including exercise, may represent a broad way to conceptualize the "high-risk" traits—heightened risk-taking, impulsivity, sensation seeking, and reward-oriented behavior (reward dependence)—commonly associated with SUDs and the bipolar disorders, particularly bipolar II disorder.[30–37] These traits may furthermore constitute an endophenotype that may explain the high rates of co-occurrence of the 2 disorders.[34] Indeed, a recent genetic study has linked sensation-seeking to dopamine dysregulation,[38] which provides further support for a shared, possibly reward-related basis.[32]

The initial hypotheses of this cross-sectional analysis were formulated without considering the possibility that individuals vulnerable to certain disorders might exhibit an increased affinity for vigorous exercise. It must be emphasized, therefore, that these findings should not be taken to demonstrate that exercise does not have a protective effect against mental illness, a hypothesis that only a prospective trial can definitively investigate. Nor should these findings be taken to indicate that exercise does not have a role in psychiatric treatment; the beneficial effects of exercise on mood and anxiety symptoms have been well-studied,[7] and drug-dependent individuals may similarly benefit from a treatment approach encouraging a deliberate pursuit of natural rewards, such as exercise, to the exclusion of drug use, even if already pursuing those rewards on their own.[39] Our cross-sectional findings may be interpreted to lend support, in any case, to the hypothesis that exercise, particularly when vigorous, can serve as a reward. Further, it introduces the related hypothesis that exercise is especially reinforced in individuals who may exhibit reward-related vulnerabilities.

This analysis has several limitations. The first is that the frequency and duration of exercise were only assessed cross-sectionally at Wave 2. Although prior research indicates that exercise engagement in adults remains relatively stable over short periods of 3 to 4 years,[40] the exercise data at Wave 2 may not be representative of exercise patterns over the preceding 3 years. The longitudinal data on remission and incidence therefore need to be interpreted within these limitations. Second, the frequency and duration of exercise were obtained by self-report, leading to the possibility that certain psychiatric disorders may influence recall. Further, it is impossible to directly ascertain exercise engagement, potentially resulting in underestimation or overestimation. Engagement in the public health dose (38%) was indeed higher than is estimated for the percentage of US adults who follow ACSM recommendations for vigorous exercise,[15] although this may be due to the substantial number of individuals excluded for any disability (n = 12,411), very likely leading to a sample that is more active than the general population. Third, although the associations of interest were statistically significant, some of the effect sizes were low, particularly for nicotine dependence and remission rates, and are therefore of uncertain clinical significance. Fourth, valid categories could not be constructed from the NESARC data for moderate exercise. Fifth, we could not meaningfully control for treatment due to lack of information regarding the temporal relationship between exercise engagement and treatment-seeking. Prospective trials will be better able to control for treatment. Similarly, it is not possible from the dataset to determine whether participants were receiving an exercise-based intervention during the period that engagement in exercise was ascertained. Future studies can delineate between the various types of exercise—prescribed or self-pursued, group or individual, regimented or unstructured, and vigorous or moderate—in an effort to better determine the clinical relevance of each in regard to mental illness.

Despite these limitations, this study represents a substantial step forward in better understanding the associations between exercise and a broad range of psychiatric disorders. Even though our findings run counter to some prevailing assumptions regarding exercise and mental health, they can be interpreted to give support to the hypothesis that exercise can serve as a reward that is particularly reinforced in individuals who have vulnerabilities in reward-related neurocircuitry. Further, it suggests that exercise, given its apparent heightened reinforcing effects in those with alcohol dependence, might be effectively incorporated into substitution or contingency management strategies in the treatment of SUDs, as demonstrated in a recent pilot study.[39] In investigating these and related hypotheses further, prospective studies will be helpful in elucidating the associations between various types of exercise and mental health, as the relationship between the 2 appears to be more complex than previously believed.

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