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Associations between aerobic and muscle-strengthening exercise with depressive symptom severity among 17,839 U.S. adults

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ABSTRACT

For the prevention and management of chronic diseases, global physical activity guidelines state that an adult should engage in regular moderate-to-vigorous aerobic physical activity (MVPA; e.g. walking, cycling, running) and muscle-strengthening exercise (MSE; e.g. strength/resistance training). However, the associations between combined MVPA-MSE with chronic health conditions are rarely examined in large population studies. In particular, little is known associations between combined MVPA-MSE with depressive disorders, one of the leading causes of disability worldwide. The aim of this study is to describe the associations between MVPA and MSE with depressive symptom severity among a large sample of U.S. adults. Data were drawn from the U.S. 2015 Behavioral Risk Factor Surveillance System. During phone interviews, MVPA, MSE and depressive symptom severity were assessed by validated questionnaires. Poisson regression with a robust error or variance were used to assess prevalence ratios (PR) of depressive symptom severity (mild, moderate, moderately severe/severe) across categories of physical activity guideline adherence (met neither [reference]; MSE only; MVPA only; met both), adjusting for a set of potential cofounders. Data were available on 17,839 adults (18–85 years). When compared with those meeting neither guideline, for mild, moderate and moderately severe/severe depressive symptoms, the PRs were lowest among meeting both guidelines (range: 0.26–0.54), followed by MVPA only (range: 0.36–0.62) and MSE only (range: 0.49–0.84). Among a large sample of U.S. adults, compared to other guideline adherence categories, meeting both MVPA-MSE guidelines was associated with a lowest likelihood of reporting depressive symptoms.

1. Introduction

Globally, one in five adults experience a common mental disorder (e.g. depression, anxiety or substance abuse disorders) each year (Steel et al., 2014), with depressive disorders one of the leading causes of disability world-wide (Greenberg et al., 2015). In 2010, the economic burden attributed to individuals with depressive disorders was estimated to be $210 billion (USD) in the U.S. alone (Greenberg et al., 2015). Given that the incidence of people living with depressive disorders has increased considerably (~18%) over the last decade (Vos et al., 2016), from a public health perspective, identifying modifiable factors that may prevent the development of depressive symptoms is imperative.

For the prevention and treatment of chronic diseases (including both physical and mental illness), the World Health Organisation (WHO) recommends adults engage in a minimum of 150 min/week of moderate-intensity aerobic physical activity (or 75 min of vigorous-intensity aerobic physical activity, or an equivalent combination) (MVPA); and at least 2 days/week of muscle-strengthening exercise (World Health Organization, 2010). Given the distinction made in the guidelines between the two types of activity (i.e. aerobic MVPA versus muscle strengthening exercise), it is important to examine the link between both aerobic and muscle strengthening exercise and depressive symptoms.

Convincing epidemiological evidence shows that physical activity can be used to prevent (Mammen and Faulkner, 2013; Schuch et al., 2018; McDowell et al., 2018a) and treat depression and/or depressive symptoms in clinical and non-clinical populations (Rebar et al., 2015; Schuch et al., 2016). However, most of this evidence comes from either observational studies that have assessed physical activity in general (i.e. a lack of distinction between activity type/modality such as aerobic physical activity versus strength training) (Mammen and Faulkner, 2013; McDowell et al., 2018a); or from interventions that have utilised

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only aerobic (e.g. walking, running, cycling) exercise to treat depressive symptoms (Nystrom et al., 2015).

Research investigating the association between muscle strengthening exercise and/or combined aerobic-muscle strengthening exercise and depressive symptoms is limited (Nystrom et al., 2015). Although evidence from clinical trials has demonstrated that resistance training alone (i.e. muscle strengthening exercise) may result in a moderate reduction in symptoms of depression (Gordon et al., 2018a) and anxiety (Gordon et al., 2017). Moreover, a recent meta-analysis of clinical exercise studies showed that when comparing aerobic exercise only and muscle strengthening exercise only, there was no significant difference between exercise modalities in reducing depressive symptoms (Gordon et al., 2018a). However, the current data remain limited, including rather few studies and small sample sizes likely lacking statistical power (Brenes et al., 2007). Moreover, importantly, no studies have investigated the independent associations between adhering to different combinations of the WHO's 2010 physical activity guidelines (World Health Organization, 2010) (which include both aerobic and muscle-strengthening exercise) and depressive symptoms among a large population sample of adults.

The aim of this study is to describe the associations between different combinations of physical activity guideline adherence and depressive symptom severity in a nationally representative sample of U.S. adults.

2. Methods

2.1. Behavioral Risk Factor Surveillance System

Data were drawn from the U.S. 2015 'Behavioral Risk Factor Surveillance System' (henceforth - BRFSS 2015). Initiated in 1984, the BRFSS is a public health surveillance system conducted with the purpose of collecting state-specific data on public health pertinent risk behaviours among U.S. adults (Centers for Disease Control and Prevention, n.d.-a). Comprehensive information on the procedures and methodology used in the BRFSS 2015 can be obtained elsewhere (Centers for Disease Control and Prevention, n.d.-b). In brief, data were collected via landline and mobile/cell phone interviews from respondents from all 50 U.S. states, Guam, the District of Columbia and Puerto Rico (Centers for Disease Control and Prevention, n.d.-b). The median response rate was 47% (range: 34%–61%) (Centers for Disease Control and Prevention, n.d.-c).

The BRFSS 2015 interviews comprised a range of items, including (but not limited to) demographic information, PA behaviours and mental health related outcomes such as depressive symptoms. From the 441,456 adults who were originally interviewed, participants were excluded if they had any missing data on physical activity (n = 57,528) and/or depressive symptoms (n = 366,089). The final sample in the present study was 17,839 (participant flow diagram shown in Fig. 1).

2.2. Physical activity assessments

Self-reported moderate to vigorous-intensity aerobic physical activity (MVPA) and muscle-strengthening exercise (MSE) were estimated using established protocols (Centers for Disease Control and Prevention, 2001). The development and psychometric testing of the physical activity survey items used in the BRFSS has been described elsewhere (Centers for Disease Control and Prevention, 2001; Yore et al., 2007).

Aerobic MVPA was assessed by asking participants "*During the past month, other than your regular job, did you participate in any physical activities or exercises such as running, calisthenics, golf, gardening, or walking for exercise?*". If they answered 'yes', they were then asked "*What type of physical activity or exercise did you spend the most time doing during the past month?*" and further prompted; "*how many times per week or per month did you take part in this activity during the past month?*" and "*when you took part in this activity, for how many minutes or hours did you usually keep at it?*". Modes of physical activity were coded by BRFSS 2015 researchers as 'aerobic' or 'non-aerobic' using a pre-established list of 56 recreation activities and leisure-time sports (Centers for Disease Control and Prevention, 2001). Examples of non-aerobic activities included golf, bowling, gardening and painting, while aerobic activities included walking, biking and running. To count toward meeting the aerobic MVPA guideline, an activity had to be classified as aerobic and be performed for ≥10 min per episode (Yore et al., 2007). For estimating the intensity for aerobic activities, using a validated method (Centers for Disease Control and Prevention, 2001), the cut-point for vigorous-intensity activities was defined as ≥60% of a respondent's estimated aerobic capacity, based on sex and age. Moderate-intensity activities were defined as activities using ≥3.0 metabolic equivalents and less than the respondent's vigorous-intensity cut-point (Centers for Disease Control and Prevention, 2001). These survey items have been shown to have acceptable concurrent validity (Cohen's k = 0.17–0.22) (using accelerometer as the standard) and test-retest relatability (Cohen's k = 0.67–0.84) (Yore et al., 2007), therefore appropriate for use in providing accurate estimates of MVPA in large population samples. Consistent with WHO guidelines, meeting the aerobic physical activity guideline was classified as at least 150 min/week moderate-intensity aerobic physical activity, or 75 min/week of vigorous-intensity aerobic physical activity, or an equivalent combination of both (WHO, 2010). Since the amount of energy expended in VPA is approximately double that of MPA (Ainsworth et al., 2011), there are additional health benefits from engaging in VPA (Gebel et al., 2015). Therefore, using a standardised scoring protocol (Centers for Disease Control and Prevention, 2001), time spent in aerobic VPA was doubled. For example, if a respondent reported 100 min of aerobic MPA/week and 30 min of aerobic VPA/week, their volume of weekly physical activity was classified as 160 MVPA min/week.

MSE was assessed by asking "*During the past month, how many times per week or per month did you do physical activities or exercises to*

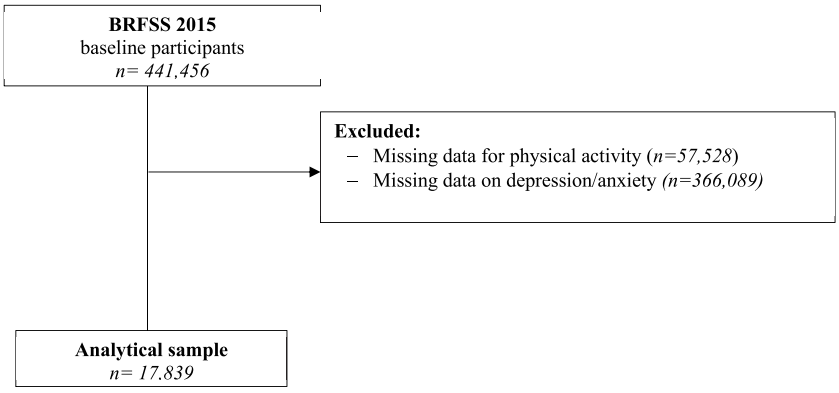

Fig. 1. Behavioral Risk Factor Surveillance System 2015 participant flow diagram.

strengthen your muscles?". Respondents were prompted, "*Do not count aerobic activities like walking, running, or bicycling. Count activities using your own body weight like yoga, sit-ups or push-ups and those using weight machines, free weights, or elastic bands*" (Centers for Disease Control and Prevention, n.d.-d). This item has acceptable test-retest reliability (Cohen's $k = 0.85–0.92$) (Yore et al., 2007) and convergent validity (using ≥2 MSE sessions/week threshold against red blood cell distribution width) (Loprinzi et al., 2015). Respondents reported MSE frequency for sessions/week or sessions/month. For those reporting their MSE frequency for sessions/month, this was divided by four to estimate weekly frequency.

2.3. Physical activity classification categories

Following the WHO recommendations (World Health Organization, 2010), each respondent was categorised into one of four groups: (i) Meet neither guidelines (aerobic MVPA = 0–149 min/week & MSE = 0–1 sessions/week); (ii) Meet MSE only (MSE ≥2 sessions/week & aerobic MVPA = 0–149 min/week); (iii) Meet aerobic MVPA only (aerobic MVPA ≥150 min/week & MSE = 0–1 sessions/week); or (iv) Meet both guidelines (aerobic MVPA ≥150 min/week & MSE = ≥2 sessions/week).

2.4. The Personal Health Questionnaire Depression Scale (PHQ-8)

The Personal Health Questionnaire Depression Scale (PHQ-8) was used to examine depressive symptom severity. The PHQ-8 consists of eight of the nine criteria on which the Diagnostic and Statistical Manual of Mental Disorders–IV (DSM-IV) diagnosis of depressive disorders is based (Edition and Association, 1994). The ninth question in the DSM-IV assesses self-injurious or suicidal thoughts (Edition and Association, 1994). This question was omitted during BRFSS 2015 data collection because it was considered that interviewers were not able to provide adequate intervention by telephone (Kroenke et al., 2009). A previous study showed that the PHQ-8 has acceptable convergent validity (against the multiple domains of Health-Related Quality of Life questionnaire as the standard), and hence considered valid and reliable instrument to assess depressive symptom severity in large, population-based studies (Edition and Association, 1994).

The PHQ-8 requires a respondent to report "*over the last 2 weeks, how many days have you felt any of the following problems*". Eight items were assessed: (i) "*had little pleasure doing things?*"; (ii) "*felt down, depressed or hopeless?*"; (iii) "*had trouble with sleep?*"; (iv) "*were tired or had little energy?*"; (v) "*ate too little or too much?*" (vi) "*felt like failure or let family down?*"; (vii) "*had trouble concentrating?*" and; (viii) "*you moved or spoken so slowly that other people could have noticed? Or the opposite – being so fidgety or restless that you were moving around a lot more than usual?*".

Using a standardised protocol, 0 to 1 day was recoded as '0'; 2 to 6 days was recoded as '1'; 7 to 11 days was recorded as '2'; and 12 to 14 days was recoded as '3' (Kroenke et al., 2009). The scores for each item were summed to produce a total score between 0 and 24. Based on a previous validation study (Kroenke et al., 2009), a total score of 0–4 represents 'no significant depressive symptoms'; 5–9 represents 'mild depressive symptoms'; 10–14, 'moderate'; 15–19, 'moderately severe'; and 20–24, 'severe'. For the purposes of this analysis, we collapsed 'moderately severe' and 'severe', hence four categories of depressive symptom severity are used in the present study: (i) no significant depressive symptoms; (ii) mild; (iii) moderate and (iv) moderately severe/severe.

2.5. Covariates

Sociodemographic (sex, age, education, income, race/ethnicity) and lifestyle characteristics (self-rated health, alcohol consumption, self-reported body mass index [BMI], smoking status) were assessed using standardised questionnaire items, and included in models as potential confounding factors, based on theoretically being associated with both physical activity (Bauman et al., 2012) and depressive symptoms (Kroenke et al., 2009). Each sociodemographic and lifestyle characteristic sub-category is consistent with BRFSS 2015 documentation (Centers for Disease Control and Prevention, n.d.-d). Since a previous diagnosis of depression is likely to be associated with current depression level, similar to a recent study (Chekroud et al., 2018), we also adjusted for previous medical professional diagnosed depressive disorder. Last, we also adjusted for the self-reporting of the following comorbidities: arthritis/rheumatoid arthritis, hypertension, high cholesterol, myocardial infarction, coronary heart disease, stroke, diabetes, chronic obstructive pulmonary disease, asthma, kidney disease, and cancer (non-skin).

2.6. Statistical analysis

All analyses were conducted using the Complex Samples module of SPSS version 23. To allow for valid population estimates, individual stratum weights were given to each BRFSS 2015 respondent. These weighting factors allowed for population estimates for nonresponse (Centers for Disease Control and Prevention, n.d.-c). Descriptive statistics were used to describe the weighted percentages (%) across all covariates, physical activity guideline adherence categories and levels of depressive symptom severity. Chi-squared tests were used to test for differences across categories of sociodemographic and lifestyle factors comparing the original BRFSS 2015 sample to the sub-sample used in the present study.

Poisson regression models with a robust error variance were used to calculate prevalence ratios (PR) assessing the associations categories of depressive symptom severity (dependant variable) across categories of physical activity classification (explanatory variable). Three Poisson regression models were conducted: (i) mild (yes vs. no; reference [ref] = no significant depressive symptoms); (ii) moderate (yes vs. no; ref = no significant depressive symptoms); and (iii) moderately severe/severe depressive symptoms (yes vs. no; ref = no significant depressive symptoms).

We used Poisson regression to report prevalence ratios because in cross-sectional studies, this statistical approach is considered more robust than the traditionally used logistic regression reporting odds ratios (Tamhane et al., 2016). For these analyses, the reference group was most physically inactive group ('meet neither'). In addition, since physical activity levels (Bauman et al., 2012) and depressive symptom severity (Kroenke et al., 2009) have been shown to differ by sex, we also conducted a sex-stratified analysis. Before conducting our analytical models, we tested for multicollinearity among potential covariates using tests variance inflation factor (VIF), with a VIF ≥2 indicating multicollinearity (Cohen et al., 2013). In this analysis, the VIFs ranged from 1.06 to 1.78, indicating no evidence of collinearity among covariates. In addition, we also checked for independence of observations to ensure that these data were correctly fitted in our final adjusted model (i.e. no evidence of under/over dispersion).

3. Results

3.1. Sample description

The final sample in the analysis was 17,839 (18–80 years) (Table 1). Over half of the sample were female, employed, within the two highest income categories, either attended college or graduated from college and had never smoked. Most were White, non-Hispanic and had 'good' to 'excellent' self-rated health. Under a quarter had a previous diagnosis of depression and < 5% were classified as a heavy drinker.

Across physical activity classification categories, 45.2% met neither guideline, 9.6% met MSE guideline only, 28.4% met aerobic MVPA guideline only and 17.8% met both guidelines. Compared to the

original BRFSS 2015 sample, among the sub-sample used in the present study, apart from sex, there were significant difference across all other categories of sociodemographic and health-related outcomes (see Appendix 1).

3.2. Prevalence of depressive symptom severity within each physical activity guideline adherence category

The unadjusted prevalence for depressive symptom severity for each physical activity category is shown in Table 2. Overall, the highest prevalence of those classified with mild, moderate, moderately severe/severe depressive symptoms was among those who met neither guidelines.

Table 1
Sample characteristics and physical activity levels of a sub-sample of 2015 U.S. Behavioral Risk Factor Surveillance System.

	Total sample
	n
Total	17,839
Sex	%[a] (n)
Male	47.9 (7254)
Female	52.1 (10,585)
Age	
18–24	11.7 (858)
25–34	15.7 (1571)
35–44	16.4 (1984)
45–54	17.8 (2865)
55–64	18.2 (4329)
65–74	12.5 (3711)
> 75	7.6 (5521)
Race/ethnicity	
White, non-Hispanic	77.8 (14,809)
Black, non-Hispanic	17.2 (2264)
Other race, non-Hispanic	1.8 (314)
Multiracial, non-Hispanic	1.2 (171)
Hispanic	2.0 (157)
Employment status	
Student	5.2 (406)
Employed	52.7 (8195)
Unemployed	6.4 (690)
Homemaker	6.4 (1110)
Retired	19.0 (5580)
Unable to work	10.2 (1802)
Education level	
Did not graduate high school	14.1 (1651)
Graduated high school	32.6 (5628)
Attended college/technical	31.4 (4957)
Graduated college	21.9 (5573)
Income categories	
Less than $15,000	12.5 (1835)
$15,000–$25,000	20.3 (2758)
$25,000–$35,000	12.3 (1771)
$35,000–$50,000	15.0 (2318)
$50,000 or more	39.9 (2318)
Body mass index (kg/m^2)	
Underweight (< 18.5)	1.5 (262)
Acceptable weight (18.5–25)	23.8 (4465)
Overweight (25–30)	35.2 (6170)
Obese (≥ 30)	34.9 (5833)
Self-rated health	
Excellent	14.9 (2374)
Very good	32.4 (5712)
Good	31.5 (5674)
Fair	14.4 (2772)
Poor	6.8 (1272)
Smoking status	
Current (daily)	16.2 (2441)
Current (some days)	6.2 (814)
Former smoker	23.6 (4776)
Never smoked	54.1 (9756)
Alcohol consumption: 'heavy drinker'[b]	4.5 (665)
Previous diagnosis of depression[c]	20.2 (3534)
Physical activity guideline adherence[d]	
Meet neither	45.2 (8112)
Muscle strengthening only	9.6 (1404)
Aerobic MVPA only	28.4 (5707)
Meet both	17.8 (2616)
Depressive symptom severity[e]	
No significant depressive symptoms	70.0 (13,021)
Mild	18.7 (3081)
Moderate	7.2 (1089)
Moderately severe/severe	4.1 (660)

[a] Data weighted using stratum weight provided by the Centers for Disease Control and Prevention (CDC) (Centers for Disease Control and Prevention, n.d.-c).
[b] To be classified as a heavy drinker an adult men had to consume ≥ 14 drinks/week and adult women ≥ 7 drinks per week.
[c] To be classified as having depression a respondent had to report having a "*doctor, nurse or other health professional*" diagnose this condition.
[d] Physical activity guideline adherence 'Meet neither': aerobic MVPA = 0–149 MSE = 0–1 sessions/week; 'MSE only'; MSE = ≥ 2 sessions/week & aerobic MVPA = 0–149 min/week; 'aerobic MVPA only' aerobic MVPA = ≥ 150 min/week & MSE = 0–1 sessions/week; and 'Meet both': aerobic MVPA = ≥ 150 min/week & MSE = ≥ 2 sessions/week.
[e] Depressive symptom severity assessed by eight-item Patient Health Questionnaire depression scale (PHQ-8).

3.3. Prevalence ratios for depressive symptom severity within each physical activity guideline adherence category

The adjusted prevalence ratios (APR) for depressive symptom severity by physical activity categories (ref = 'meet neither') are shown in Table 3. For the total sample, after adjusting for covariates, compared to those meeting neither guideline, those meeting both guidelines had the lowest prevalence of mild, moderate and moderately severe depressive symptoms (range: 0.28–0.47), followed by aerobic MVPA only (range: 0.35–0.63) and MSE only (range: 0.49–0.84).

Across the three levels of depressive symptom severity, the APRs for depressive symptom severity showed an inverse linear gradient, with the lowest for each physical activity guideline adherence category among the group with the most depressive group (i.e. moderately severe/severe).

As shown in Table 3, although the APRs tended to be similar between males and females, for the lower levels of depression (i.e. mild/moderate) meeting the MSE guideline only was not associated with a significantly reduced APR of depressive symptom severity for females. However, among the most depressed group, females who met the MSE guideline only were at a lower risk, when compared to those meeting neither guideline.

To examine for any dose-dependent associations, a sensitivity analysis was conducted to determine if meeting double the WHO PA guidelines (WHO, 2010) (i.e. MVPA = ≥ 301 min/week & MSE = ≥ 4 sessions/week) was associated with a lower APR for depressive symptom severity. As shown in Appendix 2, the APRs were generally concordant across these different PA categories. This suggests that PA levels exceeding the WHO PA guidelines did not result in a lower prevalence of depressive symptom severity.

4. Discussion

We are the first to describe the associations between combined aerobic MVPA-MSE with depressive symptom severity among a large population-based sample of adults. The key finding was that compared to other physical activity guideline adherence categories (i.e. MSE only;

Table 2
Prevalence of depressive symptom severity[a] by categories of physical activity guideline adherence[b] among a subsample of 2015 Behavioral Risk Factor Surveillance System respondents (n = 17,839).

	Physical activity guideline adherence[b]			
	Meet neither	Muscle strengthening only	Aerobic MVPA only	Meet both
Depressive symptom severity[a]	%[c] (95% CI)	%[c] (95% CI)	%[c] (95% CI)	%[c] (95% CI)
No significant depressive symptoms	63.9 (62.0, 65.8)	71.9 (67.8, 75.7)	75.0 (72.9, 77.1)	77.4 (74.0, 80.4)
Mild depressive symptoms	21.0 (19.4, 22.7)	16.5 (13.6, 19.8)	17.4 (15.6, 19.4)	15.7 (13.1, 18.8)
Moderate	9.7 (8.6, 10.9)	8.5 (6.2, 11.7)	4.4 (3.6, 5.4)	4.1 (3.0, 5.7)
Moderately severe/severe	5.4 (4.6, 6.3)	3.3 (2.1, 5.1)	3.1 (2.3, 4.3)	2.8 (1.8, 4.3)

[a] Depressive symptom severity assessed by eight-item Patient Health Questionnaire depression scale (PHQ-8).
[b] Physical activity levels: 'Meet neither': aerobic MVPA = 0–149 MSE = 0–1 sessions/week; 'MSE only'; MSE = ≥2 sessions/week & aerobic MVPA = 0–149 min/week; 'aerobic MVPA only' aerobic MVPA = ≥150 min/week & MSE = 0–1 sessions/week; and 'Meet both': aerobic MVPA = ≥150 min/week & MSE = ≥2 sessions/week.
[c] Data weighted using stratum weight provided by the Centers for Disease Control and Prevention (CDC) (Centers for Disease Control and Prevention, n.d.-c).

aerobic MVPA only), meeting both guidelines was associated with the lowest prevalence ratios for depressive symptom severity across levels of depressive symptom severity (e.g. mild, moderate, moderately severe/severe). A further key finding was that the prevalence ratios followed an inverse linear gradient, with the lowest for each physical activity category among the most depressed group. Collectively, these findings may suggest that future public health campaigns to improve mental health should promote combined MVPA-MSE, as opposed to the traditionally promoted aerobic MVPA only. Moreover, comprehensive health policies and government expenditure are needed to provide supportive environments to encourage population level MVPA-MSE uptake and adherence.

Current WHO recommendations state that adults should engage in regular aerobic MVPA and MSE (World Health Organization, 2010). However, at the population level, there is limited understanding on the associations between combined aerobic MVPA-MSE with mental health outcomes (Gordon et al., 2018a). Although, compared to meeting neither guideline, meeting either the aerobic MVPA or MSE guidelines alone was associated with a reduce likelihood of reporting depressive symptoms, meeting both guidelines was associated with the lowest adjusted prevalence ratios. While cognisant of the limitations associated with the cross-sectional nature of the present study, our results are important because, we believe, this is the first epidemiological evidence directly comparing different physical activity categories of physical activity guideline adherence and associations with depression. Interestingly, among females, meeting the MSE guideline alone did not result in lower APRs for either mild or moderate depressive symptoms. This finding is in contrast to a recent longitudinal study showing that, among ~4500 older Irish adults, high levels of grip strength were associated with a lower incidence of depression among females, compared to males (McDowell et al., 2018b). Further research is needed to examine the sex-specific associations between MSE/grip strength and depression.

The results of the present study are somewhat consistent with a clinical exercise randomised controlled trial (Sillanpaa et al., 2012), which to our knowledge, is the only study comparing discreet groupings of exercise modalities on indictors of mental health. In that study, healthy adults (n = 249, aged 39–77 years) were randomised into an aerobic MVPA, MSE, or combined training groups and controls (Sillanpaa et al., 2012). After 21-weeks of training, compared to the other groups, the combined group had greater improvements on perceptions of energy and mental agility (Sillanpaa et al., 2012). Future prospective cohort studies that incorporate regular aerobic MVPA and MSE assessments and mental health outcomes, such as incidence of medical professional diagnosed depression and anxiety, are needed to further examine the associations between different modes of physical activity and mental health outcomes.

A novel aspect of the present study is the examination of the associations between mutually exclusive groupings of physical activity guideline adherence with mental health outcomes. Using this

Table 3
Adjusted[a] prevalence ratios[b] (APR) for depressive symptom severity[c] according to levels of physical activity guideline adherence[d]: overall and by sex.

Depressive symptom severity[b]	Physical activity guideline adherence[d]	Overall APR	Males APR (95% CI)	Females APR (95% CI)
Mild[e]	Meet neither	1	1	1
	Muscle strengthening only	0.86 (0.74, 0.99)	0.75 (0.59, 0.94)	0.96 (0.79, 1.15)
	Aerobic MVPA only	0.63 (0.57, 0.69)	0.64 (0.55, 0.75)	0.63 (0.55, 0.71)
	Meet both	0.55 (0.48, 0.62)	0.58 (0.47, 0.71)	0.54 (0.45, 0.64)
Moderate[e]	Meet neither	1	1	1
	Muscle strengthening only	0.73 (0.56, 0.94)	0.65 (0.41, 0.98)	0.84 (0.61, 1.13)
	Aerobic MVPA only	0.44 (0.37, 0.53)	0.35 (0.25, 0.48)	0.50 (0.41, 0.61)
	Meet both	0.37 (0.29, 0.48)	0.38 (0.25, 0.56)	0.39 (0.28, 0.52)
Moderately severe/severe[e]	Meet neither	1	1	1
	Muscle strengthening only	0.47 (0.19, 0.39)	0.34 (0.14, 0.67)	0.59 (0.36. 0.92)
	Aerobic MVPA only	0.38 (0.30, 0.48)	0.32 (0.20, 0.49)	0.42 (0.31, 0.55)
	Meet both	0.28 (0.19, 0.39)	0.28 (0.15, 0.49)	0.30 (0.19, 0.45)

[a] Prevalence ratio was adjusted for previous diagnosis of depression, sex, age, race/ethnicity, employment, education, income, self-rated health, BMI, smoking and heavy alcohol consumption and comorbidities (hypertension, high cholesterol, myocardial infarction, coronary heart disease, stroke, diabetes, chronic obstructive pulmonary disease, asthma, kidney disease, cancer (non-skin) and arthritis/rheumatoid arthritis).
[b] PR calculated using Poisson regression with a robust error variance.
[c] Depressive symptom severity assessed by eight-item Patient Health Questionnaire depression scale (PHQ-8).
[d] Physical activity levels: 'Meet neither': MVPA = 0–149 MSE = 0–1 sessions/week; 'MSE only'; MSE = ≥2 sessions/week & MVPA = 0–149 min/week; 'MVPA only' MVPA = ≥150 min/week & MSE = 0–1 sessions/week; and 'Meet both': MVPA = ≥150 min/week & MSE = ≥2 sessions/week.
[e] Reference category = no significant depressive symptoms.

discriminant statistical approach, we expand on previous research by providing a more nuanced insight into the associations between different physical activity modes and depressive symptoms. For example, the evidence on physical activity and mental health has been typically concentrated on aerobic MVPA (Mammen and Faulkner, 2013) and sedentary behaviour (Teychenne et al., 2008), with some recent focus on MSE (Gordon et al., 2018a; Gordon et al., 2017). Despite being globally recommended, there is limited research examining the associations between combined aerobic MVPA-MSE with mental health. This lack of research is likely to be a consequence of MSE only been added to physical activity recommendations within the past decade. Moreover, MSE is often ignored in favour of only aerobic MVPA instead (Strain et al., 2016). The key findings presented here suggest that future physical activity and mental health research should continue to examine the effects of concurrent aerobic MVPA-MSE.

Although it was not within the scope of the present study to examine the underlying mechanisms explaining the relationship between various types of physical activity and depressive symptoms, it is important to acknowledge the potential pathways. While many clinical exercise studies have examined the physiological mechanisms associated with combined aerobic MVP-MSE (Coffey and Hawley, 2017; Mann et al., 2014), mechanistic research on mental health outcomes is still somewhat inconclusive and in need of further study (Gordon et al., 2018a). As discussed, there is some evidence that combined aerobic MVPA-MSE increases positive psychological outcomes such as improved sense of energy and mental agility (Sillanpaa et al., 2012), which may consequently reduce depressive symptoms. Alternatively, aerobic exercise has been shown to alter neurotransmitters such as serotonin receptors and hormones such as norepinephrine (Dishman, 1997; Laske et al., 2010), improvements in endocannabinoid system function (Tantimonaco et al., 2014) and reduce chronic inflammation (Miller et al., 2009), which may result in improved mood/reduced depressive symptoms. Psycho-social factors (e.g. social interaction) have also been suggested to potentially explain the link between physical activity and mental health (Biddle and Mutrie, 2007). However, as opposed to a single mechanism, aerobic physical activity is likely to influence mental health via a combination of psychological, psycho-social, biochemical and physiological pathways (Mammen and Faulkner, 2013). Likewise, such as combination of mechanisms could apply equally to MSE, but rather little is known on this at present. Moreover, individual preferences for certain forms of physical activity may also play a part. Logically, better mental health is unlikely to follow participation in activities that are not enjoyed or seen as intrinsically interesting or valuable. Future health promotion strategies should examine innovative ways of engaging individuals in MSE in settings that move beyond weight rooms/fitness centres, because these settings may be a barrier to participation (Howe et al., 2017). Some areas for future research include assessing the feasibility of home-based MSE, such as using resistance bands, calisthenics and body weight activities (push ups, sit-ups) (Gordon et al., 2018b).

A key strength of this study is the recruitment of a large population sample. Moreover, the comprehensive nature of the data collection allowed for adjustment for multiple covariates (e.g. sex, age, education, income, BMI, smoking, previous diagnosis of depression, alcohol consumption) A further strength is the use of the PHQ-8, a standardised instrument to assess depressive symptom severity in large population studies (Kroenke et al., 2009). Another strength was the use of mutually exclusive groupings of physical activity guideline adherence.

Limitations of this study are also acknowledged. Foremost, the cross-sectional study design limits inferences of causality for physical activity and associations with depression. We are unable to rule out the possibility of reverse causality. Prospective studies that include regular assessments of aerobic MVPA-MSE and mental health are necessary to determine the temporal sequencing and associations between combined physical activity guideline adherence with mental health. A further limitation was the use of self-report assessments of MVPA/MSE and depressive symptoms, which may have resulted in common method variance and recall bias, such as social desirability and over/under reporting (Brown et al., 2004). In addition, since the PA questions asked the respondent to recall their PA levels over 'the past month', this might have resulted in issues with accurate reporting of this behaviour. Device-based assessments, such as accelerometers could improve the validity of aerobic MVPA estimates (Brown et al., 2004). Moreover, since MSE intensity/duration was not reported, we are unable to assess how these may have influenced depressive symptom severity. Since there were differences across most sociodemographic and lifestyle factors between the original BRFSS 2015 sample to the sub-sample used in the present study, our results should be view with caution. Other limitations include the modest response rate, the non-assessment of use of anti-depressant medication, sedentary behaviour and the possibility that other unmeasured factors may have influenced results. Future studies need to take into account these factors (e.g. anti-depressant medication usage, sedentary behaviour levels) to confirm the key findings observed in the present study.

5. Conclusion

The prevention and management of depression is a key 21st century public health challenge. This study showed that, among a large population sample of U.S. adults, when compared to meeting one physical activity guideline alone, meeting both the aerobic MVPA and MSE guidelines was associated with a lower likelihood of depressive symptom severity. Future public health strategies to prevent/manage depression should promote both aerobic MVPA and MSE.

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Conflict of interest statement

All authors declare that there is no current conflict of interest to disclose with any organizations that might have an interest in the submitted work.

Financial disclosure

All authors declare that there is no financial relationships with any organizations that might have an interest in the submitted work.

References

Ainsworth, B.E., Haskell, W.L., Herrmann, S.D., et al., Aug 2011. 2011 compendium of physical activities: a second update of codes and MET values. Med. Sci. Sports Exerc. 43 (8), 1575–1581.
Bauman, A.E., Reis, R.S., Sallis, J.F., Wells, J.C., Loos, R.J., Martin, B.W., Jul 21 2012. Correlates of physical activity: why are some people physically active and others not? Lancet 380 (9838), 258–271.
Biddle, S.J., Mutrie, N., 2007. Psychology of Physical Activity: Determinants, Well-being and Interventions. Routledge.
Brenes, G.A., Williamson, J.D., Messier, S.P., et al., 2007. Treatment of minor depression in older adults: a pilot study comparing sertraline and exercise. Aging Ment. Health 11 (1), 61–68.
Brown, W., Trost, S., Bauman, A., Mummery, K., Owen, N., 2004. Test-retest reliability of four physical activity measures used in population surveys. J. Sci. Med. Sport 7 (2), 205–215.
Centers for Disease Control and Prevention, 2001. Physical activity trends—United States, 1990–1998. MMWR Morb. Mortal. Wkly Rep. 50 (9), 166.
Centers for Disease Control and Prevention Behavioral Risk Factor Surveillance System. Available at: https://www.cdc.gov/brfss/index.html.
Centers for Disease Control and Prevention Overview: BRFSS 2015. Available at: https://www.cdc.gov/brfss/annual_data/2015/pdf/overview_2015.pdf.
Centers for Disease Control and Prevention 2015 Summary Data Quality Report. Available at: https://www.cdc.gov/brfss/annual_data/2015/pdf/2015-sdqr.pdf.
Centers for Disease Control and Prevention 2015 Codebook Report. Available at: https://www.cdc.gov/brfss/annual_data/2015/pdf/codebook15_llcp.pdf.
Chekroud, S.R., Gueorguieva, R., Zheutlin, A.B., et al., Sep 2018. Association between physical exercise and mental health in 1.2 million individuals in the USA between 2011 and 2015: a cross-sectional study. Lancet Psychiatry 5 (9), 739–746.
Coffey, V.G., Hawley, J.A., May 1 2017. Concurrent exercise training: do opposites

distract? J. Physiol. 595 (9), 2883–2896.
Cohen, J., Cohen, P., West, S.G., Aiken, L.S., 2013. Applied Multiple Regression/Correlation Analysis for the Behavioral Sciences. Routledge.
Dishman, R.K., Jan 1997. Brain monoamines, exercise, and behavioral stress: animal models. Med. Sci. Sports Exerc. 29 (1), 63–74.
Edition, F., Association, A.P., 1994. Diagnostic and Statistical Manual of Mental Disorders. American Psychological Association.
Gebel, K., Ding, D., Chey, T., Stamatakis, E., Brown, W.J., Bauman, A.E., 2015. Effect of moderate to vigorous physical activity on all-cause mortality in middle-aged and older Australians. JAMA Intern. Med. 175 (6), 970–977.
Gordon, B.R., McDowell, C.P., Lyons, M., Herring, M.P., 2017. The effects of resistance exercise training on anxiety: a meta-analysis and meta-regression analysis of randomized controlled trials. Sports Med. 1–12.
Gordon, B.R., McDowell, C.P., Hallgren, M., Meyer, J.D., Lyons, M., Herring, M.P., 2018a. Association of efficacy of resistance exercise training with depressive symptoms: meta-analysis and meta-regression analysis of randomized clinical trials. JAMA Psychiat. 75 (6), 566–576 (Jun 1).
Gordon, B.R., Lyons, M., Herring, M.P., 2018b. Efficacy of resistance exercise training with depressive symptoms—reply. JAMA Psychiat. 75 (10), 1092.
Greenberg, P.E., Fournier, A.A., Sisitsky, T., Pike, C.T., Kessler, R.C., Feb 2015. The economic burden of adults with major depressive disorder in the United States (2005 and 2010). J. Clin. Psychiatry 76 (2), 155–162.
Howe, H.S., Welsh, T.N., Sabiston, C.M., 2017. The association between gender role stereotypes, resistance training motivation, and participation. Psychol. Sport Exerc. 33 (Supplement C), 123–130.
Kroenke, K., Strine, T.W., Spitzer, R.L., Williams, J.B., Berry, J.T., Mokdad, A.H., 2009. The PHQ-8 as a measure of current depression in the general population. J. Affect. Disord. 114 (1–3), 163–173.
Laske, C., Banschbach, S., Stransky, E., et al., Jun 2010. Exercise-induced normalization of decreased BDNF serum concentration in elderly women with remitted major depression. Int. J. Neuropsychopharmacol. 13 (5), 595–602.
Loprinzi, P.D., Loenneke, J.P., Abe, T., Apr 2015. The association between muscle strengthening activities and red blood cell distribution width among a national sample of U.S. adults. Prev. Med. 73, 130–132.
Mammen, G., Faulkner, G., Nov 2013. Physical activity and the prevention of depression: a systematic review of prospective studies. Am. J. Prev. Med. 45 (5), 649–657.
Mann, S., Beedie, C., Balducci, S., et al., May 2014. Changes in insulin sensitivity in response to different modalities of exercise: a review of the evidence. Diabetes Metab. Res. Rev. 30 (4), 257–268.
McDowell, C., Dishman, R., Hallgren, M., MacDonncha, C., Herring, M., 2018a. Associations of physical activity and depression: results from the Irish Longitudinal Study on Ageing. Exp. Gerontol. 112, 68–75.
McDowell, C.P., Gordon, B.R., Herring, M.P., 2018b. Sex-related differences in the association between grip strength and depression: results from the Irish Longitudinal Study on Ageing. Exp. Gerontol. 104, 147–152 (Apr).
Miller, A.H., Maletic, V., Raison, C.L., May 1 2009. Inflammation and its discontents: the role of cytokines in the pathophysiology of major depression. Biol. Psychiatry 65 (9), 732–741.
Nystrom, M.B., Neely, G., Hassmen, P., Carlbring, P., 2015. Treating major depression with physical activity: a systematic overview with recommendations. Cogn. Behav. Ther. 44 (4), 341–352.
Rebar, A.L., Stanton, R., Geard, D., Short, C., Duncan, M.J., Vandelanotte, C., 2015. A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. Health Psychol. Rev. 9 (3), 366–378.
Schuch, F.B., Vancampfort, D., Richards, J., Rosenbaum, S., Ward, P.B., Stubbs, B., Jun 2016. Exercise as a treatment for depression: a meta-analysis adjusting for publication bias. J. Psychiatr. Res. 77, 42–51.
Schuch, F.B., Vancampfort, D., Firth, J., et al., Jul 1 2018. Physical activity and incident depression: a meta-analysis of prospective cohort studies. Am. J. Psychiatry 175 (7), 631–648.
Sillanpaa, E., Hakkinen, K., Holviala, J., Hakkinen, A., Dec 2012. Combined strength and endurance training improves health-related quality of life in healthy middle-aged and older adults. Int. J. Sports Med. 33 (12), 981–986.
Steel, Z., Marnane, C., Iranpour, C., et al., 2014. The global prevalence of common mental disorders: a systematic review and meta-analysis 1980–2013. Int. J. Epidemiol. 43 (2), 476–493.
Strain, T., Fitzsimons, C., Kelly, P., Mutrie, N., 2016. The forgotten guidelines: cross-sectional analysis of participation in muscle strengthening and balance & co-ordination activities by adults and older adults in Scotland. BMC Public Health 16 (1), 1108.
Tamhane, A.R., Westfall, A.O., Burkholder, G.A., Cutter, G.R., Dec 30 2016. Prevalence odds ratio versus prevalence ratio: choice comes with consequences. Stat. Med. 35 (30), 5730–5735.
Tantimonaco, M., Ceci, R., Sabatini, S., et al., Jul 2014. Physical activity and the endocannabinoid system: an overview. Cell. Mol. Life Sci. 71 (14), 2681–2698.
Teychenne, M., Ball, K., Salmon, J., 2008. Physical activity and likelihood of depression in adults: a review. Prev. Med. 46 (5), 397–411.
Vos, T., Allen, C., Arora, M., et al., 2016. Global, regional, and national incidence, prevalence, and years lived with disability for 310 diseases and injuries, 1990–2015: a systematic analysis for the Global Burden of Disease Study 2015. Lancet 388 (10053), 1545–1602.
WHO, 2010. Global Recommendations on Physical Activity for Health (Geneva, Switzerland). .
World Health Organization, 2010. Global Recommendations on Physical Activity for Health. World Health Organization.
Yore, M.M., Ham, S.A., Ainsworth, B.E., et al., Aug 2007. Reliability and validity of the instrument used in BRFSS to assess physical activity. Med. Sci. Sports Exerc. 39 (8), 1267–1274.