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Resistance training in addition to aerobic activity is associated with lower likelihood of depression and comorbid depression and anxiety symptoms: A cross sectional analysis of Australian women

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ABSTRACT

The mental health benefits of resistance training (RT) alone or beyond those provided by aerobic physical activity (PA) are unclear. This study aimed to determine the association between meeting recommendations for aerobic PA and/or RT, and symptoms of depression and/or anxiety. Participants were Australian female members of the 10,000 Steps project (n = 5180, 50.0 ± 11.5 years). Symptoms of depression and anxiety were determined using the Depression Anxiety Stress Score. Participants were grouped as 'depression only', 'anxiety only', 'co-occurring depression and anxiety' or 'neither depression nor anxiety' based on relevant subscale score (cut-points: depression ≥ 14 points, anxiety ≥ 10 points). The International Physical Activity Questionnaire-Long Form questionnaire was used to determine PA with an additional item to specify RT frequency. Participants were classified as adhering to 'aerobic PA only' (≥ 150 min PA/week), 'RT only' (RT ≥ 2 days/week), 'aerobic PA + RT' (≥ 150 min PA/week + RT ≥ 2 days/week), or 'neither aerobic PA nor RT' (< 150 min PA/week + RT < 2 days/week). Adjusted relative risk ratios (RRR [95%CI]) were estimated using multinomial logistic regression models. Relative to the 'neither PA nor RT' (n = 2215), the probabilities of 'depression only' (n = 317) and 'co-occurring depression and anxiety' (n = 417) were lower for the 'aerobic PA only' (n = 1590) (RRR = 0.74 [0.56–0.97] and RRR = 0.76 [0.59–0.97] respectively), and 'both PA + RT' (n = 974) groups (RRR = 0.61 [0.43–0.86] and RRR = 0.47 [0.33–0.67] respectively). There were no associations between adhering to one or both recommendations and 'anxiety only' (n = 317), or between 'RT only' (n = 401) and depression and/or anxiety. Prevention and treatment strategies including both aerobic PA and RT may provide additional benefits for depression with or without comorbid anxiety.

1. Introduction

Globally, approximately 322 million (4.4%) people had a depressive disorder in 2015, and 264 million (3.6%) had an anxiety disorder (World Health Organisation, 2017). Depression is the leading global cause of disability, while anxiety is ranked sixth (World Health Organisation, 2017). Approximately half of those diagnosed with one of these conditions have a comorbidity with the other (World Health Organisation, 2017; Kircanski et al., 2017). An estimated 12–32% of the population live with symptoms of varying severity, and women are about twice as likely to experience depression or anxiety in their lifetime as men (World Health Organisation, 2017; McLean et al., 2011; Albert, 2015). Even mild symptoms of depression and anxiety can have debilitating effects on wellbeing, relationships, career and productivity (Haller et al., 2014; Shim et al., 2011; Karsten et al., 2011; Wittayanukorn et al., 2014; Cuijpers et al., 2013).

The World Health Organization (WHO) recommends 18–64 year-olds participate in muscle-strengthening activities (i.e. resistance training: RT) on 2 or more days and either ≥ 150 min of moderate-intensity physical activity (PA), ≥ 75 min of vigorous-intensity PA, or an equivalent combination per week (World Health Organisation, 2010). Yet relative to the proportion of adults who report meeting

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aerobic PA guidelines far fewer adults report meeting the RT recommendation. In the US, 23.0% of adults met the RT recommendation, 46.1% met the aerobic PA recommendation and 19.4% met both (Schoenborn et al., 2013). Similar patterns have been found in Australia (Bennie et al., 2016), the UK (UK Health and Social Care Information Centre, 2012) and Scotland (Strain et al., 2016). The prevalence of insufficient PA is concerning given the contribution of physical inactivity to the global burden of disease (Lee et al., 2012), and the even higher rates of insufficient RT are particularly concerning given RT may confer unique health benefits (Grontved et al., 2014; Grontved et al., 2012; Hardee et al., 2014; Stamatakis et al., 2018; Bakker et al., 2017; Bakker et al., 2018; Colcombe and Kramer, 2003).

Physical activity can have a role in the management of depression and anxiety and is protective against cardiovascular disease and metabolic disorders, which are common comorbidities (Celano et al., 2016; Dhar and Barton, 2016). While RT can have benefits for both depression and anxiety (Gordon et al., 2018a; Gordon et al., 2017), the majority of prior work has focused on aerobic PA or aerobic PA and RT combined without exploring the differential associations between the modes (Rebar et al., 2015; Schuch et al., 2018; Mammen and Faulkner, 2013; Stubbs et al., 2017). The few intervention studies comparing 'RT only' with 'aerobic PA only' have indicated equal effectiveness of the two modes in terms of reducing symptoms of depression or anxiety (Gordon et al., 2018a; Gordon et al., 2017). A recent observational study found the prevalence of depressive symptoms was lower in those who met both versus one of the recommendations for aerobic PA and RT (Bennie et al., 2019). A combination of aerobic PA and RT may confer unique benefits over and above that of aerobic PA or RT alone, but few studies have explored this. Additionally, few studies have explored the effect of RT and aerobic PA on co-occurring symptoms of depression and anxiety (Herring et al., 2011). This is a major gap, as comorbidity is common and is associated with unique symptom and neurobiological characteristics, and more severe and protracted symptoms than those with either disorder alone (Kircanski et al., 2017). Consequently, the relationship between PA and co-occurring symptoms of depression and anxiety may differ from that of depression or anxiety alone (Kircanski et al., 2017). The aim of this study was to determine the association between meeting recommendations for aerobic PA or RT alone and combined, and symptoms of depression and anxiety, alone or co-occurring.

2. Methods

2.1. Study design and participants

This was a cross- sectional sample from the member database of the 10,000 Steps project (www.10000steps.org.au), a web-based PA promotion initiative which commenced in Rockhampton, Australia, in 2001 (Brown et al., 2006). The Central Queensland University Human Research Ethics Committee provided approval for the current study (H15/09-210). All participants provided informed consent to participate via the online portal. As of November–December 2016, the project had approximately 330,000 members with 42,090 email addresses verified as valid at the time of the email-invitation to participate in the current study (Haapasalo et al., 2018). The overall response rate based completed surveys (n = 6982) and the total number of verified email addresses was 16.5%. The majority of those who completed the survey were women (n = 5180, 74.2%). Given the higher response rate from women, and the higher prevalence of depression and anxiety in women (World Health Organisation, 2017), this study focuses on women only. Data analysis took place in November 2018.

2.2. Study measures

2.2.1. Depression and anxiety symptoms

Symptoms of depression and anxiety were assessed using relevant DASS-21 (Depression Anxiety Stress Score) questionnaire (Parkitny and McAuley, 2010). The depression and anxiety sub-scales have shown criterion validity (depression: Area Under the Curve [AUC] = 0.77–0.91, anxiety: AUC = 0.60–0.83) in comparison to DSM-IV diagnosis, and adequate construct validity (Lee et al., 2019). Each domain comprises seven statements assessing symptom frequency last week (e.g. 'I felt I was close to panic', 'I felt I wasn't worth much as a person') and are rated on a 4-point scale (0 = never, 1 = sometimes, 2 = often, 3 = almost always). The score for each subscale is summed and multiplied by 2, making the maximum score for each domain 42. Scores were then categorized according to symptom severity (normal-extremely severe) (Parkitny and McAuley, 2010). These categories are not diagnostic but describe the continuum of severity observed in the population, i.e. 'mild' indicates symptoms above population average, not 'mild disorder' (Parkitny and McAuley, 2010). Participants were categorized into four mutually exclusive groups: 'depression only' or 'anxiety only' if responses indicated at least 'moderate' severity (depression ≥ 14, anxiety ≥ 10), and less than 'moderate' severity on the other subscale. The 'co-occurring depression and anxiety' group scored at least 'moderate' severity on both subscales. Those categorized as 'neither depression nor anxiety' scored below 'moderate' severity on both subscales.

2.2.2. Aerobic physical activity and resistance training

Aerobic PA during the previous week was measured using the International Physical Activity Questionnaire Long Form (IPAQ-LF). It assesses frequency and duration of participation in each of walking, moderate, and vigorous intensity PA as part of work, transportation, housework, gardening, sport or leisure during the last week (Bauman et al., 2009a). Total MET-minutes were calculated according to standard IPAQ scoring protocols, using MET values of 3.3 for walking, 4.0 for moderate intensity activity and 8.0 for vigorous intensity PA (Bauman et al., 2009a). Standard scoring procedures were used to subsequently classify participants' PA as 'low', 'moderate' or 'high' (Bauman et al., 2009a). The IPAQ-LF measures "total activity" across multiple domains resulting in higher reported activity relative to only assessing leisure time activity (Sjöström et al., 2006). Consequently the 'high' category (≥ 3sessions of vigorous activity per week and a total of ≥ 1500 MET-minutes per week OR ≥ 7 sessions of any activity intensity and a total of ≥ 3000 MET-minutes per week) is considered to represent a total activity level comparable to that of meeting the PA recommendation of ≥ 150 min of aerobic PA per week (Sjöström et al., 2006; Bauman et al., 2009b). Participants were asked an additional item "How many days in the last 7 days have you participated in resistance/weight training" (Plotnikoff et al., 2008) and a frequency of ≥ 2 days per week was considered meeting the WHO recommendations (World Health Organisation, 2010). Study participants were then categorized into the following PA groups: meeting 'aerobic PA only' (≥ 150 minute aerobic PA/week), 'RT only' (RT ≥ 2 days/week), 'aerobic PA + RT' (≥ 150 minute aerobic PA/week + RT ≥ 2 days/week), or 'neither aerobic PA nor RT' (< 150 minute aerobic PA/week + RT < 2 days/week).

2.2.3. Socio-demographic and behavioral measures

Household income was reported in seven categories and collapsed into categories of: ' > AUD$70,000 per annum'; '≤ AUD$70,000 per annum'; or 'unsure/prefer not to state'. Employment status was categorized as 'employed' or 'not employed'. Cigarette-smoking status was assessed using a single item and categorized as 'current smoker' or 'non-smoker' (Stringhini et al., 2011; Gordon et al., 2018b). Number of alcoholic drinks typically consumed was reported, and categorized as: 'non-drinkers' (no alcohol in the last year); 'low risk' (1–2 standard drinks on a typical occasion); or 'high risk' (≥ 3 standard drinks on a typical occasion), in line with the Australian guidelines (National Health and Medical Research Council, 2009). The Workforce Sitting Questionnaire (Chau et al., 2011) asked participants how long they

Table 1
Sample characteristics of women who responded to the Australian 10,000 Steps Project 2016 survey by symptoms of depression and/or anxiety (n = 5180).

Mental health symptoms of ≥ moderate severity[a]		Neither (n = 4129)	Anxiety[a] (n = 317)	Depression[b] (n = 317)	Depression and anxiety (n = 417)
		Mean ± standard deviation			
Age	Years	50.6 ± 11.3	47.0 ± 11.9	50.0 ± 11.5	46.9 ± 13.1
Depression score[c]	DASS (0–42)	3.3 ± 3.4	7.4 ± 3.6	18.0 ± 5.5	22.1 ± 8.0
Anxiety score[c]	DASS (0–42)	2.3 ± 2.3	12.9 ± 3.7	4.4 ± 2.6	16.4 ± 6.2
Chronic disease diagnoses	Count	1.1 ± 1.3	1.7 ± 1.6	1.4 ± 1.4	1.8 ± 1.7
		Percentage (%)			
Income	AUD$ ≤ 70,000	824 (20.0)	77 (24.3)	75 (23.7)	140 (33.6)
	AUD$ > 70,000k	2686 (65.0)	193 (60.9)	197 (62.2)	210 (50.4)
	Unsure/prefer not to say	619 (15.0)	47 (14.8)	45 (14.2)	67 (16.0)
Employment	Unemployed	574 (13.9)	45 (14.2)	49 (15.5)	85 (20.4)
	Employed	3555 (86.1)	272 (85.8)	268 (84.5)	332 (79.6)
Cigarette smoking	Current smoker	158 (3.8)	33 (10.4)	12 (3.8)	40 (9.6)
	Non-smoker	3971 (96.2)	284 (89.6)	305 (96.2)	377 (90.4)
Alcohol consumption	High risk	897 (21.7)	101 (31.9)	57 (18.0)	113 (27.1)
	Low risk	2677 (64.8)	166 (52.4)	196 (61.8)	240 (57.6)
	Non-drinker	555 (13.4)	50 (15.8)	64 (20.2)	64 (15.4)
Sitting-time	≥ 8 h/day	2786 (67.5)	237 (74.8)	239 (75.4)	329 (78.9)
	< 8 h/day	1343 (32.5)	80 (25.2)	78 (24.6)	88 (21.1)
Sleep quality	Fairly bad/very bad	868 (21.0)	122 (38.5)	142 (44.8)	239 (57.3)
	Fairly good	2432 (58.9)	169 (53.3)	152 (48.0)	154 (36.9)
	Very good	829 (20.1)	26 (8.2)	23 (7.3)	24 (5.8)
Sleep duration meets recommendation[d]	No	1706 (41.3)	206 (64.5)	177 (55.8)	275 (65.9)
	Yes	2423 (58.7)	141 (44.5)	140 (44.2)	142 (34.1)
Sleep latency	Long (> 30 min)	477 (11.6)	89 (28.1)	77 (24.3)	152 (36.5)
	Normal (≤ 30 min)	3652 (88.5)	228 (71.9)	240 (75.7)	265 (63.6)
Chronic disease diagnosis	One or more	2486 (60.2)	239 (75.4)	210 (66.3)	322 (77.2)
	None reported	1643 (39.8)	78 (24.6)	107 (33.8)	95 (22.8)
Ever diagnosed with depression and/or anxiety	Yes	785 (19.0)	160 (50.5)	160 (50.5)	265 (63.6)
	No	3344 (81.0)	157 (49.5)	157 (49.5)	152 (36.5)
Body mass index	< 18.5 kg/m^2	59 (1.4)	5 (1.6)	7 (2.2)	11 (2.6)
	18.5–24.9 kg/m^2	1664 (40.3)	110 (34.7)	108 (34.1)	101 (24.2)
	25.0–29.9 kg/m^2	1252 (30.3)	72 (22.7)	88 (27.8)	116 (27.8)
	≥ 30 kg/m^2	1154 (28.0)	130 (41.0)	114 (36.0)	189 (45.3)

[a] Cut-off for 'moderate' anxiety symptoms ≥ 10 points.
[b] Cut-off for 'moderate' depression symptoms ≥ 14 points.
[c] The internal consistency in this sample (Cronbach's alpha) was 0.91 for the DASS-21 depression subscale and 0.79 for the anxiety subscale.
[d] Recommended sleep is 7–9 h of sleep per night for < 65-year olds and 7–8 h of sleep per night for ≥ 65-year olds.

spent sitting for each of transport, at work, watching TV, using a computer or other devices and leisure on each of work and non-work days, and number of work days per week. Average daily sitting-time, calculated by summing sitting-time for work and non-work days and averaging over 7 days, was categorized as low (< 8 h/day) or high (≥ 8 h/day) (Duncan et al., 2014). Sleep dimensions were measured using three items (sleep duration, quality and latency) from the Pittsburgh Sleep Quality Index (PSQI) (Buysse et al., 1989). The PSQI has strong reliability and validity, and moderate structural validity in a variety of samples (Mollayeva et al., 2016). Sleep duration was classified as 'meeting recommendations' (7 to ≤ 9 h if 18 to < 65 years old, 7 to ≤ 8 h if ≥ 65 years old), or 'not meeting recommendations' (< 7 h or > 9 h if 18 to < 65 years old, > 8 h if ≥ 65 years old). Sleep quality was collapsed into categories of 'very good'; 'fairly good'; or 'fairly-to-very bad' (Duncan et al., 2014). Sleep latency was classified as normal (≤ 30 min) or long (> 30 min), indicating a sleep disorder (Ohayon et al., 2017).

Participants self-reported diagnosis of 17 chronic diseases: high blood pressure, diabetes type 1 or 2, coronary heart disease, chronic obstructive pulmonary disease, cerebrovascular disease, cancer, asthma, high cholesterol, arthritis, insomnia, restless legs syndrome, sleep apnea, irritable bowel syndrome, kidney disease, arthritis, and mental illness other than depression or anxiety. Participants were categorized as '≥ 1 chronic conditions' or 'None'. Participants reported if they had ever received a diagnosis of depression and/or anxiety and were dichotomized as 'prior diagnosis of depression and/or anxiety' or 'none'. Self-reported height (cm) and weight (kg) were used to calculate body mass index (BMI) and subsequently categorized as > 18.5, 18.5–24.9, 25.0–29.9 and ≥ 30.0 kg/m^2.

2.3. Statistical analysis

Descriptive statistics included means (SD) for continuous variables and count (%) for categorical variables, Cronbach's alpha calculated for DASS subscales. *t*-Tests and Chi-square tests were used to assess differences in descriptive variables between the sample and those excluded from analysis due to incomplete data. One-way ANOVA analysis was used to compare MET-minutes reported for each activity intensity, activity domain and RT days between the four activity groups. Three multinomial logistic regression models were used, and Model A represents the unadjusted association between PA groups and mental health symptom groups while Model B presents the association between PA groups and mental health symptom groups, adjusted for socio-demographic variables, sleep health measures, and sitting-time. All covariates were chosen a priori based on previous literature (Zhai et al., 2015; LeBlanc et al., 2009; Verger et al., 2009; Allen et al., 2019; Kline, 2014). Model C included the same variables as Model B, plus chronic disease diagnosis, BMI category and diagnosis of depression and/or anxiety as covariates. Chronic disease and BMI can be conceptualized as being on the causal path between PA and mental health symptoms, and previous diagnosis of depression and/or anxiety is likely associated with current symptoms of depression and/or anxiety (Kyu et al., 2016; Clarke and Currie, 2009; Kelly et al., 2011; van der Zee et al., 2019). Controlling for these variables is therefore potentially over-adjusting the model, as it cancels out the effect of PA on mental health symptoms mediated through the influence of PA on chronic disease, BMI or

previous depression and anxiety (Suttorp et al., 2015). However, Model C was included as a sensitivity analysis. A separate sensitivity analysis using an alternative threshold (≥600MET minutes) for meeting aerobic PA recommendations was also conducted. All analyses were conducted using Stata Version 14 (College Station, TX: StataCorp) in November 2018.

3. Results

The 5180 women included in the study were primarily middle-aged (50.0 ± 11.5 years) and employed (85.5%) and had at least one chronic disease diagnosis (62.9%). These are higher than average age (38 years), employment rate (56%) and chronic disease diagnosis (52%) in the Australian female population (Australian Bureau of Statistics, 2017; Australian Bureau of Statistics, 2015). The mean DASS-21 depression score was 6.0 (7.3) points and mean DASS-21 score was 4.2 (5.3) points, with 79.9% (n = 4129) classified as 'neither depression nor anxiety', 6.1% (n = 317) classified as 'depression only', 6.1% (317) classified as 'anxiety only' and 8.1% (n-417) classified as 'both depression and anxiety'. Participant characteristics by mental health symptoms are described in Table 1. Women who were excluded because of incomplete data (n = 3086, 37.3%) were younger, less likely to disclose their income or report an income of > AUD$70,000 per annum, and more likely to be smokers and have a high-risk alcohol consumption or be non-drinkers than those who were included (Supplemental Table 1). They were also more likely to have a chronic disease diagnosis, a BMI ≥ 30 kg/m^2 and meet 'aerobic PA only', and less likely to report a diagnosis depression and/or anxiety and meet 'neither aerobic PA nor RT'. There were no differences by employment status; sitting-time; or sleep quality, duration or latency.

3.1. Aerobic physical activity and resistance training

Of the study sample (n = 5180), 42.8% (n = 4129) met 'neither aerobic PA nor RT', 30.7% (n = 1590) met the 'aerobic PA only', 7.7% (n = 401) met the 'RT only', and 18.8% (n = 974) met 'aerobic PA + RT recommendation'. Fig. 1 shows the distribution of PA groups by mental health symptom groups. A comparison of total MET-minutes and the specific intensities and activity domains that characterized PA groups are described in Table 2. Notably, the 'aerobic PA + RT recommendation' group reported higher total MET-minutes, higher leisure domain MET-minutes for all intensity levels, and higher total vigorous MET-minutes than the 'aerobic PA only' group. The 'aerobic PA only' group had higher total moderate MET-minutes that the 'aerobic PA + RT recommendation' group from higher work, transport, house and yard chores MET-minutes. The 'aerobic PA + RT' group had more days of RT than the 'RT only' group.

3.2. Aerobic physical activity, resistance training and mental health symptoms

The probability of depression only and co-occurring depression and anxiety was lower for those meeting 'aerobic PA only' (ARRR = 0.74, 95%CI: 0.56–0.97 and 0.76, 95%CI: 0.59–0.97 respectively) and 'aerobic PA + RT' (ARRR = 0.61, 95%CI 0.43–0.86 and 0.47, 95%CI: 0.33–0.67 respectively), relative to the 'neither aerobic PA nor RT' group (Table 3, Model B). The magnitude of association was greater for 'aerobic PA + RT' than for 'aerobic PA only'. Adjusting for the presence of chronic disease, BMI and prior diagnosis of depression and anxiety attenuated the association between 'aerobic PA only' and depression (ARRR = 1.00, 95%CI 0.75–1.33) and co-occurring depression and anxiety (ARRR = 0.87, 95%CI 0.67–1.13) (Table 3, Model C or full results including covariates in Supplemental Table 2). Meeting 'RT only' was not associated with a change in the relative risk of depression and/or anxiety, and there were no associations between meeting activity recommendations and anxiety. In analysis with ≥600 MET minutes as the cut-off for meeting the aerobic PA recommendation, the association between 'aerobic PA only' and depression was attenuated, while all other associations remained (Supplemental Table 3).

4. Discussion

In this study of adult women, we found an association between meeting 'aerobic PA only' or 'aerobic PA + RT' and depression and co-occurring depression and anxiety. There was evidence that meeting both recommendations had a stronger association with lowered risk of symptoms of depression than only meeting the aerobic PA recommendation. This suggests a synergistic relationship between aerobic PA and RT in terms of mental health benefits, and is consistent with a recent study (Bennie et al., 2019). It also aligns with research examining the relationship between aerobic PA, RT and physical health outcomes (Grontved et al., 2014; Grontved et al., 2012; Hardee et al., 2014; Stamatakis et al., 2018; Bakker et al., 2017; Bakker et al., 2018; Colcombe and Kramer, 2003).

The stronger association observed for those meeting 'aerobic PA + RT' than for those meeting the 'aerobic PA only' may also simply reflect that more overall PA is better, which may also explain why the sensitivity analysis showed that 'aerobic PA only' was no longer associated with lower relative risk of depression when using a lower cut-off for meeting aerobic PA recommendations. Those meeting 'aerobic

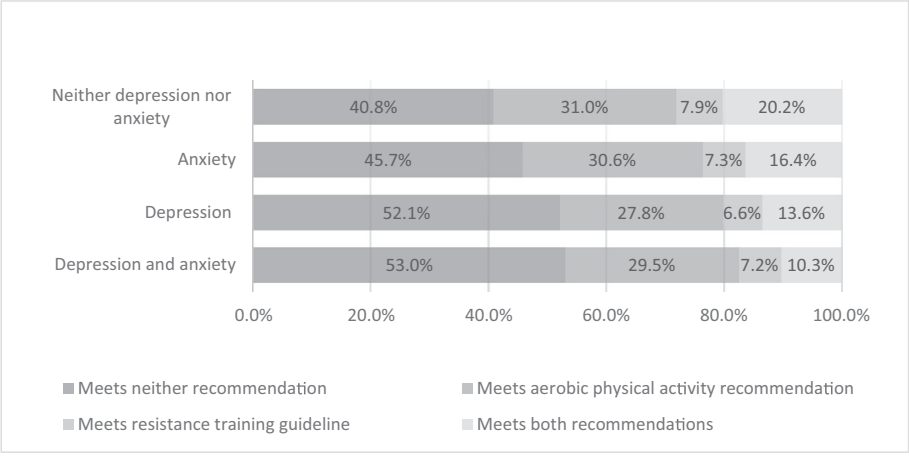

Fig. 1. Percentage meeting physical activity recommendations for women (n = 5180) who responded to the Australian 10,000 Steps Project 2016 survey by symptoms of neither depression nor anxiety (n = 4129), anxiety only (n = 317), depression only (n = 317) and both depression and anxiety (n = 417).

Table 2
Intensity and domain-specific aerobic activity by group for women who responded to the Australian 10,000 Steps Project 2016 survey (n = 5180).

	Activity recommendations met			
	Neither recommendation	Aerobic physical activity only	Resistance training only	Aerobic physical activity and resistance training
Sample size (%)	2215 (42.8)	1590 (30.7)	401 (7.7)	974 (18.8)
Total MET-minutes	1474 ± 819	6331 ± 4075	1899 ± 695	6791 ± 4830
Walking activity MET-minutes				
Work	109 ± 239	777 ± 1110	81 ± 187	589 ± 993
Transport	155 ± 250	376 ± 600	159 ± 223	352 ± 558
Leisure	318 ± 358	674 ± 664	428 ± 362	773 ± 719
Total walking MET	567 ± 488	1726 ± 1410	655 ± 439	1627 ± 1444
Moderate activity MET-minutes				
Work	50 ± 150	528 ± 996	44 ± 145	414 ± 910
Transport (cycling)	22 ± 144	104 ± 480	23 ± 123	75 ± 435
House/yard	240 ± 280	945 ± 1025	228 ± 231	736 ± 939
House chores	224 ± 266	766 ± 824	217 ± 237	627 ± 757
Leisure	57 ± 153	235 ± 457	166 ± 279	445 ± 596
Total moderate MET	725 ± 609	3261 ± 2620	784 ± 531	2871 ± 2768
Vigorous activity MET-minutes				
Work	61 ± 190	825 ± 1702	43 ± 128	692 ± 1554
House/yard	139 ± 283	752 ± 1154	113 ± 221	636 ± 1035
Leisure	132 ± 293	626 ± 479	423 ± 479	1704 ± 1459
Total vigorous MET	183 ± 332	1344 ± 1889	460 ± 481	2292 ± 2165
Resistance training				
Days per week	1.1 ± 0.3	1.2 ± 0.4	3.8 ± 1.1	4.1 ± 1.3
Sitting-time (%)				
≥8 h/day	78.1	61.9	72.1	60.4

Values are mean ± SD unless otherwise noted.

Table 3
Multinomial regression analysis for associations between depression and/or anxiety and meeting physical activity recommendations for women who responded to the Australian 10,000 Steps Project 2016 survey (n = 5180).

Recommendations met	n (%)	Model A[a] RRR (95%CI)	Model B[b] ARRR[a] (95%CI)	Model C[c] ARRR[a] (95%CI)
	Neither depression (DASS < 14) nor anxiety (DASS < 10) (n = 4129)			
Meets neither activity recommendation	1684 (40.8)	Referent group		
Aerobic physical activity only	1282 (31.1)			
Resistance training only	327 (7.9)			
Aerobic physical activity and resistance training	836 (20.3)			
	Anxiety (DASS≥10 points) (n = 317)			
Meets neither activity recommendation	145 (45.7)	1	1	1
Aerobic physical activity only	97 (30.6)	0.88 (0.67–1.15)	0.91 (0.69–1.21)	1.00 (0.75–1.33)
Resistance training only	23 (7.3)	0.82 (0.52–1.29)	0.89 (0.56–1.41)	0.95 (0.59–1.52)
Aerobic physical activity and resistance training	52 (16.4)	0.72 (0.52–1.00)	0.79 (0.57–1.11)	0.89 (0.64–1.27)
	Depression (DASS≥14) (n = 317)			
Meets neither activity recommendation	165 (52.1)	1	1	1
Aerobic physical activity only	88 (27.8)	0.70 (0.54–0.92)	0.74 (0.56–0.97)	0.78 (0.59–1.04)
Resistance training only	21 (6.6)	0.67 (0.41–1.05)	0.69 (0.43–1.12)	0.71 (0.43–1.14)
Aerobic physical activity and resistance training	43 (13.6)	0.52 (0.37–0.74)	0.61 (0.43–0.86)	0.66 (0.46–0.95)
	Depression (DASS≥14) & anxiety (DASS≥10) (n = 417)			
Meets neither activity recommendation	221 (53.0)	1	1	1
Aerobic physical activity only	123 (29.5)	0.73 (0.58–0.92)	0.76 (0.59–0.97)	0.87 (0.67–1.13)
Resistance training only	30 (7.2)	0.70 (0.47–1.04)	0.78 (0.51–1.18)	0.83 (0.54–1.30)
Aerobic physical activity and resistance training	43 (10.3)	0.39 (0.28–0.55)	0.47 (0.33–0.67)	0.55 (0.39–0.80)

[a] Model A: unadjusted relative risk ratio.
[b] Model B: adjusted relative risk ratio: age, smoking, alcohol use, household income, education level, employment, sitting-time, sleep quality, sleep duration, sleep latency.
[c] Model C: adjusted for Model B + chronic disease diagnosis.

PA + RT' recommendations reported higher total MET-minutes than the 'aerobic PA only' group (6791 [4830] vs. 6331 [4075] MET-minutes respectively) in addition to meeting the RT recommendation (Table 2). However, other studies have not observed a dose-response relationship between aerobic PA and RT participation and depressive symptoms (Bennie et al., 2019; McDowell et al., 2018). Several other factors may also contribute to our finding. Those meeting 'aerobic PA + RT' also participated in substantially more vigorous activity than those meeting the 'aerobic PA only' (2292 [2165] vs. 1344 [1889] MET-minutes respectively). Vigorous PA may be more beneficial to mental health than low or moderate intensity PA through different physiological effects, but further research is needed (Teychenne et al., 2008; Lubans et al., 2016). Previous studies have also shown that differences in mental health by activity domain. One study indicated that while leisure activity and transport activity had a positive association with better mental health, work-related PA was associated with worse mental

health (White et al., 2017). Another study demonstrated that summing leisure and transport activity with house and garden activity attenuated the positive association between leisure and transport activity and mental well-being (Peeters et al., 2014). In the current study, those meeting 'aerobic PA + RT' also participated in more leisure activities, whereas those meeting the 'aerobic PA only' reported more work, household and garden activity (Table 2). Activity domain may therefore influence associations with depression and anxiety and warrants further investigation.

Both aerobic PA and RT have been shown to independently benefit mental health via anti-depressive and anxiolytic effects (Rebar et al., 2015; Schuch et al., 2018; Mammen and Faulkner, 2013; Stubbs et al., 2017; Bennie et al., 2019), however an association between 'RT only' and depression or anxiety was not identified in the current study. Interestingly, for women meeting 'RT only' has been shown to be associated with lower prevalence of depressive symptoms in those with the most severe symptoms of depression, not in those with mild or moderate symptoms (Bennie et al., 2019). The lack of an association between 'RT only' and depression in the current study could therefore be from combining moderate and severe symptoms. However, the proportion of the sample who were categorized as 'RT only' was only 7.7% (n = 401), overall, limiting the statistical power available, as evidenced by wider confidence intervals around the point estimates for the 'RT only' group compared to the other groups (Table 3). Furthermore, the specific mechanisms that produce anti-depressive and anxiolytic effects are poorly understood, especially for RT, but may include both psychological, neurobiological and behavioral mechanisms (Lubans et al., 2016). The volume (load, length and intensity of sessions, duration of intervention) of RT necessary to elicit these effects is unclear (Gordon et al., 2018a; Gordon et al., 2017; O'Connor et al., 2010).

We did not find an association between meeting one or both PA recommendations and relative risk of anxiety symptoms (Table 2). This is in contrast to other studies that have found that while the positive effects of PA are smaller for symptoms of anxiety than depression, they still exist (Gordon et al., 2017; Rebar et al., 2015). A possible explanation for this lack of association in the current study may be differences in severity of anxiety symptoms (Table 1). On average, the anxiety only group had 'moderate' symptoms of anxiety (score: 10–14) whereas the co-occurring depression and anxiety group had 'severe' anxiety symptoms (score: 15–19). Evidence suggests the anti-depressive effect of aerobic PA and RT is greater in more severely depressed populations (Gordon et al., 2018a; Rebar et al., 2015), but whether or not there is a floor effect for the anxiolytic benefit has not been explored to the same extent. While a favorable effect of aerobic PA and RT on mental health has been shown in both non-clinical populations (Gordon et al., 2017; Wipfli et al., 2008) and participants with generalized anxiety disorder (Herring et al., 2011), further research is needed to explore the effect in populations with subclinical symptoms (Gordon et al., 2017) and those with co-occurring depression and anxiety (Kircanski et al., 2017).

4.1. Strengths and limitations

The study included a relatively large sample of women where the proportion of participants meeting neither or both guidelines was similar to that reported in large Australian (Bennie et al., 2016) and US (Bennie et al., 2019) samples, and the mean DASS depression and anxiety subscale scores is similar to normative values (Henry and Crawford, 2005). Study strengths also include a focus anxiety and depression and their co-occurrence, and inclusion of a range of key covariates. The inclusion of sleep is a particular strength due to its strong association with mental health (Franzen and Buysse, 2008). Adjusting for chronic disease, BMI and a prior diagnosis of depression and/or anxiety attenuated the association between meeting 'aerobic PA only' and depression and co-occurring depression and anxiety, though this could be due to over-adjusting. However adjustments did not appreciably alter the association between meeting 'aerobic PA + RT' and depression or co-occurring depression and anxiety.

The study included primarily middle-aged Australian women with an income above AUD$70,000, and findings may not be representative of the wider female population, or generalizable to men. Furthermore, the IPAQ does not differentiate between arobic PA and RT, and some participants may have included RT activities in the IPAQ reporting and also when reporting RT. This may have underestimated the effect of aerobic activity. Participants were also part of a community-wide physical activity promotion program (Brown et al., 2006). This may confound the prevalence of individuals meeting the aerobic PA guidelines, though the prevalence rate was similar to that previously reported in an Australian population (Bennie et al., 2016) (52.6% vs 49.5% in the current study).

The referent group labelled 'neither depression nor anxiety' included participants with mild symptoms of depression and anxiety, and those with moderate and severe symptoms were combined as 'symptoms of depression and/or anxiety'. This grouping could potentially underestimate the association between mental health symptoms and PA (Rebar et al., 2015; Bennie et al., 2019). The DASS-21 assesses symptoms experienced in the last week, so they may be transient in nature as opposed to chronic, and not necessarily be associated with activity participation. Exploring associations between meeting PA recommendations and diagnosed depression and anxiety is an important next step.

5. Conclusion

Meeting recommendations for aerobic PA, or both aerobic PA and RT, was associated with a reduced risk of reporting symptoms of depression and co-occurring symptoms of depression and anxiety in women. The magnitude of association was stronger for those meeting both recommendations, indicating the potential added benefit of engaging in both types of PA. However, it remains unclear whether there is something unique about RT in particular, or whether additional PA of any kind would produce similar benefits. Prospective analyses of these cross-sectional relationships are needed. Clarifying the dose-response relationship between activity types, symptoms of depression and anxiety and their co-occurrence will also improve understanding of the application of PA to prevent and manage symptoms of depression and anxiety.

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Declaration of competing interest

The authors do not have any conflicts of interest to declare.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ypmed.2019.105773.

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