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Associations of self-reported physical activity and anxiety symptoms and status among 7,874 Irish adults across harmonised datasets: a DEDIPAC-study

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Abstract

Background: Anxiety is an adaptive response to an objective or perceived threat; however, when symptoms become severe and chronic it that can become a maladaptive anxiety disorder. Limited evidence suggests that physical activity may be associated with prevention against anxiety. This study uses data from The Irish Longitudinal Study on Ageing (TILDA) and The Mitchelstown Cohort Study to investigate cross-sectional associations between physical activity and anxiety symptoms and status among Irish adults.

Methods: Both datasets were harmonized ($n = 7874$). The short form International Physical Activity Questionnaire measured physical activity. Participants were classified as meeting World Health Organization physical activity guidelines (≥150 min weekly of moderate intensity physical activity, ≥75 min weekly of vigorous intensity physical activity, or ≥ 600 MET-minutes) or not. They were also divided into three groups based on weekly MET-minutes of moderate-to-vigorous physical activity (Low: 0–599; Moderate: 600–1199; High: ≥1200), and three groups based on weekly minutes of walking (Low: 0–209; Moderate: 210–419; High: 420+). Anxiety symptoms were measured by the Hospital Anxiety and Depression Scale with a score of ≥8 indicating anxiety. Binomial logistic regression, adjusted for relevant confounders examined physical activity–anxiety associations.

Results: Females had higher rates of anxiety than males (28.0% vs 20.0%; $p < 0.001$). Following adjustment for relevant covariates, meeting physical activity guidelines was associated with 13.5% (95% CI: 2.0–23.7; $p = 0.023$) lower odds of anxiety. Moderate and High physical activity were associated with 13.5% (− 11.0–32.6; $p = 0.254$) and 13.6% (1.4–4.2; $p = 0.030$) lower odds of anxiety compared to Low physical activity, respectively. Moderate and High walking were associated with 2.1% (− 14.5–16.3; $p = 0.789$) and 5.1% (− 9.3–17.6; $p = 0.467$) lower odds of anxiety compared to Low walking, respectively.

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Conclusion: Meeting physical activity guidelines is associated with lower odds of anxiety, but the strength of associations did not increase considerably with increased physical activity levels.

Keywords: Physical activity, Mental health, Elderly, Ireland, Cross-sectional

Introduction

Anxiety is an adaptive response to an objective or perceived threat; however, when symptoms become severe and chronic it can develop into a maladaptive anxiety disorder [1]. As the most prevalent class of mental disorders [2], anxiety disorders can have a substantial personal and economic cost [3]. They are the sixth leading cause of years lived with disability [2], and are more disabling than many medical conditions, including arthritis, asthma, back/neck pain, and cancer, predominantly within social life and personal relationship domains [4]. Anxiety symptoms and disorders are also associated with cardiovascular disease and associated premature mortality and various other comorbid medical conditions [5, 6]. Due largely to increased disability, anxiety disorders also have a large economic burden [7]; in 2010 they had an estimated cost of over €74 billion in Europe [3]. Although the economic burden is lower compared to €126 billion for cancer in 2009 [8] and €111 billion for cardiovascular disease in 2015 [9], this still represents a substantial burden. Moreover, it is plausible that this burden is even greater in Ireland given its economic difficulties in 2007 and the large body of literature demonstrating a possible association between economic recession and mental health [10].

Among individuals with anxiety, numbers seeking care can be low [11], as anxiety is can be interpreted as a normal, healthy response to adversity [12]. Among those who do seek treatment, common frontline treatments include serotonin reuptake inhibitors [13] which can be expensive and have negative side-effects [14] and cognitive behavioural therapy [15] which is only moderately effective [16]. Thus, there is continued interest in investigating potential cost-effective and accessible prevention, self-management, and treatment strategies for anxiety symptoms and disorders.

One strategy may be physical activity. Randomised controlled trials have demonstrated the benefits of exercise, a sub-category of physical activity performed to improve physical fitness, for anxiety symptoms [17, 18], generalized anxiety disorder (GAD) [19], obsessive-compulsive disorder [20], and panic disorder [21], and among a diverse range of populations. Moreover, the available evidence supports the biological plausibility of physical activity effects on anxiety. For example, there is growing evidence that exercise can improve hippocampal functioning [22] and volume [23], potentially improving decreased hippocampal volumes displayed by people with GAD [24] and social phobia [25]. Additionally, inflammation and nitrogen and oxidative stress may be important factors in the development of anxiety disorders as they can subsequently alter neuroplasticity, neurogenesis, and neurotrophins, while these same pathways are influenced by physical activity [26]. Despite this, few epidemiological studies have examined physical activity associations with anxiety relative to other mental health disorders such as depression [27]. Some evidence exists supporting cross-sectional, inverse association of physical activity with anxiety symptoms [28] and disorders [29]. The World Health Organization (WHO) recommends engaging in ≥150 min of weekly moderate intensity physical activity, ≥75 min weekly of vigorous intensity physical activity, or an equivalent combination of weekly physical activity for health benefits [30]; however, epidemiological studies examining associations of meeting the physical activity guidelines with anxiety are sparse [31–35]. Further, the WHO recommends doubling this dose (i.e., ≥300 min of moderate, ≥150 min of vigorous, or an equivalent combination) for additional health benefits. Given the worldwide promotion of the benefits of meeting these guidelines, it is important to clarify their association with anxiety symptoms and status. Furthermore, walking is an accessible behaviour for all ages and sexes that is known to confer many physical health benefits; however, just one longitudinal [36] and few cross-sectional [37] studies have examined associations of walking with anxiety.

Conducting large-scale research projects can have a substantial cost (e.g., both financial and time), so the utilisation of existing data by data sharing, dataset pooling, and harmonisation of relevant variables may be extremely beneficial [38–40]. Benefits include improving the cost-effectiveness of research and increasing the possibility for analyses on subsamples and statistical power [41, 42]. Thus, the current study harmonised two existing datasets to examine cross-sectional associations of walking and moderate-to-vigorous physical activity with anxiety symptoms and status. The authors hypothesised that anxiety would be inversely associated with physical activity and walking and that stronger associations would be observed with increased doses of walking and physical activity.

Methods

This study adhered to Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [43].

Participating studies

The selection of participating studies has been described elsewhere [44]. Briefly, the platform for the current research was the DEterminants of DIet and Physical ACtivity Knowledge Hub (DEDIPAC-KH) [45, 46]. Within DEDIPAC, accessible cross-sectional datasets with relevant data on physical activity and anxiety were identified in a large compendium for harmonisation [47]. Two datasets, The Irish Longitudinal Study on Ageing (TILDA) and The Mitchelstown Cohort Study were harmonised for the present study.

The Irish Longitudinal Study on Ageing (TILDA) is a study of 8175 community-dwelling adults aged ≥50 years and their partners of any age, living in the Republic of Ireland [48]. For the current study, Wave One (2009–2011) data were used. Data for 1804 participants aged 55–74 year from the second phase of the Cork and Kerry Diabetes and Heart Disease (2010) Study were provided by the Mitchelstown Cohort Study [49]. This study was designed to provide a profile of glucose tolerance status, cardiovascular health, and their related factors in an Irish adult general population sample. A six-person expert consensus group agreed appropriate variable harmonisation methods for physical activity, anxiety, participant age, sex, body mass index (BMI), smoking status, marital status, and education.

Physical activity

The short-form International Physical Activity Questionnaire (IPAQ-SF) measured physical activity [50, 51]. Participants reported the number of days and duration of vigorous intensity, moderate intensity, and walking activities undertaken during the previous 7 days and were classified according to whether or not they met WHO physical activity guidelines [30]. Based on weekly metabolic equivalent,minutes (MET-mins) of moderate and vigorous physical activity, participants were divided into Low (0–599 MET·mins), Moderate (600–1199 MET·mins), and High (≥1200 MET·mins) dose categories [30]. Additionally, respondents were categorized as Low walkers if they reported walking < 210 min·week^{-1} (i.e., < 30 min·day^{-1}), Moderate walkers if they reported walking 210–419 min·week^{-1} (i.e., 30–59 min·day^{-1}), and High walkers if they walked ≥420 min·week^{-1} (i.e., ≥60 min·day^{-1}).

Anxiety

Anxiety was assessed by the Hospital Anxiety and Depression Scale anxiety subscale (HADS-A) [52] which has been validated in a random sample of adults aged ≥66 years in the Netherlands (Cronbach's α = 0.82) [53]. Probable anxiety was indicated by scores ≥8. This cut-off has been demonstrated to have good specificity and sensitivity [54].

Covariates

Covariates were selected based on known associations with physical activity or anxiety [34, 45, 55–57]. These included age (50–59, 60–69, 70–79, and 80+ years), sex (male or female), and BMI categorized as using established WHO thresholds (i.e., underweight: < 18.5 kg.m^{-2}; normal weight: 18.5–24.99 kg.m^{-2}; overweight: 25–29.99 kg.m^{-2}; obese: ≥30 kg.m^{-2}) [58]. Smoking status (never, former, or current smoker), marital status (married/living with a partner as if married, never married, separated, divorced, or widowed), and highest level of education achieved (none/primary, secondary level, third level or higher) were also assessed.

Analyses

Similar to previous analyses [44] Chi-square tests examined differences between datasets in proportions of probable anxiety status, age categories, sex, BMI categories, smoking status, education, marital status, and physical activity. To determine the source of statistically significant Chi-square tests *Z* tests were calculated for column proportions for each row in the Chi-square contingency table and Bonferroni adjusted [59]. Binomial logistic regression quantified crude and adjusted associations (i.e., odds ratios (ORs) and 95% confidence intervals (95%CIs)) between physical activity and anxiety, within each dataset. Covariates in adjusted models were age, sex, BMI, smoking status, education, and, marital status.

Within the integrated dataset, Chi-square tests examined differences in elevated anxiety symptom status, ten-year age categories, sex, BMI categories, smoking status, education, and marital status between individuals meeting and not meeting physical activity guidelines. To determine the source of statistically significant Chi-square tests *Z* tests were calculated for column proportions for each row in the Chi-square contingency table and Bonferroni adjusted [59]. Binomial logistic regression quantified crude and adjusted associations between physical activity and anxiety. Covariates in adjusted models were age, sex, BMI, smoking status, education, marital status, and dataset. Likelihood ratio tests examined covariate significance in total population analyses in the integrated dataset. Additionally, a separate test of the model was run including the interaction between physical activity and sex. Differences in continuous anxiety symptoms between those meeting and not meeting physical activity guidelines, physical activity dose groups, and sexes were quantified by one-way ANOVAs followed by Bonferroni-corrected *post-hoc* tests. The magnitude of differences in anxiety symptom scores between meeting physical activity guidelines, physical activity dose categories, and sexes were quantified by Hedges' *g* effect sizes and associated 95%CIs [60]. Effect sizes of 0.2, 0.5, and 0.8 were considered small, medium, and large, respectively [61].

Results

Dataset characteristics

Harmonised data characteristics are presented in Table 1. Results from Chi-square tests and follow-up Z tests are shown in Table 2.

Participant characteristics

A total of 7874 and 6059 respondents were included in crude and adjusted analyses, respectively. Participant characteristics by anxiety status in the integrated dataset are presented in Table 2. The overall prevalence of

Table 1 Study characteristics

	TILDA (n (%))	Mitchelstown (n (%))	*P*-value
Age (years)			
< 50	267 (4.2)$_a$	2 (0.1)$_b$	**< 0.001**
50–59	2571 (40.4)$_a$	852 (56.9)$_b$	
60–69	1995 (31.3)$_a$	621 (41.5)$_b$	
70–79	1162 (18.2)$_a$	23 (1.5)$_b$	
80+	374 (5.9)$_a$	0 (0.0)$_b$	
Sex			
Male	2779 (43.6)$_a$	720 (48.1)$_b$	**0.002**
Female	3597 (56.4)$_a$	778 (51.9)$_b$	
Body Mass Index			
Underweight	26 (0.5)	6 (0.4)	0.281
Normal	1131 (22.5)	354 (23.7)	
Overweight	2166 (43.1)	667 (44.6)	
Obese	1700 (33.8)	468 (31.3)	
Education			
Primary	1611 (26.9)$_a$	351 (24.7)$_a$	**0.002**
Secondary	2669 (44.6)$_a$	706 (49.8)$_b$	
Tertiary	1700 (28.4)$_a$	362 (25.5)$_b$	
Marital status			
Married/ living with a partner as if married	4676 (73.3)$_a$	1180 (78.9)$_b$	**< 0.001**
Single (never married)	541 (8.5)$_a$	129 (8.6)$_a$	
Separated	250 (3.9)$_a$	64 (4.3)$_a$	
Divorced	145 (2.3)$_a$	33 (2.2)$_a$	
Widowed	764 (12.0)$_a$	89 (6.0)$_b$	
Smoker			
Never	2820 (44.2)$_a$	726 (49.8)$_b$	**< 0.001**
Past	2457 (38.5)$_a$	517 (35.4)$_b$	
Current	1099 (17.2)$_a$	216 (14.8)$_b$	
Meeting PA Guidelines			
Yes	3057 (47.9)$_a$	460 (30.7)$_b$	**< 0.001**
No	3319 (52.1)$_a$	1038 (69.3)$_b$	
PA Categories			
Low	3319 (52.1)$_a$	1038 (69.3)$_b$	**< 0.001**
Moderate	440 (6.9)$_a$	87 (5.8)$_a$	
High	2617 (41.0)$_a$	373 (24.9)$_b$	
Walking categories			
Low	2839 (44.5)$_a$	914 (61.1)$_b$	**< 0.001**
Moderate	1394 (21.9)$_a$	281 (18.8)$_b$	
High	2143 (33.6)$_a$	301 (20.1)$_b$	

Different subscript letters indicate a subset of each category whose column proportions differ statistically significantly at the 0.05 level

Table 2 Participant characteristics

	HADS-A < 8 (n (%))	HADS-A ≥ 8 (n (%))	*P*-value
Meeting PA Guidelines			
Yes	2696 (45.3)$_a$	802 (42.6)$_b$	**0.038**
No	3252 (54.7)$_a$	1105 (57.4)$_b$	
PA categories			
Low	3252 (54.7)	1105 (57.4)	0.087
Moderate	411 (6.9)	116 (6.0)	
High	2285 (38.4)	705 (36.6)	
Walking categories			
Low	2831 (47.6)	922 (47.9)	0.815
Moderate	1259 (21.2)	416 (21.6)	
High	1857 (31.2)	587 (30.5)	
Age			
< 50	179 (3.0)$_a$	90 (4.7)$_b$	**< 0.001**
50–59	2436 (41.0)$_a$	987 (51.3)$_b$	
60–69	2062 (34.7)$_a$	554 (28.8)$_b$	
70–79	954 (16.1)$_a$	231 (12.0)$_b$	
80+	312 (5.2)$_a$	62 (3.2)$_b$	
Sex			
Male	2798 (47.0)$_a$	701 (36.4)$_b$	**< 0.001**
Female	3150 (53.0)$_a$	1225 (63.6)$_b$	
Body Mass Index			
Underweight	20 (0.5)$_a$	33 (0.7)$_a$	**0.011**
Normal	990 (25.8)$_a$	1160 (24.9)$_a$	
Overweight	1708 (44.4)$_a$	1883 (40.4)$_b$	
Obese	1126 (29.3)$_a$	1580 (33.9)$_b$	
Education			
Primary	1453 (26.1)	509 (27.9)	0.293
Secondary	2555 (45.8)	820 (45.0)	
Tertiary	1567 (28.1)	495 (27.1)	
Marital status			
Married/ living with a partner as if married	4443 (74.7)$_a$	1413 (73.4)$_a$	**0.013**
Single (never married)	509 (8.6)$_a$	161 (8.4)$_a$	
Separated	223 (3.8)$_a$	91 (4.7)$_a$	
Divorced	118 (2.0)$_a$	60 (3.1)$_b$	
Widowed	653 (11.0)$_a$	200 (10.4)$_a$	
Smoker			
Never	2748 (46.5)$_a$	798 (41.5)$_b$	**< 0.001**
Past	2282 (38.6)$_a$	692 (36.0)$_b$	
Current	883 (14.9)$_a$	432 (22.5)$_b$	

Different subscript letters indicate a subset of each category whose column proportions differ statistically significantly at the .05 level

anxiety was 24.5%. Females were more likely to report anxiety (χ^2 (1, $N = 7874$) = 66.76, $p < 0.001$) than males (28.0% vs 20.0%) and reported significantly higher anxiety symptoms (5.93 ± 3.55) than men (5.15 ± 3.24; $F_{(1,7872)} = 101.73$, $p < 0.001$; $g = 0.23$; 95%CI: 0.18 to 0.27). Meeting guidelines (χ^2 (1, $N = 7874$) = 4.29, $p = 0.038$), age (χ^2 (4, $N = 7867$) = 90.89, $p < 0.001$), BMI (χ^2 (3, $N = 6518$) = 11.22, $p = 0.011$), marital status (χ^2 (4, $N =$

7871) = 12.60, $p = 0.013$), and smoking status (χ^2 (2, N = 7835) = 59.61, $p < 0.001$) significantly differed according to anxiety status. Results from follow-up Z tests are shown in Table 1. The proportions of people who met physical activity guidelines (χ^2 (1, $N = 7874$) = 0.91, p = 0.34) and who had anxiety (χ^2 (1, $N = 7874$) = 0.02, p = 0.90) did not differ between those who were included in crude analyses but excluded from adjusted analyses due to missing covariate information.

Integrated dataset analyses

Results for logistic regression models run within each dataset are reported in Table 3. Integrated dataset analyses are reported in Table 3. Following full adjustment, meeting physical activity guidelines was associated with 13.5% (95% CI: 2.0 to 23.7; $p = 0.023$) lower odds of anxiety. Age, sex, education, and smoking status were significant covariates (all $p \leq 0.001$). Compared to those aged less than 50 years, those aged 50–59 (OR = 0.957, 95%CI = 0.703–1.303; $p = 0.782$), 60–69 (0.617, 0.449–0.847; $p = 0.003$), 70–79 (0.470, 0.331–0.667; $p < 0.001$), and 80+ (0.359, 0.222–0.581; $p < 0.001$) were less likely to report anxiety. Compared to females, males (0.672, 0.590–0.795; $p < 0.001$) were less likely to report anxiety. Compared to those only educated to primary level, those educated to secondary (0.780, 0.668–0.910; $p = 0.002$) and tertiary (0.745, 0.628–0.883; $p = 0.001$) level were less likely to report anxiety. Compared to current smokers, past (0.641, 0.541–0.759; $p < 0.001$) and never (0.736, 0.619–0.875; $p < 0.001$) smokers were less likely to report anxiety. A separate test of the model including the interaction between physical activity and sex was run and the interaction was not significant ($p = 0.858$).

Following full adjustment, Moderate and High physical activity levels were associated with 13.5% (95% CI: − 11.0 to 32.6; $p = 0.254$) and 13.6% (95% CI: 1.4 to 24.2; p = 0.030) lower odds of anxiety, respectively. Following full adjustment, Moderate and High walking were associated with 2.1% (95% CI: − 14.5 to 16.3; $p = 0.789$) and 5.1% (95% CI: − 9.3 to 17.6; $p = 0.467$) lower odds of anxiety, respectively.

Anxiety symptoms were significantly lower among people meeting physical activity guidelines (5.48 ± 3.35) than those not meeting the guidelines (5.67 ± 3.51; p = 0.013; $g = 0.06$, 95%CI: 0.01 to 0.10). Anxiety symptoms significantly differed according to physical activity dose ($p = 0.043$). *Post-hoc* tests showed significantly lower anxiety symptoms for High (5.48 ± 3.34) compared to Low (5.67 ± 3.51, $p < 0.001$; $g = 0.06$ 95%CI: 0.01 to 0.10) physical activity. There were no significant differences between High and Moderate (5.43 ± 3.39, $p = 0.756$; g = − 0.01, 95%CI: − 0.11 to 0.08) or Moderate and Low (p = 0.135; $g = 0.07$, 95%CI: − 0.02 to 0.16) physical activity. Anxiety symptoms did not significantly differ according to walking groups ($p = 0.740$).

Discussion

This study examined the association between meeting recommended physical activity levels and anxiety among 7874 Irish adults using secondary analysis of a harmonised dataset comprised of data from TILDA and the Mitchelstown Cohort Study. Prevalence of anxiety was high compared to similar studies [62–64], potentially related to the economic downturn in Ireland in 2007 as data for the current study were collected between 2009 and 2011. Anxiety symptoms were slightly lower among adults meeting recommended physical activity guidelines and, following full adjustment for relevant covariates, meeting recommended physical activity guidelines was significantly associated with 13.5% lower odds of anxiety (HADS≥8) in the harmonized dataset, significantly associated with 19.8% lower odds of anxiety in TILDA, and non-significantly associated with 8.2% lower odds of anxiety in the Mitchelstown Cohort Study. This further highlights physical activity as an important modifiable lifestyle factor associated with anxiety symptoms and disorders along with other lifestyle factors such as sedentary behaviour [65], sleep [66], smoking [67], and alcohol use [68]; however, the magnitude of the current association was weaker than those for these lifestyle factors in previous research. Additionally, the magnitude of the present findings are consistent with cross-sectional associations between meeting recommended levels of physical activity and elevated worry symptoms [34], and smaller than previously found associations with elevated depressive symptoms among Irish adults [44, 69].

Although a dose-response between physical activity and anxiety was not supported in the current study, compared to Low physical activity, High physical activity (i.e., exceeding recommended physical activity levels) was significantly associated with lower anxiety symptoms: 13.6% lower odds of anxiety in the harmonized dataset, and 13.9% lower odds of anxiety in TILDA. The absence of a dose response is consistent with previous associations of physical activity with anxiety symptoms measured with the HADS-A [28, 33]. However, dose-responses have been observed for diagnosed generalized anxiety disorder [34] and any diagnosed anxiety disorder [36, 70], although not consistently [71].

There has been some evidence to support that, compared to physical inactivity, engaging in physical activity levels less than those recommended and increased light intensity physical activity, may convey mental health benefits [28, 37]. One accelerometry-based study demonstrated using isotemporal substitution models that substituting 30 min of light intensity physical activity for 30 min of sedentary time (while holding total wear time

Table 3 Odds ratios (OR) and 95% confidence intervals (CI) derived from binominal logistic regression analyses as indicators of cross-sectional associations between physical activity (PA) and anxiety within sex categories and the total population

	Crude[a] (OR, 95%CI)			Adjusted[b] (OR, 95%CI)		
	Sex		Total Population	Sex		Total Population
	Male	Female		Male	Female	
TILDA						
Meeting PA Guidelines						
No	**1**	**1**	**1**	**1**	**1**	**1**
Yes	0.842 (0.702 to 1.010)	0.951 (0.822 to 1.099)	0.853 (0.762 to 0.954)**	0.778 (0.624 to 0.969)	0.883 (0.742 to 1.050)	0.802 (0.702 to 0.917)**
PA Dose Categories						
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	0.611 (0.399 to 0.934)*	0.841 (0.629 to 1.125)	0.743 (0.586 to 0.943)*	0.590 (0.353 to 0.985)*	0.885 (0.635 to 1.233)	0.775 (0.588 to 1.020)
High	0.874 (0.725 to 1.053)	0.975 (0.836 to 1.137)	0.872 (0.776 to 0.980)*	0.802 (0.640 to 1.003)	0.883 (0.735 to 1.061)	0.807 (0.702 to 0.927)**
Walking						
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	0.977 (0.768 to 1.243)	1.038 (0.864 to 1.247)	1.005 (0.869 to 1.162)	0.891 (0.665 to 1.193)	1.083 (0.873 to 1.345)	0.995 (0.837 to 1.183)
High	0.911 (0.742 to 1.118)	1.036 (0.877 to 1.224)	0.944 (0.830 to 1.073)	0.920 (0.722 to 1.172)	1.003 (0.822 to 1.224)	0.972 (0.834 to 1.133)
Mitchelstown						
Meeting PA Guidelines						
No	**1**	**1**	**1**	**1**	**1**	**1**
Yes	1.007 (0.662 to 1.533)	0.786 (0.504 to 1.227)	0.828 (0.616 to 1.114)	1.069 (0.678 to 1.684)	0.753 (0.466 to 1.216)	0.918 (0.665 to 1.267)
PA Dose Categories						
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	1.452 (0.667 to 3.161)	1.186 (0.568 to 2.477)	1.247 (0.732 to 2.124)	1.859 (0.819 to 4.217)	1.024 (0.449 to 2.336)	1.286 (0.725 to 2.284)
High	0.866 (0.732 to 1.023)	0.668 (0.395 to 1.129)	0.739 (0.531 to 1.029)	0.949 (0.582 to 1.547)	0.672 (0.385 to 1.172)	0.833 (0.582 to 1.191)
Walking						
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	1.690 (1.010 to 2.829)*	0.488 (0.292 to 0.816)**	0.851 (0.595 to 1.215)	1.926 (1.111 to 3.339)*	0.517 (0.301 to 0.888)*	0.924 (0.635 to 1.344)
High	1.047 (0.626 to 1.752)	0.610 (0.363 to 1.027)	0.744 (0.519 to 1.067)	1.136 (0.659 to 1.957)	0.597 (0.338 to 1.054)	0.801 (0.545 to 1.175)
Integrated dataset						
Meeting PA Guidelines						
No	**1**	**1**	**1**	**1**	**1**	**1**
Yes	0.866 (0.732 to 1.023)	0.933 (0.813 to 1.071)	0.850 (0.765 to 0.943)**	0.843 (0.692 to 1.028)	0.871 (0.740 to 1.024)	0.865 (0.763 to 0.980)*
PA Dose Categories						
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	0.721 (0.497 to 1.047)	0.874 (0.666 to 1.146)	0.800 (0.644 to 0.995)*	0.775 (0.503 to 1.194)	0.906 (0.666 to 1.232)	0.865 (0.674 to 1.110)
High	0.886 (0.746 to 1.053)	0.946 (0.817 to 1.096)	0.858 (0.769 to 0.958)**	0.852 (0.696 to 1.044)	0.863 (0.726 to 1.026)	0.864 (0.758 to 0.986)*
Walking						

Table 3 Odds ratios (OR) and 95% confidence intervals (CI) derived from binominal logistic regression analyses as indicators of cross-sectional associations between physical activity (PA) and anxiety within sex categories and the total population *(Continued)*

	Crude[a] (OR, 95%CI)			Adjusted[b] (OR, 95%CI)		
	Sex		Total Population	Sex		Total Population
	Male	Female		Male	Female	
Low	**1**	**1**	**1**	**1**	**1**	**1**
Moderate	1.072 (0.861 to 1.335)	0.938 (0.791 to 1.113)	0.978 (0.855 to 1.119)	1.049 (0.810 to 1.358)	0.957 (0.785 to 1.167)	0.979 (0.837 to 1.145)
High	0.939 (0.776 to 1.135)	0.971 (0.829 to 1.136)	0.916 (0.812 to 1.033)	0.976 (0.783 to 1.216)	0.934 (0.776 to 1.125)	0.949 (0.824 to 1.093)

[a]Adjusted for dataset (TILDA or Mitchelstown Cohort)
[b]Adjusted for age, sex, BMI, education, smoking, marital status, dataset
$^{*}p < 0.05$; $^{**}p < 0.01$

of the accelerometer and other activities constant) was significantly associated with a decrease in anxiety symptoms [72]. However, these findings were not supported in the present analyses of walking where anxiety symptoms and status did not differ across groups. In the Mitchelstown dataset, Moderate amounts of walking we significantly associated with 92.6% higher odds of anxiety among males, and 48.3% lower odds of anxiety among females. However, these results were potentially due to few respondents in the Moderate walking group as they were not replicated in either the TILDA or integrated datasets. The potentially important role of walking has been comparatively better-studied for depression, and somewhat remains understudied for anxiety. Given that the available literature largely supports that any physical activity is better than none, the possibility that even lower levels of moderate or vigorous intensity physical activity, increased light intensity physical activity, and increased walking may protect against anxiety and other mental health problems warrants further investigation.

Covariates that significantly contributed to the primary statistical model included age, sex, education, and smoking status, although they did not have a large influence on the magnitude of the association between physical activity and anxiety. Supporting previous findings, younger age, female sex, lower education, and smoking were significantly associated with increased likelihood of anxiety [73, 74]. From the present analyses, potentially modifiable factors such as physical activity and smoking should be considered when designing interventions, while non-modifiable factors such as age, sex, and education should be considered when identifying individuals who may be at increased risk of anxiety.

Limitations

This study has several limitations. Due to the cross-sectional design, causality cannot be inferred from these results. Indeed, the bidirectional relationship between physical activity and anxiety has been established [63]. Unfortunately, longitudinal data could not be harmonised between the datasets. Secondly, although there are many benefits to dataset harmonisation, some limitations do exist. For example, studies may use different sampling methodologies, while differences between study variables may be difficult to reconcile in the harmonisation process. In the present study, socio-economic status could not be included as a covariate due to differences between the datasets. Finally, although a well-validated and widely used measure of physical activity, the IPAQ-SF has some limitations. For example, it only measures physical activity over the previous seven days, which may expose it to acute fluctuations in chronic physical activity behaviour, while the acute effects of physical activity on anxiety may differ from its chronic effects. Moreover, the validity of self-reported physical activity can be low, especially among low socio-economic populations [75, 76], which may predispose the results to over-reporting [77]; however, misclassification due to over-reporting would underestimate the magnitude of the physical activity-anxiety relationship, as inactive people incorrectly classified as active would be at increased risk of anxiety. Moreover, self-report measures of physical activity may be more appropriate than device measures to assess adherence to the physical activity as the guidelines were predominantly devised based on data using self-reported physical activity. Self-report physical activity measures assess the perceived time spent on physical activities but, unlike device measures, do not account for the actual fragmentation of movement throughout the activity [78]. Nonetheless, future studies would benefit from device measured physical activity which can indicate both activity duration and intensity and a stronger measure of anxiety, such as physician diagnosis. Nonetheless, this study has several notable strengths, including a large, nationally representative sample, examination of WHO physical activity recommendations, walking, and a focus on anxiety symptoms and status.

Conclusions

After adjusting for important covariates, meeting WHO physical activity guidelines was significantly associated

with 13.5% lower odds of anxiety. No apparent dose response relationship between physical activity and anxiety were observed. Additionally, walking was found to be non-significantly associated with anxiety symptoms; however, further investigation of the associations of low intensity physical activity, such as walking, and physical activity doses that do not meet recommendations are required. When considered in the context of the wider literature including prospective cohort studies and randomised controlled trials, the present findings support meeting WHO guidelines to lower odds of anxiety.

Abbreviations

95%CI: 95% confidence intervals; BMI: Body mass index; DEDIPAC-KH: DEterminants of Diet and Physical ACtivity Knowledge Hub; GAD: Generalized anxiety disorder; HADS-A: Hospital Anxiety and Depression Scale – Anxiety subscale; IPAQ-SF: International Physical Activity Questionnaire; MET-mins: Metabolic equivalent,minutes; STROBE: Strengthening the Reporting of Observational Studies in Epidemiology; TILDA: The Irish Longitudinal Study on Ageing; WHO: World Health Organization

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Authors' contributions

CMcD, CMacD, and MH had full access to all data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: CMcD, CMacD, and MH. Acquisition, analysis or interpretation of data: CMcD, CMacD, MH, JL, JB, CD, and JH. Drafting of the manuscript: CMcD, CMacD, MH, AC, LC, CD, AL, and FCML. Critical revision of the manuscript for important intellectual content: All authors. Intellectual content: All authors. Statistical analysis: CMcD and MH. All authors read and approved the final manuscript.

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Availability of data and materials

The TILDA data that support the findings of this study are publicly available in the Irish Social Science Data Archive [http://www.ucd.ie/issda/data/tilda/]. The Mitchelstown data that support the findings of this study are available from Dr. Janas Harrington, University College Cork, Cork, Ireland but restrictions apply to the availability of these data, which were used under license for the current study, and so are not publicly available.

Ethics approval and consent to participate

The data collection procedures used in these original studies were in accordance with the ethical standards of the respective institutional research committees, the 1964 Helsinki Declaration, and its later amendments. Informed consent was obtained from all participants included in the original studies and all data was strictly confidential and anonymous. In the context of this ethical approval, access and permission to utilise the data from the original studies was received from the dataset owners at Trinity College Dublin and University College Cork, Ireland.

Consent for publication

N/A

Competing interests

The authors declare that they have no competing interests.

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