Mental Health

Physical activity and generalized anxiety disorder: results from The Irish Longitudinal Study on Ageing (TILDA)

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Abstract

Background: Generalized anxiety disorder (GAD) is prevalent and costly. Physical activity (PA) may protect against other mental health disorders, including depression, but its protective effect on GAD remains under-studied in the general population and unstudied among older adults. Therefore, the present study examines associations between meeting World Health Organization PA guidelines (i.e. $\geq$150 min of moderate PA, $\geq$75 min of vigorous PA or $\geq$600MET min of moderate and vigorous PA weekly) and the prevalence of probable GAD and incidence of GAD.

Methods: Participants ($n = 3950$; 56.2% female) aged $\geq$50 years completed the short-form International Physical Activity Questionnaire and the abbreviated Penn State Worry Questionnaire at baseline and the Composite International Diagnostic Interview – Short Form to clinically assess GAD 2 years later. Prospective analyses included participants without probable GAD at baseline ($n = 3236$).

Results: Prevalence and incidence of GAD were 18.1% ($n = 714$) and 0.9% ($n = 29$), respectively. More respondents with GAD were female (72.2% vs 52.7%), aged 50–59 years (51.7% vs 38.7%), had normal waist circumference (52.7% vs 47.8) and smoked (20.4% vs 13.3%; all P<0.05). Meeting PA guidelines was associated with 25% and 63% lower odds of prevalent [odds ratio (OR) = 0.75, 95% confidence interval: 0.64 to 0.88] and incident (OR = 0.37, 0.17 to 0.85) GAD, respectively, in crude models, and 17% and 57% lower odds of prevalent (OR = 0.83, 0.70 to 0.98) and incident (OR = 0.43, 0.19 to 0.99) GAD,

respectively, following adjustment for age, sex, waist circumference, social class and smoking.

Conclusions: In addition to established physical health benefits of PA, the present findings support the importance of increasing PA at the population-level for mental health.

Key words: Physical exercise, anxiety, old age

Key Messages

- This is the first population-based study to provide evidence that meeting World Health Organization physical activity guidelines is associated with lower odds of prevalent and incident generalized anxiety disorder among older adults.
- After adjustment for age, sex, waist circumference, social class and smoking, meeting World Health Organization physical activity guidelines reduced the odds of developing generalized anxiety disorder after 2 years by 57% (OR = 0.43, 95% CI: 0.19 to 0.99).
- Baseline smoking, depressive symptoms and female sex were associated with increased odds of incident generalized anxiety disorder.

Introduction

Generalized anxiety disorder (GAD) is characterized by recurrent or persistent excessive worry about every day, routine life events and activities, occurring most days for at least 6 months.[1] Lifetime risk of GAD is estimated to be 9.0%,[2] and the 12-month prevalence of GAD among adults aged ≥66 years is twice that among those aged <66 years (1.7% vs 3.4%).[3] In a given 12-month period it is estimated that GAD affects 8.9 million people in Europe.[3] Given the ageing population in Europe, the number of people with GAD can be expected to increase. GAD is highly comorbid with other psychiatric disorders,[3–5] so precise estimates of its specific personal and social costs are difficult to isolate. Nevertheless, in Germany, the annual cost per person with GAD is estimated to be €1864.[6] In Australia, it is estimated that the total medical care costs for GAD amount to $112.3 million (AUD).[7] GAD comorbid with other psychiatric disorders results in substantially increased severity and economic and personal burden.[4,8]

First-line treatments for GAD include selective serotonin reuptake inhibitors (SSRIs)[9] and psychotherapy.[10] However, SSRIs can have negative side effects, such as increased suicidality and aggression;[11] and availability, cost and extensive specialized training needed among practitioners can limit access to psychotherapy. As an accessible potential therapy with minimal risk of negative side effects, exercise has received significant attention as a treatment for depression,[12] but only one randomized controlled trial has examined exercise training as a treatment for GAD.[13] Among young adult

women with GAD, exercise improved clinical severity,[13] associated signs and symptoms,[14] sleep initiation and continuity[15] and health-related quality of life.[16] Improved symptoms of GAD, including worry, state anxiety and feelings of energy and fatigue, have also recently been reported following an acute bout of aerobic exercise among young adult women with worry scores indicative of probable GAD.[17] Despite evidence of the positive effects of exercise (i.e. planned, structured, repetitive and intentional movement intended to improve or maintain one or more components of fitness), people with anxiety disorders are less likely to engage in regular physical activity (PA; i.e. movement that is carried out by the skeletal muscles which results in energy expenditure) and display decreasing PA levels over time.[18] Additionally, in the National Comorbidity Survey Replication, 47.7% of respondents who fulfilled DSM-IV diagnostic criteria for GAD had not sought treatment in the past 12 months.[19] Although the vast majority of people with GAD eventually make treatment contact, delays are typically around 9 years.[20] Further, just 42.7% of those that sought treatment were classified as receiving at least minimally adequate treatment.[19] Thus, there is a critical need to identify both risk factors for GAD and the healthful behaviours that may attenuate those risk factors, to better inform interventions for prevention and treatment.

PA has myriad benefits among older adults, including reduced risk of mortality[21] and increased healthy ageing.[22] Mental health benefits have also been reported; prospective studies have demonstrated the protective effect of PA,

even at low levels, for depression.[23,24] Comparatively, associations between PA and anxiety have received less attention. Reported associations between PA and anxiety symptoms[25–30] and disorders[18,31,32] have been mixed and largely confined to cross-sectional analyses. The authors are aware of only one longitudinal study that examined associations of PA and incident GAD.[31] In that study, a low GAD incident rate likely precluded detection of statistically significant associations of PA and GAD; however, findings did suggest a protective effect of regular PA against GAD [odds ratio (OR) = 0.51, 95% confidence interval (CI): 0.14 to 1.93) among adolescents and young adults ($n = 2548$, aged 14–24 years). The need for prospective longitudinal studies to confirm or refute these findings and further characterize the association of PA and anxiety disorders has previously been identified.[33]

Evidence for the mental health benefits of meeting World Health Organization (WHO) PA guidelines[34] is sparse and, to the authors' knowledge, no previous study has investigated the longitudinal association between meeting WHO PA guidelines and GAD among older adults. Although the prevalence of GAD is higher among women,[35,36] women more frequently report GAD symptoms shown to be improved by regular PA and exercise,[14,37,38] and the limited available evidence of acute and chronic exercise effects among individuals with clinical or subclinical GAD has supported positive benefits for young women,[13,14,17] sex-related differences in the PA-GAD relationship remain unstudied. The current study aimed to fill these gaps in the literature.

Using two waves of data collected over 2 years from The Irish Longitudinal Study on Ageing (TILDA), the key objectives of the current study were to examine associations between meeting World Health Organization physical activity guidelines and probable GAD at Wave 1 (prevalent GAD; Aim 1) and the likelihood of being diagnosed with GAD at Wave 2 (incident GAD; Aim 2). A secondary objective was to examine potential sex-related differences in the association between physical activity and GAD (Aim 3). An exploratory objective was to examine whether increased protective benefits may be associated with increased volumes of PA (Aim 4).

Methods

This study used STROBE recommendations to guide reporting.[39]

Study population

The Irish Longitudinal Study on Ageing (TILDA) is a large prospective cohort study that assesses the social, economic and health circumstances of community-dwelling adults aged ≥50 years and their partners of any age, living in Ireland. An initial multi-stage probability sample of addresses was chosen by means of the RANSAM sampling procedure,[40] with District Electoral Divisions selected at the first stage and household addresses selected at the second stage. The response rate was 62.0%. Participants gave full informed consent to participate in the study and ethical approval was obtained from the Trinity College Dublin Faculty of Health Sciences Research Ethics Committee.

The present analyses report data from Wave 1 (2009–10)[41] and Wave 2 (2012–13).[42] Respondents ($n = 5818$) with complete short-form International Physical Activity Questionnaire (IPAQ-SF) and abbreviated Penn State Worry Questionnaire (PSWQ-A) data at Wave 1, and Composite International Diagnostic Interview – Short Form (CIDI-SF) data at Wave 2, were included in the present analyses. Respondents ($n = 1868$) were excluded for incomplete covariate data, resulting in a sample size of 3950 for cross-sectional analyses. Participants who reported probable GAD at baseline ($n = 714$) were excluded from longitudinal analyses, resulting in a sample size of 3236.

Physical activity

PA was measured using the IPAQ-SF.[43,44] Respondents reported the number of days and duration of vigorous, moderate and walking activities undertaken during the previous 7 days. Data were summed within each activity category (i.e. vigorous intensity, moderate intensity and walking) to estimate the total number of minutes engaged in PA per week. Respondents who reported walking or moderate-to-vigorous PA (MVPA) greater than a combined 16 h/day were excluded ($n = 7$). The remaining respondents were classified according to whether they met WHO PA guidelines [i.e. ≥150 min weekly of moderate PA or ≥75 min weekly of vigorous PA, or ≥600 metabolic equivalents (MET). min of weekly MVPA].[34] Based on weekly MET.min of MVPA, participants were divided into tertiles, categorized into low (0 to <600 MET. min), moderate (600 to <1200 MET. min) or high (≥1200 MET. min) dose categories,[34] and three categories, low, moderate and high, were determined as recommended [www.ipaq.ki.se].

Generalized anxiety disorder

At Wave 1, symptoms of worry were assessed using the PSWQ-A.[45] In the present sample, the PSWQ-A demonstrated excellent internal consistency (Cronbach's $\alpha = 0.94$). A score of ≥23 defined caseness of probable GAD.[46] This cut-off score has been shown to correctly identify clinical status among older adults, with 75.7%

sensitivity and 92.5% specificity.[47] At Wave 2, the CIDI-SF[48] was used to assess whether respondents fulfilled the Diagnostic and Statistical Manual of Mental Disorders-IV (DSM-IV) criteria for GAD.[1] The CIDI-SF has been shown to correctly classify CIDI cases of GAD, with an accuracy of 99.6%.[48]

Covariates

Covariates of theoretical, practical or previous empirical evidence of association with PA or GAD were included. Age was classified using four categories (i.e. 50–59 years, 60–69 years, 70–79 years and ≥80 years). Waist circumference was classified as low- or increased-risk according to WHO guidelines (i.e. males: >94 cm; females >80 cm).[49,50] Social class was defined according to the European Socioeconomic Classification (ESeC) scheme.[51] The ESeC classifies people into seven categories according to their positions within labour markets and with special attention to their employment relations. In order to improve sample coverage, those who were not in paid employment were allocated to a 'Not Working' group ($n = 1050$). Current smoking status (current vs past/never) was assessed by self-report. Baseline depressive symptoms were assessed using the Center for Epidemiological Studies Depression Scale (CES-D).[52] Reliability coefficients of the CES-D are high (0.85–0.91) among older adults.[53]

Statistical analysis

Statistical analyses were conducted using SPSS Version 22.0 (Armonk, NY: IBM Corp.). The difference in sample characteristics between those with and without probable GAD at baseline was tested by chi-square tests and one-way analysis of variance (ANOVA) for categorical and continuous variables, respectively. For significant chi-square tests, Z tests were calculated for column proportions for each row in the chi-square contingency table and Bonferroni-corrected for multiple comparisons.[54] Supplementary Table 1 (available as Supplementary data at *IJE* online) provides the proportion of people with probable GAD at Waves 1 and 2 by level of PA and significant covariates.

Cross-sectional analyses (Aim 1)

One-way ANOVA tested differences in Wave 1 worry symptoms between those meeting and not meeting PA guidelines. Hedges' g effect sizes and associated 95% confidence intervals (95% CI) were calculated to quantify the magnitude of differences in worry scores.[55] Binomial logistic regression quantified associations (i.e. odds ratios) between meeting PA guidelines and probable GAD at Wave 1 (prevalent GAD). Covariates in adjusted models were: age and sex (Model 1); Model 1 and waist circumference, social class and smoking status (Model 2); and Model 2 and depressive symptoms (Model 3). The Hosmer-Lemeshow test was performed and Nagelkerke R^2 calculated to assess the goodness-of-fit of the model. Likelihood ratio tests examined covariate significance.

Longitudinal analyses (Aim 2)

Binomial logistic regression quantified associations between meeting PA guidelines and GAD at Wave 2 (incident GAD). The Hosmer-Lemeshow test was performed and Nagelkerke R^2 calculated to assess the goodness-of-fit of the model. Likelihood ratio tests examined covariate significance.

Potential sex-related differences (Aim 3)

One-way ANOVA tested differences in Wave 1 worry symptoms between males and females. Hedges' g effect sizes and associated 95% CIs were calculated to quantify the magnitude of differences in worry scores.[55] Two-way ANOVA examined variation in Wave 1 worry symptoms by meeting PA guidelines, sex and their interaction.

Potential dose-response (Aim 4)

One-way ANOVA and Fisher's least significant difference (LSD) test planned contrasts quantified differences in Wave 1 worry symptoms between dose levels. Binomial logistic regression quantified associations between dose levels, tertiles and IPAQ categories, and prevalent probable GAD and incident GAD.

Results

Participant characteristics

Compared with the analytical sample, a greater proportion of excluded respondents (i.e. those with complete Wave 1 IPAQ-SF and PSWQ-A, and Wave 2 CIDI-SF data but missing covariate data) were male (47.7% vs 43.8%), aged 50–59 (46.2 % vs 41.1%) and ≥80 years (6.9% vs 4.8%), and current smokers (20.2% vs 14.5%; all $P < 0.05$). There were no differences in meeting PA guidelines, probable GAD status or waist circumference (all $P > 0.08$).

Wave 1 participant characteristics for the included sample are presented in Table 1. Sex ($P < 0.001$), age ($P < 0.001$), waist circumference ($P = 0.02$), smoking status ($P < 0.001$), social class ($P < 0.001$), depressive symptoms ($P < 0.001$), days per week engaged in moderate PA ($P = 0.021$), days per week engaged in vigorous PA ($P = 0.001$), weekly minutes of vigorous PA ($P < 0.001$), and weekly minutes of MVPA ($P = 0.015$) differed according to probable GAD caseness. Results from follow-up tests

Table 1. Baseline participant characteristics

	No GAD (PSWQ-A < 23; $n = 3236$) n (%)	Probable GAD (PSWQ-A ≥ 23; $n = 714$) n (%)	P-value
PSWQ (8-40) mean (SD)	12.72 (4.26)	28.84 (5.01)	<0.001
Moderate PA (days.wk^{-1}) mean (SD)	2.34 (2.77)	2.07 (2.72)	0.021
Vigorous PA (days.wk^{-1}) mean (SD)	1.03 (1.99)	0.77 (1.70)	0.001
Moderate PA (min.wk^{-1}) mean (SD)	327.18 (564.26)	309.61 (609.82)	0.458
Vigorous (PA min.wk^{-1}) mean (SD)	158.08 (418.03)	98.05 (277.59)	<0.001
MVPA (min.wk^{-1}) mean (SD)	485.26 (781.26)	407.66 (727.50)	0.015
PA Guidelines			
Meeting	1626 (50.2)$_a$	308 (43.1)$_b$	<0.001
Not meeting	1610 (49.8)$_a$	406 (56.9)$_b$	
CES-D (0-60) mean (SD)	4.28 (5.30)	10.90 (9.80)	<0.001
Sex			
Female	1703 (52.6)$_a$	516 (72.3)$_b$	<0.001
Male	1533 (47.4)$_a$	198 (27.7)$_b$	
Age category (years)			
50-59	1252 (38.7)$_a$	370 (51.8)$_b$	<0.001
60-69	1157 (35.8)$_a$	225 (31.5)$_b$	
70-79	658 (20.3)$_a$	99 (13.9)$_b$	
80+	169 (5.2)$_a$	20 (2.8)$_b$	
Waist circumference			
Normal	1550 (47.9)$_a$	376 (52.7)$_b$	0.021
Above normal	1686 (52.1)$_a$	338 (47.3)$_b$	
Social class			
Professional workers	142 (4.4)$_a$	17 (2.4)$_b$	<0.001
Managerial and technical	905 (28.0)$_a$	136 (19.0)$_b$	
Non-manual	501 (15.5)$_a$	110 (15.4)$_a$	
Skilled manual	316 (9.8)$_a$	58 (8.1)$_a$	
Semi-skilled	310 (9.6)$_a$	75 (10.5)$_a$	
Unskilled	89 (2.8)$_a$	21 (2.9)$_a$	
Farmers	212 (6.6)$_a$	22 (3.1)$_b$	
Not working	761 (23.5)$_a$	275 (38.5)$_b$	
Smoker			
Current	431 (13.3)$_a$	143 (20.0)$_b$	<0.001
Past/never	2805 (86.7)$_a$	571 (80.0)$_b$	

Each similar subscript letter denotes a subset of each category whose column proportions do not differ significantly from each other at the $P \leq 0.05$ level. Different subscript letters indicate statistically significant differences at the $P \leq 0.05$ level.

CES-D, Center for Epidemiologic Studies Depression Scale; hrs, hours; MVPA, moderate-to-vigorous physical activity; PSWQ, Penn State Worry Questionnaire; wk, week.

are shown in Table 1. Briefly, a greater proportion of respondents with probable GAD were female (72.2% vs 52.7%), aged 50–59 years (51.7% vs 38.7%), had a normal waist circumference (52.7% vs 47.8%) and were smokers (20.4% vs 13.3%; all $P < 0.05$). Depressive symptoms were higher among respondents with probable GAD ($F_{(1,3949)} = 15.87$, $P < 0.001$; $g = 1.04$, 95% CI: 0.96 to 1.13). This is equivalent to a 6.62 (95% CI: 6.08 to 7.15) point difference on the CES-D.

Cross-sectional results (Aim 1)

Worry symptoms were higher among people not meeting MVPA guidelines than among those meeting PA guidelines ($F_{(1,3949)} = 16.45$, $Pp < 0.001$; $g = 0.13$, 95% CI: 0.07 to 0.19). This is equivalent to a 0.98 (95% CI: 0.51 to 1.45) point change on the PSWQ-A.

Prevalence of probable GAD was 18.1% ($n = 714$). Table 2 presents ORs for the associations between meeting PA guidelines and probable GAD. Model 2 and 3 results are reported here. Meeting the guidelines was associated with 17.1% (OR = 0.83, 0.70 to 0.98; $P = 0.032$) and 7.0% (OR = 0.93, 0.77 to 1.12; $P = 0.435$) lower odds of probable GAD in Model 2 [$\chi^2(8) = 3.45$, $P = 0.90$; $R^2 = 0.08$] and Model 3 [$\chi^2(8) = 10.94$, $P = 0.21$; $R^2 = 0.22$], respectively. Age [$\chi^2(3) = 26.72$], sex [$\chi^2(1) = 16.64$] and depressive symptoms [$\chi^2(1) = 356.94$] were significant covariates (all $P < 0.001$).

Table 2. Odds ratios (OR) and 95% confidence intervals (CI) derived from binominal logistic regression analyses as indicators of association between physical activity (PA) and generalized anxiety disorder (GAD)

	Prevalent GAD Wave 1					Incident GAD Wave 2				
	Cases/persons at risk	Crude OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)	Cases/persons at risk	Crude OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)	Model 3 OR (95% CI)
PA										
Not meeting guidelines	406/2016	REF	REF	REF	REF	21/1610	REF	REF	REF	REF
Meeting guidelines	308/1934	0.75 (0.64 to 0.88)***	0.79 (0.66 to 0.93)**	0.83 (0.70 to 0.98)*	0.93 (0.77 to 1.12)	8/1626	0.37 (0.17 to 0.85)*	0.43 (0.19 to 0.98)*	0.43 (0.19 to 0.99)*	0.46 (0.20 to 1.08)
MET. min										
Low (0–599)	406/2016	REF	REF	REF	REF	21/1610	REF	REF	REF	REF
Moderate (600–1199)	46/271	0.81 (0.58 to 1.13)	0.80 (0.57 to 1.13)	0.87 (0.62 to 1.23)	0.91 (0.63 to 1.31)	2/225	0.68 (0.16 to 2.91)	0.70 (0.16 to 3.01)	0.74 (0.17 to 3.22)	0.76 (0.17 to 3.32)
High (≥1200)	262/1663	0.74 (0.63 to 0.88)***	0.78 (0.66 to 0.94)**	0.82 (0.69 to 0.98)*	0.93 (0.77 to 1.13)	6/1401	0.33 (0.13 to 0.81)*	0.38 (0.15 to 0.95)[§]	0.38 (0.15 to 0.95)[§]	0.41 (0.16 to 1.05)

Model 1 adjusted for, age and sex.

Model 2 adjusted for Model 1 and waist circumference, social class, and smoking.

Model 3 adjusted for Model 2 and depressive symptoms.

REF, reference category.

*$P < 0.05$;   **$P < 0.01$;   ***$P < 0.001$.

Longitudinal results (Aim 2)

Incidence of GAD was 0.9% (n = 29). Table 2 presents crude and adjusted odds ratios for the associations between meeting PA guidelines and GAD. Meeting the guidelines was associated with 56.9% (OR = 0.43, 0.19 to 0.99; P = 0.047) and 53.6% (OR = 0.46, 0.20 to 1.08; P = 0.075) reduced odds of GAD in Model 2 [$\chi^2(8)$ = 4.31, P = 0.83; R^2 = 0.10] and Model 3 [$\chi^2(8)$ = 7.72, P = 0.46; R^2 = 0.16], respectively. Sex [$\chi^2(1)$ = 5.66, P = 0.02], smoking [$\chi^2(1)$ = 6.04, P = 0.01] and depressive symptoms [$\chi^2(1)$ = 18.53, $Pp < 0.001$] were significant covariates.

Potential sex-related differences (Aim 3)

Wave 1 worry symptoms were higher among females (16.87 ± 7.99) than males (14.05 ± 6.78; $F_{(1,3949)}$ = 137.62, $P < 0.001$). The magnitude of difference was small (g = 0.38; 95% CI: 0.31 to 0.44). This is equivalent to a 2.82 (95% CI: 2.35 to 3.29) point change on the PSWQ-A. Females were more likely to report probable GAD at baseline (23.3% vs 11.4%, $P < 0.001$). There was no interaction between meeting guidelines and sex ($F_{(1,3949)}$ = 0.02, $P > 0.88$). The magnitude of difference in worry symptoms between meeting and not meeting guidelines was small among females (g = 0.08, 95% CI: 0.00 to 0.16) and males (g = 0.08, 95% CI: -0.01 to 0.18).

Dose-response results (Aim 4)

Planned contrasts showed lower worry symptoms for the High dose level compared with Low ($P < 0.001$; g = 0.13: 0.07 to 0.20) and Moderate (P = 0.66; g = 0.03:−10 to 0.16) levels, and lower worry symptoms for the Moderate dose level compared with Low level (P = 0.11; g = 0.10: −0.03 to 0.23).

Table 2, and also Supplementary Table 2 (available as Supplementary data at IJE online), present crude and adjusted odds ratios for Aim 4. Model 2 results for Low (0 to <600 MET. min), Moderate (600 to <1200 MET. min) and High (≥1200 MET. min) dose levels are reported here. Compared with the Low dose, the Moderate and High dose levels were associated with 12.6% (OR = 0.87, 0.62 to 1.23; P = 0.44) and 17.9% (OR = 0.82, 0.69 to 0.98; P = 0.032) lower odds of GAD [$\chi^2(8)$ = 4.34, P = 0.83; R^2 = 0.08].

In prospective analyses, compared with the Low dose level, the Moderate or High levels were associated with 25.9% (OR = 0.74, 0.17 to 3.22; Pp = 0.69) or 62.3% (OR = 0.38, 0.15 to 0.95; P = 0.039) reduced odds of GAD [$\chi^2(8)$ = 4.26, P = 0.83; R^2 = 0.11].

Discussion

To the authors' knowledge, this study is the largest to examine associations of PA with incident GAD, the first to do so in an older adult population and the first study to examine potential benefits of meeting WHO PA guidelines for GAD. The primary finding was that, after adjustment for age, sex, waist circumference, social class and smoking, meeting WHO PA guidelines reduced the odds of developing GAD after 2 years by 57% (OR = 0.43, 95% CI: 0.19 to 0.99).

Probable GAD was highly prevalent in the current sample at baseline. The prevalence rate was higher than previous findings of GAD in a sample of older European adults.[3] However, prevalence in the current sample was similar to a previous systematic review of the prevalence of anxiety disorders in community samples.[56] Following adjustment for age, sex, waist circumference, social class and smoking status, meeting PA guidelines was associated with significantly lower odds of prevalent probable GAD and reduced odds of incident GAD. However, similar to the association of regular PA and 12-month prevalence of major depressive disorder (MDD) (OR = 1.03; 95% CI: 0.63 to 1.67) among German adolescents and young adults,[31] a large effect range estimate that encompassed zero association between PA and prevalent GAD was found in the present study after full adjustment. Among the same sample of German adolescents and young adults, regular PA (defined as exercising daily and several times a week) compared with no PA (defined as exercising less than once a month or no exercise at all), was associated with lower 12-month prevalence of GAD (OR = 0.77; 95% CI: 0.30 to 2.01). However, unlike in the German sample, the fully adjusted model in the present study was adjusted for baseline depressive symptoms. GAD and depression are highly comorbid.[57] Indeed, this is illustrated in the present study by the differences between Models 2 and 3 (see Table 2), and an increase of just one point on the CES-D was associated with 12% (OR = 1.12, 1.10 to 1.13) and 10% (OR = 1.10, 1.06 to 1.15) increased odds of prevalent and incident GAD, respectively. However, it is plausible that this is an over-adjustment. It is unknown whether PA affects anxiety differently in older people with or without depressive symptoms, and the number of the present sample were on medication was insufficient to provide robust estimates of odds stratified on medication use.

The magnitude of the longitudinal association of PA and incident GAD reported here is: (i) larger than previously reported associations between PA and incident MDD in Canadian adults[58] and American older adults;[59] (ii) comparable to previous associations of regular PA and incident GAD (OR = 0.51, 95% CI: 0.14 to 1.93) and

any incident anxiety disorder (OR = 0.52, 95% CI: 0.37 to 0.74) among a sample of German adolescents and adults;[31] and (iii) comparable to the association between ≥3 h/week of vigorous PA, compared with <1 h/week of vigorous PA, and any incident ICD-10 anxiety disorder in a sample of rural Australian adults (OR = 0.47, 95% CI: 0.17 to 1.28).[32] Although the sample sizes of these studies were not small (n = 2527 and n = 638, respectively), the substantial variance in observed magnitude of associations suggests that larger samples are likely required to examine significant variation in incident GAD according to PA. However, taken together with previous results, the present findings add to the collective support for a protective effect of approximately 50% for PA on incident anxiety disorders, including GAD.

The current sample somewhat precluded a rigorous examination of potential sex-related differences in the longitudinal association between PA and incident GAD; however, baseline worry symptoms were significantly greater among females (g = 0.38) and, consistent with previous research, females were twice as likely to meet criteria for GAD as males (23.3% vs 11.4%).[35,36] Similarly, in fully adjusted models, females were more likely to report prevalent (OR = 2.06, 1.65 to 2.56) and incident (OR = 3.48, 1.19 to 10.21) GAD. Despite reporting lower baseline worry symptoms compared with females, associations between PA and worry symptoms were similar among males and females. Based on the available literature, similar associations between PA and worry symptoms among males were not anticipated. First of all, women have a higher likelihood of reporting GAD symptoms shown to be improved by regular PA and exercise, including fatigue, irritability, muscle tension and somatic symptoms.[14,37,38] Second, the limited available evidence for acute and chronic exercise effects among individuals with clinical or subclinical GAD supports positive benefits for young women,[13,14,17] but men remain unstudied. The present findings support the need for future investigations that more robustly examine potential sex-related differences in both the association between PA and GAD and the effects of acute and chronic exercise among individuals with GAD.

Additional significant covariates in the present study included age in cross-sectional analyses and smoking in prospective analyses. Given that the prevalence of GAD seems to increase with age, it is counter-intuitive that those aged 50–59 years (vs ≥80 years; OR = 2.12, 1.28 to 3.49) were more likely to report prevalent GAD; however, this is potentially driven by the low number of respondents aged ≥80 years (n = 169). Consistent with previous associations of smoking and GAD,[60] current smokers at baseline were more likely to develop incident GAD (OR = 3.00, 1.04 to 8.17).

Though the examination of plausible mechanisms, mediators or moderators of the association between PA and GAD was not the purpose here and beyond the scope of the current investigation, the available evidence has provided some support for several psychological and biological mechanisms that may underlie positive associations of PA with and positive effects of exercise on GAD. For example, previous evidence supported inverse, indirect associations between PA and symptoms of GAD which were expressed through positive associations with physical self-concept and self-esteem among 1036 young adult women, providing initial evidence that PA may reduce risk of GAD in young women by positively influencing specific and global physical self-concept and self-esteem.[61] Moreover, in addition to evidence that regular PA and exercise training may improve depression and anxiety via changes in neurotransmitters and neurotrophic peptides, available research also suggests that the positive effects of regular PA on anxiety disorders may be underpinned by modulation of inflammatory markers.[62] Given recent evidence from functional magnetic resonance imaging that pathological worry in GAD among older adults competes for the same prefrontal cortex resources that are involved in adaptive regulation of emotion,[63] along with evidence of interrelations between exercise-induced changes in prefrontal oxygenation and mood state responses,[64] the influence of prefrontal cortex activity on relations of PA and exercise with GAD also warrants future investigation.

Strengths and limitations

This is the largest study to date to examine associations of PA and incident GAD, and the first study to do so in an older adult population. The PA measure used allowed examination of important features of PA, including frequency, intensity and duration, so as to more robustly examine the benefits of meeting PA guidelines. However, there were several limitations. First, the use of self-reported PA predisposed the results to over-reporting;[65] however, there is no evidence to suggest that reporting errors should differ according to anxiety status. Second, previous studies have reported sex-related differences in associations of PA and anxiety disorders[66] and there has been interest in a dose-response in the association between PA and anxiety;[67] however, the low incident rate of GAD among males and across different levels of PA precluded the rigorous longitudinal examination of these research questions. Third, the assessment of GAD using different measures at Waves 1 and 2 is not ideal; however; the CIDI-SF was only introduced in Wave 2 of TILDA. Nonetheless, the present findings provide initial support for a protective

association of increased PA with reduced likelihood of GAD among a sample of older adults.

The present findings suggest that meeting WHO PA guidelines reduces the odds of developing GAD by approximately 57% among older adults. Future research should confirm the present findings in other large population samples, as well as more robustly examine the influence of PA and exercise among males with clinical or subclinical GAD. As first onset of GAD generally occurs at a much younger age,[2] younger cohorts may be required to answer further questions about the association between PA and the incidence of GAD.

Practical implications

In addition to the established physical health benefits of meeting the PA guidelines, and in light of recent findings showing that even one hour of PA is associated with reduced risk of depression,[24] the present study offers further support for the mental health benefits of meeting recommended guidelines. Given that approximately 50% of adults aged ≥60 years in Europe are physically inactive,[68] increasing PA at the population level should be considered a priority.

Supplementary Data

Supplementary data are available at *IJE* online.

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