Epidemiology and Psychiatric Sciences (2019), **28**, 436–445. © Cambridge University Press 2018
doi:10.1017/S204579601800001X

ORIGINAL ARTICLE

Associations of physical activity with anxiety symptoms and status: results from The Irish longitudinal study on ageing

C. P. McDowell[1]*, B. R. Gordon[1], K. L. Andrews[1], C. MacDonncha[1,2] and M. P. Herring[1,2]

[1] *Department of Physical Education and Sport Sciences, University of Limerick, Limerick, Ireland*
[2] *Health Research Institute, University of Limerick, Limerick, Ireland*

Aims. Anxiety is debilitating and associated with numerous mental and physical comorbidities. There is a need to identify and investigate low-risk prevention and treatment strategies. Therefore, the purpose of this study was to investigate cross-sectional and longitudinal associations between different volumes of moderate-to-vigorous physical activity (PA) and anxiety symptoms and status among older adults in Ireland.

Methods. Participants ($n = 4175$; 56.8% female) aged $\geqslant 50$ years completed the International PA Questionnaire (IPAQ) at baseline, and the anxiety subscale of the Hospital Anxiety and Depression Scale at baseline and follow-up (2009–2013). Participants were classified according to meeting World Health Organisation PA guidelines, and divided into IPAQ categories. Respondents without anxiety at baseline ($n = 3165$) were included in prospective analyses. Data were analysed in 2017.

Results. Anxiety symptoms were significantly higher among females than males ($p < 0.001$). Models were adjusted for age, sex, waist circumference, social class, smoking status and pain. In cross-sectional analyses, meeting PA guidelines was associated with 9.3% (OR = 0.91, 95% confidence interval 0.78–1.06) lower odds of anxiety. Compared with the inactive group, the minimally- and very-active groups were associated with 8.4% (OR = 0.92, 0.76–1.10) and 18.8% (OR = 0.81, 0.67–0.98) lower odds of anxiety, respectively. In prospective analyses, meeting guidelines was associated with 6.3% (OR = 0.94, 0.63–1.40) reduced odds of anxiety. Compared with the inactive group, the minimally and very-active groups were associated with 43.5% (OR = 1.44, 0.89–2.32) increased, and 4.3% (OR = 0.96, 0.56–1.63) reduced odds of anxiety. The presence of pain, included in models as a covariate, was associated with a 108.7% (OR = 2.09, 1.80–2.42) increase in odds of prevalent anxiety, and a 109.7% (OR = 2.10, 1.41–3.11) increase in odds of incident anxiety.

Conclusion. High volumes of PA are cross-sectionally associated with lower anxiety symptoms and status, with a potential dose–response apparent. However, significant associations were not observed in prospective analyses. The low absolute number of incident anxiety cases ($n = 109$) potentially influenced these findings. Further, as older adults may tend to experience and/or report more somatic anxiety symptoms, and the HADS focuses primarily on cognitive symptoms, it is plausible that the HADS was not an optimal measure of anxiety symptoms in the current population.

Received 31 August 2017; Accepted 29 December 2017; First published online 31 January 2018

Key words: Anxiety, cross-sectional, elderly, Ireland, longitudinal, physical activity.

Introduction

Anxiety is the sixth leading cause of disability worldwide (Baxter *et al.* 2014), affecting 4.2% of people aged 55+ years globally (Baxter *et al.* 2013), and accounting for 325–418 years lived with disability per 100 000 persons aged 50 years and older (Baxter *et al.* 2014). In Ireland, 13% of older adults have reported clinically significant anxiety symptoms (Barrett *et al.* 2011). Anxiety has also been associated with numerous mental and physical comorbidities (Vancampfort *et al.* 2017), such as pain, and early mortality (Roest *et al.* 2012). Further, health services are continually required to adapt and respond to the increasing absolute number of older adults with mood disorders requiring treatment as a result of an ageing population within the European Union (Rechel *et al.* 2013).

Although the majority of those who suffer from anxiety do not seek treatment (Demyttenaere *et al.* 2004), maladaptive anxiety symptoms are costly because of direct psychiatric and non-psychiatric treatment costs (Chisholm *et al.* 2016). Among those who do seek treatment, the first-line treatment remains pharmacotherapy, such as selective

* Address for correspondence: PESS 1039, Department of Physical Education and Sport Sciences, University of Limerick, Limerick, Ireland
(Email: cillian.mcdowell@ul.ie)

serotonin reuptake inhibitors (SSRIs) (Baldwin *et al.* 2011; Reinhold *et al.* 2011). Nonetheless, SSRIs do not work for about one-third of patients and are associated with the development or worsening of chronic physical diseases, obesity, diabetes and cardio-metabolic diseases (Correll *et al.* 2015; de Vries *et al.* 2016; Vancampfort *et al.* 2016, 2017). Thus, there is a continued need to identify and investigate alternative prevention and treatment strategies.

Through improvements in functional status and wellbeing and social benefits, physical activity (PA) has been shown to be pivotal to the concept of 'healthy ageing' (Bauman *et al.* 2016). Additionally, it is easily accessible and has few negative side effects. As a result, there has been continued interest in the benefits of regular PA for psychological status among the elderly. Compared with depression, the association between PA and anxiety has received significantly less attention. Recent large-scale cross-sectional evidence demonstrates an inverse association between PA and anxiety (Stubbs *et al.* 2017a), supporting previous longitudinal evidence of the inverse association between PA and subsequent anxiety among older adults (Heesch *et al.* 2011; Pasco *et al.* 2011). However, longitudinal associations between PA and anxiety symptoms in the general population have been mixed (de Moor *et al.* 2008; ten Have *et al.* 2011; Brunes *et al.* 2015; Kang *et al.* 2016). Experimental evidence has supported the anxiolytic effects of exercise training among non-clinical adult populations (Rebar *et al.* 2015), chronically ill patients (Herring *et al.* 2010) and individuals with anxiety disorders (Herring *et al.* 2012; Stubbs *et al.* 2017b). Additionally, experimentally increasing sedentary behaviour has been demonstrated to increase anxiety among active young adults (Edwards & Loprinzi, 2016).

There is limited evidence regarding a dose–response relationship between PA and mental health outcomes. Evidence suggests large variability in the preference for and tolerance of different exercise intensities, and a 'one size fits all' approach may not work, but examining this dose–response in large populations may help to best formulate specific PA recommendations for mental health. Evidence to support a dose–response relationship between PA and anxiety from epidemiological studies (Dunn *et al.* 2001; Sanchez-Villegas *et al.* 2008; Heesch *et al.* 2011; ten Have *et al.* 2011) and randomised controlled trials (Wipfli *et al.* 2008; Jayakody *et al.* 2013) is mixed. There is evidence to suggest that the dose and modality of exercise considered efficacious for the treatment of depression is similar to that included in PA guidelines for the general population (Haskell *et al.* 2007; Stanton & Reaburn, 2014); however, evidence to support meeting these recommended guidelines to improve anxiety is sparse.

Thus, the present study used data from The Irish Longitudinal Study of Ageing (TILDA) to (1) examine cross-sectional and longitudinal associations between meeting PA guidelines and anxiety symptoms and status, and (2) characterise the potential cross-sectional and longitudinal dose–response relationship between PA and anxiety symptoms and status. Because anxiety symptoms have higher prevalence among women (Brunes *et al.* 2015; Kang *et al.* 2016) and sex-related differences in anxiety symptom response to PA have been recently reported (Brunes *et al.* 2015), an exploratory objective was (3) to examine potential sex-related differences in the association between PA and anxiety.

Methods

This study used STROBE recommendations to guide reporting (Von Elm *et al.* 2008).

Study population and measures

Data for the first (Barrett *et al.* 2011) and second (Nolan *et al.* 2014) waves of TILDA were gathered between October 2009 and February 2011 and between April 2012 and January 2013, respectively, and analysed in 2017. TILDA is a nationally representative, equal probability sample (Whelan, 1979) of community-dwelling adults aged $\geqslant$50 years, and their partners of any age, resident in the Republic of Ireland. 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. Further study design details are published elsewhere (Kenny *et al.* 2010). From 8504 participants who responded to the first wave, PA and anxiety data at waves 1 and 2 were available for 6094 respondents. Following exclusion of participants with incomplete covariate data (n = 1917), cross-sectional analyses in the present study focused on 4175 participants (56.8% female) aged $\geqslant$50 years with complete data. Respondents who reported anxiety at baseline (n = 1010) were excluded from longitudinal analyses, leaving a sample of 3165 anxiety-free older adults who were included in longitudinal analyses.

Anxiety symptoms were assessed at waves 1 and 2 using the anxiety subscale of the Hospital Anxiety and Depression Scale (HADS-A) (Zigmond & Snaith, 1983). The scale consists of seven items rated on a four-point Likert scale from 0 (not at all) to 3 (very often indeed) with five items reverse scored. The HADS-A is scored such that higher scores indicate greater anxiety symptoms. Probable anxiety was indicated by scores $\geqslant$8, which has been associated with good sensitivity and specificity (Bjelland *et al.* 2002). The

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

HADS-A has previously been validated in a sample of elderly subjects selected from the general population (Spinhoven *et al.* 1997) and shown to have high internal consistency in TILDA (Cronbach's $\alpha = 0.84$) (Santini *et al.* 2015).

PA was measured at wave 1 using the short International PA Questionnaire (IPAQ) (Craig *et al.* 2003), for which respondents are asked to report the number of days and duration of the vigorous, moderate and walking activities they undertook 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 as meeting MVPA guidelines (i.e. reporting $\geqslant$150 min weekly of MVPA, or $\geqslant$75 min weekly of vigorous PA, or $\geqslant$500 MET.minutes weekly) or not. Three categories, inactive, minimally active and very active, were determined as recommended (http://www.ipaq.ki.se). IPAQ categories were preferred to IPAQ MET continuous score because of the highly asymmetric distribution of this continuous score. For the current study, only wave 1 PA data were used.

Participants also provided information at wave 1 regarding variables that may influence the association of PA with anxiety. Participant characteristics and environmental variables included age, sex, waist circumference, social class and the presence of pain. Pain was assessed by a single question 'Are you often troubled with pain?' Age was classified using four categories (i.e. 50–59, 60–69, 70–79 and 80+ years). Waist circumference was classified as low- or increased-risk according to WHO guidelines (i.e. males: >94 cm; females >80 cm) (WHO, 2000; Grundy *et al.* 2005). Social class was defined according to the European Socioeconomic Classification (EseC) scheme (Rose & Harrison, 2007). The ESeC classifies people 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 ($n = 1112$). Smoking status was assessed by self-reported current or never/previous smoker.

Statistical analysis

Statistical analyses were conducted using SPSS Version 22.0 (Armonk, NY, USA: IBM Corp.). The χ^2 tests examined differences in meeting PA guidelines, anxiety, sex, age, waist circumference, social class, smoking and pain categories between those included and excluded from analyses [i.e. those with complete IPAQ-SF (wave 1) and HADS-A (waves 1 and 2) data but missing covariate data]. The χ^2 tests examined differences in pain, sex, age, waist circumference, social class and smoking categories between meeting and not meeting MVPA guidelines. For significant χ^2 tests, Z tests were calculated for column proportions for each row in the χ^2 contingency table and Bonferroni-corrected for multiple comparisons (Sharpe, 2015).

One-way analyses of variance (ANOVAs) and Fisher's least significant difference planned contrasts quantified differences in waves 1 and 2 anxiety symptoms between those meeting and not meeting PA guidelines, IPAQ categories and sexes. Two-way ANOVAs examined variation in waves 1 and 2 anxiety symptoms by meeting PA guidelines, sex and their interaction, and IPAQ categories, sex and their interaction. To move beyond null-hypothesis significance testing in favour of estimation based on effect sizes and confidence intervals (Cumming, 2013), Hedges' g effect sizes and associated 95% confidence intervals (95% CI) were calculated to quantify the magnitude of differences in anxiety scores between different volumes (i.e. PA guidelines and IPAQ categories) of PA, and between sexes.

Binomial logistic regression quantified associations [i.e. crude and adjusted odds ratios (ORs)] between both meeting MVPA guidelines and IPAQ categories and anxiety status at waves 1 and 2. Covariates in adjusted models were pain, age, sex, waist circumference, social class and smoking status.

Results

Participant characteristics

Compared with the analytic sample, a significantly greater proportion of excluded respondents were aged $\geqslant$80 years (7.6% *v.* 5.1%), male (47.2% *v.* 43.2%), current smokers (18.5% *v.* 14.8%) and did not experience pain (69.0% *v.* 63.5%; all $p < 0.05$). There were no significant differences between excluded and included participants for meeting PA guidelines, anxiety status or waist circumference (all $p > 0.24$). Wave 1 participant characteristics are presented in Table 1. Pain [χ^2 (1, $N = 4175$) = 21.54, $p < 0.001$], sex [χ^2 (1, $N = 4175$) = 75.50, $p < 0.001$], age [χ^2 (3, $N = 4175$) = 67.74, $p < 0.001$] and social class [χ^2 (7, $N = 4175$) = 88.98, $p < 0.001$] significantly differed according to meeting MVPA guidelines. Waist circumference [χ^2 (1, $N = 4175$) = 1.03, $p > 0.31$] and smoking status [χ^2 (1, $N = 4175$) = 0.95, $p > 0.32$] did not significantly differ. Results from follow-up tests are shown in Table 1. Briefly, a statistically significant greater proportion of respondents who were aged 70–79 or $\geqslant$80

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

Table 1. *Baseline participant characteristics*

	Not meeting MVPA Guidelines ($n = 2120$) [n (%)]	Meeting MVPA Guidelines ($n = 2055$) [n (%)]
MVPA (mins wk^{-1}) [median (IQR)]	0.00 (0.00)	600.00 (900.00)
Anxiety symptoms [mean (S.D.)]	5.51 (3.73)	5.22 (3.50)
Sex		
Female	1334 (63.4)$_a$	1029 (50.1)$_b$
Male	776 (36.6)$_a$	1026 (49.9)$_b$
Age category (years)		
50–59	784 (37.0)$_a$	892 (43.4)$_b$
60–69	701 (33.1)$_a$	759 (36.9)$_b$
70–79	485 (22.9)$_a$	339 (16.5)$_b$
80+	150 (7.1)$_a$	65 (3.2)$_b$
Waist circumference		
Normal	1020 (48.1)	1021 (49.7)
At risk	1100 (51.9)	1034 (50.3)
Social class		
Professional workers	77 (3.6)$_a$	95 (4.6)$_a$
Managerial and technical	528 (24.9)$_a$	548 (26.7)$_a$
Non-manual	349 (16.5)$_a$	294 (14.3)$_a$
Skilled manual	190 (9.0)$_{a,}$	205 (10.0)$_a$
Semi-skilled	188 (8.9)$_a$	231 (11.2)$_b$
Unskilled	67 (3.2)$_a$	52 (2.5)$_a$
Farmers	69 (3.3)$_a$	170 (8.3)$_b$
Not working	652 (30.8)$_a$	460 (22.4)$_b$
Smoking status		
Current	325 (15.3)$_a$	293 (14.3)$_b$
Past/never	1795 (84.7)$_a$	1762 (85.7)$_b$
Pain status		
Yes	845 (39.9)$_a$	677 (32.9)$_b$
No	1275 (60.1)$_a$	1378 (67.1)$_b$

mins, minutes; MVPA, moderate-to-vigorous physical activity; wk, week.
Different subscript letters indicate a subset of each category whose column proportions differ statistically significantly at the 0.05 level.

years, female or experienced pain were not meeting MVPA guidelines (all $p < 0.05$). Wave 1 anxiety symptoms were significantly higher among females (5.82 ± 3.69) than males (4.76 ± 3.40; $F_{(1,4174)} = 90.58$, $p < 0.001$). The magnitude of difference was small but significant ($g = 0.30$; 95% CI 0.24–0.36).

Cross-sectional associations between IPAQ categories and anxiety

Prevalence of anxiety was 24.2% ($n = 1010$). Planned contrasts showed significantly lower anxiety symptoms for the very active (5.17 ± 3.50) group compared with the inactive (5.60 ± 3.75, $p = 0.002$; $g = 0.12$, 95% CI 0.04–0.20) group, and no significant differences between the minimally active (5.35 ± 3.58) group and the very active ($p = 0.17$; $g = 0.05$, 95% CI −0.02 to 0.12) or inactive ($p = 0.07$; $g = 0.05$, 95% CI −0.02 to 0.12) groups.

There was a significant interaction between IPAQ categories and sex ($F_{(2,4169)} = 4.19$, $p = 0.02$). Among females, the magnitude of differences between the inactive and minimally active ($g = 0.02$, 95% CI −0.08 to 0.11) and very active ($g = 0.07$, 95% CI −0.03 to 0.17) groups were statistically non-significant and small. There was a non-significant, small difference between the minimally active and very active groups ($g = 0.05$, 95% CI −0.05 to 0.15). Among males, the magnitude of differences between the inactive and minimally active ($g = 0.13$, 95% CI 0.01–0.26) group was non-significant and small. There were also non-significant, small differences between the very active and minimally active ($g = -0.04$, 95% CI −0.15 to 0.06) and inactive ($g = 0.09$, 95% CI −0.03 to 0.21) groups.

Table 2 presents crude and adjusted ORs for the associations between PA tertile and anxiety status. Fully adjusted ORs are reported here. Minimally active and very active groups were non-significantly

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

Table 2. *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*

	Unadjusted OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Meeting PA guidelines			
No	REF	REF	REF
Yes	0.85 (0.74–0.98)[a]	0.88 (0.76–1.02)	0.91 (0.78–1.06)
IPAQ categories			
Inactive	REF	REF	REF
Minimally active	0.85 (0.72–1.01)	0.87 (0.73–1.04)	0.92 (0.76–1.10)
Very active	0.75 (0.63–0.90)[b]	0.77 (0.64–0.93)	0.81 (0.67–0.98)[a]

REF, reference category.
[a]$p < 0.05$; [b]$p < 0.01$.
Model 1 adjusted for age, sex, waist circumference, social class, smoking status.
Model 2 adjusted for age, sex, waist circumference, social class, smoking status, pain.

associated with 8.4% (95% CI −9.8 to 23.6%; $p = 0.34$) and significantly associated with 18.8% (95% CI 1.9–32.9%; $p = 0.03$) lower odds of anxiety, respectively.

Cross-sectional associations between meeting PA guidelines and anxiety

Anxiety symptoms were significantly higher among people not meeting MVPA guidelines (5.51 ± 3.73) than those meeting PA guidelines (5.22 ± 3.50; $F_{(1,4173)} = 6.23$, $p = 0.01$; $g = 0.08$, 95% CI 0.02–0.14).

There was no significant interaction between meeting PA guidelines and sex ($F_{(1,4171)} = 0.30$, $p = 0.58$). The magnitude of difference between meeting and not meeting PA guidelines was statistically non-significant and small among females ($g = 0.05$, 95% CI −0.03 to 0.14) and males ($g = 0.02$, 95% CI −0.08 to 0.11).

Table 2 presents crude and adjusted ORs for the associations between meeting PA guidelines and anxiety status. Fully adjusted ORs are reported here. Meeting the guidelines was non-significantly associated with 9.3% (95% CI −5.5 to 21.9%; $p = 0.21$) lower odds of anxiety.

Longitudinal associations between IPAQ categories and anxiety

Incidence of anxiety was 3.4% ($n = 109$). Planned contrasts showed non-significantly reduced anxiety symptoms for the very active group (2.41 ± 2.36) compared with the minimally active (2.55 ± 2.51, $p = 0.15$; $g = 0.06$, 95% CI −0.02 to 0.14) and inactive (2.48 ± 2.39, $p = 0.53$; $g = 0.03$, 95% CI −0.06 to 0.12) groups, and a non-significant difference between the inactive and minimally active ($p = 0.48$; $g = -0.03$, 95% CI −0.12 to 0.06) groups.

There was no significant interaction between IPAQ categories and sex ($F_{(2,3161)} = 0.05$, $p = 0.95$). Among females, there were non-significant differences between the inactive group and the minimally active ($g = -0.06$, 95% CI −0.17 to 0.05) and very active ($g = -0.02$, 95% CI −0.14 to 0.10) groups. There was a small, non-significant difference between the minimally active and very active ($g = 0.04$, 95% CI −0.08 to 0.16) groups. Among males, the magnitude of differences between the inactive group and the minimally active ($g = -0.04$, 95% CI −0.18 to 0.10) and very active ($g = -0.03$, 95% CI −0.16 to 0.11) groups were non-significant and small. There was a small, non-significant difference between the minimally active and very active ($g = 0.02$, 95% CI −0.10 to 0.13) groups.

Table 3 presents crude and adjusted ORs for the associations between IPAQ categories and anxiety status. Fully adjusted ORs are reported here. The very active group was non-significantly associated with 4.3% (95% CI −62.7 to 43.6%; $p = 0.87$) reduced odds of anxiety. The minimally active group was associated with 43.5% (95% CI −12.3 to 132.3%; $p = 0.14$) increased odds of anxiety.

Longitudinal associations between meeting PA guidelines and anxiety

Anxiety symptoms did not significantly differ between people meeting (2.44 ± 3.38) and not meeting (2.52 ± 2.47; $F_{(1,3165)} = 0.69$, $p = 0.41$; $g = 0.03$, 95% CI −0.04 to 0.10) MVPA guidelines.

There was no significant interaction between meeting PA guidelines and sex ($F_{(13163)} = 0.31$, $p = 0.58$). The magnitude of difference between meeting and not meeting PA guidelines was statistically non-significant and small among females ($g = 0.01$, 95% CI

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

Table 3. *Odds ratios (OR) and 95% confidence intervals (CI) derived from binominal logistic regression analyses as indicators of prospecctive associations between physical activity (PA) and anxiety*

	Unadjusted OR (95% CI)	Model 1 OR (95% CI)	Model 2 OR (95% CI)
Meeting PA guidelines			
No	REF	REF	REF
Yes	0.81 (0.55–1.18)	0.91 (0.61–1.35)	0.94 (0.63–1.40)
IPAQ categories			
Inactive	REF	REF	REF
Minimally active	1.23 (0.77–1.96)	1.35 (0.84–2.18)	1.44 (0.89–2.32)
Very active	0.75 (0.63–0.90)[b]	0.91 (0.54–1.55)	0.96 (0.56–1.63)

IPAQ, International PA Questionnaire; REF, reference category.
[a]$p < 0.05$.
Model 1 adjusted for age, sex, waist circumference, social class, smoking status.
Model 2 adjusted for age, sex, waist circumference, social class, smoking status, pain.

−0.09 to 0.10) and males ($g = -0.03$, 95% CI −0.13 to 0.07).

Table 3 presents crude and adjusted ORs for the associations between meeting PA guidelines and anxiety status. Fully adjusted ORs are reported here. Meeting PA recommendations was non-significantly associated with 6.3% (95% CI −39.7 to 37.2%; $p = 0.75$) reduced odds of anxiety.

Discussion

To the authors' knowledge, this is the largest cross-sectional and longitudinal investigation of meeting PA guidelines and anxiety among older adults. The present unadjusted cross-sectional and longitudinal findings appear to support the beneficial effects of meeting PA guidelines or engaging in high levels of PA to reduce the likelihood of anxiety symptoms and status. However, following adjustment only high volumes of MVPA were significantly associated with lower prevalence of anxiety, while all prospective associations between PA and anxiety were small and no longer significant, suggesting a potential moderating effect by one or more covariates.

A dose–response was observed in cross-sectional analyses; there were no significant findings in prospective analyses. Previous research has reported a graded relationship between PA and the relative risk of developing anxiety (Sanchez-Villegas *et al.* 2008), and a cross-sectional dose–response relationship between PA and cognition in older adults (de Souto Barreto *et al.* 2016); however, evidence has been mixed (ten Have *et al.* 2011).

The crude and adjusted odds of reduced anxiety observed in the current study are small compared with previous research. For example, large-scale cross-sectional evidence (Stubbs *et al.* 2017a) and longitudinal evidence in older adults (Pasco *et al.* 2011) has demonstrated a 23.1 and 45% reduction in odds of anxiety, respectively. However, similarly small reductions in anxiety symptoms to those observed in the present study have previously been observed in older adults (Ivanova *et al.* 2017). Anxiety symptom expression can differ between age groups (Diefenbach *et al.* 2001; Wolitzky-Taylor *et al.* 2010), and older adults may tend to experience and/or report more somatic symptoms (Davies *et al.* 1993). Indeed, the potential utility of developing specific instruments to measure anxiety symptoms among older adults has previously been noted (Bryant *et al.* 2008). Thus, it is plausible that the HADS was a less than optimal measure of anxiety symptoms and status in the current population given its focus on cognitive symptoms.

Pain is a well-established comorbidity in anxiety disorders. There is evidence for a reverse causal link (Gureje, 2008), shared risk factors (Gureje, 2008) and overlap among the neuroanatomy thought to be involved in pain processing and anxiety (LeDoux, 2000; Vogt, 2005; Zhuo, 2008). PA and exercise also improve pain and anxiety. For example, prolonged exercise in healthy individuals has improved pain tolerance (Jones *et al.* 2014) and modulation (Ellingson *et al.* 2012). Although the present study did not directly examine the association between pain and anxiety, pain was included as a covariate in the analyses. The presence of pain was associated with a 108.7% (95% CI 79.8–142.3%, $p < 0.001$) increase in odds of experiencing concurrent anxiety, and a 109.7% (95% CI 41.5–210.8%, $p < 0.001$) increase in odds of developing anxiety during 2-year follow-up. Therefore, future research should examine the potential moderating/mediating role that pain plays in the PA–anxiety relationship.

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

Anxiety was significantly higher among females, supporting previous epidemiological evidence that European females are twice as likely to suffer anxiety disorders (Alonso *et al.* 2004) or possible anxiety (Brunes *et al.* 2015) than males. Genetic (Feingold, 1994; McLean & Anderson, 2009), neurobiological (Altemus, 2006; McLean & Anderson, 2009), psychological (Bekker & van Mens-Verhulst, 2007) and bio-environmental (McLean & Anderson, 2009) factors potentially underlie sex-related differences in mental health. Poorer baseline mood, and subsequently larger improvements following acute exercise, have also been observed in females (McDowell *et al.* 2016); however, in the present study, although the cross-sectional interaction between sex and meeting PA guidelines was significant, the magnitude of associations were small among both females and males.

Although not examined in the present study, social support may play an important role in the PA–anxiety relationship. Social support has been shown to play a key role in recovery from affective disorders (Hallgren *et al.* 2017), and cross-sectional studies have demonstrated inverse associations between social support and mental health in the general population (Grav *et al.* 2012) and older adults (Golden *et al.* 2009; Liu *et al.* 2016). Social support is also positively associated with PA engagement among older adults (Koyanagi *et al.* 2017; Smith *et al.* 2017). It is plausible that social support plays a moderating/mediating role in the PA–mental health relationship.

Limitations and strengths

Firstly, questionnaire-based activity measures can be problematic and susceptible to over-reporting (Manini *et al.* 2006); thus, it is plausible that the relationship between PA and anxiety may have been underestimated. Indeed, in the current study, the overall average weekly MVPA of 470 min far exceeds recommendations (PAGAC, 2008). However, there was substantial variation in reported MVPA, and the overall mean weekly MVPA is potentially misleading as the median amount of weekly MVPA was 120 min. Secondly, it is plausible that the association between PA and anxiety could be bi-directional, and anxiety symptoms and disorders cause declines in PA levels (Da Silva *et al.* 2012). It is plausible that anxiety symptoms may take longer than 2 years to emerge in a general population survey, and so the 2-year follow-up may have resulted in a lower incident anxiety rate; however, as the HADS assesses anxiety symptoms experienced in the last week, a 2-year follow-up should have been more than sufficient to observe the development of new anxiety cases. Additionally, non-measured variables, such as genetic variation (De Moor *et al.* 2008), could have influenced both PA levels and the development of anxiety. Nonetheless, the present study also has notable strengths, including the use of a large national sample of elderly community-dwelling males and females and direct examination of the importance of meeting recommended PA guidelines.

Future research

Future research should investigate (1) the anxiolytic effect of sub-guideline levels of PA, which has been shown to reduce odds of mortality (Hupin *et al.* 2015), (2) the potential moderating/mediating roles of pain and/or social support in the PA–anxiety relationship and (3) the potential anxiogenic influence of sedentary behaviour independent of PA levels.

Acknowledgements

The authors have no financial disclosures. The authors disclose no conflicts of interest. The TILDA study was supported by the Irish Government, the Atlantic Philanthropies and Irish Life PLC. This work was also supported by the Health Research Board of Ireland (Grant reference: HRA_PHS/2012/30). The sponsors played no role in study design, methods, subject recruitment, data collection, analysis or preparation of the paper.

Financial Support

This research received no specific grant from any funding agency, commercial or not-for-profit sectors.

Conflict of Interest

None.

Ethical Standard

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008.

Availability of Data and Materials

Dataset files are publicly accessible and provided by The Irish Longitudinal Study on Ageing. Information on how to access these is available at www.tilda.tcd.ie.

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press

Supplementary Material

The supplementary material for this article can be found at https://doi.org/10.1017/S204579601800001X.

References

Alonso J, Angermeyer MC, Bernert S, Bruffaerts R, Brugha TS, Bryson H, Girolamo GD, Graaf RD, Demyttenaere K, Gasquet I (2004). Prevalence of mental disorders in Europe: results from the European Study of the Epidemiology of Mental Disorders (ESEMeD) project. *Acta Psychiatrica Scandinavica* **109**, 21–27.

Altemus M (2006). Sex differences in depression and anxiety disorders: potential biological determinants. *Hormones and Behavior* **50**, 534–538.

Baldwin DS, Waldman S, Allgulander C (2011). Evidence-based pharmacological treatment of generalized anxiety disorder. *International Journal of Neuropsychopharmacology* **14**, 697–710.

Barrett A, Burke H, Cronin H, Hickey A, Kamiya Y, Kenny RA, Layte R, Maty S, McGee H, Morgan K (2011). Fifty plus in Ireland 2011: first results from the Irish Longitudinal Study on Ageing (TILDA). Retrieved from: https://epubs.rcsi.ie/psycholrep/45/

Bauman A, Merom D, Bull FC, Buchner DM, Fiatarone Singh MA (2016). Updating the evidence for physical activity: summative reviews of the epidemiological evidence, prevalence, and interventions to promote 'Active Aging'. *The Gerontologist* **56**, S268–S280.

Baxter A, Scott K, Vos T, Whiteford H (2013). Global prevalence of anxiety disorders: a systematic review and meta-regression. *Psychological Medicine* **43**, 897–910.

Baxter A, Vos T, Scott K, Ferrari A, Whiteford H (2014). The global burden of anxiety disorders in 2010. *Psychological Medicine* **44**, 2363–2374.

Bekker MH, van Mens-Verhulst J (2007). Anxiety disorders: sex differences in prevalence, degree, and background, but gender-neutral treatment. *Gender Medicine* **4**, S178–S193.

Bjelland I, Dahl AA, Haug TT, Neckelmann D (2002). The validity of the Hospital Anxiety and Depression Scale: an updated literature review. *Journal of Psychosomatic Research* **52**, 69–77.

Brunes A, Gudmundsdottir SL, Augestad LB (2015). Gender-specific associations between leisure-time physical activity and symptoms of anxiety: the HUNT study. *Social Psychiatry and Psychiatric Epidemiology* **50**, 419–427.

Bryant C, Jackson H, Ames D (2008). The prevalence of anxiety in older adults: methodological issues and a review of the literature. *Journal of Affective Disorders* **109**, 233–250.

Chisholm D, Sweeny K, Sheehan P, Rasmussen B, Smit F, Cuijpers P, Saxena S (2016). Scaling-up treatment of depression and anxiety: a global return on investment analysis. *Lancet Psychiatry* **3**, 415–424.

Correll CU, Detraux J, De Lepeleire J, De Hert M (2015). Effects of antipsychotics, antidepressants and mood stabilizers on risk for physical diseases in people with schizophrenia, depression and bipolar disorder. *World Psychiatry* **14**, 119–136.

Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, Pratt M, Ekelund U, Yngve A, Sallis JF (2003). International physical activity questionnaire: 12-country reliability and validity. *Medicine and Science in Sports and Exercise* **35**, 1381–1395.

Cumming G (2013). The new statistics why and how. *Psychological Science* **25**, 7–29.

Da Silva MA, Singh-Manoux A, Brunner EJ, Kaffashian S, Shipley MJ, Kivimäki M, Nabi H (2012). Bidirectional association between physical activity and symptoms of anxiety and depression: the Whitehall II study. *European Journal of Epidemiology* **27**, 537–546.

Davies KN, Burn WK, McKenzie FR, Brothwell JA, Wattis JP (1993). Evaluation of the hospital anxiety and depression scale as a screening instrument in geriatric medical inpatients. *International Journal of Geriatric Psychiatry* **8**, 165–169.

De Moor MHM, Boomsma DI, Stubbe JH, Willemsen G, de Geus EJC (2008). Testing causality in the association between regular exercise and symptoms of anxiety and depression. *Archives of General Psychiatry* **65**, 897–905.

de Souto Barreto P, Delrieu J, Andrieu S, Vellas B, Rolland Y (2016). Physical Activity and Cognitive Function in Middle-Aged and Older Adults: An Analysis of 104,909 People from 20 Countries. In *Mayo Clinic Proceedings*, pp. 1515–1524. Elsevier.

de Vries YA, de Jonge P, van den Heuvel E, Turner EH, Roest AM (2016). Influence of baseline severity on antidepressant efficacy for anxiety disorders: meta-analysis and meta-regression. *British Journal of Psychiatry*.

Demyttenaere K, Bruffaerts R, Posada-Villa J, Gasquet I, Kovess V, Lepine J, Angermeyer MC, Bernert S, de Girolamo G, Morosini P (2004). Prevalence, severity, and unmet need for treatment of mental disorders in the World Health Organization World Mental Health Surveys. *Journal of the American Medical Association* **291**, 2581–2590.

Diefenbach G, Stanley M, Beck J (2001). Worry content reported by older adults with and without generalized anxiety disorder. *Aging and Mental Health* **5**, 269–274.

Dunn AL, Trivedi MH, O'Neal HA (2001). Physical activity dose-response effects on outcomes of depression and anxiety. *Medicine and Science in Sports and Exercise* **33**, S587–S597.

Edwards MK, Loprinzi PD (2016). Experimentally increasing sedentary behavior results in increased anxiety in an active young adult population. *Journal of Affective Disorders* **204**, 166–173.

Ellingson LD, Colbert LH, Cook DB (2012). Physical activity is related to pain sensitivity in healthy women. *Medicine and Science in Sports and Exercise* **44**, 1401–1406.

Feingold A (1994). Gender differences in personality: a meta-analysis. *Psychological Bulletin* **116**, 429.

Golden J, Conroy RM, Bruce I, Denihan A, Greene E, Kirby M, Lawlor BA (2009). Loneliness, social support networks, mood and wellbeing in community-dwelling elderly. *International Journal of Geriatric Psychiatry* **24**, 694–700.

Grav S, Hellzèn O, Romild U, Stordal E (2012). Association between social support and depression in the general

population: the HUNT study, a cross-sectional survey. *Journal of Clinical Nursing* **21**, 111–120.

Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, Gordon DJ, Krauss RM, Savage PJ, Smith SC (2005). Diagnosis and management of the metabolic syndrome. *Circulation* **112**, 2735–2752.

Gureje O (2008). Comorbidity of pain and anxiety disorders. *Current Psychiatry Reports* **10**, 318–322.

Hallgren M, Lundin A, Tee FY, Burström B, Forsell Y (2017). Somebody to lean on: social relationships predict post-treatment depression severity in adults. *Psychiatry Research* **249**, 261–267.

Haskell WL, Lee I-M, Pate RR, Powell KE, Blair SN, Franklin BA, Macera CA, Heath GW, Thompson PD, Bauman A (2007). Physical activity and public health. Updated recommendation for adults from the American College of Sports Medicine and the American Heart Association. *Circulation*.

Heesch KC, Burton NW, Brown WJ (2011). Concurrent and prospective associations between physical activity, walking and mental health in older women. *Journal of Epidemiology and Community Health* **65**, 807–813.

Herring MP, Jacob ML, Suveg C, Dishman RK, O'Connor PJ (2012). Feasibility of exercise training for the short-term treatment of generalized anxiety disorder: a randomized controlled trial. *Psychotherapy and Psychosomatics* **81**, 21–28.

Herring MP, O'Connor PJ, Dishman RK (2010). The effect of exercise training on anxiety symptoms among patients: a systematic review. *Archives of Internal Medicine* **170**, 321–331.

Hupin D, Roche F, Gremeaux V, Chatard J-C, Oriol M, Gaspoz J-M, Barthélémy J-C, Edouard P (2015). Even a low-dose of moderate-to-vigorous physical activity reduces mortality by 22% in adults aged $\geqslant$60 years: a systematic review and meta-analysis. *British Journal of Sports Medicine* **49**, 1262–1267.

Ivanova E, Burns RJ, Deschênes SS, Knäuper B, Schmitz N (2017). A longitudinal investigation of anxiety and depressive symptomatology and exercise behaviour among adults with type 2 diabetes mellitus. *Canadian Journal of Diabetes* **41**, 73–81.

Jayakody K, Gunadasa S, Hosker C (2013). Exercise for anxiety disorders: systematic review. *British Journal of Sports Medicine* **48**, 187–196.

Jones MD, Booth J, Taylor JL, Barry BK (2014). Aerobic training increases pain tolerance in healthy individuals. *Medicine and Science in Sports and Exercise* **46**, 1640–1647.

Kang H-J, Bae K-Y, Kim S-W, Shin I-S, Yoon J-S, Kim J-M (2016). Anxiety symptoms in Korean elderly individuals: a two-year longitudinal community study. *International Psychogeriatrics* **28**, 423–433.

Kenny RA, Whelan BJ, Cronin H, Kamiya Y, Kearney P, O'Regan C, Ziegel M (2010). The design of the Irish longitudinal study on ageing. Retrieved from: www.lenus.ie/hse/bitstream/10147/301640/1/DesignReport2010.pdf

Koyanagi A, Stubbs B, Smith L, Gardner B, Vancampfort D (2017). Correlates of physical activity among community-dwelling adults aged 50 or over in six low-and middle-income countries. *PLoS ONE*, **12**.

LeDoux JE (2000). Emotion circuits in the brain. *Annual Review of Neuroscience*, **23**, 155–184.

Liu L, Gou Z, Zuo J (2016). Social support mediates loneliness and depression in elderly people. *Journal of Health Psychology* **21**, 750–758.

Manini TM, Everhart JE, Patel KV, Schoeller DA, Colbert LH, Visser M, Tylavsky F, Bauer DC, Goodpaster BH, Harris TB (2006). Daily activity energy expenditure and mortality among older adults. *Journal of the American Medical Association* **296**, 171–179.

McDowell CP, Campbell MJ, Herring MP (2016). Sex-related differences in mood responses to acute aerobic exercise. *Medicine and Science in Sports and Exercise* **48**, 1798–1802.

McLean CP, Anderson ER (2009). Brave men and timid women? A review of the gender differences in fear and anxiety. *Clinical Psychology Review* **29**, 496–505.

Nolan A, O'Regan C, Dooley C, Wallace D, Hever A, Cronin H, Hudson E, Kenny R (2014). The over 50s in a changing Ireland: economic circumstances, health and well-being. *Dublin: Trinity College: The Irish Longitudinal Study on Ageing*.

Pasco JA, Williams LJ, Jacka FN, Henry MJ, Coulson CE, Brennan SL, Leslie E, Nicholson GC, Kotowicz MA, Berk M (2011). Habitual physical activity and the risk for depressive and anxiety disorders among older men and women. *International Psychogeriatrics* **23**, 292–298.

Physical Activity Guidelines Advisory Committee (2008). Physical Activity Guidelines Advisory Committee Report, 2008. US Department of Health and Human Services: Washington, DC, pp. A1–H14.

Rebar AL, Stanton R, Geard D, Short C, Duncan MJ, Vandelanotte C (2015). A meta-meta-analysis of the effect of physical activity on depression and anxiety in non-clinical adult populations. *Health Psychology Review* **9**, 366–378.

Rechel B, Grundy E, Robine J-M, Cylus J, Mackenbach JP, Knai C, McKee M (2013). Ageing in the European Union. *The Lancet* **381**, 1312–1322.

Reinhold JA, Mandos LA, Rickels K, Lohoff FW (2011). Pharmacological treatment of generalized anxiety disorder. *Expert Opinion on Pharmacotherapy* **12**, 2457–2467.

Roest AM, Zuidersma M, de Jonge P (2012). Myocardial infarction and generalised anxiety disorder: 10-year follow-up. *British Journal of Psychiatry* **200**, 324–329.

Rose D, Harrison E (2007). The European socio-economic classification: a new social class schema for comparative European research. *European Societies* **9**, 459–490.

Sanchez-Villegas A, Ara I, Guillen-Grima F, Bes-Rastrollo M, Varo-Cenarruzabeitia JJ, Martinez-Gonzalez MA (2008). Physical activity, sedentary index, and mental disorders in the SUN cohort study. *Medicine and Science in Sports and Exercise* **40**, 827.

Santini ZI, Koyanagi A, Tyrovolas S, Haro JM (2015). The association of relationship quality and social networks with depression, anxiety, and suicidal ideation among older married adults: findings from a cross-sectional analysis of the Irish Longitudinal Study on Ageing (TILDA). *Journal of Affective Disorders* **179**, 134–141.

Sharpe D (2015). Your chi-square test is statistically significant: now what? *Practical Assessment, Research and Evaluation* **20**, 2–10.

Smith GL, Banting L, Eime R, O'Sullivan G, van Uffelen JG (2017). The association between social support and physical

activity in older adults: a systematic review. *International Journal of Behavioral Nutrition and Physical Activity* **14**, 56.

Spinhoven P, Ormel J, Sloekers P, Kempen G, Speckens A, Van Hemert A (1997). A validation study of the Hospital Anxiety and Depression Scale (HADS) in different groups of Dutch subjects. *Psychological Medicine* **27**, 363–370.

Stanton R, Reaburn P (2014). Exercise and the treatment of depression: a review of the exercise program variables. *Journal of Science and Medicine in Sport* **17**, 177–182.

Stubbs B, Koyanagi A, Hallgren M, Firth J, Richards J, Schuch F, Rosenbaum S, Mugisha J, Veronese N, Lahti J (2017a). Physical activity and anxiety: a perspective from the World Health Survey. *Journal of Affective Disorders* **208**, 545–552.

Stubbs B, Vancampfort D, Rosenbaum S, Firth J, Cosco T, Veronese N, Salum GA, Schuch FB (2017b). An examination of the anxiolytic effects of exercise for people with anxiety and stress-related disorders: a meta-analysis. *Psychiatry Research*.

ten Have M, de Graaf R, Monshouwer K (2011). Physical exercise in adults and mental health status: findings from the Netherlands mental health survey and incidence study (NEMESIS). *Journal of Psychosomatic Research* **71**, 342–348.

Vancampfort D, Koyanagi A, Hallgren M, Probst M, Stubbs B (2017). The relationship between chronic physical conditions, multimorbidity and anxiety in the general population: a global perspective across 42 countries. *General Hospital Psychiatry* **45**, 1–6.

Vancampfort D, Rosenbaum S, Schuch FB, Ward PB, Probst M, Stubbs B (2016). Prevalence and predictors of treatment dropout from physical activity interventions in schizophrenia: a meta-analysis. *General Hospital Psychiatry* **39**, 15–23.

Vogt BA (2005). Pain and emotion interactions in subregions of the cingulate gyrus. *Nature Reviews Neuroscience* **6**, 533–544.

Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP (2008). The Strengthening the Reporting of Observational Studies in Epidemiology [STROBE] statement: guidelines for reporting observational studies. *Gaceta Sanitaria* **22**, 144–150.

Whelan BJ (1979). RANSAM: a random sample design For Ireland. *Economic and Social Review* **10**, 169–174.

World Health Organisation. (2000) Obesity: preventing and managing the global epidemic. Geneva: WHO Technical Report Series 894. p. 252. Available at: http://www.who.int/nutrition/publications/obesity/WHO_TRS_894/en/. Accessed on 10/10/2017.

Wipfli BM, Rethorst CD, Landers DM (2008). The anxiolytic effects of exercise: a meta-analysis of randomized trials and dose–response analysis. *Journal of Sport and Exercise Psychology* **30**, 392–410.

Wolitzky-Taylor KB, Castriotta N, Lenze EJ, Stanley MA, Craske MG (2010). Anxiety disorders in older adults: a comprehensive review. *Depression and Anxiety* **27**, 190–211.

Zhuo M (2008). Cortical excitation and chronic pain. *Trends in Neurosciences* **31**, 199–207.

Zigmond AS, Snaith RP (1983). The hospital anxiety and depression scale. *Acta Psychiatrica Scandinavica* **67**, 361–370.

https://doi.org/10.1017/S204579601800001X Published online by Cambridge University Press