General Hospital Psychiatry 58 (2019) 45–50

Contents lists available at ScienceDirect

General Hospital Psychiatry

journal homepage: www.elsevier.com/locate/genhospsych

Associations of physical activity with anxiety symptoms and disorders: Findings from the Swedish National March Cohort

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ARTICLE INFO

Keywords:
Exercise
Physical activity
Anxiety
MVPA

ABSTRACT

Objective: Regular physical activity (PA) is associated with less self-reported anxiety, but prospective studies linked to clinician diagnoses of anxiety disorder remain scarce. We examined whether the PA levels recommended for general health are related to anxiety symptoms and disorders.
Method: In total, 43,863 Swedish adults were surveyed in 1997 and responses linked to medical registers until 2010. Weekly durations of habitual moderate and vigorous leisure time PA were self-reported. Cross-sectional and prospective relationships between the total duration (minutes) of PA, 0–149 ('below'), 150–299 ('achieve'), and ≥300 min ('exceed') with self-reported anxiety symptoms and incident anxiety disorder were explored. Associations were explored using logistic and Cox proportional hazard regression models.
Results: Of 27,053 participants with complete data (mean age = 49.0 years, SD = 15.9, 66% female), 76% met the recommended duration of PA (≥150 min), and 38% exceeded this duration. At baseline, 2573 participants (9.5%) reported elevated anxiety symptoms. In cross-sectional analyses, engaging in ≥150 min of MVPA/week was associated with 24% (OR = 0.76, 95% CI = 0.68–0.86) lower odds of anxiety symptoms. Exceeding the weekly duration was associated with 36% (OR = 0.64, 95% CI = 0.57–0.72) lower odds. During the 13-year follow-up, 198 incident cases of anxiety disorder (0.8%) were identified. No significant prospective relationships were found.
Conclusions: Engaging in leisure time PA at levels recommended for general health may reduce the risk of elevated anxiety symptoms. As the incidence of anxiety disorder was likely under-estimated, further prospective studies are needed to determine the relationship between PA and incident anxiety disorder.

1. Introduction

Anxiety is a common mental health complaint which can impair socio-occupational functioning and reduce life quality. Symptoms include pervasive nervousness, worry, and pessimistic thoughts which, if left untreated, can develop into an anxiety disorder. The global prevalence of anxiety disorders ranges from 2.4 to 29.8% in the past year [1], although subthreshold anxiety is also common and problematic across the lifespan [2,3]. The burden of anxiety is elevated by the risk of numerous co-morbid chronic medical conditions [4], including cardiovascular diseases and associated premature mortality [5,6]. Consequently, the global economic cost of anxiety is substantial due to lost workplace productivity and increased healthcare utilization [7,8].

Medication and psychological therapy are frontline treatments for anxiety disorders [9]. While the efficacy of these approaches is well established [10–12], relapse remains common and maintenance of treatment response is frequently sub-optimal [13]. Thus, there is a need to identify alternative prevention and treatment strategies which can be

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https://doi.org/10.1016/j.genhosppsych.2019.03.001
Received 21 September 2018; Received in revised form 28 February 2019; Accepted 9 March 2019

self-regulated and have positive effects on somatic health. Physical activity (PA) is a potential alternative therapy for anxiety. Previous systematic reviews suggest that acute and chronic exercise (planned, structured, repetitive PA to maintain or enhance fitness) is helpful in reducing anxiety symptoms among otherwise healthy adults, adults with diverse chronic illnesses, and adults with an anxiety or stress-related disorder [14–16], and recent large-scale cross-sectional evidence demonstrates an inverse association between PA and anxiety [17]. Physical activity is also protective against cardiovascular and metabolic disorders, which are more prevalent in people with anxiety [5]. However, longitudinal relationships between PA and anxiety in the general population have been mixed [18–20], and few prospective studies have utilized clinician-diagnoses of anxiety. This is important to reduce the misclassification bias that arises when anxiety is self-rated.

It is also desirable to identify the optimal 'dose' of PA needed to reduce the risk of developing anxiety. The World Health Organization (WHO) guidelines for maintaining general health recommend ≥150 min of moderate-to-vigorous PA (MVPA) per week, ≥75 min of vigorous-intensity PA per week, or a combination of moderate- and vigorous-intensity activity equivalent to 600 MET-min per week [21]. Exceeding these levels with ≥300 min per week of moderate intensity PA, or > 150 min of vigorous intensity PA is further recommended for 'additional health benefits'. These guidelines are widely promoted to improve population-level health, yet it is unclear whether they are applicable to the prevention of common mental health problems. To address this issue, McDowell et al. explored associations between PA and anxiety in 4175 middle-aged and older adults (> 50 years) using self-rated PA (International Physical Activity Questionnaire; IPAQ) and anxiety (Hospital Anxiety and Depression Scale) [22]. To assess a possible dose-response, activity levels were categorized into 'meeting' versus 'not meeting' the WHO guidelines. Results showed that high volumes of PA were cross-sectionally associated with lower anxiety symptoms and status; however, significant associations were not observed in prospective analyses. While promising, the study was limited by a relatively short follow-up period (two years), resulting in a low absolute number of incident cases, and anxiety was self-rated, increasing the risk of misclassification bias [22].

Large-scale prospective studies of associations between PA and clinician-diagnosed anxiety remain scarce. Moreover, additional prevention research is needed to determine the optimal duration of PA needed to reduce the risk of elevated anxiety symptoms and disorders, particularly relative to WHO PA guidelines. To address this, we examined cross-sectional and prospective associations between different durations of PA (below, achieving, and exceeding WHO recommended levels) with self-reported and clinician-diagnosed anxiety in a large cohort of adults followed over 13 years.

2. Method

2.1. Participants

Data originate from the Swedish National March Cohort study [23]. All baseline survey data were collected during a four-day national fundraising event arranged by the Swedish Cancer in September 1997. The 13 year follow-up period was between October 1st 1997 and December 31st 2010. Approximately 3600 Swedish cities and villages were involved. In total, 43,863 participants completed a 36-page survey with detailed questions about health behaviours and lifestyle, including specific questions on PA habits (type, frequency and duration). Reliability and validity data for the activity questionnaire has been published previously, and the survey has been used extensively [24]. Exclusion criteria (for all analyses) included: participants who were younger than 18 years at the beginning of the follow-up (n = 1741), those who emigrated (n = 465) or died (n = 8), or that had a primary diagnosis of any mental disorder (ICD-8: 290-315 ICD-9 290-319 ICD-10 F00-F99) before the beginning of the follow-up. After removing these cases the survey sample consisted of 40,569 participants. Missing data on the main exposure variable (PA) was 32% (n = 13,133), leaving 27,436 adults. Differences between the analytic sample and those excluded are briefly described under Results. For the cross-sectional analyses, 383 participants (1.4%) who did not provide information for the main outcome, *'How often do you feel worried, tense or anxious?'* were excluded, leaving a final sample of 27,053 participants. In prospective analyses, to examine only incident cases, we further excluded 2573 participants based on the presence of self-rated anxiety at baseline. Thus, the final analytic sample consisted of 24,480 participants. The original study complies with the guidelines of the Declaration of Helsinki. The Research Ethics Vetting Board in Stockholm approved the original study. Informed consent was obtained from all participants. While the total number actually given a questionnaire during the fundraising event could not be assessed, all those who handed in a completed questionnaire consented to follow-up.

2.2. Primary outcomes: elevated anxiety symptoms and anxiety disorder

Indications of anxiety symptoms were assessed at baseline with the question, *'How often do you feel worried, tense or anxious?'* where the last two response alternatives (never, sometimes, *often, always*) were categorized as having elevated anxiety symptoms. The occurrences of incident anxiety disorders (ICD-10 codes: F40.1, F41.0, F41.1, F41.2, F41.3, F41.8, F41.9, F42, F42.0, F42.1, F42.2, F42.8, F42.9, F48.9, and F48.0) during the 13-year follow-up were ascertained through linkages to existing nationwide, complete and continuously updated specialist medical registers, including inpatient and outpatient records. Thus, all diagnoses were made by a specialist clinician, often a psychiatrist or clinical psychologist. Accurate linkages - and thus essentially complete follow-up - were attained using the individually unique National Registration Numbers (NRNs), assigned to all Swedish residents as identifiers both in the baseline questionnaire and in all registers.

2.3. Exposure: habitual physical activity

The average weekly duration of leisure time PA was estimated by asking participants how much time per week they usually spent in 'exercise, athletics, and sports', including: (1) walking; (2) strenuous exercise (e.g. jogging, swimming); and (3) hard training/competition; each rated separately. The formulation of the PA question implied that these activities were undertaken in a purposeful or structured manner; thus, walking was included in the definition of MVPA, as previously recommended [21]. For each question, there were six response alternatives: 0, 0–1, 2, 3, 4, and ≥5 h per week. Ratings were made separately for summer and winter and then averaged. Hours per week were converted into minutes: 0, 30, 120, 180, 240, and 300 min, respectively. After adding the total number of MVPA minutes, participants were categorized as 'below' (0–149 min), 'achieving' (150–299 min) or 'exceeding' (≥300 min) the WHO recommended durations. The last category is recommended for attaining additional health benefits from PA [21], but has rarely been assessed in previous studies. The method used to calculate MVPA is comparable to recent studies using METs-minutes [25]. The PA questionnaire has been used extensively and is described in detail elsewhere [24,26,27].

2.4. Covariates

Based on previous evidence of association with PA and/or anxiety [16,19,22], the following variables were included in the statistical models:

Body mass index (BMI): was calculated from self-reported weight and height (kg/m^2) then categorized according to the WHO's BMI classification for adults; not overweight (< 25), overweight (25– < 30), and obese (≥30). Due to the small number of observation for underweight (1.3%), this group was collapsed with the first category.

Occupation: was obtained by a single question 'What is your present occupation?' Participants were classified into five groups; full-time, part-time, unemployed, retired, and other (including students).

Smoking status: was assessed by asking participants if they had ever smoked cigarettes for six months or more. Those answering yes were coded as 'ever smokers'.

Comorbidities: were assessed based on the twelve self-reported conditions that were treated by a medical doctor, including asthma, heart attack, high blood pressure, angina pectoris, angina pectoris in legs (claudication), lipid disturbance, stroke, rheumatoid arthritis, tuberculosis (TB), cancer, diabetes, multiple sclerosis. A total score was determined by adding each condition.

Age and sex: age was categorized into three groups based on the distribution of data; < 45, 46–59 and ≥60 years. Sex was considered a confounder due to the reported gender differences in anxiety.

2.5. Statistical analyses

2.5.1. Cross-sectional analyses

The prevalence of anxiety is reported for the total sample and separately by PA group. Chi-square tests assessed bivariate associations between anxiety and the covariates. Logistic regression was used to assess associations between PA levels (below, achieve and exceed) and elevated anxiety symptoms at baseline. Four models were tested: Crude, Model A (adjusted for sex and age); Model B (further adjusted for occupation and smoking), and Model C (further adjusted for BMI and comorbidities). Odd ratios, 95% confidence intervals (CIs) and *p*-values are reported.

2.5.2. Prospective analyses

We report the number of anxiety cases (n, %), and the incidence rate (total sample and separately by each activity group). The incidence rate ratio (IRR) of anxiety and associated CI was calculated using Poisson regression adjusted for survival year. Cox proportional hazard regression models assessed associations between PA levels (below, achieve, exceed) and incident anxiety disorder. Four models were tested, identical to those used in the cross-sectional analyses. Hazard ratios (95% CIs) and *p*-values are reported. Before running the models, we used Schoenfeld residuals to test the assumption of proportional hazards for each covariate adjusting for other covariates in the model. As PA habits could have changed during the 13-year follow-up, we also performed a sensitivity analysis with anxiety outcomes registered within 6 years. In the fully adjusted models, potential moderating effects of age and gender were explored by entering interaction terms into each model. Sensitivity analyses were run using complete cases; results are available as Supplementary material. All analyses were performed using STATA version 14.

3. Results

3.1. Participant characteristics

Participant characteristics are shown in Table 1 stratified by PA level. Sixty-six percent were female (mean age = 49.0 years, SD = 15.9), 30% had a tertiary education, and 71.7% were employed (full/part time). Thirty-nine percent were overweight or obese and 39% indicated having ever smoked cigarettes (≥6 months). Seventy-six percent of participants engaged in ≥150 min of MVPA per week, and 38% exceeded the recommended weekly duration (≥300 min). Compared to the group that exercised below the recommended level, those who achieved ≥150 min of MVPA per week included more women and older adults. They were also more highly educated and more likely to be in retirement. The 'achieve' group was less overweight/obese (40.1% compared to 47.9% in the 'below' group) and had fewer smokers (38.1% compared to 42.0%). Compared to the 'achieve' group, the 'exceed' group (i.e., those who exercised ≥300 min per week), included more men and younger adults with lower levels of education. This group was less overweight/obese (32.3% compared to 40.1% in the 'achieve' group) but smoked as much as the 'achieve' group. See Supplementary Table 1 for additional information about participant characteristics. There were some differences between the analytic and excluded sample (i.e. those with missing data on covariates). The non-analytic sample included more participants that were: male, smokers, older, had at least one comorbidity, and were overweight/obese (Supplementary Table 2).

Table 1
Participant characteristics by PA level.

Characteristic (n = 27,053)	Physical activity level: Below	Achieve	Exceeding
Total	(n = 6471)	(n = 10,272)	(n = 10,310)
Female*; n (%)	4083 (63.1)	7080 (68.9)	6588 (63.9)
Age group*; n (%)			
< 45	2434 (37.6)	3707 (36.1)	4288 (41.6)
45–59	2441 (37.7)	3576 (34.8)	3045 (29.5)
≥60	1596 (24.7)	2989 (29.1)	2977 (28.9)
Educational level*; n (%)			
Compulsory (≤9 year)	3100 (48.3)	4736 (46.5)	4535 (44.4)
Upper-secondary (10–12 years)	1434 (22.4)	2093 (20.5)	2614 (25.6)
Vocational and other	58 (0.9)	85 (0.8)	96 (0.9)
Tertiary	1823 (28.4)	3276 (32.2)	2979 (29.1)
Occupation*; n (%)			
Full-time	3074 (56.8)	4461 (51.8)	4100 (46.9)
Part-time	580 (10.7)	961 (11.2)	799 (9.1)
Unemployed	188 (3.5)	254 (3.0)	279 (3.2)
Retired	1107 (20.5)	2249 (26.1)	2378 (27.2)
Other	460 (8.5)	694 (8.1)	1185 (13.6)
BMI**; mean (SD), median	25.3 (4.0), 24.8	24.6 (3.5), 24.2	24.0 (3.2), 23.6
BMI group*; n (%)			
Not overweight (< 25)	3240 (52.2)	5955 (59.9)	6773 (67.7)
Overweight	2244 (36.2)	3279 (33.0)	2777 (27.7)
Obese (≥30)	723 (11.7)	706 (7.1)	462 (4.6)
Ever smokers*; n (%)			
No	3716 (58.0)	6298 (61.9)	6359 (62.4)
Yes	2689 (42.0)	3874 (38.1)	3827 (37.6)
Having at least 1 co-morbidity*; n (%)			
No	4480 (69.2)	7139 (69.5)	7489 (72.6)
Yes	1991 (30.8)	3133 (30.5)	2821 (27.4)
Anxiety at baseline*; n (%)			
No	5727 (88.5)	9307 (90.6)	9446 (91.6)
Yes	744 (11.5)	965 (9.4)	864 (8.4)

Below: < 150 min/week; achieve: 150– < 300 min/week; exceed: ≥300 min/week; *significant by Chi-squared test (*p*-value < 0.05), **significant by Kruskal-Wallis test (*p*-value < 0.05).

3.2. Prevalence of elevated anxiety symptoms

Of the 27,053 participants with complete baseline data, 2573 (9.5%) reported having elevated anxiety symptoms. The prevalence of these symptoms was higher among women (11.1% compared to 6.5% in men), young people, participants with secondary/vocational education, and among participants who were unemployed. Those who were obese (BMI ≥ 30), smoked, or had ≥1 co-morbidity also reported a higher prevalence of anxiety symptoms. Finally, participants who exceeded the recommended PA levels had a lower prevalence of anxiety (9.4% in the 'achieve' group, and 8.4% in the 'exceed' group, compared to 11.5% in the 'below' group). Further details are available in Supplementary Table 3.

Table 2
Cross-sectional associations between physical activity and anxiety.

Physical activity level	OR	95% CI	p
Crude model (n = 27,053; cases = 2573)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	0.80	0.72–0.88	< 0.001
Exceed (≥300 min)	0.70	0.63–0.78	< 0.001
Model A (n = 27,053; cases = 2573)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	0.78	0.71–0.86	< 0.001
Exceed (≥300 min)	0.68	0.61–0.75	< 0.001
Model B (n = 22,502; cases = 2069)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	0.76	0.68–0.85	< 0.001
Exceed (≥300 min)	0.64	0.57–0.72	< 0.001
Model C (n = 21,740; cases = 1983)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	0.76	0.68–0.86	< 0.001
Exceed (≥300 min)	0.64	0.57–0.72	< 0.001

Model A adjusted for sex and age; model B further adjusted for occupation and smoking; model C further adjusted for BMI and comorbidities.

3.3. Cross-sectional associations between physical activity and elevated anxiety symptoms

Table 2 shows results from cross-sectional analyses of associations between PA and elevated anxiety symptoms. Compared to the 'below' group, those who achieved or exceeded the recommended weekly duration of MVPA had 20% and 30% lower odds, respectively, of having anxiety symptoms (crude model). In the fully adjusted Model C, engaging in ≥150 min of MVPA/week was associated with 24% (OR = 0.76, 95% CI = 0.68–0.86) lower odds of anxiety symptoms, and engaging in ≥300 min was associated with 36% (OR = 0.64, 95% CI = 0.57–0.72) lower odds. In the fully adjusted model, the difference between the 'achieve' and 'exceed' group was statistically significant (OR = 0.84, 95% CI = 0.75–0.94, $p < 0.01$). Gender and age did not moderate any of these associations. A sensitivity analysis based on complete case analysis (n = 21,740) indicated nearly identical results (see Supplementary Table 4).

3.4. Incidence of anxiety disorders

During the 13-year follow-up, there were 198 (0.8%) incident cases of anxiety disorder. The incidence rate was 63 cases per 100,000 person-years (95% CI = 55.0–72.6). The occurrence rate of anxiety was 1.6 times higher among women than men (IRR = 0.6, 95% CI = 0.4–0.8). Anxiety disorders were more common among older adults compared to those < 45 years. The incidence rates did not differ significantly between groups. Further details are available in Supplementary Table 5.

3.5. Longitudinal associations between physical activity and anxiety disorders

Results from Cox proportional hazard regression models are shown in Table 3. Hazard ratios and their corresponding 95% CIs are shown. No statistically significant associations were found between PA levels and incident anxiety disorder. Engaging in ≥300 min of MVPA/week lowered the hazards of anxiety disorder by 11%, but the reduced risk was not significant. These results were consistent in all crude and adjusted models, and the hazard ratios did not differ significantly between the models. PA and age/gender interaction terms entered into the fully adjusted model were not significant. A sensitivity analysis based on complete case analysis (n = 19,757) indicated nearly identical results (see Supplementary Table 6).

Table 3
Longitudinal associations between physical activity and anxiety.

Physical activity level	HR	95% CI	p
Crude model (n = 24,480; cases = 198)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	1.06	0.74–1.50	0.756
Exceed (≥300 min)	0.78	0.53–1.13	0.181
Model A (n = 24,480; cases = 198)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	1.04	0.73–1.48	0.818
Exceed (≥300 min)	0.77	0.53–1.12	0.172
Model B (n = 20,433; cases = 156)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	1.04	0.69–1.57	0.832
Exceed (≥300 min)	0.87	0.57–1.32	0.508
Model C (n = 19,757; cases = 149)			
Below (< 150 min)	1	–	–
Achieve (150– < 300 min)	1.07	0.70–1.63	0.747
Exceed (≥300 min)	0.92	0.60–1.43	0.722

Model A adjusted for sex and age; model B further adjusted for occupation and smoking; model C further adjusted for BMI and comorbidities.

4. Discussion

This is one of the largest national studies to examine associations between recommended PA levels, elevated anxiety symptoms, and incident clinician-diagnosed anxiety disorder in adults. There has been increased public and research interest in lifestyle interventions to reduce anxiety disorders [28,29], which are not always responsive to medication [30], frequently go untreated [31], and are shown to be increasing in some adult populations [32].

Overall, the results indicate that regular leisure time PA was associated with a reduced risk of elevated anxiety symptoms in adults. Achieving the weekly recommended duration of MVPA (≥150 min per week) was cross-sectionally associated with 24% lower odds of anxiety symptoms, while exceeding this duration with ≥300 min per week, or about 40 min per day, reduced the odds by 36%. Thus, a dose-response was observed where longer durations of habitual PA were cross-sectionally associated with lower risk of elevated anxiety symptoms. Neither age nor gender moderated these relationships. Longitudinally, no significant associations were seen. However, of relevance to the interpretation of these prospective findings, all diagnoses were obtained from specialist inpatient and outpatient registers. In Sweden, patients may be referred to specialist healthcare following a period of treatment in primary healthcare, suggesting a high degree of symptom severity in the cohort diagnosed with anxiety. This is also a likely explanation for the low incidence rate (0.8%), and the absence of significant longitudinal associations. Other factors that could partly explain the low incidence rate include changes in diagnostic practices among clinicians. One UK study found that general practitioner (GP) recordings of anxiety diagnoses fell over a ten-year period, while self-reported anxiety symptoms increased during the same period [33]. Whether or not a similar diagnostic trend has occurred among specialist clinicians in Sweden is unclear, but remains a possibility.

The cross-sectional results are consistent with previous studies. Using data from the World Health Survey, Stubbs et al. [17] examined associations between PA and anxiety among 237,964 individuals from 47 countries. 'Low' PA levels (IPAQ), were cross-sectionally associated with an increased prevalence of anxiety. The anxiolytic effects of PA have also been demonstrated in experimental studies. Structured PA (exercise) appears to have both acute [34] and long-term benefits [35] in generalized anxiety disorder, and some evidence of positive effect in the treatment of posttraumatic stress disorder [36,37], social phobia [38], and obsessive-compulsive disorder [39,40]. Reviews of the literature confirm that both aerobic [41] and resistance exercise training [42] have positive effects on anxiety symptoms in the general population and diverse patient groups [15,16].

Due to the high prevalence [1,43], and substantial comorbidity associated with anxiety [31,44], research has increasingly focused on the prevention of anxiety disorders, but prospective studies have reported inconsistent findings [19,45–47]. A recent longitudinal study from the Netherlands involving 2923 adults aged 18–65 years (57% with a current anxiety or depressive disorder), found that infrequent sports participation was associated with greater symptom severity and increased odds of disorder onset two years later [18]. This relationship was bi-directional; over time, a diagnosis or greater symptom severity was prospectively associated with poorer sports participation and less PA, suggesting a mutually reinforcing relationship between anxiety and lower PA [18].

The neurobiological pathways underpinning the effects of PA on anxiety symptoms are not fully elucidated, but understanding these links may inform the development of new preventative strategies [48]. PA has been shown to upregulate monoamine neurotransmitters in the brain linked to anxiety and mood disorders [49,50]. Exercise also appears to regulate the hypothalamo-pituitary-adrenal (HPA) axis, leading to reductions in glucocorticoid stress hormones [51]. A developing literature supports the role of inflammation, oxidative and nitrogen stress, and neurotrophins as key mediators in the pathogenesis of anxiety disorders [48]. Some studies suggest that higher 'doses' of PA are needed to elicit these biological mechanisms [50]. In line with this, the current study adds the observation that leisure time PA performed at levels recommended for general health (and above) is cross-sectionally associated with lower odds of elevated anxiety symptoms.

This study has notable strengths. The cross-sectional analyses (the main based on a large participant sample, and the comprehensive baseline survey enabled relevant covariates to be included in the fully adjusted regression models. The PA questionnaire has been validated in previous studies [24,27], and permitted examination of associations between PA durations linked to public health guidelines. Some potential limitations are also acknowledged. The exposure was self-reported which may have overestimated PA levels generally [52]. In total, 76% of participants reported achieving the recommended PA level. This figure is high, but consistent with a recent *Lancet* study (n = 1.9 million participants) indicating that 65% of adults from high income countries in Europe (83% in Finland) reported achieving the recommended PA duration [53]. Causality cannot be inferred in cross-sectional data, and these analyses relied on a single item to assess elevated anxiety symptoms, rather than a validated scale. In prospective analyses, our use of clinician diagnoses of anxiety is a strength because it reduces misclassification bias, but as noted, the incidence of anxiety disorders was likely underestimated. Currently in Sweden, there is no national register for recording mental health diagnoses obtained through primary healthcare; instead we relied on the available specialist medical registers which are used extensively in Swedish longitudinal research. We also acknowledge that a diagnosis of anxiety disorder could be linked to the number of contacts with a clinician, and these data were not available for inclusion in the analyses. As subjects participated on a voluntary basis, the SNMC may be prone to a healthy volunteer bias, which could unintentionally affect the representativeness of the cohort and reduce generalizability of study findings. For example, compared with the general Swedish population in 1997, the cohort members were less educated, more overweight or obese, and smoked less than average [23]. However, the approach of selecting study subjects from a restricted source population according to specified criteria has been used frequently in cohort studies [54]. The purpose of such approaches is to enhance feasibility of a study and to increase prevalence of exposure and completeness of follow-up, which further increases validity and precision of the study. Potential bias due to lack of representativeness needs to be balanced against the probable bias from incomplete follow-up in a more representative sample [55]. In prospective analyses, multiple anxiety disorders were combined into a single outcome. However, not all anxiety disorders are identical; post-traumatic stress disorder (PTSD) following a traumatic event may be unavoidable and unrelated to PA, whereas chronic stress and worry linked to generalized anxiety disorder (GAD) may be more modifiable with exercise. A final limitation concerns the absence of an adequate measure of social deprivation, which is shown to be a major risk factor for mental health disorders, and may also impact on physical activity levels [56,57].

In sum, our findings suggest that leisure time PA performed at levels recommended for general health may reduce elevated anxiety symptoms. Future research should investigate the anxiolytic effect of both sub-guideline levels of PA, which have been shown to reduce odds of mortality [58], and those sufficiently exceeding recommended levels of MVPA for 'additional health benefits'; the potential moderating/mediating roles of social support in the PA–anxiety relationship; and, how sedentary behaviour influences anxiety, independently of PA levels. Emerging research shows that cardiovascular and metabolic disorders are more prevalent in those with anxiety [5]. Future research should investigate the effects of PA interventions on these key health outcomes. As the incidence of anxiety disorder was likely under-estimated in this study, further prospective studies based on accurate estimates of anxiety disorder are also warranted.

Conflicts of interest

None.

Acknowledgements

We thank Statistics Sweden for scanning the questionnaires. We would also like to thank the Swedish Cancer Society and the volunteers who were involved in data collection.

Funding

This work was supported by ICA AB; Telefonaktiebolaget LM Ericsson; the Swedish Cancer Society [Grant CAN 2012/591]; a Karolinska Institutet Distinguished Professor Award [2368/10-221 to HOA]; and funds from the Regional Agreement on Medical Training and Clinical Research between Stockholm County Council and Karolinska Institutet [YTL]. The funders played no role in the design of the study, the data collection or the analysis, or in the decision to publish or the preparation of the manuscript.

Ethical standards

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.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.genhosppsych.2019.03.001.

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