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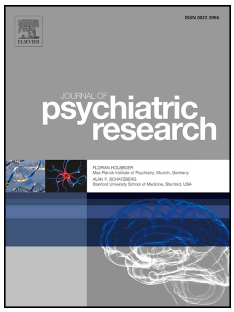

Leisure time physical activity and future psychological distress: A thirteen year longitudinal population-based study

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PII: S0022-3956(17)31122-6

DOI: 10.1016/j.jpsychires.2018.02.025

Reference: PIAT 3323

To appear in: *Journal of Psychiatric Research*

Received Date: 11 October 2017

Revised Date: 24 February 2018

Accepted Date: 26 February 2018

Please cite this article as:

Leisure time physical activity and future psychological distress: a thirteen year longitudinal population-based study

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Running title: Physical activity and psychological distress

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Conflict of Interest: The authors declare that they have no conflict of interest.

Funding:

BS is part funded by the National Institute for Health Research (NIHR) Biomedical Research Centre at South London and Maudsley NHS Foundation Trust and King's College London. The views expressed are those of the author(s) and not necessarily those of the NHS, the NIHR or the Department of Health.

Abstract (246/250)

A number of cross-sectional studies have suggested that physical activity (PA) is negatively associated with psychological distress in adulthood. A paucity of regionally representative and longitudinal studies has considered this relationship. This study investigated the association between leisure time light and moderate-vigorous PA (MVPA) and psychological distress over 13 years in a regionally representative sample. A total of 4754 men (mean age: 47.2 years) and 5571 women from (mean age: 46.9 years) the Tromsø Study were followed for 13 years. Light PA and MVPA was captured at baseline and psychological distress was captured using the Hopkins Symptom Check List-10 scale. Ordinary least square and Poisson regression models were used, adjusting for multiple confounders to investigate the relationship between light PA/MVPA and psychological distress. In the fully-adjusted model, accounting sociodemographics, history of parental psychopathology, socioeconomic status, marital status, smoking, social support and risk factors, we found evidence that both light PA (β 0.11, 95% CI: 0.03, 0.19; p<0.01) and MVPA (β 0.19, 95% CI: 0.12, 0.26; p<0.001) confered protection against psychological distress at follow-up. Among men, a lower MVPA was associated with 14% (RR=1.14, 95% CI: 1.01, 1.28) increased risk of clinically significant psychological distress; while among women, the risk was 15% (RR=1.15, 95% CI: 1.06, 1.26; p<0.001). In this regionally representative cohort, our study suggests that both higher levels of light PA and MVPA confer protection against future psychological distress. However, a key limitation of this study is that psychological distress at baseline was not controlled-for.

Keywords: Physical activity; exercise; anxiety; depression; distress; psychological distress; well-being

Introduction

Leisure time physical activity (PA) has a wide range of physical and mental health benefits (Penedo & Dahn, 2005; Sheikh, Lund, & Braaten, 2014). Conversely, physical inactivity is the fourth leading cause of preventable mortality in the world, mainly due to the increased cardiovascular risks associated with it (Kohl et al., 2012). Among people with established mental illness, physical exercise, i.e. a structured form of physical exertion, is acknowledged as an essential aspect in the multidisciplinary treatment of depression (Schuch, Vancampfort, Richards, et al., 2016; Schuch, Vancampfort, Rosenbaum, Richards, Ward, & Stubbs, 2016; Schuch, Vancampfort, Rosenbaum, Richards, Ward, Veronese, et al., 2016), anxiety (Stubbs, Vancampfort, et al., 2017), and psychosis (J. Firth, Cotter, Elliott, French, & Yung, 2015; Joseph Firth et al., 2017; Pajonk, Wobrock, Gruber, & et al., 2010; Davy Vancampfort et al., 2017). In the past decade, from a public health perspective there has been an increased interest in the beneficial effects of PA on mental health (Lubans, Plotnikoff, & Lubans, 2011). Nowadays it is well-established that PA has a protective effect for future depression (Harvey et al., 2017), and cognitive decline (Stubbs, Chen, Chang, Sun, & Ku, 2017). It is associated with less suicidal ideation (D. Vancampfort et al., 2018) while acute bouts reduce feelings of state anxiety (Ensari, Greenlee, Motl, & Petruzzello, 2015). Psychological well-being, is however a much broader concept than the absence of mental illness and refers to a positive state of well-being where individuals realize their potential, experience positive emotions, and are able to maintain interpersonal relationships, work productively, contribute to their community and cope with psychological distress (Gong, Palmer, Gallacher, Marsden, & Fone, 2016; Naci & Ioannidis, 2015; Sheikh, Abelsen, & Olsen, 2014, 2016a, 2016b, 2017). Other evidence suggests that individuals with higher symptoms of psychological distress are denied the same job opportunities as their peers, thereby restricting them to jobs with lower income (Dworsky & Courtney, 2007; Rizvi et al., 2015).

Psychological distress is a term that encapsulates unpleasant feelings and negative emotions that affect day-to-day functioning and affects a sizable share of the population in both high-income and low-to-middle-income countries (Gong et al., 2016; Perales, Pozo-Cruz, & Pozo-Cruz, 2014; Sheikh, 2018a, 2018b). Perhaps unsurprisingly psychological distress has been associated with the risk of developing more severe mental health conditions and physical health issues including premature mortality, particularly due to cardiovascular and metabolic disease (Gong et al., 2016; Hamer, Kivimaki, Stamatakis, & Batty, 2012; Lazzarino, Hamer, Stamatakis, & Steptoe, 2013; Perales et al., 2014; Russ et al., 2012; Sheikh et al., 2016a). In addition, the considerable financial and human costs of psychological distress, has led to a pressing need to identify potentially modifiable risk factors which may be important for the development of efficient public health policies (Ding et al., 2016; Ekelund et al., 2016; Gong et al., 2016; Perales et al., 2014; Sheikh, 2017b, 2017c, 2018a, 2018b; Sheikh et al., 2016a). A nation-wide survey showed that over 10.2% of the population in Norway reported to have experienced psychological distress within the last two weeks (FHI, 2015), while a regionally representative survey of Tromsø region in Norway showed that over 9.3% of the adult population had clinically significant psychological distress (Sheikh et al., 2016a).

One key risk factor that has been associated with higher psychological distress in multiple cross-sectional studies is physical inactivity (Hamer, Biddle, & Stamatakis, 2017; Hamer, Stamatakis, & Steptoe, 2009). A recent large nationally representative cross-sectional study in Scotland demonstrated a clear dose response benefit between lower PA levels and reduced psychological distress (Hamer et al., 2017). Another cross-sectional study among 4,337 adults in Singapore demonstrated that higher levels of PA also appear to confer protection against psychological distress (Sloan et al., 2013). Whilst these studies have provided a useful insight into the relationship between PA and psychological distress, the

cross-sectional nature precludes any inferences on the directionality of the observed relationships. However, there is a paucity of regionally representative and longitudinal studies that has investigated this relationship. Nonetheless, one four-year study in Australia including 17,080 people demonstrated that higher levels of moderate-vigorous PA (MVPA) was associated with a reduced incidence of psychological distress (Perales et al., 2014). Whilst helpful, the relatively short follow-up time period and lack of focus on leisure time light PA, which can also have benefits for health (Fuzeki, Engeroff, & Banzer, 2017), calls for future research.

Given the aforementioned, we set out to explore the relationship between leisure time light PA and MVPA levels and subsequent psychological distress levels using data from the regionally representative Tromsø Study over a 13 year period. The specific research questions were: (1) are those with lower levels of leisure time light PA or MVPA more likely to experience a higher psychological distress?, and; (2) do these associations differ significantly by gender?

Material and methods

Study population

The Tromsø Study is a representative, prospective cohort study of the adult population residing in the municipality of Tromsø, Norway (Jacobsen, Eggen, Mathiesen, Wilsgaard, & Njølstad, 2012). Between 1974 and 2007–2008, six waves of the Tromsø Study were conducted (referred to as Tromsø I–VI) (Jacobsen et al., 2012). The present study has a two-wave design. To be eligible for the present analyses, participants had to have attended both Tromsø IV (1994-95) and Tromsø VI (2007-08) (N = 10,325). The study sample included respondents aged 25–74 years at Tromsø IV, and 38–87 years at Tromsø VI (Sheikh, 2017a; Sheikh et al., 2016b).

Study variables

Leisure time light physical activity and moderate to vigorous physical activity (Tromsø IV)

Leisure time PA was measured with two identical questions on light PA (not sweating or out of breath) and MVPA (sweating/out of breath) on a four-point Likert scale: “How has your weekly average physical activity in leisure time been during this last year?,” The response alternatives were: ‘none’, ‘less than 1’, ‘1-2’, and ‘3 or more’ hours/week. The scores were inverted, so that a higher score represents lower leisure time PA. Cronbach alpha for the two items was 0.36 (inter-item covariance: 0.23). Light PA and MVPA exist on a continuum; therefore, we also constructed a composite PA as sum of scores from two indicators (light and MVPA). All associations with composite PA are presented in appendix (Online Supplementary Material).

Psychological distress (Tromsø VI)

Psychological distress was measured by the Hopkins symptom checklist (HSCL-10) scale, which is widely used in epidemiological studies (Sheikh, 2017b, 2018a; Sheikh et al., 2016b). Respondents rated each of the 10 items in the HSCL-10 on a four-point scale ranging from *not at all* (1) to *extremely* (4). We found an acceptable degree of internal consistency for the four-point scale in this sample (Cronbach's alpha 0.86, mean inter-item correlation: 0.41, McDonald's omega coefficient for composite reliability: 0.87) (Sheikh et al., 2016b). A composite variable was constructed as the sum of the 10 items (Sheikh et al., 2016b). An HSCL-10 score of 18.5 has been proposed as the cut-off for predicting clinically significant cases of psychological distress (Strand et al., 2003). Therefore, in addition to the continuous HSCL-10, we also constructed a binary variable by classifying respondents with scores below 18.5 as reference group (HSCL-10 = 0), and those with scores ≥18.5 as clinically significant cases of psychological distress (HSCL-10 = 1).

Confounding variables

Data on confounding variables were taken from the Tromsø IV questionnaire. The confounding variables age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, social support, and education, were chosen based on *a priori* knowledge of PA correlates in the general population (Bauman et al., 2012) and of the association between PA and psychological distress (Hamer et al., 2017; Hamer et al., 2009; Sheikh, 2017b, 2017c, 2018a, 2018b; Sheikh et al., 2016a).

Valid information on age and gender was obtained from Statistics Norway by using the unique personal identification number of each participant. Mother's/father's history of

psychopathology was measured as: “Does your mother/father have/has your mother/father ever had psychiatric disorders?” (yes, no). The test-retest reliability of mother's history of psychopathology and father's history of psychopathology in Tromsø Study were Kappa: 0.57 (95% CI: 0.52–0.62) and Kappa: 0.61 (95% CI: 0.53–0.69), respectively (Sheikh, 2017a). Subjective childhood socioeconomic status was measured by the question, “How was your family’s financial situation during childhood?” on a 4-point scale (1 = very good, 2 = good, 3 = difficult, 4 = very difficult). The reliability of childhood socioeconomic status was good [Kappa: 0.61, 95% confidence interval (CI) 0.59, 0.63] in Tromsø Study (Sheikh, 2017c). Daily smoking was measured by the question, “Do you smoke cigarettes daily?” (yes /no). The test-retest reliability of this variable was good (Kappa: 0.67, 95% CI: 0.63–0.71) in Tromsø Study (Sheikh, 2017c). Social support was measured with two questions on number of friends and perceived social isolation as “How many good friends do you have whom you can talk confidentially with and who give you help when you need it?” and “Do you feel that you have enough good friends?” (yes, no). Those who reported ‘no’ to the second question were categorized as socially isolated. Cronbach’s alpha for the two items on social support was 0.32 (inter-item covariance: 0.19). Education level was measured on a 5-point scale as: 1) college or university (4 years or more); 2) college or university (less than 4 years); 3) high school diploma; 4) vocational school or technical school; and 5) primary and secondary school or similar (i.e., 7–10 years of schooling). The test-retest reliability of education level was very good (Kappa: 0.91, 95% CI: 0.91, 0.92) in Tromsø Study (Sheikh, 2017c).

Ethical approval

This investigation was carried out in accordance with the latest version of the Declaration of Helsinki. The Tromsø Study has been approved by the Regional Committee for Medical and Health Research Ethics, the Data Inspectorate, and the Norwegian Directorate of

Health. Written informed consent was obtained from all individual participants included in the study.

Statistical analysis

All analyses were conducted using Stata version 15 (StataCorp LLC). Normality assumption for ordinary least square (OLS) regression model was assessed (Stata command -acprplot-), and satisfied (Hamilton, 2013); therefore, the PA variables were not transformed. To assess the collinearity of regressors, we estimated variance inflation factors (VIFs) in Stata (-vif-) (Hamilton, 2013). In the fully-adjusted model, mean VIF was 1.08, and none of the individual regressor's VIF were greater than 1.25 (VIF for age). Baseline characteristics of the study sample were determined with means (standard error), and proportions (Table 1). Missing values were generated with multiple imputation with chained equations. A comparison between the complete-case (excluding missing) and the imputed dataset is presented with proportions (%), and mean (standard error) (see Table 1). We estimated Pearson product-moment correlations between all variables considered in this study (Table 2). For the continuous variable of psychological distress, we assessed the association between indicators of leisure time PA and psychological distress by OLS regression analysis. For binary variable of psychological distress (clinically significant psychological distress), we used modified Poisson regression models and relative risks (RRs) were estimated (Barros & Hirakata, 2003; Sheikh et al., 2017; Zou, 2004).

To test whether estimates of *both* light PA and MVPA are jointly different from 0, we used the Stata command –test- (Hamilton, 2013). The null hypothesis was that there was no relationship between *both* light PA and MVPA and psychological distress ($\beta_{\text{light PA}} = 0$ *and* $\beta_{\text{MVPA}} = 0$).

Multivariable regression analysis were used for adjusted models, and all the confounding variables were included, along with the independent variable of interest (see Table 3 and Table 4). Adjusted OLS estimates (β), and relative risks (RRs) with corresponding 95% CIs are presented (see Table 3 and Table 4). Results of complete-case analysis, i.e., excluding missing, are presented in Online Supplementary Material (Table S9 and Table S10). No statistically significant multiplicative interactions were observed with age, childhood socioeconomic status, marital status, smoking status, or educational attainment (data not shown). In order to control for potential heteroscedasticity, we estimated robust standard errors in all models (Huber, 1967; White, 1980). Results of complete-case analysis (i.e., excluding missing) are presented in Online Supplementary Material (Table S7 and Table S8).

Results

The percentage of missing information for indicators of leisure time PA and psychological distress was as follows: light PA (0.4%), MVPA (0.7%) and psychological distress (15.0%). Men were more likely than women to not report light PA ($p<0.05$). Participants with missing information on MVPA were likely to be older ($p<0.05$). Participants with missing information on psychological distress tended to be female, older, to have a lower education level and lower light PA ($p<0.05$).

The majority of the respondents in our study sample were aged 45 and over (61.9%) at baseline (Tromsø IV), were female (54.0%) and were married or registered partners (63.9%) (Table 1). Mothers history of psychopathology (6.5%) were reported more often than fathers history of psychopathology (2.5%) (Table 1). Parental history of psychopathology was significantly ($p<0.001$) associated with a higher psychological distress among respondents (Table 2). Men reported a significantly higher light PA ($r=0.06$, $p<0.001$), while women reported a significantly higher MVPA ($r=-0.19$, $p<0.001$), and a higher psychological distress ($r=-0.18$, $p<0.001$) (Table 2). A higher childhood financial conditions were significantly associated with a higher light PA ($r=0.03$, $p<0.01$), a higher MVPA ($r=0.04$, $p<0.001$), and a higher psychological distress ($r=0.10$, $p<0.001$) (Table 2). Daily smoking was significantly associated with a lower light PA ($r=0.07$, $p<0.001$), a lower MVPA ($r=-0.06$, $p<0.001$), and a higher psychological distress ($r=-0.02$, $p<0.05$) (Table 2). A higher light PA was significantly associated with lower psychological distress ($r=0.04$, $p<0.05$) (Table 2). A higher MVPA was significantly associated with a lower age ($r=0.19$, $p<0.001$), a higher number of friends ($r=-0.19$, $p<0.001$), a higher education level ($r=-0.20$, $p<0.001$), a higher light PA ($r=0.22$, $p<0.001$), and a lower psychological distress ($r=0.11$, $p<0.001$) (Table 2). Perceived social isolation ($r=-0.14$, $p<0.001$) and a higher education level ($r=-0.09$, $p<0.001$) were significantly associated with psychological distress (Table 2).

In the complete-case analysis (i.e, excluding missing), *both* light PA and MVPA (jointly) had a significant effect on psychological distress [F (2, 7218) = 6.05, p = 0.002]. Associations of composite PA (i.e., sum of light PA and MVPA) are presented in appendix (Online Supplementary Material). Women reported a significantly higher composite PA (r=-0.09, p<0.001) (Table S4). A higher childhood financial conditions were significantly associated with a higher composite PA (r=0.04, p<0.01) (Table S4). Daily smoking was significantly associated with a lower composite PA (r=0.10, p<0.001) (Table S4). A higher composite PA was significantly associated with a lower age (r=-0.09, p<0.001), a higher number of friends (r=-0.01, p<0.001), a higher education level (r=-0.19, p<0.001), and a lower psychological distress (r=0.09, p<0.001) (Table S4).

Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education, lower light PA was significantly associated with a higher level of psychological distress (β=0.11, 95% CI: 0.03, 0.19; p<0.01) (Table 3). Similarly, in the fully-adjusted model, a lower MVPA was significantly associated with a higher level of psychological distress (β=0.19, 95% CI: 0.12, 0.26; p<0.001) (Table 3). When the binary variable that reflected clinically significant cases of psychological distress was used, a lower light PA was associated with 9% increased risk of psychological distress (RR=1.09, 95% CI: 1.02, 1.15; p<0.01), while a lower MVPA was associated with 15% increased risk of psychological distress (RR=1.15, 95% CI: 1.07, 1.23; p<0.001) (Table 3).

Table S1 presents the multiplicative interaction between indicators of PA and gender, regressed on psychological distress. On OLS scale, statistically significant multiplicative interactions were observed between light PA and psychological distress (p<0.05), and between MVPA and psychological distress (p<0.05) (Table S1). The association between PA and psychological distress was significantly stronger among women, than men (Table 3).

However, when both light PA and MVPA were considered together in the model, only the MVPA*gender interaction ($p<0.05$) was statistically significant (Table S1). Moreover, on the RR scale, the multiplicative interactions between both indicators of PA and gender were not statistically significant (Table S1).

Table S5 presents the multiplicative interaction between composite PA and gender, regressed on psychological distress. The corresponding results for complete-case analysis (excluding missing) are presented in Table S7 (Online Supplementary Material). On OLS scale, statistically significant ($p=0.046$) multiplicative interactions were observed between composite PA and gender; however, the PA*gender interaction was not statistically significant ($p=0.529$) on the RR scale (Table S5). On the OLS scale, the association between composite PA and psychological distress was significantly stronger among women, than men (Table S5).

Table 4 presents the fully-adjusted association between light PA, MVPA and psychological distress, stratified by gender. The corresponding results for complete-case analysis (excluding missing) are presented in Table S10 (Online Supplementary Material). A lower light PA or MVPA was associated with higher psychological distress among both men and women (Table 4). When continuous variable of psychological distress was used as an outcome, the association was slightly stronger among women (Table 4). However, when the binary variable that reflected clinically significant cases of psychological distress was used, the association between light PA and psychological distress was stronger among men, while the association between MVPA and psychological distress was slightly stronger among women (Table 4). Among men, a lower light PA was associated with 15% (RR=1.15, 95% CI: 1.03, 1.29) increased risk of clinically significant psychological distress; while among women, the risk was 6% (RR=1.06, 95% CI: 0.98, 1.14) (Table 4). Moreover, a lower MVPA was associated with 15% increased risk of clinically significant psychological distress among

women (RR=1.15, 95% CI: 1.06, 1.26; p<0.001), while the risk was 14% among men (RR=1.14, 95% CI: 1.01, 1.28) (Table 4).

Table S6 presents the fully-adjusted association between composite PA and psychological distress, stratified by gender. The corresponding results for complete-case analysis (excluding missing) are presented in Table S8 (Online Supplementary Material). A lower composite PA was associated with psychological distress among both men and women (p<0.001) (Table S6). When continuous variable of psychological distress was used as an outcome, the composite PA-psychological distress association was slightly stronger among women (β=0.15, 95% CI: 0.07, 0.22), than men (β=0.10, 95% CI: 0.04, 0.16) (Table S6). However, when the binary variable that reflected clinically significant cases of psychological distress was used, the association was slightly stronger among men, than women. Among men, a lower composite PA was associated with 11% (RR=1.11, 95% CI: 1.04, 1.20) increased risk of clinically significant psychological distress; while among women, the risk was 8% (RR=1.08, 95% CI: 1.03, 1.13) (Table S6).

Discussion

To the best of our knowledge, the current study is the first regionally representative study with a long follow up period (i.e. over ten years) to investigate the specific relationship between leisure time light PA and MVPA and incident psychological distress. In sum, our data suggest that after adjustment for multiple potential confounders (history of parental psychopathology, socioeconomic status, marital status, smoking, social support and risk factors) that both light PA and MVPA during leisure time may confer protection against psychological distress. These findings suggest that physical inactivity is independently involved in the pathogenesis of psychological distress.

To date, there is a paucity of regionally representative prospective cohort studies that have considered the relationship between PA and psychological distress. Most previous studies that assessed the association between physical inactivity and mental health outcomes in adulthood have relied on very small and selective study samples. These samples are prone to selection bias, and are not helpful in making population estimates. The only potentially comparable study is that of Perales et al (Perales et al., 2014) who found over a four-year period that higher levels of MVPA were notably associated with reduced psychological distress. Nonetheless, a key argument for valuing cross-sectional evidence on the associations between PA and psychological distress is that PA appears to be stable across life span (Friedman et al., 2008). Moreover, a few longitudinal studies (Gerber et al., 2013; Gerber et al., 2015; Gudmundsson et al., 2015; Josefsson, Lindwall, & Archer, 2014; Lindwall, Gerber, Jonsdottir, Börjesson, & Ahlborg Jr, 2014; Lindwall, Larsman, & Hagger, 2011) have shown that PA plays a protective role for burnout and certain mood disorders.

Our study advances the literature in several ways. First, we were able to adjust for multiple factors that previous studies have not considered which are strongly associated with future psychological distress including a family history of psychopathology (Payton, 2009),

and social support (Khatib, Bhui, & Stansfeld, 2013; Sheikh, 2017b, 2018b; Sheikh et al., 2016a). Second, we were able to distinguish that both leisure time light PA and MVPA appear to have beneficial impact on protecting against future psychological distress. It is known that lighter PA is a popular form of activity, particularly among older adults, and our data add to the benefits of this type of activity on future psychological distress (Stubbs, Chen, et al., 2017). Third, to the best of our knowledge, the current study is also the longest follow-up over thirteen years and undertaking research over such a time period clearly has benefits to better understand the long-term potential public health impact of leisure time PA on health.

Whilst our data offer some novel insights, it is important that some limitations are considered. First, given that we did not have a measure of psychological distress at baseline, we were unable to control for or remove people with pre-existing psychological distress. This means that some of the relationship between PA and psychological distress may be influenced by the baseline cross sectional relationships between these variables reported previously which we could not control for. In addition, reverse causation remains a concern, given that psychological distress may discourage people from engaging in physical activities and this cannot be ruled out. Indeed, the psychological state of respondents at the time of reporting PA may confound the association between PA and subsequent psychological distress in multiple ways (Aneshensel, Estrada, Hansell, & Clark, 1987; Sheikh, 2017a; Sheikh et al., 2016b). It is probable that some individuals might had been suffering from chronic psychological distress when they participated in Tromsø IV. Indeed, history of psychological distress is a strong predictor of psychological distress in later-life (Davies et al., 2015). Thus, we recommend that in order to overcome this limitation, future longitudinal studies measure and account for baseline psychological distress. Second, leisure time PA was captured with a self-report instrument and thus we cannot rule out the possibility of reporting errors (Aneshensel et al., 1987; Vanhees et al., 2005). Third, whilst our paper adjusted for a multitude of novel potential

confounders, some important factors such as physical co-morbidities including diabetes were absent. Fourth, there is an increasing body of evidence that sedentary behavior is negatively associated with health outcomes and we did not consider this. Fifth, only 'leisure time' PA was measured in the Tromsø Study, and this is only a fraction of the total daily/weekly PA. For example, we did not assess levels of occupational PA. However, previous research suggests that the time spent in occupational PA is not related to subsequent psychological distress levels (Kim, Shin, Nam, Choi, & Kim, 2008). Nevertheless, future longitudinal research should explore in more detail the different associations with psychological distress between different types of PA. Finally, PA was measured with two questions on a four-point Likert scale; therefore, it was not possible to convert PA levels to time spent physically active.

It must be noted that while a 13-year follow-up is a strength in terms of the long-term effects of PA on psychological distress, other variables may have affected psychological distress as well. For instance, previous evidence has shown that education (Sheikh, 2018a; Sheikh, Abelsen, et al., 2014), smoking (Sheikh, 2017c), objective social support (Sheikh, 2018b), and perceived social support (Sheikh, 2017b, 2018b) are longitudinally associated with psychological distress in adulthood.

In conclusion, in this regionally representative and long-term follow up study, our data suggest that higher levels of both leisure time light PA and MVPA may play a protective role against psychological distress. By identifying the specific protective factors of psychological distress, we can develop programs/interventions aimed at increasing the level of leisure time PA in vulnerable groups susceptible to psychological distress. Future research is required to confirm/refute these findings and understand potential underlying mechanisms.

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Table 1. General characteristics of the study sample (n=10,325).

Characteristics		Complete-case dataset	Imputed dataset
		n (%)	(%)
Age, years (in 1994)	Mean (standard error, SE)	47.03 (0.12)	-[b]
	25-34	1987 (19.2)	-[b]
	35-44	1944 (18.8)	-[b]
	45-54	3630 (35.2)	-[b]
	55-64	2016 (19.5)	-[b]
	65-74	748 (7.2)	-[b]
Gender	Male	4754 (46.0)	-[b]
	Female	5571 (54.0)	-[b]
History of psychopathology, mother	Yes	676 (6.5)	-[b]
	No	9649 (93.5)	-[b]
History of psychopathology, father	Yes	256 (2.5)	-[b]
	No	10069 (97.5)	-[b]
Childhood socioeconomic status[a]	Mean (standard error, SE)	2.32 (0.01)	2.32 (0.01)
Marital status [a]	Single	2166 (21.0)	21.0
	Married or registered partnership	6588 (63.9)	63.9
	Widowed, divorced or separated	1552 (15.1)	15.1
Daily smoking[a]	Yes	3378 (32.8)	32.7
	No	6936 (67.3)	67.3
Number of friends[a]	Mean (SE)	4.95 (0.05)	4.94 (0.05)
Perceived social isolation[a]	Socially isolated	1684 (18.1)	18.0
	Not socially isolated	7631 (81.9)	82.0
Education[a]	Mean (SE)	2.46 (0.01)	2.46 (0.01)
Physical activity (light) [a]	Mean (SE)	3.05 (0.01)	3.05 (0.01)
Physical activity (MVPA) [a]	Mean (SE)	1.95 (0.01)	1.95 (0.01)
Psychological distress (HSCL-10)[a]	Mean (SE)	12.67 (0.04)	12.95 (0.04)

[a]The numbers for some variables do not add up to 10,325 due to missing values.
[b]There were no missing values, so no imputations were made for these variables.
SE: standard error; HSCL-10: Hopkins Symptom Check List-10; scale (10–40), where 10 represents lowest level of psychological distress, and 40 represents highest level of psychological distress; MVPA: moderate to vigorous physical activity

Table 2. Bivariate Pearson product-moment correlations between variables (n=10,325)

	1	2	3	4	5	6	7	8	9	10	11	12
	r	r	r	r	r	r	r	r	r	r	r	r
1. Age	1.00											
2. Gender	0.01	1.00										
3. History of psychopathology, mother	-0.04[c]	-0.05[c]	1.00									
4. History of psychopathology , father	-0.05[c]	-0.02[a]	0.06[c]	1.00								
5. Childhood socioeconomic status	0.22[c]	0.06[c]	0.07[c]	0.03[a]	1.00							
6. Smoking	-0.11[c]	-0.02	0.01	0.01	-0.01	1.00						
7. Number of friends	-0.01	-0.07[c]	-0.03[b]	-0.01	-0.05[c]	-0.01	1.00					
8. Perceived social isolation	0.05[c]	-0.06[c]	-0.07[c]	-0.05[c]	-0.10[c]	0.03[b]	0.19[c]	1.00				
9. Education	-0.26[c]	0.06[c]	0.03[a]	0.03[b]	-0.14[c]	-0.15[c]	0.04[c]	-0.06[c]	1.00			
10. light PA	-0.01	0.06[c]	-0.01	-0.01	0.03[b]	0.07[c]	-0.06[c]	-0.01	-0.10[c]	1.00		
11. MVPA	0.19[c]	-0.19[c]	-0.01	-0.01	0.04[c]	0.09[c]	-0.04[c]	-0.01	-0.20[c]	0.22[c]	1.00	
12. HSCL-10	-0.03	-0.18[c]	0.12[c]	0.04[c]	0.10[c]	0.10[c]	-0.08[c]	-0.14[c]	-0.09[c]	0.04[a]	0.11[c]	1.00

[a]p<0.05
[b]p<0.01
[c]p<0.001

Table 3. Association between physical activity and psychological distress (n=10,325).

	Psychological distress (HSCL-10)[g]
	OLS estimates
	Adjusted
	β (95% CI)
Physical activity (light)[f]	0.11 (0.03, 0.19)[a, c, e]
Physical activity (MVPA) [f]	0.19 (0.12, 0.26)[b, d, e]
	Relative risk estimates
	Adjusted
	RR (95% CI)
Physical activity (light) [f]	1.09 (1.02, 1.15)[a, e]
Physical activity (MVPA)[f]	1.15 (1.07, 1.23)[b, e]

[a] $p<0.01$
[b] $p<0.001$
[c] Model $R^2=0.094$
[d] Model $R^2=0.095$
[e] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[f] Physical activity was measured in 1994-1995.
[g] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA

Table 4. Association between physical activity and psychological distress, stratified by gender.

	Psychological distress (HSCL-10)[j]	
	Men	**Women**
	OLS estimates	
	Adjusted	**Adjusted**
	β (95% CI)	**β (95% CI)**
Physical activity (light)[i]	0.09 (-0.01, 0.19)[a, d, h]	0.13 (0.01, 0.25)[b, h, f]
Physical activity (MVPA)[i]	0.15 (0.06, 0.23)[c, e, h]	0.23 (0.12, 0.34)[c, h, g]
	Relative risk estimates	
	Adjusted	**Adjusted**
	RR (95% CI)	**RR (95% CI)**
Physical activity (light)[i]	1.15 (1.03, 1.29)[b, h]	1.06 (0.98, 1.14)[h]
Physical activity (MVPA)[i]	1.14 (1.01, 1.28)[b, h]	1.15 (1.06, 1.26)[c, h]

[a] $p<0.1$
[b] $p<0.05$
[c] $p<0.001$
[d] Model $R^2=0.055$
[e] Model $R^2=0.057$
[f] Model $R^2=0.083$
[g] Model $R^2=0.085$
[h] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[i] Physical activity was measured in 1994-1995.
[j] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA

Table S1. Association between physical activity and gender, and psychological distress (n=10,325).

	Psychological distress (HSCL-10)[j]		
	OLS estimates		
	Adjusted	**Adjusted**	**Mutually adjusted**
	β (95% CI)	**β (95% CI)**	**β (95% CI)**
Physical activity (light)[i]	0.15 (0.03, 0.27)[a, d, g]	-	0.09 (-0.03, 0.22)[f, h]
Physical activity (MVPA)[i]	-	0.27 (0.16, 0.38)[c, e, g]	0.25 (0.14, 0.36)[c, f, h]
Men (reference=women)	-1.27 (-1.59, -0.94)[c, d, g]	-0.82 (-1.25, -0.40)[c, e, g]	-0.79 (-1.27, -0.32)[f, h]
Light PA*gender	-0.07 (-0.23, 0.09)[a, d, g]	-	-0.04 (-0.20, 0.12)[f, h]
MVPA*gender	-	-0.16 (-0.30, -0.02)[a, e, g]	-0.15 (-0.30, -0.01)[a, f, h]
	Relative risk estimates		
	Adjusted	**Adjusted**	**Mutually adjusted**
	RR (95% CI)	**RR (95% CI)**	**RR (95% CI)**
Physical activity (light)[i]	1.06 (0.98, 1.13)[g]	-	1.03 (0.95, 1.11)[h]
Physical activity (MVPA)[i]	-	1.16 (1.06, 1.27)[c, g]	1.15 (1.05, 1.26)[b, h]
Men (reference=women)	0.37 (0.27, 0.51)[c, g]	0.52 (0.32, 0.84)[b, g]	0.45 (0.27, 0.75)[b, h]
Light PA*gender	1.09 (0.96, 1.24)[g]	-	1.10 (0.96, 1.26)[h]
MVPA*gender	-	0.97 (0.84, 1.12)[g]	0.95 (0.82, 1.10)[h]

[a] $p<0.05$
[b] $p<0.01$
[c] $p<0.001$
[d] Model $R^2=0.097$
[e] Model $R^2=0.098$
[f] Model $R^2=0.099$
[g] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[h] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, education + light physical activity, and MVPA
[i] Physical activity was measured in 1994-1995.
[j] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA

Table S2. Association between physical activity and psychological distress, stratified by gender (n=10,325).

	Psychological distress (HSCL-10)[h]	
	Men	**Women**
	OLS estimates	
	Mutually adjusted	**Mutually adjusted**
	β (95% CI)	**β (95% CI)**
Physical activity (light)[g]	0.05 (-0.05, 0.16) [d, f]	0.08 (-0.04, 0.21)[e,f]
Physical activity (MVPA) [g]	0.14 (0.05, 0.23)[b, d, f]	0.21 (0.10, 0.33)[c, e, f]
	Relative risk estimates	
	Mutually adjusted	**Mutually adjusted**
	RR (95% CI)	**RR (95% CI)**
Physical activity (light) [g]	1.12 (0.99, 1.27)[a, f]	1.03 (0.95, 1.11)[f]
Physical activity (MVPA)[g]	1.10 (0.97, 1.25)[f]	1.15 (1.05, 1.25)[b, f]

[a] $p<0.1$
[b] $p<0.01$
[c] $p<0.001$
[d] Model $R^2=0.057$
[e] Model $R^2=0.085$
[f] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, education + light physical activity, and MVPA
[g] Physical activity was measured in 1994-1995.
[h] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA

Table S3. Distribution of composite physical activity variable (n=10,325).

Characteristics		Complete-case dataset	Imputed dataset
		n (%)	(%)
Composite physical activity	Mean (SE)	5.01 (0.02)	5.01 (0.02)

SE:standard error.

Table S4. Bivariate Pearson product-moment correlations between composite physical activity and covariates (n=10,325)

	Composite physical activity
	r
Age	0.12[a]
Gender	-0.09[a]
History of psychopathology, mother	-0.01
History of psychopathology , father	-0.01
Childhood socioeconomic status	0.04[a]
Smoking	0.10[a]
Number of friends	-0.06[a]
Perceived social isolation	-0.01
Education	-0.19[a]
HSCL-10	0.09[a]

[a]p<0.001

Table S5. Role of gender as a moderator in the association between composite physical activity and psychological distress (n=10,325).

	Psychological distress (HSCL-10)[f]
	OLS estimates[d]
	Adjusted[d]
	β (95% CI)[d]
Composite physical activity[e]	0.17 (0.10, 0.25)[b, c]
Men (reference=women)	-0.89 (-1.35, -0.42)[b, c]
Composite physical activity*gender	-0.09 (-0.19, -0.01)[a, c]
	Relative risk estimates[d]
	Adjusted[d]
	RR (95% CI)[d]
Composite physical activity[e]	1.08 (1.03, 1.13)[b]
Men (reference=women)	0.40 (0.25, 0.64)[b]
Composite physical activity*gender	1.03 (0.94, 1.12)

[a] $p<0.05$
[b] $p<0.001$
[c] Model $R^2=0.098$
[d] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[e] Composite physical activity was measured in 1994-1995.
[f] Psychological distress was measured in 2007-2008.
CI: confidence interval

Table S6. Association between composite physical activity and psychological distress, stratified by gender (n=10,325).

	Psychological distress (HSCL-10)[g]	
	Men (n=4754)	**Women (n=5571)**
	OLS estimates[e]	
	Adjusted[e]	**Adjusted[e]**
	β (95% CI)[e]	**β (95% CI)[e]**
Composite physical activity[f]	0.10 (0.04, 0.16)[b, c, e]	0.15 (0.07, 0.22)[b, d, e]
	Relative risk estimates[d]	
	Adjusted[e]	**Adjusted[e]**
	RR (95% CI)[e]	**RR (95% CI)[e]**
Composite physical activity[f]	1.11 (1.04, 1.20)[a, e]	1.08 (1.03, 1.13)[a, e]

[a] $p<0.01$
[b] $p<0.001$
[c] Model $R^2=0.057$
[d] Model $R^2=0.085$
[e] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[f] Composite physical activity was measured in 1994-1995.
[g] Psychological distress was measured in 2007-2008.
CI: confidence interval

Table S7. Role of gender as a moderator in the association between composite physical activity and psychological distress (complete-case analysis, i.e., excluding missing; n=7235).

	Psychological distress (HSCL-10)[f]
	OLS estimates[d]
	Adjusted[d]
	β (95% CI)[d]
Composite physical activity[e]	0.10 (0.02, 0.19)[a, c]
Men (reference=women)	-0.96 (-1.48, -0.43)[b, c]
Composite physical activity*gender	-0.05 (-0.15, -0.06)[c]
	Relative risk estimates[d]
	Adjusted[d]
	RR (95% CI)[d]
Composite physical activity[e]	1.07 (1.01, 1.14)[a]
Men (reference=women)	0.47 (0.26, 0.84)[a]
Composite physical activity*gender	1.01 (0.90, 1.12)

[a] $p<0.05$
[b] $p<0.001$
[c] Model $R^2=0.094$
[d] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[e] Composite physical activity was measured in 1994-1995.
[f] Psychological distress was measured in 2007-2008.
CI: confidence interval

Table S8. Association between composite physical activity and psychological distress, stratified by gender (complete-case analysis, i.e., excluding missing).

	Psychological distress (HSCL-10)[f]	
	Men (n=3479)	**Women (n=3756)**
	OLS estimates[d]	
	Adjusted[d]	**Adjusted[d]**
	β (95% CI)[d]	**β (95% CI)[d]**
Composite physical activity[e]	0.07 (0.01, 0.13)[a, b, e]	0.08 (-0.01, 0.17)[c, e]
	Relative risk estimates[d]	
	Adjusted[d]	**Adjusted[d]**
	RR (95% CI)[d]	**RR (95% CI)[d]**
Composite physical activity[e]	1.08 (0.98, 1.18)[d]	1.06 (1.00, 1.13)[d]

[a] $p<0.05$
[b] Model $R^2=0.054$
[c] Model $R^2=0.085$
[d] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[e] Composite physical activity was measured in 1994-1995.
[f] Psychological distress was measured in 2007-2008.
CI: confidence interval

Table S9. Association between physical activity and psychological distress (complete-case-analysis, i.e., excluding missing).

		Psychological distress (HSCL-10)[g]
		OLS estimates
		Adjusted
		β (95% CI)
Physical activity (light)[f]	N=7274	0.04 (-0.05, 0.13)[c, e]
Physical activity (MVPA)[f]	N=7257	0.14 (0.06, 0.22)[b, d, e]
		Relative risk estimates
		Adjusted
		RR (95% CI)
Physical activity (light)[f]	N=7274	1.05 (0.97, 1.14)[e]
Physical activity (MVPA)[f]	N=7257	1.12 (1.02, 1.23)[a, e]

[a] $p<0.01$
[b] $p<0.001$
[c] Model $R^2=0.092$
[d] Model $R^2=0.094$
[e] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[f] Physical activity was measured in 1994-1995.
[g] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA

Table S10. Association between physical activity and psychological distress, stratified by gender (complete-case-analysis, i.e., excluding missing).

	Psychological distress (HSCL-10)[j]	
	Men	**Women**
	OLS estimates	
	Adjusted	**Adjusted**
	β (95% CI)	**β (95% CI)**
Physical activity (light)[i]	0.02 (-0.08, 0.13)[d, h]	0.05 (-0.09, 0.19)[f, h]
Physical activity (MVPA) [i]	0.15 (0.06, 0.24)[c, e, h]	0.14 (0.01, 0.27)[b, h, g]
	Relative risk estimates	
	Adjusted	**Adjusted**
	RR (95% CI)	**RR (95% CI)**
Physical activity (light) [i]	1.08 (0.93, 1.25)[h]	1.04 (0.94, 1.15)[h]
Physical activity (MVPA)[i]	1.12 (0.96, 1.30)[h]	1.13 (1.01, 1.26)[b, h]

[a] $p<0.1$
[b] $p<0.05$
[c] $p<0.001$
[d] Model $R^2=0.052$
[e] Model $R^2=0.055$
[f] Model $R^2=0.084$
[g] Model $R^2=0.085$
[h] Adjusted for age, gender, history of parental psychopathology, childhood socioeconomic status, marital status, daily smoking, number of friends, perceived social isolation, and education.
[i] Physical activity was measured in 1994-1995.
[j] Psychological distress was measured in 2007-2008.
CI: confidence interval; MVPA: moderate to vigorous PA