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Research paper

Passive and mentally-active sedentary behaviors and incident major depressive disorder: A 13-year cohort study

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ABSTRACT

Background: Regular physical activity reduces the risk of depression onset and is an effective treatment for mood disorders. Recent studies have reported that sedentary behavior (SB) increases the risk of depression in adults, but relationships of different types of SBs with depression have not been examined systematically. We explored longitudinal relationships of passive (e.g. watching TV) and mentally-active (e.g. office-work) SBs with incident major depressive disorder (MDD).

Methods: Self-report questionnaires were completed by 40,569 Swedish adults in 1997; responses were linked to clinician-diagnosed MDD obtained from medical registers until 2010. Relationships between passive, mentally-active and total SBs with incident MDD were explored using survival analysis with Cox proportional hazards regression. Models controlled for leisure time moderate-vigorous physical activity and occupational physical activity. Moderating effects of gender were examined.

Results: In fully-adjusted models, including only non-depressed adults at baseline, those reporting ≥ 3 h of mentally-active SBs on a typical day (versus < 3 h) had significant lower hazards of incident MDD at follow-up (HR = 0.74, 95% CI = 0.58–0.94, $p = 0.018$). There was a non-significant positive relationship of passive SBs with incident MDD (HR = 1.20, 95% CI = 0.96–1.52, $p = 0.106$). The association between total SBs (passive and mentally-active combined) was not significant (HR = 0.91, 95% CI = 0.75–1.10, $p = 0.36$). Gender did not moderate these associations.

Limitations: Physical activity and SBs were self-reported.

Conclusion: Mentally-active SBs may have beneficial effects on adults' mental well-being. These effects are largely independent of habitual physical activity levels.

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1. Introduction

Depression is a prevalent and debilitating disorder associated with considerable socio-occupational impairment (Pratt et al., 2016). Although evidence-based treatments have grown, the success of interventions and maintenance of treatment responses remains limited (Pybis et al., 2017). Thus, there is a need for improved understanding of factors associated with depression onset so that efficacious treatment strategies can be developed and therapeutic outcomes optimized.

Within this context, physical activity is receiving considerable research attention. Low levels of physical activity are consistently associated with an elevated risk of depression, while structured physical activity (exercise) is an effective treatment for mood disorders (Harvey et al., 2017; Schuch et al., 2018). As distinct from physical inactivity, sedentary behavior has been operationalized as any waking activity characterized by an energy expenditure of ≤ 1.5 metabolic equivalents and a sitting or reclining posture (Barnes et al., 2012). Common sedentary behaviors include TV viewing, computer use, and reading. High volumes of sedentary time have been identified in studies using objective assessments. A recent US study of 7,985 middle-aged and older adults reported that sedentary behavior accounted for 12.3 h of a 16-hour waking day (Diaz et al., 2017). Extended durations of sedentary behavior have also been linked to increased risk of cardiovascular disease, diabetes, and premature mortality (Dempsey et al., 2016; Young et al., 2016), and these associations have been observed after controlling for time spent in leisure-time moderate-to-vigorous physical activity (MVPA) (Ekelund et al., 2016).

Observational evidence also suggests that there are relationships between sedentary behaviors and mental health. In a meta-analysis, the pooled risk ratios of depression for sedentary behaviors were 1.31 (95% CI = 1.16–1.48) in 13 cross-sectional studies and 1.14 (95% CI = 1.06–1.21) in 11 longitudinal studies (Zhai et al., 2015). Two recent trials have also shown that experimentally-induced time spent in sedentary behaviors in free-living conditions, lasting one and two weeks respectively, can have adverse effects on mood and depression (Edwards and Loprinzi, 2016; Endrighi et al., 2016). In one trial, sedentary behaviors were linked to both negative mood states and heightened levels of Interleukin-6, suggesting a potential underlying inflammatory mechanism. However, some studies have not observed sedentary behavior-depression relationships in women (Teychenne et al., 2014), and with few exceptions (Atkin et al., 2012; Hamer and Stamatakis, 2014), relationships of different types of sedentary behaviors with depression have not been examined systematically. For example, in a study examining associations of TV viewing, internet use and reading with mental health in a large sample of older adults, TV viewing time at baseline (≥6 vs. < 2 h) was associated with higher depressive symptoms and worse global cognitive functioning, while internet use and reading were associated with less depressive symptoms (Hamer and Stamatakis, 2014). In another study, the association of four non-occupational sedentary behaviors (both individually and in total) with mental wellbeing were examined (Atkin et al., 2012). TV viewing, computer use and total non-occupational sitting time increased the risk of poor mental health in women, while computer use increased the risk poor mental health in men only. Taken together, these findings suggest possible differential effects of passive (e.g., TV viewing) and mentally-active (e.g., reading) sedentary behaviors on mental-health related outcomes. Whilst informative, previous research has notable limitations; most studies have reported subjective changes in depression severity rather than clinician-based diagnoses, sample sizes have generally been small and follow-up periods have tended to be short (Zhai et al., 2015).

With increasing evidence for the beneficial effects of exercise in the treatment of depression (Hallgren et al., 2016; Schuch et al., 2016) and interest in exercise prescription for psychiatric disorders more-generally (Rosenbaum et al., 2016), the potential role of different types of SB in the prevention and treatment of mood disorders is of interest. We examined longitudinal relationships of passive and mentally-active sedentary behaviors with clinician-diagnosed major depressive disorder in a large national sample of Swedish adults. Given the variable associations found for men and women in previous studies, we also assessed gender differences in these relationships.

2. Methods

2.1. Participants

Data originate from the Swedish National March Cohort study (SNMC: http://ki.se/en/meb/the-swedish-national-march-cohort-nmc). The National March was a four day national fundraising event arranged by the Swedish Cancer Society in some 3600 Swedish cities and villages in September 1997. In total, 43,863 participants completed a 36-page questionnaire with detailed questions about health behaviors and lifestyle, including detailed questions on physical activity habits (type, frequency and duration) and planned exercise, and sedentary behaviors (2 questions, described below). Reliability and validity data for the activity questionnaire has been published previously, and the survey has been used extensively (Bellocco et al., 2010; Lagerros et al., 2009; Yang et al., 2015). Exclusion criteria included: participants who were younger than 18 years at the beginning of the follow-up (1,741), those who emigrated (465) or died (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 were excluded. The final sample consisted of 40,560 participants. The original study complies with the guidelines of the Declaration of Helsinki. The Research Ethics Vetting Board in Stockholm approved the original study and all subjects gave informed consent.

2.2. Primary outcome: major depressive disorder (MDD)

The occurrences of incident MDD (ICD codes: F32.0, F32.1, F32.2, F32.8, F32.9, F33.0, F33.1, F33.2, F33.4, F33.8, F33.9) during the 13-year follow-up to 31st December 2010 were ascertained through linkages to existing nationwide, complete and continuously updated medical registers, including both inpatient and outpatient records. 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. While the total number actually given a questionnaire during the fund raising event could not be assessed, all those who handed in a completed questionnaire consented to follow-up.

2.3. Exposure variables: passive and mentally-active sedentary behaviors

Two questions assessed participation in passive and mentally-active sedentary behaviors. Both were prefaced with the following: *How physically active are you on an ordinary weekday? Specifically, how much time per day/night do you devote to activities that require effort similar to: (a) Watching TV, listening to music, sitting in the bathtub?* (passive sedentary behaviors); and *(b) Office work, sitting in a meeting, knitting/sewing?* (mentally-active sedentary behaviors). Each activity group was also illustrated with a picture. For each question, eight response alternatives were provided to estimate the amount of time typically spent in each activity (in minutes): 0–4, 5–9, 10–19, 20–39, 40–89, 90–179, 180–359, and 360–720. The mid-point of each response was calculated and added to determine a continuous sedentary behaviors score for each type of behavior. In addition, two binary sedentary behavior outcomes were created based on the distribution of responses, where the last two categories were combined. This corresponds to 180 min (3 h) or more per day/night spent in each type of sedentary behavior; approximately the upper quartile of the continuous distribution. Thus, we selected sedentary behavior cut-points based partly on the

distribution of the survey data. As only 1.2% of respondents indicated spending 360–720 min (the highest category) per day in passive sedentary activities; combining the highest two categories created a more representative exposure variable. Knitting and sewing were included in question (b) as these were common leisure pursuits (primarily among females) at the time of the survey and involve energy expenditures comparable to sedentary office work. The passive and mentally-active sedentary behavior variables were also combined to create a total sedentary behavior variable, dichotomized as ≥6 versus < 6 h (Zhai et al., 2015). The sedentary behavior items were derived from a physical activity questionnaire which has been used extensively and is described elsewhere (Lagerros et al., 2009; Lagerros et al., 2006).

2.4. Confounding variables

Based on previous studies, the following variables were included in the statistical models:

Self-reported depression was assessed at baseline by asking respondents: *How often do you feel sad, low-spirited, depressed?* The four response alternatives were: seldom/never, sometimes, often, and always. The last two categories were merged into a binary variable ('depressed' versus not).

Body mass index was calculated based on self-reported height and weight (kg/m^2); the proportion overweight was estimated using the World Health Organization's recommended cut-point of ≥25.

Occupation-related physical activity was assessed by asking: *During the past 12 months, how physically demanding has your daily work/occupation been?* The four response alternatives were: light, mostly sedentary; light, but I have moved a little; rather strenuous; and very strenuous. The first two categories were combined and coded as 'light occupational physical activity'.

Leisure-time physical activity was assessed by asking: *During the past 12 months, how much time per week, on average, have you devoted to athletics, exercise, sports and outdoor life?* Two separate items were then rated; (a) *Moderately strenuous exercise, such as fast walking, jogging or swimming?* And (b) *Vigorous, hard training or competition?* The total number of hours per week engaged in moderate and vigorous exercise were indicated by selecting one of six alternatives: 0, 0–1, 2, 3, 4, and 5+ h. The two items were summed into a single continuous variable: moderate-to-vigorous physical activity (MVPA) and converted to minutes. A binary variable was also created (≥150 min per week, as recommended for general health) (Garber et al., 2011).

Employment status was ascertained by the question: *What is your current main occupation?* The following responses were coded as 'employed': paid fulltime work, paid part time work, run your own business, student.

Education was assessed with four categories: compulsory school, upper-secondary, other vocational, and tertiary.

2.5. Other variables

Self-rated health status was assessed by asking: *How would you describe your health?* The five response alternatives were: very bad, bad, neither good nor bad, good, and very good. Additional covariates included in the statistical models were age and gender.

2.6. Statistical analyses

Participant characteristics are presented as descriptive statistics, stratified by gender. Means and standard deviations (SDs) are shown for continuous variables; the total *n* and percentage (%) for categorical variables. Average time-to-event in days was estimated by calculating the mean and median number of days between completion of the baseline questionnaire and the first recorded incidence of MDD. The censoring date was either the date of death or the follow-up date for those who did not develop depression. Associations between baseline sedentary behaviors and incident MDD during the 13 year follow-up (1st October 1997–31st December 2010) were assessed using survival analysis with Cox proportional hazards regression (time to diagnosis). The strength and direction of associations are reported as hazard ratios (HR) with corresponding 95% confidence intervals (CI) and p-values. Both passive and mentally-active sedentary behaviors were considered as different predictors for the hazard of depression, and included together in different comparative models. First, they were used in a Cox proportional hazards regression, adjusted for age, gender and baseline self-reported depression (Model 1). Next, the model was adjusted for additional confounders: employment status, education and BMI (Model 2). Finally, the model was further adjusted for leisure-time moderate-vigorous physical activity (MVPA) and occupational physical activity (Model 3). We ran separate models that included the passive and mentally-active sedentary behavior variables together and a separate model for total sedentary behavior only, using the same co-variates in all models. In a second analytic step, participants with indications of depression at baseline (I feel sad/depressed often or always) were removed and the analyses repeated, without adjustment for depression. Cases with indications of the outcome (having depression) at baseline were removed, to reduce the risk of reverse causality in the analyses.

Moderating effects of gender were formally examined by creating a gender by passive sedentary behavior, and gender by mentally-active sedentary behavior variable, and including both in the final adjusted models. We assessed the underlying assumption of proportional hazard over time for the effect of each sedentary behavior using the scaled Schoenfelds residuals (Grambsch and Therneau, 1994). No violation of the proportionality assumption was detected. Missing data on included variables varied between 1.2% and 4.5%; and missingness was at random. Statistical analyses were performed using SPSS version 24, and SAS version 9.4.

3. Results

3.1. Participant characteristics

Baseline participant characteristics are shown in Table 1. Sixty-four percent of the total sample were women with a mean age of 51.6 years (SD = 16.1, range = 18–94). Most participants were employed (48.9%) or retired (27.1%) with post-secondary education. In total, 5.8% of the sample reported indications of depression at baseline (often or always sad/depressed). Self-rated general health was mostly 'good' or 'very good' (82.5%), and the mean BMI was 24.6 (SD = 3.5). At work, most participants (76%) reported light physical activity levels and 34.2% met the weekly recommended levels of MVPA (≥150 min). Participants reported spending on average 323 min (SD = 216) per day in all sedentary behaviors. In total, 17.5% engaged in ≥180 min of passive sedentary behaviors per day, and 35.6% engaged in ≥180 min of mentally-active sedentary behaviors per day, as defined previously.

Between October 1997 (baseline) and December 2010 (follow-up) there were 706 (1.7%) reported incident cases of clinician-diagnosed MDD in the cohort, of which 506 (72%) were women. The mean time-to-event was 2938 days (SD = 1142 days), or approximately 8.0 years (SD = 3.2 years). The median time-to-event was 3033 days (8.3 years).

3.2. Associations between sedentary behaviors and incident major depressive disorder (MDD)

Findings from the survival analyses are shown in Table 2 (total sample, adjusted for baseline self-reported depression) and Table 3 (non-depressed sample), respectively. Passive and mentally-active sedentary behaviors were negatively correlated; that is, as mentally-active behaviors increased, passive sedentary behaviors decreased (Pearson $r = -0.72$, $p < 0.001$).

Table 1
Background characteristics of participants (final sample, n = 40,569).

Characteristic	Men (n = 14,556)	Women (n = 26,013)
Gender; *n* (%)	14,556 (35.9)	26,013 (64.1)
Age; mean (SD)	53.4 (17.2)	50.5 (15.3)
Highest education; *n* (%)		
Compulsory (years 7–9)	2643 (18.3)	4390 (16.8)
Upper-secondary (10–12)	3624 (24.8)	4577 (17.6)
Other vocational	4897 (33.6)	9251 (35.6)
Tertiary	3392 (23.3)	7795 (30.0)
Employment status; *n* (%)		
Employed	7097 (48.8)	12,759 (49.0)
Retired	4983 (34.2)	6010 (23.1)
Other	820 (5.6)	590 (2.3)
Student	407 (2.8)	1146 (1.4)
Unemployed	281 (1.9)	932 (3.6)
Long-term sick-leave	178 (1.2)	433 (1.7)
Occupational physical activity; *n* (%)		
Light, mostly sedentary	2713 (18.6)	3983 (15.3)
Light, move a little	8379 (57.6)	15,743 (60.5)
Rather strenuous	2853 (19.6)	5351 (20.6)
Very strenuous	412 (2.8)	645 (2.5)
Mentally-active sedentary behaviors		
Total minutes per day, mean (SD)	180 (207)	205 (203)
≥180 min; *n* (%)	4766 (32.7)	9693 (37.3)
Passive sedentary behaviors		
Total minutes per day, mean (SD)	134 (92)	124 (85)
≥180 min; *n* (%)	2833 (19.5)	4249 (16.3)
All sedentary behaviors, mean (SD)	314 (219)	329 (215)
Moderate to vigorous physical activity (MVPA)		
Total minutes per week, mean (SD)	242 (273)	195 (214)
≥150 min; *n* (%)	4926 (33.8)	8947 (34.4)
Health status		
Depressed (often/always); *n* (%)	526 (3.6)	1843 (7.1)
Self-rated health (poor/very poor); *n* (%)	360 (2.5)	689 (2.6)
Body Mass Index (BMI), mean (SD)	25.0 (3.0)	24.3 (3.7)

Table 2
Longitudinal associations of passive and mentally-active sedentary behaviors with incident major depressive disorder over 13 years (all participants, n = 40,569).

	Model 1			Model 2			Model 3		
	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*
Sedentary behavior category									
All sedentary behaviors (≥6 h)	0.92	0.79–1.08	0.351	0.91	0.77–1.07	0.261	0.93	0.79–1.10	0.445
Passive sedentary behaviors (≥3 h)	1.28	1.06–1.55	**0.009**	1.24	1.02–1.51	**0.030**	1.26	1.03–1.53	**0.021**
Mentally-active sedentary behaviors (≥3 h)	0.71	0.58–0.87	**0.001**	0.70	0.57–0.86	**0.001**	0.71	0.57–0.88	**0.002**
Interaction									
Gender	–			–			1.40	0.51–3.18	0.417
Gender*Passive sedentary behaviors	–			–			0.94	0.61–1.44	0.790
Gender*Mentally-active sedentary behaviors	–			–			0.70	0.43–1.15	0.170

Notes: Table shows the Hazard Ratios (HR), Confidence Interval (CI) and significance (p) values. Model 1 adjusted for age, gender and baseline self-reported depression, Model 2 adjusted for (Model 1 plus) Body Mass Index (BMI), employment status, education; Model 3 adjusted for (Model 2 plus) occupational physical activity and leisure-time physical activity (MVPA). Gender interaction terms were included in the fully adjusted model only. In all models, the reference category is < 6 h per week for All sedentary behaviors, and < 3 h per week for both passive and mentally-active sedentary behaviors.

Across all analyses, no association was found between self-reported total sedentary behaviors at baseline and incident MDD over the 13-year follow-up. When the exposure variables were examined separately in the pooled analyses (all participants), and after adjustment for all relevant co-variates (Model 3), those who reported engaging in ≥3 h of passive sedentary behaviors on a typical day had significantly higher hazards for developing MDD at follow-up, compared to those who engaged in < 3 h (HR = 1.26, 95% CI = 1.03–1.53, $p = 0.021$). Conversely, in fully adjusted models, a favourable (negative) association was observed between mentally-active sedentary behaviors (≥3 h versus < 3 h) and incident MDD (HR = 0.71, 95% CI = 0.57–0.88, $p = 0.002$). Next, participants with probable depression at baseline were removed. Here also in the fully adjusted models, a significant negative association was found between mentally-active sedentary behaviors and reduced risk of incident MDD (HR = 0.74, 95% CI = 0.58–0.94, $p = 0.018$). The association between passive sedentary behaviors and MDD approached statistical significance in Model 1, adjusted for age and gender only (HR = 1.22, 95% CI = 0.98–1.53, $p = 0.067$), but was attenuated in the fully adjusted model (HR = 1.20, 95% CI = 0.96–1.52, $p = 0.106$). As shown in Tables 2 and 3, gender did not moderate any of these associations.

4. Discussion

In the context of understanding the associations of different types of sedentary behaviors with depression (Teychenne et al., 2010; Zhai et al., 2015), this is the first study to examine prospective relationships of passive and mentally-active sedentary behaviors with incident major

Table 3
Longitudinal associations of passive and mentally-active sedentary behaviors with incident major depressive disorder over 13 years (non-depressed sample, n = 37,504).

	Model 1			Model 2			Model 3		
	HR	95% CI	*p*	HR	95% CI	*p*	HR	95% CI	*p*
Sedentary behavior category									
All sedentary behaviors (≥6 h)	0.88	0.74–1.05	0.173	0.88	0.73–1.06	0.180	0.91	0.75–1.10	0.364
Passive sedentary behaviors (≥3 h)	1.22	0.98–1.53	0.067	1.18	0.94–1.49	0.145	1.20	0.96–1.52	0.106
Mentally-active sedentary behaviors (≥3 h)	0.72	0.57–0.90	**0.004**	0.72	0.57–0.91	**0.006**	0.74	0.58–0.94	**0.018**
Interaction									
Gender	–			–			1.18	0.47–2.96	0.721
Gender*Passive sedentary behaviors	–			–			1.04	0.63–1.69	0.873
Gender*Mentally-active sedentary behaviors	–			–			0.65	0.37–1.13	0.127

Notes: Table shows the Hazard Ratios (HR), Confidence Interval (CI) and significance (p) values. Model 1 adjusted for age and gender, Model 2 adjusted for (Model 1 plus) Body Mass Index (BMI), employment status, education; Model 3 adjusted for (Model 2 plus) occupational physical activity and leisure-time physical activity (MVPA). Gender interaction terms were included in the fully adjusted model only. In all models, the reference category is < 6 h per week for All sedentary behaviors, and < 3 h per week for both passive and mentally-active sedentary behaviors.

depressive disorder in adults. Across all analyses, and after adjusting for relevant covariates, including both leisure-time moderate-vigorous physical activity and occupational physical activity, there was a significant negative (beneficial) relationship of mentally-active sedentary behaviors with incident depression (26% lower risk). Conversely, there was a significant positive relationship between time spent in passive sedentary behaviors and risk of incident depression; however, this relationship was not significant in the fully-adjusted non-depressed sample. When the two exposures were combined, the association of total sedentary behaviors with MDD was not statistically significant in either model, highlighting the distinct effects of passive and mentally-active sedentary behaviors. These relationships were not substantially attenuated by physical activity levels in occupational and leisure settings, and gender did not appear to moderate these associations. Of relevance to the interpretation of these findings, all diagnoses were obtained from psychiatric inpatient and outpatient registers. In Sweden, treatment within psychiatric care often occurs following an initial period of treatment in primary care, indicating a high degree of symptom severity in the present cohort. Therefore, the findings may not be directly generalizable to populations exhibiting sub-threshold depression.

There are several possible explanations for the differential effects of passive and mentally-active sedentary behaviors on depression. One plausible explanation relates to the context of these activities. Office work and 'sitting in a meeting' normally occur in work environments. Employment is linked to better mental health, even when it involves sedentary behaviors, as it can promote a sense of autonomy, self-reliance and achievement (Lee et al., 2017). Also relevant are findings showing that active participation and engagement in work-related tasks can be associated with greater work satisfaction and happiness (Boyatzis et al., 2003). In contrast to mentally-active sedentary behaviors, there are those that demand minimal cognitive effort, such as TV-viewing and listening to music (both assessed here). Physical and mental inertia are key features of depression and research has consistently shown that depressed individuals are less physically active than age-gender matched controls, and spend more time engaged in passive behaviors generally (Mammen and Faulkner, 2013; Teychenne et al., 2010). Indeed, behavioral activation techniques, which are commonly used to treat depression, aim to reduce symptom severity by encouraging the initiation of appropriate 'active' behaviors (Donde et al., 2018). Of importance, some studies indicate that the amount of time spent in mentally-passive activities predicts depression status longitudinally. For example, a study in the USA examined prospective (10-year) relationships of physical activity, TV-viewing time and incident depression in 49,821 women (Lucas et al., 2011). Higher physical activity levels reduced the risk of subsequent depression, while higher levels of TV-viewing time (≥21 h versus 0–1 h per week) significantly increased the risk of incident depression (Lucas et al., 2011). This association is one of the more consistently reported findings in the sedentary behavior-depression literature (Zhai et al., 2015), yet it remains unclear why these activities are linked to mood disorders. We observed similar trends in our data, although the association between passive sedentary behaviors and MDD was no longer statistically significant in the fully-adjusted non-depressed sample.

The difference between passive and mentally-active sedentary behaviors is perhaps analogous to passive and active learning in educational research, where the latter technique is shown to be more effective. It may be speculated that the process of engaging in mentally active tasks, such as reading and problem solving, is inherently rewarding. Humans are intrinsically motivated to inquire, understand, and make causal inferences; protracted TV-viewing is far removed from these innately rewarding behaviors. Thus, the negative mood states associated with mentally-passive activities, along with the increased risk of overweight and related inflammatory conditions linked to sedentary behaviors in general could partly explain the association between passive sedentary behaviors and depression (Rethorst et al., 2014). Other physiological mechanisms could also underlie these relationships. Sedentary behaviors impact adversely on glycemic control, and there is evidence that glycemic variability may influence brain health and cognitive decline (Wheeler et al., 2017). However, it remains to be seen whether or not this variability is linked to different types of sedentary behavior.

Sub-analyses from a recent meta-analysis indicated that long-time (≥6 vs < 2 h/day) TV-viewing, a passive sedentary behavior, was associated with greater risk of depression (RR = 1.13, 95% CI = 1.06–1.21) (Zhai et al., 2015). Unlike the current study, however, mentally-active sedentary behaviors were associated with an increased risk of depression. Moreover, the association between total sedentary behaviors and depression was inverse (i.e. detrimental). These differences may partly be explained by two factors; first, our findings may not be directly comparable to this review, as the variable we used to classify mentally-active sedentary behaviors (office work, sit in a meeting, knit/sew) was different to that used in the meta-analysis (prolonged computer and internet use). Second, the review included two longitudinal studies that only measured passive sedentary behaviors (TV-viewing) (Hamer and Stamatakis, 2013; Lucas et al., 2011), and one of these was the largest prospective study to date with 49,821 participants (Lucas et al., 2011). Thus, when the data were pooled for meta-analysis, a disproportionate number of participants had been exposed to passive rather than mentally-active sedentary behaviors, which may have influenced the inverse association found in this review.

While most reviews report inverse associations between sedentary behaviors and depression in both adults (Teychenne et al., 2010), and adolescents (Liu et al., 2015), some individual studies have not

observed these effects. Teychenne et al. (2014) examined prospective relationships between different types of sedentary behaviors (TV viewing, computer use, overall sitting time and screen time) and risk of depression in socioeconomically disadvantaged women aged 18–45 years (Teychenne et al., 2014). No significant associations were observed between any sedentary behavior variables and depression during the three-year follow-up, although depressive symptoms were associated cross-sectionally with more TV-viewing time (≥240 min per day). Other studies have combined different types of sedentary behaviors, an approach that does not enable the differential effects of sedentary activities to be explored (Sanchez-Villegas et al., 2008; Yancey et al., 2004). One study examined longitudinal associations of total self-reported sitting time and health-related symptoms in middle-aged Australian women over six years. As in the present study, no significant relationships were found between total sitting time, which combined different types of sedentary behaviors (e.g. watching TV, reading, working at a computer), and depression at follow-up (Peeters et al., 2013).

Several study limitations are acknowledged. Both physical activity and levels of sedentary behaviors were self-reported and may lead to overestimation of activity levels and underestimation of time spent sedentary. The two exposure variables (passive and mentally-active sedentary behaviors) did not refer to all relevant types of sedentary behaviors, including reading and internet use. However, the items are taken from a validated questionnaire used previously (Lagerros et al., 2006, 2009). It would have been ideal to have more information about the context of the sedentary behaviors assessed here, but this information was not available in the questionnaire. Research has not yet determined whether the 'context' or the 'type' of sedentary behaviors is more important in these associations, and how each relates to the other. For example, if all work-related sedentary behaviors are pooled in future analyses, this could mean that passive and mentally-active sedentary behaviors are combined, which could be problematic as some workplaces involve, for example, seated manual work (with minimal energy expenditure), while other workplaces involve activities with considerable cognitive effort. The baseline survey was conducted before the advent of smartphones, and the internet was a relatively new phenomenon in 1997. No assessment of physical activity or sedentary behaviors was made between the baseline survey and follow-up period. It is therefore possible that patterns of sedentary behaviors changed during these intervening years, and this could not be accounted for in the statistical models. The baseline measure of depression was self-reported and based on a single item, thus providing only an indication of depression status, not a diagnosis. We focused on diagnoses obtained through psychiatric registers. While it is possible that individuals who seek specialist care differ from those seeking treatment through primary care, this is less likely in Sweden, where healthcare is free (or available at minimal cost). Finally, there is the risk that findings from a larger dataset may identify inflated effect sizes, and we recognize that statistical significance does not equate to clinical significance. The primary outcome here was clinician-diagnosed major depression, where relatively small magnitude changes in hazard rates may have clinical meaning in terms of reduced risk and harm. What we see in these data are quite consistent results; HRs across all models for mentally-active sedentary behaviors are approximately 0.7, indicating a moderate effect of the exposure. The magnitude of this effect held after various adjustments. The confidence intervals are quite narrow, and this may partly reflect the large sample size. As in all prospective regression models, we assume no residual confounding, and that the associations lie on a causal pathway.

Despite these potential limitations, the study has several notable strengths, including a large participant sample which enabled the detection of associations even after the adjustment of several confounding factors, a long follow-up period enabling sufficient time for depressive symptoms to emerge in the population, and objective assessment of incident depression by a qualified clinician, obtained through registry data. These features are noteworthy as previous studies have largely been restricted to small samples with short follow-up periods, and subjective ratings of depression severity (Zhai et al., 2015). The questionnaire used was comprehensive, allowing relationships of passive and mentally active sedentary behaviors with depression to be observed, while adjusting for factors known to influence these associations, including both occupational and leisure time physical activity. Finally, the demographic profile of these participants suggests that our findings are likely to be generalizable to other adult populations in developed countries.

In sum, our findings suggest differential effects of passive and mentally-active sedentary behaviors, where the latter appear to reduce the risk of depression onset. Future studies should examine the distinct effects of these ubiquitous daily exposures on specific psychiatric disorders. With recommendations on reducing all types of sedentary behaviors now being incorporated into physical activity and public health guidelines, potentially beneficial behaviors may be inadvertently discouraged. To confirm our findings and to better understand their implications, additional longitudinal studies are needed which assess specific types of sedentary behaviors and include reference to internet and smartphone usage. Further studies of gender effects and the complex interaction between sedentary behaviors and physical activity are also warranted.

Contributions

MH and NO conceived the study. MH wrote the first draft. MH and ZZ conducted statistical analyses. All authors made substantial contributions to subsequent revisions of the manuscript. YTL and RB are project leaders for the SNMC.

Declarations of interest

None.

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Supplementary materials

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