



Original research

Sitting time and depression in young women over 12-years: The effect of physical activity

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ABSTRACT

Objectives: Lack of physical activity (PA) and prolonged sitting time (ST) are associated with increased risk of mortality and chronic illnesses, including depression. While there have been claims that the two risks are 'independent', their joint and stratified effects are unclear. The aim of this study was to explore the combined effects of physical activity and sitting time on the 12 year risk of depressive symptoms (DS) in young women.

Design: Cohort-9061 young participants in the Australian Longitudinal Study on Women's Health completed triennial surveys from 2000 (age 22–27), to 2012.

Methods: Generalised Estimating Equation models were used to calculate the joint effects of PA and ST on DS, with <4 h/day of ST and the highest PA quartile as the reference categories. Relationships between PA and DS, and between ST and DS, were also examined after stratification by ST and PA respectively.

Results: In the adjusted joint effects model, compared with the reference category (low sitting, high PA), odds for DS were significantly higher in women who sat for >4, 6 and 8 h/day and reported doing no PA. In every physical activity category, women who sat for ≥ 10 h/day were at highest risk of DS (OR for lowest physical activity quartile, 1.72 [95% CI = 1.38–2.14]; OR for highest physical activity quartile, 1.49 [95% CI = 1.16–1.91]). After stratification by ST, odds of DS were reduced in women who reported any physical activity (compared with none), except when ST was >10 h/day. After stratification by physical activity, the increased risk of sitting 8–10 h/day was attenuated by any physical activity, but there was no reduction in risk of depressive symptoms with increasing PA levels in women who sat for ≥ 10 h per day.

Conclusions: These data suggest that there are both joint and stratified effects of too little activity and too much sitting on the risk of depressive symptoms in young women. High levels of PA are protective against the hazards of high ST at this life stage, except in women with very high levels of sitting.

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Practical implications

- For young women who sit more than 10 h per day, physical activity does not protect against the risk of depressive symptoms.
- However, as little as 17 min a day of at least moderate intensity physical activity offers protection against depressive symptoms for those sitting less than 10 h per day.
- Health professionals should be mindful of the volume of both sedentary behaviour and physical activity when assessing client's behavioural health risks.

1. Introduction

Depression is the most common mental health condition in the general population, with serious implications for long term health outcomes and quality of life. Estimates suggest that around one in eight people worldwide suffer from depression at any time, and that the prevalence has increased markedly in recent years.^{1,2} Depressive disorders are estimated to become the second principal cause of global disease burden by 2030.³

Several systematic reviews of population-based prospective cohort studies have provided strong evidence that regular physical activity protects against the onset of depression symptoms and major depressive disorders.^{4–6} Moreover, a meta-analysis of 49 prospective cohort studies has recently confirmed that high levels of physical activity reduce the odds of developing depression in

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men and women of all ages, and in different geographic locations.⁷ As the oldest study included in that review was published in 1988, with another four published before 2000, our understanding of the protective effects of physical activity on depression and depressive symptoms is not new.

There is however a more recent and growing body of evidence to suggest that sedentary behaviour (particularly in the form of prolonged sitting time) has detrimental effects on depression and depressive symptoms. Indeed, a recent meta-analysis of 11 prospective observational studies found that the highest levels of sedentary behaviour were associated with a 14% increased risk of depression (when compared with the lowest levels).⁸ The authors noted that the effects were unchanged when analyses were 'adjusted' for physical activity, but that the heterogeneity of the overall model was reduced when only studies that 'adjusted' for physical activity were included, pointing to an 'independent' effect of sedentary behaviour on risk of depression. However, in their discussion, the authors suggested that sedentary behaviour may 'displace' physical activity, and that lack of physical activity might therefore explain the observed increased likelihood of depressive symptoms.

However, while sedentary behaviour and physical activity are at either end of the movement continuum, people who sit for long hours each day may also be extremely physically active, and there is currently some confusion about whether the adverse health effects of these two behaviours are 'independent' each other. In their 2015 systematic review and meta-analysis of the relationships between hospitalizations, all-cause mortality, cardiovascular disease, diabetes, and cancer in adults, Biswas and colleagues found that "prolonged sedentary time was independently associated" with deleterious health outcomes, but noted that the negative effects of high sitting time were "lower in magnitude in people with high levels of physical activity."⁹

In 2016, Ekelund et al. confirmed this observation; they used a harmonized meta-analysis to demonstrate that high levels of physical activity (at least 60 min per day) eliminated the negative effects of sitting time on all-cause mortality.¹⁰ A similar approach was used to demonstrate that high volumes of physical activity markedly reduce the increased risks of sitting on cardiovascular disease, and, to a lesser extent, cancer mortality.¹¹ These analyses clearly demonstrated the joint effects of physical activity and sedentary behaviour on mortality.

To our knowledge, only two studies have examined the joint effects of physical activity and sedentary behaviour on mental health outcomes. In 2008, Sanchez-Villagas et al. observed a 25% lower risk of mental disorders after 6 years among Spanish graduates who reported high physical activity and low sedentary time, compared with those who reported low physical activity and high sedentary time.¹² In 2013, analysis of data from the mid-age cohort of the Australian Longitudinal Study of Women's Health (ALSWH) showed a gradual increase in risk of depressive symptoms with higher levels of sitting-time and lower levels of physical activity, up to a tripled risk in women who sat >7 h/day and did no physical activity, (compared with women who sat ≤4 h/day and met physical activity guidelines).¹³

While both studies assessed the joint effects of physical activity and ST on depressive symptoms, neither assessed the potential moderating effects of physical activity on relationships between sitting time and depressive symptoms, and conversely, the potential moderating effects of sitting time in the relationships between physical activity and depressive symptoms, which have rarely been investigated.¹⁴

In this paper, we examine relationships between physical activity, sitting time and depressive symptoms in a large cohort of young adult women. This is important because the prevalence of depression is high in young adulthood, and higher in women than in

men.^{1,15} Our previous work with this cohort has shown that 31–40% of 24–36 year old women report physical activity levels that are above the upper range of the current Australian guidelines.¹⁶ At the same time, many have occupations that require them to sit for long periods. Data from this cohort therefore provide an opportunity for examining the joint and potential moderating effects in relationships between sitting time, physical activity and depressive symptoms, especially when both sitting time and physical activity are high.

The aim of this study was to assess the joint and stratified effects of sitting and physical activity on depressive symptoms over 12 years, using data from the young cohort of the ALSWH, who were between 22 and 39 years old at the time of data collection.

2. Methods

The ALSWH is a prospective study of factors shaping the health and well-being of three cohorts of Australian women (young, born in 1973–1978; mid-age, 1946–1951; and older, 1921–1926), who were randomly recruited from the national Medicare health insurance database. The focus of this paper is on the young cohort which was, at the time of recruitment, generally representative of women the same age in the Australian population.¹⁷ An update of the profile of the continuing cohort was published in 2015.¹⁸ The study was approved by the Universities of Newcastle and Queensland Research Ethics Committees and all participating women provided informed consent.

The women completed surveys with questions about a range of health issues, behaviours, health services and social and demographic factors in 1996, 2000 and then at three year intervals to 2012. Full details of each survey can be found at www.ALSWH.org.au. As the physical activity (PA) questions were different in the first survey in 1996, data from the second survey in 2000 were used as the baseline for the current study, with data also drawn from surveys conducted in 2003, 2006, 2009 and 2012. Women were included at each stage if they provided data on the explanatory variables in one year (2000, 2003, 2006, 2009) and the outcome variable at the next survey (2003, 2006, 2009, 2012). The numbers of women included at each stage are shown in Supplementary Fig. S1.

Depressive symptoms were assessed using the 10-item Center for Epidemiological Studies Depression Scale (CESD-10), with a range of scores from 0 to 30.¹⁹ Scores were dichotomized as depressive symptoms (≥10) or no depressive symptoms (<10).¹⁹

Sitting time was assessed by the question "Think about all the time you spend sitting EACH DAY while at home, at work, while getting from place to place or during your spare time. How many hours EACH DAY do you typically spend sitting down while doing things like visiting friends, driving, reading, watching television, or working at a desk or computer on (a) a usual week-day and (b) a usual weekend-day". Mean sitting time in h/day was calculated as $((\text{weekday sitting} \times 5 + \text{weekend day sitting} \times 2) / 7)$, and cleaned using protocols developed by van Uffelen et al.²⁰ This question is similar to that included in the International Physical Activity Questionnaire, which has been shown to have good reliability (correlation coefficient 0.77 for women) and moderate criterion validity (correlation coefficient 0.44 for women) against accelerometers (<100 counts/min).²¹ Sitting-time data were categorised as 0 to 4 h/day, 4 to <6 h/day, 6 to <8 h/day, 8 to <10 h/day and ≥10 h/day, in line with previous studies.²² Physical activity scores were calculated from questions about time spent in walking, moderate and vigorous activity, using established protocols,²³ (Score = walking + moderate min per week*3.33 MET) + (vigorous min per week*6.66 MET), and categorized as quartiles of PA (described as lowest (median value 1.3 MET.h/week);

low (6.6 MET.h/week); moderate (15.0 MET.h/week); or high (32.9 MET.h/week). The physical activity measure has been shown to have acceptable measurement characteristics.²⁴

Socio-demographic and behavioural variables, including age, area of residence, highest level of education, and marital status, smoking status, and alcohol consumption were categorised as shown in Table 1. Health-related variables included: number of chronic conditions diagnosed by a doctor in the previous 3 years (including various cardiovascular, metabolic, respiratory and musculoskeletal conditions, 13 in total, see Table 1); and BMI (kg/m²; calculated using self-reported weight and height, and categorised as underweight, BMI < 18.5; normal weight, 18.5 ≤ BMI < 25; overweight, 25 ≤ BMI < 30; or obese, BMI ≥ 30.²⁵

Differences in baseline covariates between the PA groups (none, low, moderate and high) were analysed using the Chi-square test for categorical variables and ANOVA for continuous variables. The joint effects of sitting-time and PA on depressive symptoms were investigated using linear generalised estimating equation models with a 3-year time lag, in which PA and sitting scores measured at surveys 2 to 5 were matched with depressive symptoms scores measured at surveys 3 to 6. Odds ratios for the occurrence of depressive symptoms were calculated for each category of sitting by each quartile of PA, with <4 h/day of sitting and the highest PA quartile as the reference category. To enhance comparability of results, models were adjusted for the same covariates as in previous studies.^{22,26} These covariates were also entered into models using a 3-year time lag, with measures taken from surveys 2 to 5.

The moderating effects of ST on the relationship between PA and depressive symptoms were then investigated using data stratified by ST level, and the moderating effects of PA on the relationship between ST and depressive symptoms were examined, after stratification of the data by PA categories. We tested the trends for probability of DS for the joint effects, and within each stratum of ST and physical activity, using the Wald test. All statistical analyses were conducted in SPSS version 22. P-values were based on two-sided tests and were considered statistically significant at $p < 0.05$.

3. Results

Of the 8921 women who returned baseline depressive symptoms data in 2003, 2716 had missing data on explanatory variables in 2000 (see Supplementary Table S1). Therefore the analysis sample included 6205 women. Characteristics of these women are shown in Table 1. In 2000 their mean age was 24.6 (range 20.6 to 28.5) years. There were no differences between the included and excluded women in terms of age, PA, sitting time, number of children, BMI and chronic conditions. The included women were slightly more likely to be from rural areas, to have higher education, and to be married/partnered, non-smokers, and low risk drinkers ($p < 0.05$).

The prevalence data for DS, ST and PA at each survey are shown in Supplementary Table S1. The proportion of women with DS decreased slightly between 2003 (24.9%) and 2012 (19.6%). The proportions of women in each ST category remained relatively stable across surveys; around 10% reported sitting for more than 10 h/day. Notably, women in the highest PA quartile had a median PA score of 32.9 MET.h/week, which is equivalent to 42 min of vigorous PA daily.

The joint effects of PA and sitting time on depressive symptoms (p for trend < 0.001) are shown in Fig. 1. Among women in the least active quartile (median 1.33 MET-h/week, or ≈5 min of daily moderate intensity PA), there was a clear dose-response relationship, with ORs for DS from 1.2 to 1.72, compared with the referent category (low sitting, high PA). Dose-response relationships were less evident in the other PA categories. However, in every PA category,

women who sat the most (≥10 h per day) had markedly increased odds of depressive symptoms (range OR 1.35–1.72), regardless of PA level.

When the data were stratified by sitting category (Table 2), there were significant reductions in the odds of DS in sitting strata 2, 3 and 4 ($p < 0.001$). Reporting any amount of PA above the lowest category reduced the risk of depressive symptoms in each of the ST strata. The exception was in the highest ST category; there was no reduction in risk of depressive symptoms with increasing PA levels in women who sat for ≥10 h per day.

When stratified by PA level (Table 3), there was a significant trend across all PA strata ($p < 0.02$). Compared with women in each PA quartile who sat the least, the data confirmed that the odds of depressive symptoms were 39–62% higher in women who sat the most (≥10 h per day). In the lowest PA quartile, women who sat for 8–<10 h/day were also at increased risk of depressive symptoms, but this increase was attenuated in the other PA strata.

4. Discussion

The aim of this study was to assess the joint and stratified effects of sitting and physical activity on depressive symptoms over 12 years, in young adult women.

The main findings from the analysis of the joint effects of physical activity and sitting time were that, regardless of physical activity, sitting for more than 10 h/day increased the likelihood of depressive symptoms by between 21 and 73%, and there was a clear dose-response relationship between sitting time and depressive symptoms in women who reported minimal physical activity.

Stratification by sitting time showed the attenuating effects of physical activity on risks of depressive symptoms across all levels of sitting time, except in the highest sitting time category (>10 h/day). Most importantly, when sitting time was very high, the dose-response protective relationship between physical activity and depressive symptoms was lost. Stratification by physical activity also confirmed the hazards of sitting >10 h/day, regardless of physical activity level, but showed an attenuating effect of even low levels of physical activity (about 17 min. of moderate intensity activity/day) on the 30% increase risk of DS when sitting for 8–10 h/day, which was observed in the lowest physical activity category.

Numerous prospective studies have clearly demonstrated the beneficial effects of physical activity and the harmful effects of high sitting time on depressive symptoms. The meta-analysis by Schuch et al. showed that, compared with the lowest physical activity levels, the highest levels reduced the odds of depressive symptoms by 17%.⁷ The risk reductions associated with high physical activity were somewhat greater in our study (19–28%), when the effects of sitting time were taken into account. Moreover, the meta-analysis by Zhai et al. showed that increasing sitting time was associated with a 14% increased risk of depressive symptoms in prospective studies.⁸ The risk estimates were markedly higher in our study when reported sitting time was >10 h/day (ORs 1.39–1.62 in the different physical activity strata). Overall, the pattern of our results was similar to that seen for physical activity stratified relationships between sitting time and CVD mortality, which also showed the strongest relationships between sitting and CVD mortality when physical activity levels were low.¹¹ However, as suggested by Katzmarcyk and Pate, it is important to also consider the effects of sitting time on relationships between physical activity and depressive symptoms.¹⁰ Our results indicate that the dose-response relationship between physical activity and depressive symptoms is similar at most levels of sitting, but is not evident when sitting time exceeds 10 h/day.

Table 1
Characteristics of the included and excluded women in 2000. (ALSWH 1973–78 cohort).

	Analysis samplen = 6205	Excluded from analysisn = 2716	P-values ^a
Age (mean (SD))	24.6 (1.5)	24.5 (1.5)	0.300
	%	%	
Physical activity			0.337
Lowest (1.3 MET.h/week)	24.7	25.3	
Low (6.6 MET.h/week)	25.0	21.8	
Moderate (15.0 MET.h/week)	23.8	22.8	
High (32.9 MET.h/week)	25.5	27.1	
Missing	1.1	3.0	
Sitting time			0.105
0–<4 h/day	20.1	21.5	
4–<6 h/d ay	26.3	24.6	
6–<8 h/day	21.8	20.7	
8–<10 h/day	16.1	13.7	
≥10 h/day	10.0	9.7	
Missing	5.7	9.7	
Socio-demographic factors			
Area of residence			0.005
Urban	54.0	58.0	
Rural	41.9	37.7	
Remote	3.8	3.7	
Missing	0.4	0.6	
Education			<0.001
<12 years of school	10.0	14.1	
12 years of school	23.8	24.1	
Post school certificate	24.3	23.1	
Degree/higher degree	40.2	33.8	
Missing	3.3	4.8	
Marital status			<0.001
Partnered/married	46.4	39.3	
Single	51.9	57.9	
Separated/widowed	1.3	2.5	
Missing	0.4	0.7	
Number of children			0.301
None	81.7	83.0	
One	10.9	10.8	
Two	5.7	4.3	
Three or more	1.7	1.0	
Missing	0.1	0.8	
Lifestyle factors			
Smoking status			<0.001
Non smoker	58.3	51.8	
Ex smoker	14.4	14.2	
Current smoker	26.6	32.9	
Missing	0.7	1.1	
Alcohol status			<0.001
Non drinker	8.6	10.7	
Rare drinker	28.8	29.1	
Low risk drinker	58.7	54.6	
Risky/high risk drinker	3.4	4.9	
Missing	0.6	0.9	
Health-related factors			
BMI			0.226
Underweight	6.9	6.5	
Healthy	57.6	52.7	
Overweight	18.1	16.5	
Obese	9.7	9.2	
Missing	8.8	15.0	
Chronic conditions ^b			0.301
None	60.6	57.8	
One	25.8	26.4	
Two	9.4	9.5	
Three or more	3.9	4.6	
Missing	0.9	1.6	

^a Chi-squared except ANOVA for age.

^b Chronic conditions included: arthritis, type1/type2 diabetes, heart disease, stroke, thrombosis, asthma, bronchitis, osteoporosis, cancer (breast, cervical, bowel, other), chronic fatigue syndrome, HIV or AIDS, Hepatitis (B or C), other major illness.

The potential mechanisms underlying the observed relationships between physical activity, sitting time and mental health are thought to include effects mediated by endorphins and neurotransmitters, enhanced blood flow to brain regions involved in emotional regulation; disruption of the hypothalamic-pituitary-adrenocortical axis that regulates the endocrine response to stress, changes in body temperature and improved sleep.^{27,28} Physical

activity may also allow time away from stressful situations, is associated with improved self-esteem, and may provide opportunities for social engagement. Conversely, sedentary time may reduce opportunities for social interaction.^{5,30}

Our data clearly show the importance of considering *both* these behaviours when considering risk of developing depressive symptoms, because patterns of moving and sitting vary enormously

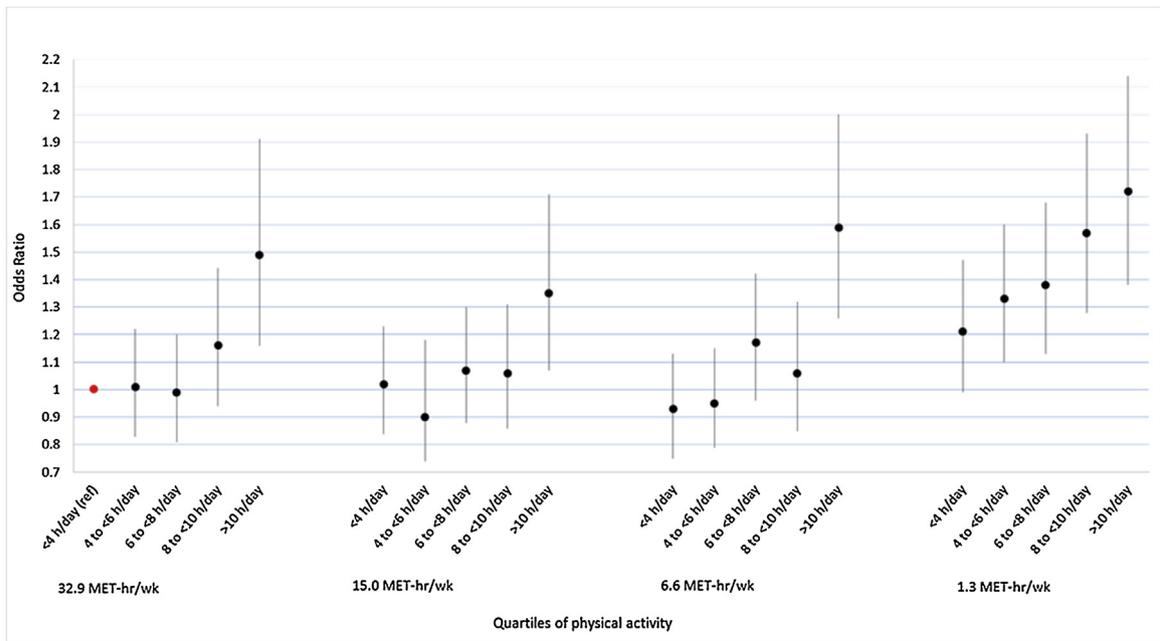


Fig. 1. Joint effects of physical activity and sitting time on depressive symptoms (cumulative N=23,552 observations; 5241 ‘cases’ (DS)). Reference category high PA (32.9 MET-h/wk) and low sitting (<4h/day). Median MET.h/week values are equivalent to ≈5 min/day (Q1); 17 min/day (Q2); 38 min/day (Q3); and 85 min/day (Q4) of moderate intensity physical activity.

Table 2

Associations between physical activity and depressive symptoms (N = number of observations; and DS cases) stratified by sitting time category.

Sitting (categories)	Quartiles of PA Met-h/wk ^a			
	Q1 Lowest (1.3 Met-h/wk)	Q2 (6.6 Met-h/wk)	Q3 (15.0 Met-h/wk)	Q4 Highest (32.9 Met-h/wk)
1 (0 to <4 h/d)	1.00 [Reference] (N = 1230; 292)	0.77 (0.63–0.94) (N = 1265; 236)	0.83 (0.68–1.01) (N = 1440; 283)	0.81 (0.66–0.99) (N = 1437; 285)
2 (4 to <6 h/d)	1.00 [Reference] (N = 1432; 371)	0.71 (0.59–0.85) (N = 1574; 299)	0.67 (0.56–0.80) (N = 1690; 300)	0.75 (0.62–0.91) (N = 1604; 324)
3 (6 to <8 h/d)	1.00 [Reference] (N = 1132; 305)	0.84 (0.70–1.02) (N = 1286; 298)	0.77 (0.64–0.94) (N = 1431; 295)	0.72 (0.59–0.88) (N = 1413; 279)
4 (8 to <10 h/d)	1.00 [Reference] (N = 1006; 206)	0.69 (0.55–0.86) (N = 959; 206)	0.69 (0.56–0.86) (N = 1176; 237)	0.75 (0.60–0.94) (N = 981; 212)
5 (≥10 h/d)	1.00 [Reference] (N = 712; 237)	0.92 (0.72–1.19) (N = 634; 185)	0.82 (0.63–1.05) (N = 645; 161)	0.89 (0.67–1.17) (N = 505; 134)

Reference categories are the groups in the lowest quartile of physical activity for all categories of sitting.

^a = median MET-h/week in each PA category. The equivalent amounts of time spent in moderate intensity activity are ≈5 min/day (Q1); 17 min/day (Q2); 38 min/day (Q3); and 85 min/day (Q4). Covariates: area of residence, education, marital status, number of children, smoking status, alcohol status, BMI, chronic conditions.

Table 3

Associations between sitting time and depressive symptoms (N = number of observations; and DS cases) stratified by quartiles of physical activity.

Quartiles of PA Met-h/week ^a	Sitting (categories)				
	1 (0 to <4 h/d)	2 (4 to <6 h/d)	3 (6 to <8 h/d)	4 (8 to <10 h/d)	5 (≥10 h/d)
Q1 Lowest (1.3 Met-h/week)	1.00 [Reference] (N = 1230; 292)	1.09 (0.90–1.31) (N = 1432; 371)	1.13 (0.92–1.38) (N = 1132; 305)	1.30 (1.06–1.61) (N = 1006; 302)	1.41 (1.12–1.77) (N = 712; 237)
Q2 (6.6 Met-h/week)	1.00 [Reference] (N = 1265; 236)	1.01 (0.83–1.23) (N = 1574; 299)	1.21 (0.99–1.50) (N = 1286; 298)	1.08 (0.85–1.37) (N = 959; 206)	1.62 (1.26–2.08) (N = 634; 185)
Q3 (15.0 Met-h/week)	1.00 [Reference] (N = 1440; 283)	0.89 (0.74–1.07) (N = 1690; 300)	1.08 (0.89–1.31) (N = 1431; 295)	1.07 (0.87–1.33) (N = 1176; 237)	1.39 (1.09–1.76) (N = 645; 161)
Q4 Highest (32.9 Met-h/week)	1.00 [Reference] (N = 1437; 285)	1.01 (0.84–1.23) (N = 1604; 324)	1.00 (0.82–1.22) (N = 1413; 279)	1.19 (0.96–1.48) (N = 981; 212)	1.54 (1.19–1.99) (N = 505; 134)

Reference categories are the groups with <4h/day of sitting for all quartiles of physical activity.

^a = median MET-h/week in each PA category. The equivalent amount of time spent in moderate intensity activity are ≈5 min/day (Q1); 17 min/day (Q2); 38 min/day (Q3); and 85 min/day (Q4). Covariates: area of residence, education, marital status, number of children, smoking status, alcohol status, BMI, chronic conditions.

at this life stage. The results clearly show that the highest levels of sitting time (>10h/day) are associated with large increases in risk of depressive symptoms, regardless of physical activity level, but that at slightly lower levels of sitting (8–10h/day) there

is some protection against depressive symptoms when physical activity is as little as 17 min/day. Women whose work and travel commitments enforce high periods of sitting should therefore be encouraged to accumulate even low levels of daily physical activity.

We acknowledge that making time for structured physical activity may be challenging for women at this life stage, when most have commitments to paid and unpaid work, and many have childcare responsibilities.²⁹ Notwithstanding the challenges to being more physically active, confirmation that sitting for more than 10 h/day significantly increases the risk of depressive symptoms regardless of physical activity, is important, and suggests that such high levels of sitting should be avoided.

Although two earlier studies assessed the joint effects of physical activity and sitting time on depressive symptoms, to our knowledge, this is the first study to have examined the interactions carefully using both joint and stratified analyses, and the first to focus on young adults. By using four categories for physical activity and five categories for sitting time, we were able to examine the effects across the full range of exposures, which is important when dose-response relationships may not always be linear. Further, the study included a large representative population-based sample, long-term follow-up, and inclusion of many confounding variables.

The main limitation of this study is that all the data were self-reported and may therefore be prone to bias. However, previous assessments of the CESD-10,^{19,30} 7-day physical activity recall,³¹ and total sitting time,²¹ have indicated acceptable psychometric properties. Unfortunately, our sitting time measure was for total sitting time, and we could not distinguish between 'passive' (e.g. TV viewing) and mentally active (e.g. reading and problem solving) sitting. This may be important, as two recent cohort studies have shown differential associations of passive and mentally-active sedentary behaviors, where the former appear to increase the risk of depression, which the latter may protect against depression onset. Future studies should therefore aim to identify the potentially unique effects of these variables on mental health outcomes.^{32,33} We acknowledge that there may be an issue of 'reverse' causality in these data. Although the models used a time lagged approach, with the exposure preceding the outcome by three years, previous research has shown that, while women who met the PA guidelines were less likely to report depressive symptoms, depressive symptoms were associated with lower levels of PA. However, this association was not apparent for depressive symptoms and future sitting time.¹³

5. Conclusion

There is a very strong dose-response relationship between sitting time and depressive symptoms when physical activity levels are low; even moderate daily sitting times (4–8 h per day) are associated with significantly increased risk of depressive symptoms. Although physical activity markedly attenuates the risks of depression associated with sitting, when sitting time is greater than 10 h/day the protective effects of physical activity are minimal. Given the disease burden attributable to depressive disorders, our findings suggest that young adult women should be encouraged to keep sitting time to less than 8 h per day and to maintain at least low levels of physical activity. Sitting for 10 h per day or more should be avoided.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.jsams.2019.06.010>.

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