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Physical activity, sedentary behavior and depression among disadvantaged women

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Abstract

This study investigated associations between components of physical activity (PA; e.g. domain and social context) and sedentary behaviors (SBs) and risk of depression in women from disadvantaged neighborhoods. A total of 3645 women, aged 18–45 years, from disadvantaged neighborhoods, self-reported their PA, SB and depressive symptoms. Crude and adjusted odds ratios and 95% confidence intervals were calculated for each component of PA, SB and risk of depression using logistic regression analyses, adjusting for clustering by women's neighborhood of residence. Being in a higher tertile of leisure-time PA and transport-related PA was associated with lower risk of depression. No associations were apparent for domestic or work-related PA. Women who undertook a small proportion of their leisure-time PA with someone were less likely to be at risk of depression than those who undertook all leisure-time PA on their own. Women reporting greater time sitting at the computer, screen time and overall sitting time had higher odds of risk of depression compared with those reporting low levels. The domain and social context of PA may be important components in reducing the risk of depression. Reducing time spent in SB may be a key strategy in the promotion of better mental health in women from disadvantaged neighborhoods.

Introduction

Participation in regular physical activity (PA) [1] as well as reducing sedentary behaviors (SBs) such as television (TV) viewing [2] has a strong cardioprotective role. However, recent research has indicated that these behaviors may also play an important role in the treatment and prevention of depression [3]. Depression is the world's most incapacitating illness [4], with nearly 20% of women from developed countries suffering from depression within their lifetime [5]. Several population groups have been found to be at a greater risk of depression, including women [6] and adults of low socioeconomic position (SEP) [7]. These population groups are also at increased risk of physical inactivity [8, 9], highlighting the importance of research that focuses on those target groups in order to improve mental health through the promotion of healthy lifestyles (i.e. increasing PA and reducing SB).

Much research has indicated the beneficial effect of PA on the risk of depression [10]. However, little is known about the specific characteristics of PA that are most beneficial to mental health, for example the domain and social context in which PA occurs. Although various observational [11] and intervention [12] studies have found leisure-time PA to be inversely associated with depression among women, few studies have assessed the association with PA undertaken in other domains (e.g. work related, domestic and transport related). Until now, only three observational studies had

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specifically compared the association between PA in various domains and risk of depression in women [11, 13, 14]. All three studies concluded that leisure-time PA was inversely associated with risk of depression. One of the three also found an association in the opposite direction between domestic (household) PA and risk of depression [13], and another demonstrated a positive association between work-related PA and risk of depression [14]. No associations were evident between transport-related PA and risk of depression in women [11]. However, that study did not distinguish between different types of transport-related PAs (e.g. walking or cycling) which may be an important factor [11].

Similarly, the association between PA undertaken in different social contexts and risk of depression has received very little research attention. Only one observational study has considered the social context of PA and its association with risk of depression in women [11]. That study found that being active with a family member was associated with lower odds of depression, compared with never being active with a family member. Conversely, two intervention studies have compared the effects of differing social contexts of PA on depressive symptoms in women [15, 16]. Both interventions compared individual (home-based) PA programs with group-based (accompanied) activity programs and found significant effects of both formats in reducing participant's depressive symptoms, with no clear benefit of either format over the other. However, one of those studies included a small sample size as well as a short follow-up period which limited results [16].

Recently research attention has focused on the association between SB (e.g. TV viewing and computer use) and depression, but this remains poorly understood. Most observational studies have found positive associations between time spent in SB (e.g. TV and computer use) and risk of depression [3, 17–21]. In contrast, two intervention studies assessing the risk of computer or Internet use and risk of depression found inverse associations between computer use and depression [22, 23], suggesting that time spent on the computer may reduce risk of depression. Only one study has assessed whether the relationship between SB and depression may be moderated by PA [3]. That longitudinal study found lower levels of SB to be associated with reduced risk of depression when PA levels were low, yet it was not a critical aspect when PA levels were high [3].

The purpose of the current study was to examine the associations between components of PA (e.g. domains and social context) and risk of depression as well as the association between SBs (e.g. TV viewing and computer use) and risk of depression using data from a large population-based sample of women living in socioeconomically disadvantaged areas. Furthermore, the study aimed to test for the presence of an interaction between PA, SB and risk of depression. It was hypothesized that leisure-time PA would be more strongly associated than other domains of PA with lower risk of depression and that activities undertaken in a social context (i.e. PA with somebody) would be more strongly associated with lower risk of depression, compared with PAs undertaken alone. It was also hypothesized that SBs such as TV viewing and sitting at the computer would be associated with higher risk of depression. Finally, it was hypothesized that the positive association between SB and risk of depression would be stronger among women doing none/low levels of PA than those who were highly active.

Methods

Analyses were based on cross-sectional survey data collected in 2007–08 from the Resilience for Eating and Activity Despite Inequality (READI) study. Data used in the present analyses were provided by 3645 women living in socioeconomically disadvantaged areas of Victoria, Australia, aged between 18 and 45 years. Methods have been described in detail elsewhere [24] and are summarized below.

Participants

Participants were randomly recruited from 80 Victorian neighborhoods (suburbs; 40 rural and 40 urban) of low SEP, based on the Australian Bureau of Statistics Socioeconomic Index for Areas [25]. The

electoral roll was then used to randomly select approximately 150 women from each of the 80 suburbs, aged between 18 and 45 years.

Surveys were sent to a sample of 11 940 women, and a total of 4934 women returned a completed survey, representing a response rate of 45% [24]. Of the respondents, 571 women were excluded due to residing in 'non-READI' neighborhoods. A further nine women were excluded due to falling outside the valid age range (i.e. either younger than 18 years or older than 46 years, or had data missing on this variable). Three women were excluded as the survey was not completed by the woman it was addressed to and two women later withdrew from the study. This left a total of 4349 women included in the overall study. Since pregnancy is likely to affect both PA levels [26, 27] and risk of depression [28], 284 women (6%) were excluded from analyses because they reported being pregnant, did not know their pregnancy status or did not complete this question. A further 420 women (10%) were excluded due to having missing data on one or more covariates. This left a total of 3645 women (74% of the original respondents) with data for inclusion in the analyses.

Procedures

The study was approved by the Deakin University Human Research Ethics Committee. Women were sent a pre-survey letter in the mail, informing them that they had been selected to take part in a study on women's health and that the survey would be sent to them shortly. Surveys were posted 1 week later. Following the Dillman protocol [29], non-respondents received a mailed reminder 2 weeks later and a second reminder with a replacement survey a further 2 weeks later. Women received small incentives (e.g. tea bags and $1 scratch lottery tickets) with their initial survey package. Written consent to participate was obtained from all respondents.

Measures

Domain of PA

Self-reported PA was measured using the long-form self-administered version of the International Physical Activity Questionnaire (IPAQ-L), a validated and reliable measure involving a 7-day recall of PA behaviors [30]. Questions included the frequency and duration of time spent undertaking various intensities (walking, moderate and vigorous) of PA in leisure time, transport-related activity, work-related activity and domestic PA. For each of these four domains, participants were required to estimate the number of days, hours and minutes they spent undertaking such activities in the past week.

The total duration of PA was calculated for each variable by multiplying the frequency of activities by the duration within each domain. Further, leisure-time and work-related PA variables were summed across intensities (walking, moderate and vigorous) and transport-related PA was summed across activities (walking and cycling) to give a total duration of PA within each domain. Total (global) weekly duration of PA across all domains was also calculated. Because of the skewed nature of the distributions and the large proportions of women reporting no PA on several variables, each continuous PA variable was transformed into a categorical variable with three levels based on the tertiles within the respective distributions.

Social context of PA

The social context of leisure-time PA was assessed through the following question, developed for this study: 'Thinking about all of your walking, moderate and vigorous leisure-time PA in the last 7 days, about how much of this was done ON YOUR OWN (as opposed to with someone else like family, friend or in an exercise group or class)?'. Response categories included: all, most (about three-fourth), about half, a little (about one-fourth) and none. The reliability of this measure was tested and found to be adequate (Kappa value = 0.625) [31].

Sedentary behavior

Three measures of SBs were included in the survey: time spent sitting at a computer, time spent sitting watching TV and overall time spent sitting. Time spent sitting watching TV and time spent sitting

using the computer were examined separately. Participants were asked to estimate the number of hours and minutes they spent undertaking those activities on a usual weekday, as well as a weekend day. Overall sitting in the past week was assessed using the IPAQ-L. Participants were asked to estimate the number of hours and minutes spent sitting on a usual weekday, as well as a weekend day. These measures have been found to be reliable and valid in an Australian adult population [32].

Computer time, TV viewing time and sitting time were each summed to give a total weekly duration of time spent usually undertaking each of those SBs. This was done by multiplying the duration of each SB performed on weekdays by 5 (days) then adding this to the weekend days total duration [duration multiplied by 2 (days)]. The variable 'weekly screen time' (TV viewing + computer use) was created by summing the weekly duration for the variables 'TV viewing' and 'computer use'. Each continuous SB variable was then transformed into a categorical variable based on the tertiles of the distribution.

Depressive symptoms

Depressive symptoms were assessed using the 10-item version of the Centre for Epidemiologic Studies Depression Scale (CES-D), a well-validated measure of depression [33, 34] that has been used in previous studies examining the association between PA and depression [35]. It includes questions that relate to various symptoms of depression that may have been experienced in the past week, which indicate whether a woman is at risk of depression. Respondents rated themselves on a four-point severity scale. CES-D scores of 10 or greater indicated that the participant was at risk of depression [34, 36, 37].

Covariates

Self-reported age, body mass index [BMI; not overweight (<25), overweight (25–29.9) and obese (>30)], marital status, education, employment status, household income, children living at home, country of birth and physical health were included in the analyses as potentially confounding factors (see Table I), as these variables were bivariately associated with the risk of depression in chi-square analyses.

Statistical analyses

Demographic characteristics, PA, SB and risk of depression were initially examined using descriptive univariate analyses performed using SPSS version 14.0 statistical software. Bivariable associations between domains of PA, social context of PA, SB and risk of depression were examined using chi-square analyses. Crude and adjusted (controlling for confounding factors described earlier) odds ratios (ORs) and 95% confidence intervals (CIs) were then calculated for each of the PA and SB variables and risk of depression using logistic regression analyses. Further, logistic regression analyses were used to test for an interaction between SB (i.e. weekly sitting time), PA (i.e. total weekly leisure-time PA) and risk of depression. Logistic regression analyses controlled for clustering by neighborhood of residence using STATA version 10.1 statistical software package.

Results

Table I presents the sociodemographic characteristics and risk of depression among participants. The mean age of participants was 35 years. Just over half of the women (53%) were classed as not overweight. The majority of participants was born in Australia (89%) and was married/defacto (66%). A total of 1874 (51%) reported their highest qualification as completing high school or an apprenticeship or certificate/diploma. Just under half reported a weekly household income of $1500 or less and the majority of women had children living at home (62%). A total of 1328 (36%) participants were classified as being at risk of depression (according to the CES-D).

Table II shows the proportion of women at risk of depression according to PA and SB variables from chi-square analyses. Leisure-time walking, moderate and vigorous PA and total leisure-time PA were

Table I. *Frequencies of sociodemographic characteristics among women living in socioeconomically disadvantaged neighborhoods (n = 3645)*

Characteristics	*n*	%
Age		
Under 25 years	608	17
25–29 years	503	14
30–34 years	538	15
35–39 years	777	21
40+ years	1219	33
BMI category		
Not overweight (<25)	1943	53
Overweight (25–29.9)	919	25
Obese (30+)	783	22
Country of birth		
Australia	3243	89
Other	402	11
Marital status		
Married or defacto	2390	66
Separated widowed or divorced	311	8
Never married	944	26
Highest qualification		
Did not complete high school	799	22
High school/trade apprentice/ certificate diploma	1874	51
University or higher degree	972	27
Household income		
No income	21	<1
$1–119 per week	18	<1
$120–299 per week	54	2
$300–499 per week	151	4
$500–699 per week	296	8
$700–999 per week	509	14
$1000–1499 per week	593	16
⩾$1500 per week	632	17
Other	1371	38
Employment status		
Working full-time	1409	39
Working part-time	1092	30
Unemployed/laid off	82	2
Keeping house/raise children	829	23
Studying full-time	224	6
Retired	9	<1
Children living at home (up to 18 years)		
Yes	2261	62
No	1384	38
Long-term illness/injury?		
Yes	406	11
No	3239	89
At risk of depression		
Not at risk (<10)	2317	64
At risk (⩾10)	1328	36

each inversely associated with risk of depression. Although women in the middle tertile of moderate work-related PA (reporting 0.1–6 hours per week) were less likely to be at risk of depression than those reporting higher or lower durations, no association was found between work-related walking, vigorous or total work-related PA and risk of depression. No other domains of PA (transport related or domestic) were related to risk of depression.

The proportion of participants at risk of depression was higher among women who reported doing all leisure-time PA on their own, when compared with those who reported doing some proportion of their leisure-time PA with someone. Of the SB variables, risk of depression was positively associated with TV viewing time, screen time and overall sitting time but not associated with time spent sitting at the computer.

Table III shows the crude and adjusted (for confounders) ORs and 95% CIs from logistic regression models predicting the odds of risk of depression according to PA and SB variables.

Physical activity

Both the unadjusted and adjusted results showed that compared with those in the lowest tertile of total leisure-time PA per week (reporting less than 40 min), those in the middle and highest tertiles (greater than 40 min) had lower odds of risk of depression. When examined according to specific intensities, both the unadjusted and adjusted results indicated that compared with those who reported no walking, those who reported some walking in leisure time had lower odds of risk of depression. Results from both unadjusted and adjusted models showed that compared with women who reported no moderate-intensity leisure-time PA, women in the middle tertile (reporting between 0.1 and 1.33 hours) of moderate-intensity leisure-time PA per week had lower odds of risk of depression. Both the unadjusted and adjusted results showed that compared with those who reported no vigorous leisure-time PA per week, those in the highest tertile (reporting greater than 1.9 hours) had lower odds of risk of depression.

Table II. *Proportion of women at risk of depression according to PA domain and social context and SBs*

Variables	Category (per week)	*n*	Not at risk of depression (%)	At risk of depression (%)	*P*
Leisure-time PA					
Walking	No LT walking	1376	58	42	<0.001
	0.1–2 hours per week	1214	67	33	
	>2 hours per week	1000	67	33	
Moderate	No moderate LTPA	2621	62	38	<0.001
	0.1–1.33 hours per week	431	72	28	
	>1.33 hours per week	511	66	34	
Vigorous	No vigorous LTPA	2392	61	39	<0.001
	0.1–1.9 hours per week	562	67	33	
	>1.9 hours per week	627	70	30	
Total leisure-time PA	<40 min per week	1153	56	44	<0.001
	41 min–3.4 hours per week	1145	67	33	
	>3.4 hours per week	1226	68	32	
Work PA					
Walking	No walking at work	1951	63	37	0.129
	0.1–8 hours per week	831	66	34	
	>8 hours per week	774	62	38	
Moderate	No moderate work PA	2143	64	36	0.015
	0.1–6 hours per week	708	67	33	
	>6 hours per week	694	60	40	
Vigorous	No vigorous work PA	2569	64	36	0.905
	0.1–5 hours per week	504	64	36	
	>5 hours per week	510	63	37	
Total work PA	No work PA	1581	63	37	0.230
	0.1–14.5 hours per week	951	66	34	
	>14.5 hours per week	943	63	37	
Transport PA					
Walking	<30 min per week	1267	62	38	0.161
	31–2.5 hours per week	1230	65	35	
	>2.5 hours per week	1068	65	35	
Cycling	No cycling for transport	3273	63	37	0.066
	0.1–1 hour per week	169	69	31	
	>1 hour per week	115	71	29	
Total transport PA	<30 min per week	1201	62	38	0.102
	30 min–2.5 hours per week	1201	65	35	
	>2.5 hours per week	1100	66	34	
Domestic PA total	<3 hours per week	1095	63	37	0.506
	3–11.7 hours per week	1140	65	35	
	>11.7 hours per week	1233	65	35	
Total global PA	<11.5 hours per week	1055	64	36	0.132
	11.5–32.3 hours per week	1060	67	33	
	>32.3 hours per week	1108	63	37	
Social context of leisure-time PA	All LTPA was done on own	710	63	37	<0.001
	Most (three-fourth) LTPA done on own	528	72	28	
	About half LTPA done on own	454	66	34	
	A little (one-fourth) done on own	381	69	31	
	All LTPA done with someone	470	68	32	

Table II. *Continued*

Variables	Category (per week)	*n*	Not at risk of depression (%)	At risk of depression (%)	*P*
SB					
Computer time	<4.75 hours per week	1110	66	34	0.094
	4.75–21.5 hours per week	1127	64	36	
	>21.5 hours per week	1173	61	39	
TV viewing	<13.7 hours per week	1152	67	33	<0.001
	13.7–22.7 hours per week	1196	65	35	
	>22.7 hours per week	1207	59	41	
Screen time	<23.5 hours per week	1125	68	32	<0.001
	23.5–46.3 hours per week	1109	63	37	
	>46.3 hours per week	1149	60	40	
Sitting time	<30.7 hours per week	1162	67	33	<0.001
	30.7–54.5 hours per week	1171	66	34	
	>54.5 hours per week	1198	59	41	

While moderate-intensity work-related PA was associated with risk of depression in the unadjusted model, this was no longer significant in the adjusted model. Both the unadjusted and adjusted results indicated that compared with those in the lowest tertile (reporting less than 30 min per week) of transport-related PA, those in the highest tertile (reporting greater than 2.5) had lower odds of risk of depression. When examined according to specific activities, the adjusted results show that compared with those who reported less than 30 min per week of walking for transport, those who reported greater than 2.5 hours per week had lower odds of risk of depression. No associations were evident between domestic PA and odds of risk of depression in either unadjusted or adjusted models.

Social context of PA

Before and after adjusting for covariates, results showed that compared with those women who reported doing all leisure-time PA on their own, those who reported doing about three-fourth (most) leisure-time PA alone (i.e. about a quarter with others) had lower odds of risk of depression. However, this was the only category of social context to reach statistical significance.

Sedentary behavior

Both the unadjusted and adjusted results showed that compared with women in the lowest tertile (reporting less than 4.75 hours) of computer time per week, those in the highest tertile (reporting greater than 21.5 hours) had higher odds of risk of depression. TV viewing was not significantly associated with risk of depression in the adjusted model. Associations between women in the middle tertile (23.5–46.3 hours) of total screen time and risk of depression were not significant in the adjusted model. However, both the unadjusted and adjusted results showed that compared with women who reported less than 23.5 hours of total screen time per week, those who reported more than 46.3 hours per week had higher odds of risk of depression.

Unadjusted and adjusted results indicated that compared with women in the lowest tertile (reporting less than 30.7 hours) of sitting time per week, those in the highest tertile (reporting more than 54.5 hours) had higher odds of risk of depression.

Although there were significant main effects between mid and high amounts of leisure-time PA and risk of depression, there were no interactions between leisure-time PA, SB (sitting time) and risk of depression in either the unadjusted or the adjusted models.

Discussion

The current study provides novel findings regarding the domain and social context of PA as well as

Table III. *Crude and adjusted[a] odds of risk of depression according to PA and SB variables (hours/week)[b]*

Variables	Category (per week)	Crude OR	95% CI	*P*	Adjusted[a] OR	Adjusted[a] 95% CI	*P*
Leisure-time PA							
Walking	No LT walking	1.00			1.00		
	0.1–2 hours per week	0.67	0.58–0.78	<0.001	0.72	0.62–0.84	<0.001
	>2 hours per week	0.69	0.59–0.81	<0.001	0.72	0.61–0.84	<0.001
Moderate	No moderate LTPA	1.00			1.00		
	0.1–1.33 hours per week	0.63	0.51–0.77	<0.001	0.67	0.54–0.84	0.001
	>1.33 hours per week	0.83	0.68–1.02	0.076	0.89	0.72–1.11	0.318
Vigorous	No vigorous LTPA	1.00			1.00		
	0.1–1.9 hours per week	0.76	0.63–0.92	0.005	0.85	0.70–1.04	0.118
	>1.9 hours per week	0.65	0.54–0.79	<0.001	0.69	0.56–0.85	<0.001
Total leisure-time PA	<40 min per week	1.00			1.00		
	41 min–3.4 hours per week	0.63	0.54–0.75	<0.001	0.67	0.57–0.80	<0.001
	>3.4 hours per week	0.61	0.53–0.71	<0.001	0.65	0.56–0.76	<0.001
Work PA							
Walking	No walking at work	1.00			1.00		
	0.1–8 hours per week	0.87	0.74–1.03	0.104	0.92	0.77–1.10	0.373
	>8 hours per week	1.06	0.91–1.24	0.419	1.05	0.88–1.25	0.596
Moderate	No moderate work PA	1.00			1.00		
	0.1–6 hours per week	0.85	0.72–1.00	0.055	0.86	0.72–1.03	0.098
	>6 hours per week	1.17	1.01–1.36	0.039	1.10	0.93–1.30	0.281
Vigorous	No vigorous work PA	1.00			1.00		
	0.1–5 hours per week	0.97	0.83–1.15	0.756	0.99	0.83–1.18	0.916
	>5 hours per week	1.03	0.86–1.23	0.724	0.94	0.77–1.15	0.535
Total work PA	No work PA	1.00			1.00		
	0.1–14.5 hours per week	0.87	0.73–1.03	0.109	0.94	0.78–1.13	0.493
	>14.5 hours per week	0.99	0.86–1.15	0.937	0.95	0.80–1.13	0.583
Transport PA							
Walking	<30 min per week	1.00			1.00		
	31–150 min per week	0.88	0.76–1.03	0.108	0.88	0.75–1.03	0.106
	>150 min (2.5 hours) per week	0.86	0.73–1.02	0.077	0.82	0.69–0.98	0.027
Cycling	No cycling for transport	1.00			1.00		
	0.1–1 hour per week	0.76	0.54–1.08	0.125	0.87	0.61–1.26	0.467
	>1 hour per week	0.69	0.46–1.04	0.076	0.76	0.51–1.13	0.169
Total transport PA	<30 min per week	1.00			1.00		
	30 min–2.5 hours per week	0.87	0.74–1.02	0.094	0.87	0.74–1.03	0.108
	>2.5 hours per week	0.84	0.71–1.00	0.044	0.82	0.69–0.98	0.026
Domestic PA total	<3 hours per week	1.00			1.00		
	3–11.7 hours per week	0.91	0.76–1.09	0.323	0.96	0.80–1.15	0.675
	>11.7 hours per week	0.92	0.77–1.09	0.336	0.96	0.79–1.17	0.716
Total global PA	<11.5 hours per week	1.00			1.00		
	11.5–32.3 hours per week	0.88	0.75–1.04	0.143	0.88	0.75–1.04	0.148
	>32.3 hours per week	1.05	0.89–1.26	0.548	0.99	0.83–1.19	0.944

Table III. *Continued*

Variables	Category (per week)	Crude OR	95% CI	*P*	Adjusted[a] OR	Adjusted[a] 95% CI	*P*
Social context of leisure-time PA							
	All LTPA done on own	1.00			1.00		
	Most (three-fourth) done on own	0.67	0.53–0.86	0.001	0.69	0.53–0.89	0.004
	Half done on own	0.86	0.65–1.14	0.288	0.87	0.66–1.15	0.330
	A little (one-fourth) done on own	0.75	0.56–1.00	0.050	0.75	0.56–1.01	0.062
	All LTPA with someone	0.81	0.64–1.03	0.082	0.86	0.67–1.11	0.253
SB							
Computer time	<4.75 hours per week	1.00			1.00		
	4.75–21.5 hours per week	1.06	0.89–1.27	0.484	1.12	0.93–1.36	0.218
	>21.5 hours per week	1.20	1.02–1.41	0.025	1.35	1.14–1.60	<0.001
TV viewing	<13.7 hours per week	1.00			1.00		
	13.7–22.7 hours per week	1.09	0.91–1.29	0.342	1.05	0.87–1.26	0.626
	>22.7 hours per week	1.40	1.18–1.67	<0.001	1.19	0.99–1.43	0.059
Screen time	<23.5 hours per week	1.00			1.00		
	23.5–46.3 hours per week	1.21	1.02–1.44	0.030	1.13	0.93–1.37	0.206
	>46.3 hours per week	1.41	1.20–1.66	<0.001	1.31	1.09–1.58	0.004
Sitting time	<30.7 hours per week	1.00			1.00		
	30.7–54.5 hours per week	1.04	0.87–1.26	0.657	0.95	0.78–1.14	0.4566
	>54.5 hours per week	1.40	1.19–1.65	<0.001	1.28	1.06–1.53	0.009

[a]Adjusted for age, BMI, marital status, physical health/injury, income, education, employment status, children living at home and country of birth.
[b]Both models adjusted for clustering by neighborhood.

the SBs associated with risk of depression in women from socioeconomically disadvantaged neighborhoods.

Results showed that women who reported participating in greater amounts of leisure-time PA (greater than 40 min per week) were less likely to be at risk of depression than those who reported undertaking less than this. Further, results indicated an inverse relationship with risk of depression when examining the duration of leisure-time PA undertaken in each intensity (i.e. walking, moderate and vigorous). These findings suggest that greater doses of leisure-time PA may reduce the risk of depression, or alternatively people experiencing depressive symptoms spend less time in leisure-time PA, consistent with findings from previous studies [11].

The present study also found that undertaking a high dose of transport-related PA (e.g. greater than 2.5 hours) was associated with lower risk of depressive symptoms compared with those who reported lower doses. However, when examined according to each transport-related activity separately (cycling and walking), only high doses of transport-related walking was associated with a reduced likelihood of depression, suggesting that it may be the type of PA used for transport that is important. This finding is in contrast to previous studies that specifically examined and found no association between transport-related PA and risk of depression [11, 14]. However, the sample sizes of both previous studies were much smaller than that of the current study, perhaps reducing the power to detect smaller associations.

Consistent with previous studies [11], no association was found between any intensity of work-related or domestic PA and risk of depression in this study. This finding suggests that it may be the type/mode of PA, rather than the dose (i.e. intensity and duration) that is most important in determining

the relationship with risk of depressive symptoms. These findings may be due to women's lack of enjoyment or control when participating in work-related and domestic PA.

A number of physiological hypotheses have been suggested to explain the inverse association between PA and depression including the 'endorphin hypothesis', which suggests that PA produces endorphin secretion, which in turn reduces pain and produces feelings of euphoria [38]. However, the production of endorphins requires a high exercise intensity [39]. Since walking for leisure was inversely associated with risk of depression in the current study, other hypotheses such as the serotonin hypothesis [40] may be more applicable. The serotonin hypothesis suggests that exercise may reduce depression by increasing the synthesis of serotonin [41, 42], a neurotransmitter found in the brain that regulates mood and stress [43]. Furthermore, spending time outdoors (in natural light) may provide additional mental health benefits when undertaking PA as exposure to light has been found to increase serotonin synthesis [44]. Non-physiological hypotheses may also play a role in explaining the inverse association between PA and depression. These relate to distraction effects by which improvements in mental well-being following exercise may be due to the diversion of negative thoughts during the activity [45]. Alternatively, improvements following PA may be the sense of mastery and success derived from achieving goals [45].

The social context of PA was found to be associated with risk of depression in the current study, although the association was not linear and only held for those women reporting undertaking one-quarter of their leisure-time PA with someone else. The finding that reduced risk of depression was associated with doing about one-quarter of PA with someone else, but not 50% or more, is not easily explained. This may have been related to the particular categories of PA analyzed. However, in further investigation of this association, we re-categorized social context as: all leisure-time PA done on own (reference category), more than half (but not all) leisure-time PA done on own and less than half leisure-time PA done on own. Yet, results showed no significant associations between either one of those categories and risk of depression (data not shown). Further investigation of this non-linear association is required.

The current study suggested that additional mental health benefits may come from undertaking some leisure-time PA with someone else, yet not all PA with others may be associated with a lower risk of depression. This is consistent with findings from the only other cross-sectional study that has examined the association between the social context of PA and risk of depression [11]. That study found that being active with a family member was associated with a lower risk of depression, yet being active with a friend was not. Conversely, our findings may also suggest that perhaps women at risk of depression prefer to participate in PA by themselves as social withdrawal is a symptom of minor depression [46]. Since social support is widely known to be linked to lower levels of depression [47], the social context of PA may be an important component in the relationship between PA and depression.

The current study found that undertaking greater doses of computer use, screen and overall sitting time were associated with an increased risk of depressive symptoms. This is consistent with several studies that assessed SB in terms of computer/Internet use [48] and overall sitting time [21], suggesting that greater doses of SB increase the risk of depression or alternatively people experiencing depressive symptoms spend greater amounts of time in SBs.

The findings of this study indicated no interaction between SB, PA and risk of depression. In other words, contrary to expectancies, and to the findings of one existing study [3], positive associations between SB and risk of depression were not altered by participants' leisure-time PA levels. In the previous study [3], depression was not reported exclusively as the outcome measure [e.g. the outcome measure (mental disorder) also included stress and anxiety] and a longitudinal design was used, which may account for the differences in results. However, similar to our findings, studies investigating physical health and disease

parameters have found the relationship between SB and physical health conditions such as obesity, metabolic syndrome and type 2 diabetes to be independent of PA [49–51]. Therefore, assessing the joint SB–PA–depression relationship may be an important point of consideration and area for further research.

One major limitation of the current study is its cross-sectional design, which does not allow for causality or the direction of relationships to be determined. A second limitation is that self-report measures were used to assess PA, SB and risk of depression; however, all measures were well validated [30, 33]. Future studies could utilize objective measures such as accelerometers for assessing PA and SB. Finally, women with missing data on any covariates (e.g. education, income and BMI) were excluded from regression analyses in the present study. Chi-square analyses showed that a significantly greater proportion of women excluded for this reason were at risk of depression when compared with those who were included. Therefore, a disproportionately higher number of women at risk of depression may have been missed in analyses.

A major strength of this study is the large, population-based sample of women living in socioeconomically disadvantaged neighborhoods, which provided good power to detect associations, even after controlling for a range of important covariates. Few studies have examined the association between domain and social context of PA and risk of depression or between SB and risk of depression, particularly in women [10]. Furthermore, only one previous study has assessed the interaction between SB, PA and risk of depression [3]. This study extends this evidence to socioeconomically disadvantaged women who are a population group at a great risk of physical inactivity [8, 9] and depression [7].

Conclusion

Given that depression is the world's most incapacitating illness [52], strategies to prevent and manage depression are increasingly important. Recognizing the cross-sectional nature of the current study, these findings suggest that promoting PA, particularly for leisure and transport, could be an important aspect in preventing depression. Furthermore, mental health guidelines may be developed to include some aspect of social/accompanied leisure-time PA for additional mental health benefits. Guidelines should also recommend reducing time spent in SBs (e.g. sitting time and computer use) in order to further reduce risk of depression. However, confirmation of these findings using prospective and intervention study designs is required.

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Conflict of interest statement

None declared.

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