Preventive Medicine 53 (2011) 284–288

Contents lists available at ScienceDirect

Preventive Medicine

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

Associations of objectively-assessed physical activity and sedentary time with depression: NHANES (2005–2006)

Jeff K. Vallance [a,*], Elisabeth A.H. Winkler [b], Paul A. Gardiner [b], Genevieve N. Healy [b,c], Brigid M. Lynch [d], Neville Owen [b,c]

[a] Faculty of Health Disciplines, Athabasca University, 1 University Drive, Athabasca, AB, Canada T9S-3A3
[b] The University of Queensland, School of Population Health, Cancer Prevention Research Centre, Brisbane, Queensland, Australia
[c] Baker IDI Heart and Diabetes Institute, Melbourne, VIC, Australia
[d] Department of Population Health Research, Alberta Health Services, Calgary, Alberta, Canada

ARTICLE INFO

Article history:
Received 9 February 2011
Received in revised form 22 April 2011
Accepted 17 July 2011
Available online 23 July 2011

Keywords:
Physical activity
Sedentary behavior
Depression
Actigraph accelerometer

ABSTRACT

Background. Studies provide conflicting evidence for the protective effects of moderate-to-vigorous-intensity physical activity on depression. Recent evidence suggests that sedentary behaviors may also be associated with depression.

Purpose. To examine the associations of accelerometer-derived moderate-to-vigorous-intensity physical activity and sedentary time with depression among a population-based sample.

Methods. Cross-sectional study using 2,862 adults from the 2005–2006 US National Health and Nutrition Examination Survey. ActiGraph accelerometers were used to derive both moderate-to-vigorous-intensity physical activity and sedentary time.

Results. Depression occurred in 6.8% of the sample. For moderate-to-vigorous-intensity physical activity, compared with those in quartile 1 (least active), significantly lower odds of depression were observed for those participants in quartiles 2 (OR = 0.55, 95% CI, 0.34 to 0.89), 3 (OR = 0.49, 95% CI, 0.26 to 0.93), and 4 (most active) (OR = 0.37, 95% CI, 0.20 to 0.70) (p for trend $p<0.01$). In overweight/obese participants only, those in quartile 4 (most sedentary) had significantly higher odds for depression than those in quartile 1 (least sedentary) [quartile 3 vs 1 (OR = 1.94, 95% CI, 1.01 to 3.68) and 4 vs 1 (OR = 3.09, 95% CI, 1.25 to 7.68)].

Conclusion. The current study identified lower odds of depression were associated with increasing moderate-to-vigorous-intensity physical activity and decreasing sedentary time, at least within overweight/obese adults.

Introduction

Depressive disorder is expected to be one of the top three contributors to the burden of disease by 2020 (Murray and Lopez, 1997). Studies have provided conflicting evidence for the protective effects of moderate-to-vigorous intensity physical activity (MVPA) on depression. Some studies indicated a significant protective effect (Strawbridge et al., 2002); others have not (Cooper-Patrick et al., 1997, Weyerer, 1992). However, studies have had methodological limitations, including limited definitions of MVPA (e.g., sports-related physical activity) (Weyerer, 1992), and the use of non-validated self-report physical activity assessments (Strawbridge et al., 2002).

Sedentary behaviors have been inversely associated with premature mortality, type 2 diabetes, cardiovascular disease, and cardiometabolic biomarkers (Owen et al., 2010). Sedentary behaviors involve low energy expenditure (1.0–1.5 METS) and are characterized by prolonged sitting and the absence of whole-body movement (Owen et al., 2010). A review of seven observational studies found sedentary behaviors were associated with an increased risk of depressive symptoms (Teychenne et al., 2010). With the exception of a single, non population-based study, which utilized accelerometers (Sanchez et al., 2008), all of the remaining studies used self-report measures and only considered a limited set of screen-based sedentary behaviors.

Although most studies have reported an association between obesity and depression risk (Herva et al., 2006, Simon et al., 2006), the potential moderating role of body mass index (BMI) on the associations of MVPA and sedentary time with depression is unknown. To date, no population-based studies have examined associations of objectively-assessed MVPA and sedentary time with depression. The primary objective of this study was to examine the associations of accelerometer-assessed MVPA and sedentary time with depression in a population-based sample of adults. Exploratory secondary objectives were to explore the potential moderating roles of gender, age and overweight/obesity on these associations.

* Corresponding author.
E-mail address: jeffv@athabascau.ca (J.K. Vallance).

0091-7435/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.ypmed.2011.07.013

Materials and methods

Study sample

The 2005–2006 National Health and Nutrition Examination Survey (NHANES) cycle included a nationally-representative sample of non-institutionalized civilian US citizens, selected with a complex multi-stage design. The survey consisted of a household interview and an examination conducted in a mobile examination centre (MEC). The study complied with the Declaration of Helsinki and protocols were approved by the National Center for Health Statistics Ethics Review Board. Written informed consent was obtained from participants. All ambulatory adults who attended the MEC were eligible to wear an accelerometer. From an initial sample of 4979 adult participants (≥20 years of age), 3079 had 4 or more days of valid accelerometer data. Of these, 2862 also completed a depression screener. A further 98 (3.4%) participants were excluded from the main results due to missing data on relevant covariates, leaving a final sample size of 2764. Most data were missing at random and reweighting of the MEC was used to correct for biases in non-response to the accelerometer component (Troiano et al., 2008). After re-weighting there were negligible differences between the weighted characteristics of this study sample and the US population (data not shown).

Accelerometer data collection and analysis

MVPA and sedentary time were derived from ActiGraph AM-7164 accelerometer (ActiGraph of Ft. Walton Beach, FL) data, which is designed to record the magnitude of acceleration of primarily ambulatory activities. The NHANES protocol involved recording acceleration data in 1-minute time intervals while participants wore the monitor for 7 days on their right hip, attached by an elastic belt, and during all waking hours, except while bathing or swimming.

An automated program was adapted to summarize the accelerometer data (SAS 9.1) (Matthews et al., 2008). Common cutoffs were used to differentiate MVPA (counts/minute ≥1952) from light intensity activity (100–1951 counts/minute) (Freedson et al., 1998). A pragmatic cutoff of <100 counts/minute was chosen to categorize sedentary time (Matthews et al., 2008). Non-wear time was defined as intervals of at least 60 consecutive minutes of zero counts, allowing for interruptions (Healy et al., 2011). To be considered valid, days of data collection required at least 600 minutes (10 hours) of wear time and no excessive counts (>20,000 counts per minute). To allow for relationships that may not necessarily be linear, MVPA (average hours/day) and sedentary time (average hours/day) were examined as quartiles, having first corrected for wear time via the residuals method (Healy et al., 2011) to remove variation caused by variability in time the accelerometers were worn by participants.

Outcome measures

Depression

Depression was assessed using the Patient Health Questionnaire-9 (PHQ-9), which has good criterion, construct, and external validity (Kroenke et al., 2001). Participants were asked, "Over the last 2 weeks, how often have you been bothered by any of the following problems?" for each of the 9 DSM-IV criteria, which included such items as "Feeling tired or having little energy" and "Feeling down, depressed, or hopeless". Response options were "not at all," "several days," "more than half the days" and "nearly every day." Symptoms were considered present if reported for at least "more than half the days," or at least "several days" in the case of "thoughts that you would be better off dead, or of hurting yourself in some way."*Major depression* was diagnosed if 5 or more symptoms were present, including depressed mood or anhedonia (i.e., inability to experience pleasurable emotions). *Other depression* was diagnosed if 2 to 4 depressive symptoms were present, including depressed mood or anhedonia (Kroenke et al., 2001). Due to low numbers, *major depression* was combined with *other depression* for analysis.

Potential confounders

Demographic characteristics (age, gender, ethnicity, education, and marital status) were measured via interviewer-administered questionnaire in participants' homes. Behavioral characteristics were smoking (based on serum cotinine ng/mL) and total energy intake (kcal), which was assessed via 24-hour dietary recall interview. Comorbidities (i.e., arthritis, coronary heart disease, angina, stroke, thyroid problems, cancer, and diabetes) were assessed via questionnaire, while BMI (normal (<25) or overweight/obese (≥25) was measured in the MEC.

Statistical analyses

In accordance with the NHANES design, linearized variance estimates were used and data were weighted to the US population in Stata v.11 (College Station, TX, Stata Corporation). Binary logistic regression analyses examined the associations of MVPA and sedentary time with depression. Results were presented adjusted for age, ethnicity, and gender (Model 1) and fully adjusted (Model 2). Model 2 included all variables from Model 1; MVPA and sedentary time (i.e. the associations were mutually adjusted); and, all other potential confounders that had any evidence of association with depression (i.e., $p<0.2$), specifically, marital status, education, smoking, arthritis, stroke, and thyroid problems. Results were reported as odds ratios (OR) with 95% confidence intervals (CI), and the p-value for linear trend. Statistical significance was set at $p<0.05$ for main effects.

Interactions examined whether associations of MVPA and sedentary time with depression varied by gender, age (≥55 years of age), or BMI, (adjusting as per Model 2). To avoid the problem of inflated standard errors, interactions were examined without weighting.

Results

Participant characteristics

Participant characteristics, weighted to the US adult population, are presented in Table 1. The average age was 45.7 (SD = 13.7) years with 50.2% women. The majority (67.7%) were either overweight/obese ($n=2000$) with an average BMI of 28.4 (SD = 6.6). Participants wore their accelerometer 4 to 7 days (median = 6) for an average of 14.6 (SD = 1.5) hours per day, of which 8.5 (SD = 2.2) hours per day were spent sedentary. Overall, adults spent on average 25.6 (SD = 18.2) minutes per day [Median = 20.2; from 0 to 206.4 (min/max)] engaged in MVPA. Depression occurred in 6.8% of the sample. At the bivariate level, depressed and non-depressed participants were significantly different across several demographic, medical, and behavioral characteristics (Table 1).

Associations between MVPA and depression

Significant linear trends in depression across quartiles of MVPA were seen in both Model 1 and Model 2 (Table 2). In the fully adjusted model, the association was sizeable; participants in quartile 4 of MVPA (i.e., representing the most active 25% of the adult US population) had 2.7-fold lower odds of depression participants in quartile 1 (i.e., representing the least active 25% of the adult US population).

Associations between sedentary time and depression

Model 1 indicated a significant linear trend between sedentary time and depression across quartiles of quartiles of sedentary time ($p=0.02$ for linear trend, Table 2). In Model 1, participants

Table 1
Demographic, behavioral, and health characteristics of study participants.[†]

	Overall ($n=2862$)	Depression[*] ($n=195$)	No Depression ($n=2667$)	p[**]
Age	45.7 (13.7)	46.6 (14.2)	45.6 (13.7)	0.74
Gender				
Men	1,417 (48.5)	87 (40.3)	1,330 (49)	
Women	1,445 (51.5)	108 (59.7)	1,337 (51)	0.04
Race / ethnicity				
Mexican American	579 (7.6)	42 (10.1)	537 (7.5)	
Other Hispanic	84 (3.5)	7 (5.3)	77 (3.3)	
Non-Hispanic White	1,498 (73.1)	85 (63.6)	1,413 (73.7)	
Non-Hispanic Black	598 (10.9)	54 (16.6)	544 (10.5)	
Other race	103 (4.9)	7 (4.4)	96 (5.0)	0.80
Education				
<9th grade	338 (5.5)	34 (8.9)	304 (5.3)	
9-11th grade	392 (9.6)	46 (20.4)	346 (8.9)	
High school grad	685 (24.6)	48 (29.0)	637 (24.4)	
Some college	840 (33.2)	47 (29.2)	793 (33.5)	
College grad	606 (27.0)	20 (12.5)	586 (27.9)	<0.00
Marital status				
Married	1,687 (60.7)	92 (48.8)	1,595 (61.4)	
Widowed	256 (5.6)	21 (5.2)	235 (5.7)	
Divorced	287 (10)	23 (14.6)	264 (9.7)	
Separated	83 (2.2)	12 (6.5)	71 (1.9)	
Never married	362 (14.4)	30 (16.1)	332 (14.3)	
Live w/ partner	186 (7.1)	17 (8.8)	169 (7.0)	0.04
Smoking[a]				
Yes	620 (24.6)	67 (37.1)	553 (23.8)	<0.01
Body mass index[b]	28.4 (6.6)	29.8 (7.9)	28.5 (6.7)	0.10
Normal	851 (33.3)	52 (30.7)	799 (33.4)	
Overweight	1,017 (33.1)	55 (25.2)	962 (33.6)	
Obese	983 (33.6)	86 (44.1)	897 (33.0)	0.11
Total energy intake[c]	2249.0 (1006)	2055.9 (888.2)	2237.7 (1000.4)	0.05
Medical conditions[d]				
Arthritis	712 (23.7)	75 (39.5)	712 (23.7)	<0.01
Angina	76 (2.2)	13 (6.1)	89 (2.4)	0.02
Coronary heart disease	110 (3.3)	11 (4.0)	121 (3.3)	0.59
Stroke	82 (2.1)	12 (6.7)	94 (2.3)	0.01
Thyroid	267 (9.6)	30 (18.9)	297 (10.2)	0.03
Cancer	238 (7.9)	20 (12.1)	258 (8.2)	0.23
Diabetes	321 (8.8)	39 (13.8)	321 (8.8)	0.14
Accelerometer wear-time[e] (valid days only)	14.6 (1.9)	14.4 (2.2)	14.6 (1.9)	0.26
Moderate-to-vigorous-intensity physical activity (MVPA)[f]	20.2 (0,206.4)	9.8 (0,177.3)	19.5 (0,206.4)	<0.01
Sedentary time[g]	8.5 (2.2)	8.9 (2.6)	8.5 (2.2)	0.22

Table presents *N* (%), mean (SD), or median (min, max) for non-normal data.
[†] Means, SD, median, and % are weighted to the US population (2000); n is not.
[*] Either *Major depression* or *other depression* as per PHQ-9 scoring, consistent with DSM-IV.
[**] p for difference between participants with and without depression (in weighted analyses with linearized variance estimation, as per the NHANES complex survey design).
[a] Based on cotinine level (≥10 ng/mL considered smoker); % excludes those with missing data (495/7/77 adults/depressed/non-depressed).
[b] Normal: <25 $kg.m^{-2}$; Overweight: 25 $kg.m^{-2}$ – 29.9; Obese ≥30 $kg.m^{-2}$).
[c] Energy intake (kcal) per day. Missing data for 459 adults, 3 depressed, 41 non-depressed.
[d] % reported is for those with each condition; % excludes "missing" adults/depressed/nondepressed: adults (10/0/5 arthritis, 17/1/5 angina, 26/1/8 coronary, stroke 4/0/3, 10/0/5 thyroid, 9/1/1 cancer, 6/1/1 diabetes).
[e] Accelerometer wear (hours) per day.
[f] Minutes per day of MVPA (counts/minute, cpm≥1,952) corrected for accelerometer wear-time.
[g] Sedentary (<100 cpm) hours per day corrected for accelerometer wear-time.

in quartile 4 (i.e., the most sedentary) had nearly 3 times higher odds of depression than participants in quartile 1 (i.e., the least sedentary). In the fully adjusted model, this association was slightly weaker and no longer statistically significant ($p=0.09$). The associations were not so close to the null as to have indicated minimal effect, as the odds of depression were still more than double for those who were most, compared with the least, sedentary (quartile 4 versus 1; Table 2).

Moderating effects of gender, age, and BMI

There were no interactions of MVPA with gender ($F=0.06$, $df=3,13$, $p=0.98$) or age ($F=0.34$, $df=3,13$, $p=0.80$). There was a significant interaction of MVPA with BMI ($F=2.71$, $df=3,13$, $p<0.01$). This interaction (Fig. 1) indicated a significant association between MVPA and depression in overweight/obese adults (quartile 2 vs 1 [OR=0.59, 95% CI, 0.35 to 1.00, $p=0.05$], 3 vs 1 [OR=0.34, 95% CI, 0.18 to 0.62, $p<0.01$], and 4 vs 1 [OR=0.24, 95% CI, 0.12 to 0.47, $p<0.01$]), but no association in normal weight adults.

There were no significant interactions of sedentary time with gender ($F=0.74$, $df=3,13$, $p=0.55$) or age ($F=0.28$, $df=3,13$, $p=0.84$), but a significant interaction was observed between sedentary time and BMI ($F=5.34$, $df=3,13$, $p=0.04$). This interaction (Fig. 1) indicated that sedentary time was associated with significantly increased odds of depression in overweight/obese adults (quartile 3 vs 1 [OR=1.94, 95% CI, 1.01 to 3.68, $p=0.05$]; and 4 vs 1 [OR=3.09, 95% CI, 1.25 to 7.68, $p=0.02$]), but not normal weight adults. In adults of normal weight, there was either no association, or reduced odds of depression (quartile 2 vs 1 [OR=0.39, 95% CI, 0.15 to 0.99, $p=0.05$]).

Comment

This study is the first to examine associations of accelerometer-derived MVPA and sedentary time with depression within a nationally representative population-based sample of adults. It extends on previous research by using objective assessments as opposed to self-report (Strawbridge et al., 2002), and by using a nationally representative, general adult population as opposed to a restricted sub-sample of the population (Sanchez et al., 2008).

One of the main findings in this study was a strong association between objectively-assessed MVPA and depression, having controlled for relevant confounding variables. This was consistent with the body of evidence demonstrating the impact of MVPA (or physical activity) on depressive symptoms in the general population (Teychenne et al., 2008). Interestingly, the reduced odds of depression were seen even at quite low levels of MVPA. For example, participants in quartile 2 had markedly lower odds of depression than those in quartile 1 (OR=0.55), despite only performing 8.52 to 19.22 minutes/day of MVPA. A previous study examining 1947 adults aged 50 years and over found that self-report physical activity was marginally protective for both depression (using the DSM-IV criteria) prevalence (OR=0.90, 95% CI, 0.79 to 1.01) and protective for incident depression (OR=0.83, 95% CI, 0.73 to 0.96) (Strawbridge et al., 2002). The use of objectively-assessed MVPA, and an established method for identifying depression may partly explain the stronger associations observed in this current study.

The current findings provided some evidence of an association of sedentary time with depression. In the general population, the association was not statistically significant, but was sizeable with approximately double the odds of depression seen for the most, compared with least sedentary in the population (i.e., quartile 4 vs 1). This was somewhat consistent with the only previous study to examine a similar topic using accelerometers (Sanchez et al., 2008), which found a significant association between accelerometer-derived sedentary time and depressive symptoms among their sample of overweight and obese women.

There are plausible biological and physical mechanisms that could causally link more MVPA with less depression. These include increases in brain neurotransmitters such as endorphins (Phillips et al., 2001) and increases in physical fitness associated with higher levels of MVPA (Stewart et al., 1994). More accepted is the hypothesis suggesting that depression risk may be reduced given the increasing synthesis of serotonin, a neurotransmitter responsible for regulating mood and stress, resulting from increases in MVPA (Ernst et al., 2006). Future

Table 2
Adjusted odds of depression across quartiles of accelerometer-derived moderate-to-vigorous-intensity physical activity (MVPA) and sedentary time in US adults.

	Model 1[a] ($n=2862$)			Model 2[b] ($n=2848$)		
	Depression ($n=195$)		OR (95% Confidence Interval)	Depression ($n=194$)		OR (95% Confidence Interval)
	Yes	No		Yes	No	
MVPA (Quartiles[c])						
Q1 (<8.52 minutes/day)	96	881	1 (referent)	95	876	1 (referent)
Q2 (8.52 to <19.22 minutes/day)	46	659	0.41 (.25, 0.67)**	46	656	0.55 (0.34,0.89)*
Q3 (19.22 to 36.00 minutes/day)	31	588	0.29 (0.15, 0.55)**	31	585	0.49 (0.26, 0.93)*
Q4 (>=36.00 minutes/day)	22	539	0.19 (0.10, 0.37)***	22	537	0.37 (0.20, 0.70)**
p for trend			*<0.01*			*<0.01*
Sedentary time (Quartiles[c])						
Q1 (<7.08 hours/day)	38	643	1 (referent)	38	640	1 (referent)
Q2 (7.08 to <8.34 hours/day)	37	633	1.07 (0.59, 1.94)	37	630	0.86 (0.47, 1.60)
Q3 (8.34 to <9.81 hours/day)	44	660	1.29 (0.71, 2.36)	44	657	1.11 (0.57, 2.16)
Q4 (>=9.81 hours/day)	76	731	2.83 (1.29, 6.20)*	75	727	2.01 (0.87, 4.64)
p for trend			*0.02*			*0.09*

* $p \leq 0.05$.
** $p < 0.01$.
*** $p < 0.001$ for association with depression ("major" or "other" depression based on PHQ-9).
[a] Model 1 Odds Ratios are adjusted for gender, ethnicity, and age.
[b] Model 2 Odds Ratios are adjusted for gender, ethnicity, age, marital status, education, smoking, arthritis, stroke, thyroid problems, and sedentary time (quartiles) or MVPA (quartiles).
[c] Cut-points reflect the bottom (1) through top (4) 25% of values observed in the US adult population, having adjusted for accelerometer wear time.

studies should explore the potential influence of these adverse conditions. Self-esteem has been positively associated with higher levels of MVPA (Stewart et al., 1994). Individuals who are physically active may have higher self-esteem and self-efficacy due to meeting physical activity goals and challenges. Less is known about underlying mechanisms for the association of sedentary time with depression. Displacement of physical activity by sedentary behaviors (Teychenne et al., 2010) is unlikely to completely explain the associations, as results were adjusted for MVPA, however displacement of light intensity activities might be important. Alternatively, social/psychological theories, such as the social withdrawal hypothesis, suggest that increased sedentary time may remove individuals from social interactions, and therefore increase their risk for depression (Kraut et al., 1998).

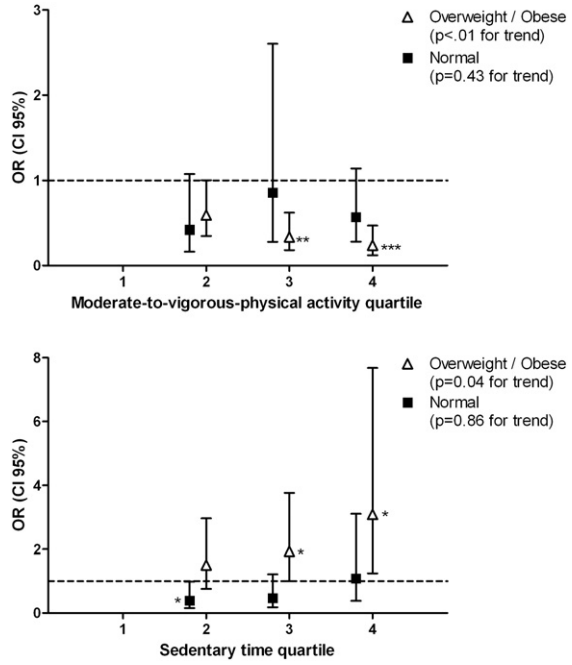

Fig. 1. Adjusted odds of depression (PHQ-9) according to level of accelerometer-derived moderate-to-vigorous-intensity physical activity (MVPA) (Top) and sedentary time (Bottom) for normal ($n=845$) compared with overweight/obese participants ($n=1992$). *$p \leq 0.05$; **$p<0.01$; ***$p<0.001$ for association with depression. Note. MVPA quartiles (i.e. <8.52, 8.52 to <19.22, 19.22 to <36.00, >=36.00 minutes per day) and sedentary quartiles (i.e., <7.08, 7.08 to <8.34, 8.34 to <9.81, >=9.81 hours per day) are corrected for accelerometer wear-time (residuals method). Odds Ratio (95% Confidence Interval) adjusted for gender, ethnicity, age, marital status, education, smoking, arthritis, stroke, thyroid problems, and MVPA (quartiles) or sedentary time (quartiles).

Studies have documented the independent associations of excess adiposity and sedentary behavior with depression (Simon et al., 2006, Teychenne et al., 2010). In the present study, we extended such findings by observing that BMI may partially moderate the association between sedentary time and depression (p for interaction = 0.04) as well as between MVPA and depression (p for interaction <0.01). The interactions suggested that being sedentary for large portions of the day may be more hazardous with respect to depression for adults who are overweight or obese compared with those who have a healthy body weight.

This study has several strengths including the objective measurement of MVPA and sedentary time, and the large, ethnically diverse population-based sample of adults. There may be some underestimation of MVPA due to activities not captured by accelerometer, and the sedentary time measure is limited by the use of a cut-point with only limited validation and use of automated estimation of wear-time. Unfortunately, without concurrent diary information, the various domains of activity and sedentary time could not be assessed in this study. Future studies may need to collect such data, as recent research (albeit based on self-report) indicates associations between physical activity and depression may vary depending on domain (McKercher et al., 2009). Although there were some biases in non-response to the accelerometry (Troiano et al., 2008), after re-weighting there were negligible differences between the weighted characteristics of this study sample and the US population (data not shown). Furthermore, the cross-sectional design limits causal inference. While a substantial body of experimental evidence does support the existence of causal associations of MVPA with reduced depression (Dunn et al., 2005, Dunn et al., 2001), cross-sectional associations seen in the general population need to be treated cautiously (De Moor et al., 2008).

These new findings suggest that both MVPA and sedentary time were independently associated with depression among adults in US adults, either generally or at least in some segments of the population. Policies and programs to increase physical activity in the adult population are ongoing. These initiatives may have a beneficial impact on depression, particularly on those who are overweight or obese.

Conflict of interest statement
The authors declare that there are no conflicts of interest.

Acknowledgments

Vallance is supported by a Population Health Investigator Award from Alberta Innovates—Health Solutions and a New Investigator Award from the Canadian Institutes of Health Research. Winkler, Gardiner, Healy, and Owen are supported by a Program Grant (#569940) from the National Health and Medical Research Council of Australia (NHMRC) and by Research Infrastructure funding from Queensland Health. Healy is also supported by a NHMRC (#569861)/National Heart Foundation of Australia (PH 374 08B 3905) Postdoctoral Fellowship. Lynch is supported by a NHMRC Public Health Training Fellowship (#586727) and an Alberta Innovates—Health Solutions Fellowship.

References

Cooper-Patrick, L., Ford, D.E., Mead, L.A., Chang, P.P., Klag, M.J., 1997. Exercise and depression in midlife: a prospective study. Am. J. Public Health 87, 670–673.
De Moor, M.H., Boomsma, D.I., Stubbe, J.H., Willemsen, G., De Geus, E.J., 2008. Testing causality in the association between regular exercise and symptoms of anxiety and depression. Arch. Gen. Psychiatry 65, 897–905.
Dunn, A.L., Trivedi, M.H., Kampert, J.B., Clark, C.G., Chambliss, H.O., 2005. Exercise treatment for depression: efficacy and dose response. Am. J. Prev. Med. 28, 1–8.
Dunn, A.L., Trivedi, M.H., O'neal, H.A., 2001. Physical activity dose–response effects on outcomes of depression and anxiety. Med. Sci. Sports Exerc. 33, S587–S597 discussion 609–10.
Ernst, C., Olson, A.K., Pinel, J.P., Lam, R.W., Christie, B.R., 2006. Antidepressant effects of exercise: evidence for an adult-neurogenesis hypothesis? J. Psychiatry Neurosci. 31, 84–92.
Freedson, P.S., Melanson, E., Sirard, J., 1998. Calibration of the Computer Science and Applications Inc. accelerometer. Med. Sci. Sports Exerc. 30, 777–781.
Healy, G.N., Matthews, C.E., Dunstan, D.W., Winkler, E., Owen, N., 2011. Sedentary time and cario-metabolic biomarkers in US adults: NHANES 2003–06. Eur. Heart J. 32, 590–597.
Herva, A., Laitinen, J., Miettunen, J., Veijola, J., Karvonen, J.T., Laksy, K., et al., 2006. Obesity and depression: results from the longitudinal Northern Finland 1966 Birth Cohort Study. Int. J. Obes. (Lond.) 30, 520–527.
Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukopadhyay, T., Scherlis, W., 1998. Internet paradox. A social technology that reduces social involvement and psychological well-being? Am. Psychol. 53, 1017–1031.
Kroenke, K., Spitzer, R.L., Williams, J.B., 2001. The PHQ-9: validity of a brief depression severity measure. J. Gen. Intern. Med. 16, 606–613.
Matthews, C.E., Chen, K.Y., Freedson, P.S., Buchowski, M.S., Beech, B.M., Pate, R.R., et al., 2008. Amount of time spent in sedentary behaviors in the United States, 2003–2004. Am. J. Epidemiol. 167, 875–881.
Mckercher, C.M., Schmidt, M.D., Sanderson, K.A., Patton, G.C., Dwyer, T., Venn, A.J., 2009. Physical activity and depression in young adults. Am. J. Prev. Med. 36, 161–164.
Murray, C.J., Lopez, A.D., 1997. Alternative projections of mortality and disability by cause 1990–2020: Global Burden of Disease Study. Lancet 349, 1498–1504.
Owen, N., Healy, G.N., Matthews, C.E., Dunstan, D.W., 2010. Too much sitting: the population health science of sedentary behavior. Exerc. Sport Sci. Rev. 38, 105–113.
Phillips, W.T., Kiernan, M., King, A.C., 2001. Effects of physical activity on physical and psychological health: implications for exercise adherence and psychophysiological mechanisms. In: Singer, J. (Ed.), Handbook of Health Psychology. Lawrence Erlbaum, London.
Sanchez, A., Norman, G.J., Sallis, J.F., Calfas, K.J., Rock, C., Patrick, K., 2008. Patterns and correlates of multiple risk behaviors in overweight women. Prev. Med. 46, 196–202.
Simon, G.E., Von Korff, M., Saunders, K., Miglioretti, D.L., Crane, P.K., Van Belle, G., et al., 2006. Association between obesity and psychiatric disorders in the US adult population. Arch. Gen. Psychiatry 63, 824–830.
Stewart, A.L., Hays, R.D., Wells, K.B., Rogers, W.H., Spritzer, K.L., Greenfield, S., 1994. Long-term functioning and well-being outcomes associated with physical activity and exercise in patients with chronic conditions in the Medical Outcomes Study. J. Clin. Epidemiol. 47, 719–730.
Strawbridge, W.J., Deleger, S., Roberts, R.E., Kaplan, G.A., 2002. Physical activity reduces the risk of subsequent depression for older adults. Am. J. Epidemiol. 156, 328–334.
Teychenne, M., Ball, K., Salmon, J., 2008. Physical activity and likelihood of depression in adults: a review. Prev. Med. 46, 397–411.
Teychenne, M., Ball, K., Salmon, J., 2010. Sedentary behavior and depression among adults: a review. Int. J. Behav. Med. 17, 246–254.
Troiano, R.P., Berrigan, D., Dodd, K.W., Masse, L.C., Tilert, T., Mcdowell, M., 2008. Physical activity in the United States measured by accelerometer. Med. Sci. Sports Exerc. 40, 181–188.
Weyerer, S., 1992. Physical inactivity and depression in the community. Evidence from the Upper Bavarian Field Study. Int. J. Sports Med. 13, 492–496.