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Associations between objectively assessed and self-reported sedentary time with mental health in adults

Health Survey for England

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Abstract

Background: There is increasing interest in the association between sedentary behavior and mental health, although most studies have relied solely on self-reported measures, thus making results prone to various biases. The aim was to compare associations between objectively assessed and self-reported sedentary time with mental health in adults.

Methods: Participants were drawn from the 2008 Health Survey for England. The sample consisted of 11,658 (self report analysis) and 1,947 (objective data) men and women. Sedentary and physical activity were objectively measured using accelerometers (Actigraph GT1M) worn around the waist during waking hours for 7 consecutive days. The 12 – item General Health Questionnaire was administered to assess psychological distress. Objective sedentary time was defined as <200 cpm.

Results: The highest tertile of objective sedentary time was associated with higher risk of psychological distress (multivariate adjusted OR=1.74, 95% CI, 1.07, 2.83), as was the highest tertile of self reported total sitting time (OR=1.34, 95% CI, 1.15, 1.56). Self-reported, but not objective, moderate-vigorous physical activity was associated with lower risk of psychological distress. Only objective light-intensity activity was associated with lower risk of psychological distress.

Conclusions: Sedentary time is associated with adverse mental health although future work is required to explore the underlying mechanisms.

Key words: accelerometry, sedentary, physical activity, mental health, depression.

Strengths and limitations

- Use of objective physical activity assessment
- Large representative sample of the general population
- The main limitation is the cross-sectional design
- Future studies are required to examine the biological plausibility.

Introduction

Adults spend approximately 60 – 70% of their waking hours in sedentary activities (1,2), which are characterized by energy expenditure below 1.5 metabolic equivalents while in a sitting or reclined posture. There is increasing interest in the association between sedentary behavior and mental health (3-12). Several longitudinal studies have demonstrated an association of self reported TV/computer time (7) and TV time alone (8) with higher risk of mental disorders, including depression and anxiety, at follow-up. However, data from other studies suggest that not all types of sedentary behaviors are related with adverse mental health (5,9). For example, in a sample of older adults from the English Longitudinal Study of Ageing, TV time but not computer use was associated with higher depressive symptoms (9). Thus, it is unclear if the effects are being driven by physiological processes linked to excessive sitting or the contrasting environmental and social contexts in which they occur.

The majority of studies to date in this area have relied on self reported measures of sedentary behaviors or total sitting time, thus making it difficult to tease apart associations between sedentary and mental health outcomes. Self-report is a potential limitation in this context as subjective mental state is a complex measure comprising of cognitive and somatic symptoms, thus self-reported mental health and sedentary behavior might have conceptual overlap. Therefore, the aim of this study was to examine the association between both objectively-assessed and self-reported sedentary time with mental health in a population sample of adults. We hypothesized that if the effects are being driven by physiological processes linked to excessive sitting we would observe consistent associations between objective and self-reported assessments of sedentary time with mental health. On the contrary, if the associations

were only observed for self-reported sedentary time this might reflect a context specific effect or reporting bias.

Methods

Sample and study design

The Health Survey for England (HSE) is a continuous survey that annually draws a nationally-representative general population sample of adults living in households. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit and the Postcode Address File as the sampling frame for households. Stratification was based on geographical areas and not on individual characteristics of the population. In the present analysis we used data from the 2008 HSE, which had a special focus on physical activity and fitness (13). In the 2008 HSE the household response rate for the core sample was 64%. Ethical approval for the 2008 survey was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). These analyses considered participants aged between 16 to 95 years and over with valid data on all demographic, behavioural, and clinical variables of interest.

Assessment of sedentary time and physical activity

Objective measures. A sub-sample of HSE 2008 participants were asked to wear a uni-axial accelerometer that records movement on the vertical axis, the Actigraph GT1M (Actigraph, Pensacola, FL, USA), during waking hours for seven consecutive days. The accelerometer provides a measure of the frequency, intensity, and duration of physical activity and allows classification of activity levels as sedentary, light, moderate to vigorous (MVPA). The raw accelerometry data were processed using

specialist software (KineSoft, New Brunswick, Canada) to produce a series of standardised outcome variables (1,2). Only participants that wore the accelerometer for a minimum of 10 hours per day were included in the present analyses. Although participants with at least one day of valid wear have been included in these analyses, the majority (70%) had between six and seven days and 84% had at least three valid days. We used the following cutoff points to calculate daily times in each activity intensity band: sedentary (<1.5 MET): 0-199 counts/minute; light (1.5-3 MET) 200-2,019 counts/minute; MVPA (>3 MET): ≥2,020 counts/minute (1,2). All physical activity and sedentary behaviour variables were converted to time (in minutes) per valid day.

Self report. The self-reported measures have been described in detail elsewhere (1,14). Briefly, sedentary behavior was assessed using a set of questions enquiring about weekday and weekend time spent on (i) TV (including DVDs and videos) viewing and (ii) any other sitting during non-work times, including reading and computer use. For those participants who were professionally active [i.e. those who answered 'yes' to the question 'In the last 4 weeks, did you do any paid or unpaid work either as an employee or as self-employed (including voluntary or part time work)?'], another set of questions assessed the average daily times spent sitting or standing while at work ('On an average workday in the last 4 weeks, how much time did you usually spend sitting down or standing up?'). Physical activity was assessed using the long version of the HSE questionnaire that was used in the 1997 survey for the first time and was repeated in the 1998, 2006 and 2008 surveys. Questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose and any recreational exercise (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports or racket sports).

Weekly self-reported MVPA hours/week was calculated as number of days of participation multiplied by time per day in each activity type. As with objectively assessed physical activity, tertiles of TV, non-TV leisure-time sitting, total sitting, and MVPA time were derived for the analyses.

Psychological distress

Mental health was assessed using the 12 item version of the General Health Questionnaire (GHQ-12), a widely-utilized measure of psychological distress in population-based studies (15,16). We employed a GHQ-12 cut off score of ≥4 to denote psychological distress. This definition has been validated against standardised psychiatric interviews and has been strongly associated with depression and anxiety (17).

Demographic and clinic variables

Computer-assisted personal interviewing modules assessed respondents' demographics, occupational status, long-standing illness, alcohol consumption, and smoking habits. Height and weight were also measured for the calculation of body mass index, computed as weight (kilograms) divided by squared height (metres).

Statistical analyses

Participants were categorised into tertiles for sedentary and activity categories. We used multiple logistic regression to compute odds ratios (OR) with accompanying 95% confidence intervals (CI) for the association between sedentary time/activity and psychological distress. The models were adjusted for potential confounding factors, including age, sex, smoking (never; previous; current), frequency of alcohol intake (at

least 1/wk; monthly; rarely or never), BMI (normal weight, BMI<25; overweight, BMI 25 – 30; obese, BMI > 30 kg/m^2), social occupational group (professional and managerial occupations; skilled non-manual; routine and manual), highest educational qualification, (non mental health-related) long standing illness, and Actigraph wear time (for analyses involving accelerometry). Finally, the models were mutually adjusted for MVPA in the analyses using sedentary or light activity as the main exposure, or sedentary when using MVPA as the main exposure. Models were run for each main exposure including an interaction term between the main exposure and sex. This interaction term was not significant in any of the models, so analysis was sex-adjusted, but not sex stratified. The complex samples module in SPSS was used to take into account the survey design, which adjusted for uneven non-response and accounted for the clusters and stratum used in data collection. A sensitivity analysis was run for accelerometry-measured sedentary time, using a more conservative cut off of <100 CPM. Due to the large difference in sample size between accelerometry and self-reported outcomes, a second sensitivity analysis was conducted to test whether observed differences in results between accelerometry and self-reported exposures were due to differences between the accelerometry and non-accelerometry samples. Logistic regression models were run substituting sedentary/physical activity tertiles for sample type (accelerometry / non-accelerometry sample). All analyses were conducted using SPSS version 21.

Results

Descriptives

Of the self-report sample used in the analyses (11,658), 12.7% reported psychological distress (see Table 1). Respondents with psychological distress were more likely to be

female, from a lower social class, have a lower educational qualification, be out of paid work, smoke, report a non-mental health longstanding illness, and have problems with usual activities than those without psychological distress (all p<0.001). Respondents with psychological distress were also more sedentary and spent on average 31 and 25 min/day more in TV and non-TV leisure-time sitting respectively, and 10 min/d less in self-reported MVPA (p<0.001).

Accelerometry-measured sedentary time and physical activity

Table 2 presents multivariable-adjusted associations between accelerometry-measured sedentary time and physical activity, with psychological distress. Sedentary time (<200 CPM) was directly associated with psychological distress after adjustment for all covariables including MVPA, although this was more apparent in the highest tertile (OR=1.74, 95% CI, 1.07, 2.83). Light activity (200 to 2018 CPM) was inversely associated with risk for psychological distress, although the association was not linear. MVPA, however, was not associated with psychological distress in any models.

Self-reported sedentary time and physical activity

Table 3 presents the associations between self-reported sedentary time and physical activity with psychological distress. Total sitting time was directly associated with risk of psychological distress, although only the highest tertile of sitting was different to the referent group (OR=1.34, 95% CI, 1.15, 1.56). This association was largely driven by 'non- TV viewing' sedentary time as the associations for TV viewing demonstrated an inconsistent pattern. MVPA was inversely associated with risk of psychological distress in a dose-response manner (p<0.001 for all models).

Sensitivity analysis

In the sensitivity analysis using a different sedentary cut off of 100 CPM (Supplemental Table 1) similar results were found, (multivariate adjusted OR of psychological distress for the highest tertile of sedentary time compared to the lowest tertile = 2.04, 95% CI, 1.29, 3.21, p=0.005). We also examined if there were differences in prevalence of psychological distress between the accelerometry sample and main sample (Supplemental Table 2). Sample type (accelerometry vs non-accelerometry), however, was not a significant predictor of psychological distress, after adjusting for relevant covariates (age, sex, smoking, employment status, longstanding illness, and self-reported MVPA and TV time).

Discussion

The aim of this study was to examine the association between objectively assessed and self reported sedentary time with mental health in a population sample of adults. Our findings consistently show an association between sedentary time and adverse mental health whether using objective or self reported measures of sedentary time. Nevertheless, in contrast to previous evidence (4,5,8,9) the associations between context specific sedentary time (TV viewing) and psychological distress were far less consistent. Given that subjective mental state is a complex measure comprising cognitive (depressed mood) and somatic symptoms (eg, lethargy, tiredness, lack of appetite, pain), this might partly influence an individual's assessment of context specific sedentary time. Our findings are not consistent with data from NHANES that showed null associations between objectively assessed sedentary time and depressive symptoms in the main sample, although did find an association among overweight/ obese adults in sensitivity analyses (18). Nevertheless, our study used a composite

measure of psychological distress consisting of items on anxiety and depression, thus can not be directly compared to the measure of depressive symptoms used in NHANES.

There is mounting evidence to suggest detrimental effects of excess sedentary time on mental health, although plausible biological mechanisms are currently lacking. There are numerous data showing associations between sedentary time and cardio-metabolic risk factors (2,19,20), thus the links with mental health might act partly through these mechanisms. In particular, the role of low grade inflammation in depression has gained substantial attention (21), although in a recent study C-reactive protein did not explain the link between TV viewing and depressive symptoms in older adults (22). Psychosocial mechanisms might also be important. For example, passive sedentary activities such as TV viewing might encourage social isolation and limit the development of social networks.

We are not aware of any other studies that have compared associations of objective and self reported sedentary/MVPA in relation to mental health outcomes. There was a consistent association between sedentary time and adverse mental health whether using objective or self reported measures, albeit stronger with the objective measure. In contrast, we observed a discrepancy in results between self-reported and objectively assessed MVPA in relation to psychological distress, showing associations only for self-reported measures. In our recent studies, where we also compared accelerometry and self-reported exposures but in relation to cardiometabolic outcomes (1,14), we found associations between MVPA and most outcomes for both

self-reported and objective measures. Thus, one interpretation of the present results is that self reported mental health and MVPA might have conceptual overlap causing participants with poor mental health to mis-report their activity levels. In addition, cognitive impairement that is sometimes associated with depression (23) could impair recall introducing bias into the results. Nevertheless, one might view objective and self reported activity as different measures since objective assessment cannot take context into account and, by definition, measure slightly different aspects of MVPA. In this regard, context might be extremely important as some of the effects of physical activity on mental health are most likely driven by factors such as social interaction whereas accelerometry is simply a measure of body movement and cannot capture contextual information such as 'where' and 'who with'.

Few studies have examined associations between objectively assessed physical activity and mental health, and those that have reveal inconsistent findings. For example, in a small cohort of elderly Japanese participants, physical activity was assessed objectively over one year, and inverse associations of activity with depression and stressful life events were observed (24,25). In NHANES an inverse dose response association was observed between MVPA and depressive symptoms (18). In a sample of 40 healthy females who completed a once-a-day mood rating scale for one week we found inverse associations of depressive symptoms with objectively assessed light and moderate intensity activity but not vigorous (26). Other evidence is also equivocal (27,28). The present findings suggested that only objectively assessed light intensity activity was associated with lower risk of psychological distress, which is consistent with prior evidence showing associations between objective light-intensity physical activity and self rated health in older adults

(29). Data from randomised controlled trials also show that light/moderate intensity exercise has greater antidepressive effects (30), effects on positive mood (31), and on reducing symptoms of fatigue compared with vigorous intensity (32,33). Our findings therefore suggest that modifying the balance between sedentary time and light intensity activity could be beneficial for mental health, as suggested by other recent studies (10, 29).

The main limitation of this study is the cross-sectional design, which precludes us from making any inferences about direction or causality. Sedentary behavior has been longitudinally associated with risk of future depression in some (7,8), but not all (9,11) studies thus the issue of causality remains unclear. Second, since accelerometry measures were only collected over one week we do not know if this reflects habitual sedentary patterns in contrast to self-reported questions that enquired about activity over the last 4 weeks. However, strong test-retest reliability for MVPA (r=0.89 for men, r=0.76 in women) was demonstrated in our validation study of 106 British adults from the general population, who wore accelerometers for two non-consecutive weeks over a month period (34). Undoubtedly, controlled trials are the best test of causality. However, studies of community samples have several advantages in that they are more representative. In the present study we aimed to minimise possible confounding by controlling for key covariables. Future studies are required to examine the biological plausibility of a possible association between sedentary behaviour and mental health which would further our understanding of this area.

Taken together, observational studies of representative community samples are an important approach for establishing links between sedentary behaviour and health

outcomes, although further work is required to establish if the existing evidence reflects causal associations.

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Author contributions

MH had full access to the data, and takes responsibility for the integrity and accuracy of the results. NC performed all statistical analyses under supervision of ES. MH drafted the manuscript. All authors contributed to the concept and design of study, and critical revision of the manuscript.

Conflict of interest

None of the authors have any competing interests to declare.

Data sharing

There is no additional data available.

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Table 1: Sample characteristics in relation to psychological distress.

	GHQ<4			GHQ>=4			
Categorical variables		%	N		%	N	*p**
sex (% male)		48.1	10172		38.2	1486	*<0.001*
social class (% semi-skilled manual or lower)		21.7	10172		26.4	1486	*<0.001*
qualification (% secondary school or lower)		50.8	10172		58.1	1486	*<0.001*
% not in paid work		33.9	10172		53.6	1486	*<0.001*
smoking (% current)		20.6	10172		29.9	1486	*<0.001*
Alcohol consumption (% 5+ times a week)		18.5	10172		16.4	1486	*<0.001*
% with LSI** (non-mental health)		39.8	10172		57.3	1486	*<0.001*
% problems with usual activities		10.4	10172		40.5	1486	*<0.001*
Continuous variables	M	SD	N	M	SD	N	*p*
Age (years)	50.0	(17.6)	10172	48.3	(17.2)	1486	*0.149*
BMI (kg/m^2)	27.3	(5.0)	10172	27.8	(6.0)	1486	*0.046*
TV viewing (mins/day)	167.9	(99.6)	10172	199.3	(133.1)	1486	*<0.001*
non-TV leisure-time sitting (mins/day)	126.7	(92.0)	10172	152.0	(119.0)	1486	*<0.001*
Total leisure-time sitting (mins/day)	294.6	(136.8)	10172	351.3	(17.4)	1486	*<0.001*
Self-reported MVPA (mins/day)	45.7	(67.2)	10172	35.3	(63.7)	1486	*<0.001*
Accel sedentary time (mins/day)	578.5	(93.2)	1698	574.1	(98.1)	249	*0.386*
Accel light physical activity time (mins/day)	293.9	(85.3)	1698	288.6	(90.5)	249	*0.436*
Accel MVPA time (mins/day)	29.2	(25.5)	1698	25.7	(22.4)	249	*0.027*
Accel wear time per valid day (mins)	835.9	(74.7)	1698	822.8	(77.3)	249	*0.004*

*p calculated by chi-square for categorical, and by Mann-Whitney U test for continuous
**Longstanding illness

Table 2: Multivariable-adjusted associations between accelerometry-measured sedentary time, light intensity activity, and MVPA, with psychological distress.

	N	Model 1[a]	Model 2[b]	Model 3[c]
Tertiles of sedentary time				
Low	649	1.00	1.00	1.00
Med	649	1.00 (0.66, 1.53)	1.05 (0.68, 1.62)	1.09 (0.70, 1.71)
High	649	1.52 (0.98, 2.35)	1.59 (1.01, 2.51)	1.74 (1.07, 2.83)
p		*0.072*	*0.071*	*0.037*
Tertiles of light PA time				
Low	649	1.000	1.000	1.000
Med	649	0.62 (0.42, 0.92)	0.56 (0.37, 0.84)	0.56 (0.37, 0.84)
High	649	0.79 (0.53, 1.17)	0.74 (0.49, 1.12)	0.73 (0.48, 1.12)
p		*0.056*	*0.021*	*0.020*
Tertiles of MVPA				
Low	649	1.000	1.000	1.000
Med	649	0.67 (0.45, 0.99)	0.81 (0.54, 1.22)	0.90 (0.59, 1.37)
High	649	0.84 (0.55, 1.28)	1.05 (0.68, 1.62)	1.27 (0.80, 2.04)
p		*0.130*	*0.432*	*0.283*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of accel-measured MVPA (for sedentary and light PA exposures) or sedentary time (for MVPA exposure)

Table 3: Multivariable-adjusted associations between self-reported total sitting time, sedentary behaviours, and MVPA with psychological distress

	N	Model1	Model2	Model3
Tertiles of total sitting				
Low	3836	1.00	1.00	1.00
Med	3910	1.11 (0.95, 1.29)	0.99 (0.85, 1.16)	0.97 (0.83, 1.13)
High	3912	2.07 (1.79, 2.38)	1.41 (1.21, 1.64)	1.34 (1.15, 1.56)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of TV time				
Low	3304	1.00	1.00	1.00
Med	4432	0.89 (0.77, 1.03)	0.84 (0.72, 0.98)	0.83 (0.71, 0.97)
High	3922	1.56 (1.35, 1.80)	1.14 (1.00, 1.35)	1.11 (0.95, 1.30)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of non-TV leisure-time sitting				
Low	4208	1.00	1.00	1.00
Med	3673	0.99 (0.86, 1.15)	0.95 (0.82, 1.10)	0.95 (0.82, 1.10)
High	3777	1.55 (1.35, 1.77)	1.26 (1.09, 1.45)	1.23 (1.07, 1.42)
p		*<0.001*	*<0.001*	*0.001*
Tertiles of weekly MVPA				
Low	3876	1.000	1.000	1.000
Med	3864	0.56 (0.49, 0.65)	0.69 (0.59, 0.79)	0.70 (0.60, 0.81)
High	3918	0.52 (0.45, 0.60)	0.63 (0.54, 0.73)	0.65 (0.56, 0.76)
p		*<0.001*	*<0.001*	*<0.001*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of self-reported MVPA (for TV and sitting exposures) or total sitting time time (for MVPA exposure)

Supplemental Table 1: Multivariable-adjusted associations between accelerometry-measured sedentary time (100CPM cut-off) and psychological distress

	N	Model 1[a]	Model 2[b]	Model 3[c]
Tertiles of sedentary time (<100CPM)				
Low	649	1.00	1.00	1.00
Med	649	1.11 (0.74, 1.68)	1.19 (0.78, 1.82)	1.24 (0.81, 1.90)
High	649	1.71 (1.11, 2.61)	1.88 (1.21, 2.92)	2.04 (1.29, 3.21)
p		*0.027*	*0.012*	*0.005*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of accel-measured MVPA (for sedentary and light PA exposures) or sedentary time (for MVPA exposure)

Supplemental Table 2: Multivariable-adjusted associations between accelerometry/non accelerometry sample and psychological distress

	N	Model 1[a]	Model 2[b]	Model 3[c]
Sample				
Accelerometer sample	1944	1.00	1.00	1.00
Non-accelerometer sample	9714	0.99 (0.86, 1.15)	0.98 (0.84, 1.15)	0.97 (0.83, 1.13)
p		*0.927*	*0.830*	*0.684*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of self-reported MVPA and TV time

STROBE Statement— Associations between objectively assessed and self-reported sedentary time with mental health in adults Health Survey for England

	Page No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	4	Explain the scientific background and rationale for the investigation being reported
Objectives	4	State specific objectives, including any prespecified hypotheses
Methods		
Study design	5	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	5	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	5-6	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	6	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	6	Describe any efforts to address potential sources of bias
Study size	7	Explain how the study size was arrived at
Quantitative variables	7	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	7-8	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	8	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	8	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	9	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	8-10	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	10	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	10	Summarise key results with reference to study objectives
Limitations	10	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	10/13	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	12	Discuss the generalisability (external validity) of the study results
Other information		
Funding	12	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from Health Survey for England

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Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from Health Survey for England

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Short title: Sedentary behavior and mental health

Word count = 2,699

Abstract

Objectives: There is increasing interest in the association between sedentary behavior and mental health, although most studies have relied solely on self-reported measures, thus making results prone to various biases. The aim was to compare associations between objectively assessed and self-reported sedentary time with mental health in adults.

Setting: Community dwelling population sample drawn from the 2008 Health Survey for England.

Participants: 11,658 (self-report analysis) and 1,947 (objective data) men and women.

Primary outcome: The 12 – item General Health Questionnaire was administered to assess psychological distress. Sedentary and physical activity (exposure) were objectively measured using accelerometers (Actigraph GT1M) worn around the waist during waking hours for 7 consecutive days.

Results: The highest tertile of objective sedentary time was associated with higher risk of psychological distress (multivariate adjusted OR=1.74, 95% CI, 1.07, 2.83), as was the highest tertile of self reported total sitting time (OR=1.34, 95% CI, 1.15, 1.56). Self-reported, but not objective, moderate-vigorous physical activity was associated with lower risk of psychological distress. Only objective light-intensity activity was associated with lower risk of psychological distress.

Conclusions: Sedentary time is associated with adverse mental health.

Key words: accelerometry, sedentary, physical activity, mental health, depression.

Strengths and limitations

- Use of objective physical activity assessment
- Large representative sample of the general population
- The main limitation is the cross-sectional design
- Future studies are required to examine the biological plausibility.

Introduction

Adults spend approximately 60 – 70% of their waking hours in sedentary activities (1,2), which are characterized by energy expenditure below 1.5 metabolic equivalents while in a sitting or reclined posture. There is increasing interest in the association between sedentary behavior and mental health (3-12). Several longitudinal studies have demonstrated an association of self reported TV/computer time (7) and TV time alone (8) with higher risk of mental disorders, including depression and anxiety, at follow-up. However, data from other studies suggest that not all types of sedentary behaviors are related with adverse mental health (5,9). For example, in a sample of older adults from the English Longitudinal Study of Ageing, TV time but not computer use was associated with higher depressive symptoms (9). Thus, it is unclear if the effects are being driven by physiological processes linked to excessive sitting or the contrasting environmental and social contexts in which they occur.

The majority of studies to date in this area have relied on self reported measures of sedentary behaviors or total sitting time, thus making it difficult to tease apart associations between sedentary and mental health outcomes. To our knowledge, only one population study has previously examined associations between objectively assessed sedentary time and depressive symptoms, which demonstrated null associations (13). Self-report is a potential limitation in this context as subjective mental state is a complex measure comprising of cognitive and somatic symptoms, thus self-reported mental health and sedentary behavior might have conceptual overlap. Therefore, the aim of this study was to examine the association between both objectively-assessed and self-reported sedentary time with mental health in a

population sample of adults. We hypothesized that if the effects are being driven by physiological processes linked to excessive sitting we would observe consistent associations between objective and self-reported assessments of sedentary time with mental health. On the contrary, if the associations were only observed for self-reported sedentary time this might reflect a context specific effect or reporting bias.

Methods

Sample and study design

The Health Survey for England (HSE) is a continuous survey that annually draws a nationally-representative general population sample of adults living in households. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit and the Postcode Address File as the sampling frame for households. Stratification was based on geographical areas and not on individual characteristics of the population. In the present analysis we used data from the 2008 HSE, which had a special focus on physical activity and fitness (14). In the 2008 HSE the household response rate for the core sample was 64%. Ethical approval for the 2008 survey was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). These analyses considered participants aged between 16 to 95 years and over with valid data on all demographic, behavioural, and clinical variables of interest.

Assessment of sedentary time and physical activity

Objective measures. A sub-sample of HSE 2008 participants were asked to wear a uni-axial accelerometer that records movement on the vertical axis, the Actigraph GT1M (Actigraph, Pensacola, FL, USA), during waking hours for seven consecutive

days. The accelerometer provides a measure of the frequency, intensity, and duration of physical activity and allows classification of activity levels as sedentary, light, moderate to vigorous (MVPA). The raw accelerometry data were processed using specialist software (KineSoft, New Brunswick, Canada) to produce a series of standardised outcome variables (1,2). Only participants that wore the accelerometer for a minimum of 10 hours per day were included in the present analyses. Although participants with at least one day of valid wear have been included in these analyses, the majority (70%) had between six and seven days and 84% had at least three valid days. We used the following cutoff points to calculate daily times in each activity intensity band: sedentary (<1.5 MET): 0-199 counts/minute; light (1.5-3 MET) 200-2,019 counts/minute; MVPA (>3 MET): ≥2,020 counts/minute (1,2). All physical activity and sedentary behaviour variables were converted to time (in minutes) per valid day.

Self report. The self-reported measures have been described in detail elsewhere (1,15). Briefly, sedentary behavior was assessed using a set of questions enquiring about weekday and weekend time spent on (i) TV (including DVDs and videos) viewing and (ii) any other sitting during non-work times, including reading and computer use. For those participants who were professionally active [i.e. those who answered 'yes' to the question 'In the last 4 weeks, did you do any paid or unpaid work either as an employee or as self-employed (including voluntary or part time work)?'], another set of questions assessed the average daily times spent sitting or standing while at work ('On an average workday in the last 4 weeks, how much time did you usually spend sitting down or standing up?'). Physical activity was assessed using the long version of the HSE questionnaire that was used in the 1997 survey for the first time and was repeated in the 1998, 2006 and 2008 surveys. Questions

included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose and any recreational exercise (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports or racket sports). Weekly self-reported MVPA hours/week was calculated as number of days of participation multiplied by time per day in each activity type. As with objectively assessed physical activity, tertiles of TV, non-TV leisure-time sitting, total sitting, and MVPA time were derived for the analyses.

Psychological distress

Mental health was assessed using the 12 item version of the General Health Questionnaire (GHQ-12), a widely-utilized measure of psychological distress in population-based studies (16,17). We employed a GHQ-12 cut off score of ≥4 to denote psychological distress. This definition has been validated against standardised psychiatric interviews and has been strongly associated with depression and anxiety (18).

Demographic and clinic variables

Computer-assisted personal interviewing modules assessed respondents' demographics, occupational status, long-standing illness, alcohol consumption, and smoking habits. Height and weight were also measured for the calculation of body mass index, computed as weight (kilograms) divided by squared height (metres).

Statistical analyses

Participants were categorised into tertiles for sedentary and activity categories. We used multiple logistic regression to compute odds ratios (OR) with accompanying

95% confidence intervals (CI) for the association between sedentary time/activity and psychological distress. The models were adjusted for potential confounding factors, including age, sex, smoking (never; previous; current), frequency of alcohol intake (at least 1/wk; monthly; rarely or never), BMI (normal weight, BMI<25; overweight, BMI 25 – 30; obese, BMI > 30 kg/m^2), social occupational group (professional and managerial occupations; skilled non-manual; routine and manual), highest educational qualification, (non mental health-related) long standing illness, and Actigraph wear time (for analyses involving accelerometry). Finally, the models were mutually adjusted for MVPA in the analyses using sedentary or light activity as the main exposure, or sedentary when using MVPA as the main exposure. Models were run for each main exposure including an interaction term between the main exposure and sex. This interaction term was not significant in any of the models, so analysis was sex-adjusted, but not sex stratified. The complex samples module in SPSS was used to take into account the survey design, which adjusted for uneven non-response and accounted for the clusters and stratum used in data collection. A sensitivity analysis was run for accelerometry-measured sedentary time, using a more conservative cut off of <100 CPM. Due to the large difference in sample size between accelerometry and self-reported outcomes, a second sensitivity analysis was conducted to test whether observed differences in results between accelerometry and self-reported exposures were due to differences between the accelerometry and non-accelerometry samples. Logistic regression models were run substituting sedentary/physical activity tertiles for sample type (accelerometry / non-accelerometry sample). All analyses were conducted using SPSS version 21.

Results

Descriptives

Of the self-report sample used in the analyses (11,658), 12.7% reported psychological distress (see Table 1). Respondents with psychological distress were more likely to be female, from a lower social class, have a lower educational qualification, be out of paid work, smoke, report a non-mental health longstanding illness, and have problems with usual activities than those without psychological distress (all $p<0.001$). Respondents with psychological distress were also more sedentary and spent on average 31 and 25 min/day more in TV and non-TV leisure-time sitting respectively, and 10 min/d less in self-reported MVPA ($p<0.001$).

Accelerometry-measured sedentary time and physical activity

Table 2 presents multivariable-adjusted associations between accelerometry-measured sedentary time and physical activity, with psychological distress. Sedentary time (<200 CPM) was directly associated with psychological distress after adjustment for all covariables including MVPA, although this was more apparent in the highest tertile (OR=1.74, 95% CI, 1.07, 2.83). Light activity (200 to 2018 CPM) was inversely associated with risk for psychological distress, although the association was not linear. MVPA, however, was not associated with psychological distress in any models.

Self-reported sedentary time and physical activity

Table 3 presents the associations between self-reported sedentary time and physical activity with psychological distress. Total sitting time was directly associated with risk of psychological distress, although only the highest tertile of sitting was different to the referent group (OR=1.34, 95% CI, 1.15, 1.56). This association was largely

driven by 'non- TV viewing' sedentary time as the associations for TV viewing demonstrated an inconsistent pattern. MVPA was inversely associated with risk of psychological distress in a dose-response manner ($p<0.001$ for all models).

Sensitivity analysis

In the sensitivity analysis using a different sedentary cut off of 100 CPM (Supplemental Table 1) similar results were found, (multivariate adjusted OR of psychological distress for the highest tertile of sedentary time compared to the lowest tertile = 2.04, 95% CI, 1.29, 3.21, p=0.005). We also examined if there were differences in prevalence of psychological distress between the accelerometry sample and main sample (Supplemental Table 2). Sample type (accelerometry vs non-accelerometry), however, was not a significant predictor of psychological distress, after adjusting for relevant covariates (age, sex, smoking, employment status, longstanding illness, and self-reported MVPA and TV time). Lastly, we examined the influence of number of valid Actigraph wear days but there were no associations found with psychological distress as the outcome.

Discussion

The aim of this study was to examine the association between objectively assessed and self reported sedentary time with mental health in a population sample of adults. Our findings consistently show an association between sedentary time and adverse mental health whether using objective or self reported measures of sedentary time. Nevertheless, in contrast to previous evidence (4,5,8,9) the associations between context specific sedentary time (TV viewing) and psychological distress were far less consistent. Given that subjective mental state is a complex measure comprising cognitive (depressed mood) and somatic symptoms (eg, lethargy, tiredness, lack of

appetite, pain), this might partly influence an individual's assessment of context specific sedentary time. Our findings are not consistent with data from NHANES that showed null associations between objectively assessed sedentary time and depressive symptoms in the main sample, although did find an association among overweight/ obese adults in sensitivity analyses (13). Nevertheless, our study used a composite measure of psychological distress consisting of items on anxiety and depression; thus our data can not be directly compared to the measure of depressive symptoms used in NHANES.

There is mounting evidence to suggest detrimental effects of excess sedentary time on mental health, although plausible biological mechanisms are currently lacking. There are numerous data showing associations between sedentary time and cardio-metabolic risk factors (2,19,20), thus the links with mental health might act partly through these mechanisms. In particular, the role of low grade inflammation in depression has gained substantial attention (21), although in a recent study C-reactive protein did not explain the link between TV viewing and depressive symptoms in older adults (22). Psychosocial mechanisms might also be important. For example, passive sedentary activities such as TV viewing might encourage social isolation and limit the development of social networks.

We are not aware of any other studies that have compared associations of objective and self reported sedentary/MVPA in relation to mental health outcomes. There was a consistent association between sedentary time and adverse mental health whether using objective or self reported measures, albeit stronger with the objective measure.

In contrast, we observed a discrepancy in results between self-reported and objectively assessed MVPA in relation to psychological distress, showing associations only for self-reported measures. In our recent studies, where we also compared accelerometry and self-reported exposures but in relation to cardiometabolic outcomes (1,14), we found associations between MVPA and most outcomes for both self-reported and objective measures. Thus, one interpretation of the present results is that self reported mental health and MVPA might have conceptual overlap causing participants with poor mental health to mis-report their activity levels. For example, symptoms such as lethargy may cause individuals to under report their activity. In addition, cognitive impairement that is sometimes associated with depression (23) could impair recall introducing bias into the results. Nevertheless, one might view objective and self reported activity as different measures since objective assessment cannot take context into account and, by definition, measure slightly different aspects of MVPA. In this regard, context might be extremely important as some of the effects of physical activity on mental health are most likely driven by factors such as social interaction whereas accelerometry is simply a measure of body movement and cannot capture contextual information such as 'where' and 'who with'. We did not, however, take contextual information into account in our analysis of self reported MVPA.

Few studies have examined associations between objectively assessed physical activity and mental health, and those that have reveal inconsistent findings. For example, in a small cohort of elderly Japanese participants, physical activity was assessed objectively over one year, and inverse associations of activity with depression and stressful life events were observed (24,25). In NHANES an inverse dose response association was observed between MVPA and depressive symptoms

(18). In a sample of 40 healthy females who completed a once-a-day mood rating scale for one week we found inverse associations of depressive symptoms with objectively assessed light and moderate intensity activity but not vigorous (26). Other evidence is also equivocal (27,28). The present findings suggested that only objectively assessed light intensity activity was associated with lower risk of psychological distress, which is consistent with prior evidence showing associations between objective light-intensity physical activity and self rated health in older adults (29). Data from randomised controlled trials also show that light/moderate intensity exercise has greater antidepressive effects (30), effects on positive mood (31), and on reducing symptoms of fatigue compared with vigorous intensity (32,33). Lighter intensity activity may be more beneficial for mental health as greater exertion during vigorous forms of exercise may produce discomfort and shortness of breath, thus feel less enjoyable. Our findings therefore suggest that modifying the balance between sedentary time and light intensity activity could be beneficial for mental health, as suggested by other recent studies (10, 29).

The main limitation of this study is the cross-sectional design, which precludes us from making any inferences about direction or causality. Sedentary behavior has been longitudinally associated with risk of future depression in some (7,8), but not all (9,11) studies; thus the issue of causality remains unclear. Second, since accelerometry measures were only collected over one week we do not know if this reflects habitual sedentary patterns in contrast to self-reported questions that enquired about activity over the last 4 weeks. However, strong test-retest reliability for MVPA (r=0.89 for men, r=0.76 in women) was demonstrated in our validation study of 106 British adults from the general population, who wore accelerometers for two non-

consecutive weeks over a month period (34). Undoubtedly, controlled trials are the best test of causality. However, studies of community samples have several advantages in that they are more representative. In the present study we aimed to minimise possible confounding by controlling for key covariables. Future studies are required to examine the biological plausibility of a possible association between sedentary behaviour and mental health which would further our understanding of this area.

Taken together, observational studies of representative community samples are an important approach for establishing links between sedentary behaviour and health outcomes, although further work is required to establish if the existing evidence reflects causal associations.

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Author contributions

MH had full access to the data, and takes responsibility for the integrity and accuracy of the results. NC performed all statistical analyses under supervision of ES. MH drafted the manuscript. All authors contributed to the concept and design of study, and critical revision of the manuscript.

Conflict of interest

None of the authors have any competing interests to declare.

Data sharing

No additional data available.

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Table 1: Sample characteristics in relation to psychological distress.

Categorical variables	GHQ<4 %	N	GHQ>=4 %	N	*p**
sex (% male)	48.1	10172	38.2	1486	*<0.001*
social class (% semi-skilled manual or lower)	21.7	10172	26.4	1486	*<0.001*
qualification (% secondary school or lower)	50.8	10172	58.1	1486	*<0.001*
% not in paid work	33.9	10172	53.6	1486	*<0.001*
smoking (% current)	20.6	10172	29.9	1486	*<0.001*
Alcohol consumption (% 5+ times a week)	18.5	10172	16.4	1486	*<0.001*
% with LSI** (non-mental health)	39.8	10172	57.3	1486	*<0.001*
% problems with usual activities	10.4	10172	40.5	1486	*<0.001*
Continuous variables	**M SD**	**N**	**M SD**	**N**	***p***
Age (years)	50.0 (17.6)	10172	48.3 (17.2)	1486	*0.149*
BMI (kg/m^2)	27.3 (5.0)	10172	27.8 (6.0)	1486	*0.046*
TV viewing (mins/day)	167.9 (99.6)	10172	199.3 (133.1)	1486	*<0.001*
non-TV leisure-time sitting (mins/day)	126.7 (92.0)	10172	152.0 (119.0)	1486	*<0.001*
Total leisure-time sitting (mins/day)	294.6 (136.8)	10172	351.3 (17.4)	1486	*<0.001*
Self-reported MVPA (mins/day)	45.7 (67.2)	10172	35.3 (63.7)	1486	*<0.001*
Accel sedentary time (mins/day)	578.5 (93.2)	1698	574.1 (98.1)	249	*0.386*
Accel light physical activity time (mins/day)	293.9 (85.3)	1698	288.6 (90.5)	249	*0.436*
Accel MVPA time (mins/day)	29.2 (25.5)	1698	25.7 (22.4)	249	*0.027*
Accel wear time per valid day (mins)	835.9 (74.7)	1698	822.8 (77.3)	249	*0.004*

*p calculated by chi-square for categorical, and by Mann-Whitney U test for continuous
**Longstanding illness

Table 2: Multivariable-adjusted associations between accelerometry-measured sedentary time, light intensity activity, and MVPA, with psychological distress.

	N	Model 1[a]	Model 2[b]	Model 3[c]
Tertiles of sedentary time				
Low	649	1.00	1.00	1.00
Med	649	1.00 (0.66, 1.53)	1.05 (0.68, 1.62)	1.09 (0.70, 1.71)
High	649	1.52 (0.98, 2.35)	1.59 (1.01, 2.51)	1.74 (1.07, 2.83)
p		*0.072*	*0.071*	*0.037*
Tertiles of light PA time				
Low	649	1.000	1.000	1.000
Med	649	0.62 (0.42, 0.92)	0.56 (0.37, 0.84)	0.56 (0.37, 0.84)
High	649	0.79 (0.53, 1.17)	0.74 (0.49, 1.12)	0.73 (0.48, 1.12)
p		*0.056*	*0.021*	*0.020*
Tertiles of MVPA				
Low	649	1.000	1.000	1.000
Med	649	0.67 (0.45, 0.99)	0.81 (0.54, 1.22)	0.90 (0.59, 1.37)
High	649	0.84 (0.55, 1.28)	1.05 (0.68, 1.62)	1.27 (0.80, 2.04)
p		*0.130*	*0.432*	*0.283*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of accel-measured MVPA (for sedentary and light PA exposures) or sedentary time (for MVPA exposure)

Table 3: Multivariable-adjusted associations between self-reported total sitting time, sedentary behaviours, and MVPA with psychological distress

	N	Model1	Model2	Model3
Tertiles of total sitting				
Low	3836	1.00	1.00	1.00
Med	3910	1.11 (0.95, 1.29)	0.99 (0.85, 1.16)	0.97 (0.83, 1.13)
High	3912	2.07 (1.79, 2.38)	1.41 (1.21, 1.64)	1.34 (1.15, 1.56)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of TV time				
Low	3304	1.00	1.00	1.00
Med	4432	0.89 (0.77, 1.03)	0.84 (0.72, 0.98)	0.83 (0.71, 0.97)
High	3922	1.56 (1.35, 1.80)	1.14 (1.00, 1.35)	1.11 (0.95, 1.30)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of non-TV leisure-time sitting				
Low	4208	1.00	1.00	1.00
Med	3673	0.99 (0.86, 1.15)	0.95 (0.82, 1.10)	0.95 (0.82, 1.10)
High	3777	1.55 (1.35, 1.77)	1.26 (1.09, 1.45)	1.23 (1.07, 1.42)
p		*<0.001*	*<0.001*	*0.001*
Tertiles of weekly MVPA				
Low	3876	1.000	1.000	1.000
Med	3864	0.56 (0.49, 0.65)	0.69 (0.59, 0.79)	0.70 (0.60, 0.81)
High	3918	0.52 (0.45, 0.60)	0.63 (0.54, 0.73)	0.65 (0.56, 0.76)
p		*<0.001*	*<0.001*	*<0.001*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of self-reported MVPA (for TV and sitting exposures) or total sitting time time (for MVPA exposure)

Associations between objectively assessed and self-reported sedentary time with mental health in adults: an analysis of data from the Health Survey for England

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Abstract

Objectives: There is increasing interest in the association between sedentary behavior and mental health, although most studies have relied solely on self-reported measures, thus making results prone to various biases. The aim was to compare associations between objectively assessed and self-reported sedentary time with mental health in adults.

Setting: Community dwelling population sample drawn from the 2008 Health Survey for England.

Participants: 11,658 (self-report analysis) and 1,947 (objective data) men and women.

Primary outcome: The 12 – item General Health Questionnaire was administered to assess psychological distress. Sedentary and physical activity (exposure) were objectively measured using accelerometers (Actigraph GT1M) worn around the waist during waking hours for 7 consecutive days.

Results: The highest tertile of objective sedentary time was associated with higher risk of psychological distress (multivariate adjusted OR=1.74, 95% CI, 1.07, 2.83), as was the highest tertile of self reported total sitting time (OR=1.34, 95% CI, 1.15, 1.56). Self-reported, but not objective, moderate-vigorous physical activity was associated with lower risk of psychological distress. Only objective light-intensity activity was associated with lower risk of psychological distress.

Conclusions: Sedentary time is associated with adverse mental health. ~~although future work is required to explore the underlying mechanisms.~~

Key words: accelerometry, sedentary, physical activity, mental health, depression.

Strengths and limitations

- Use of objective physical activity assessment
- Large representative sample of the general population
- The main limitation is the cross-sectional design
- Future studies are required to examine the biological plausibility.

Introduction

Adults spend approximately 60 – 70% of their waking hours in sedentary activities (1,2), which are characterized by energy expenditure below 1.5 metabolic equivalents while in a sitting or reclined posture. There is increasing interest in the association between sedentary behavior and mental health (3-12). Several longitudinal studies have demonstrated an association of self reported TV/computer time (7) and TV time alone (8) with higher risk of mental disorders, including depression and anxiety, at follow-up. However, data from other studies suggest that not all types of sedentary behaviors are related with adverse mental health (5,9). For example, in a sample of older adults from the English Longitudinal Study of Ageing, TV time but not computer use was associated with higher depressive symptoms (9). Thus, it is unclear if the effects are being driven by physiological processes linked to excessive sitting or the contrasting environmental and social contexts in which they occur.

The majority of studies to date in this area have relied on self reported measures of sedentary behaviors or total sitting time, thus making it difficult to tease apart associations between sedentary and mental health outcomes. To our knowledge, only one population study has previously examined associations between objectively assessed sedentary time and depressive symptoms, which demonstrated null associations (13). Self-report is a potential limitation in this context as subjective mental state is a complex measure comprising of cognitive and somatic symptoms, thus self-reported mental health and sedentary behavior might have conceptual overlap. Therefore, the aim of this study was to examine the association between both objectively-assessed and self-reported sedentary time with mental health in a population sample of adults. We hypothesized that if the effects are being driven by

physiological processes linked to excessive sitting we would observe consistent associations between objective and self-reported assessments of sedentary time with mental health. On the contrary, if the associations were only observed for self-reported sedentary time this might reflect a context specific effect or reporting bias.

Methods

Sample and study design

The Health Survey for England (HSE) is a continuous survey that annually draws a nationally-representative general population sample of adults living in households. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit and the Postcode Address File as the sampling frame for households. Stratification was based on geographical areas and not on individual characteristics of the population. In the present analysis we used data from the 2008 HSE, which had a special focus on physical activity and fitness (14). In the 2008 HSE the household response rate for the core sample was 64%. Ethical approval for the 2008 survey was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). These analyses considered participants aged between 16 to 95 years and over with valid data on all demographic, behavioural, and clinical variables of interest.

Assessment of sedentary time and physical activity

Objective measures. A sub-sample of HSE 2008 participants were asked to wear a uni-axial accelerometer that records movement on the vertical axis, the Actigraph GT1M (Actigraph, Pensacola, FL, USA), during waking hours for seven consecutive days. The accelerometer provides a measure of the frequency, intensity, and duration

of physical activity and allows classification of activity levels as sedentary, light, moderate to vigorous (MVPA). The raw accelerometry data were processed using specialist software (KineSoft, New Brunswick, Canada) to produce a series of standardised outcome variables (1,2). Only participants that wore the accelerometer for a minimum of 10 hours per day were included in the present analyses. Although participants with at least one day of valid wear have been included in these analyses, the majority (70%) had between six and seven days and 84% had at least three valid days. We used the following cutoff points to calculate daily times in each activity intensity band: sedentary (<1.5 MET): 0-199 counts/minute; light (1.5-3 MET) 200-2,019 counts/minute; MVPA (>3 MET): ≥2,020 counts/minute (1,2). All physical activity and sedentary behaviour variables were converted to time (in minutes) per valid day.

Self report. The self-reported measures have been described in detail elsewhere (1,15). Briefly, sedentary behavior was assessed using a set of questions enquiring about weekday and weekend time spent on (i) TV (including DVDs and videos) viewing and (ii) any other sitting during non-work times, including reading and computer use. For those participants who were professionally active [i.e. those who answered 'yes' to the question 'In the last 4 weeks, did you do any paid or unpaid work either as an employee or as self-employed (including voluntary or part time work)?'], another set of questions assessed the average daily times spent sitting or standing while at work ('On an average workday in the last 4 weeks, how much time did you usually spend sitting down or standing up?'). Physical activity was assessed using the long version of the HSE questionnaire that was used in the 1997 survey for the first time and was repeated in the 1998, 2006 and 2008 surveys. Questions included frequency (number of days in the last 4 weeks) and duration (minutes per

day) of participation in walking for any purpose and any recreational exercise (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports or racket sports). Weekly self-reported MVPA hours/week was calculated as number of days of participation multiplied by time per day in each activity type. As with objectively assessed physical activity, tertiles of TV, non-TV leisure-time sitting, total sitting, and MVPA time were derived for the analyses.

Psychological distress

Mental health was assessed using the 12 item version of the General Health Questionnaire (GHQ-12), a widely-utilized measure of psychological distress in population-based studies (16,17). We employed a GHQ-12 cut off score of ≥4 to denote psychological distress. This definition has been validated against standardised psychiatric interviews and has been strongly associated with depression and anxiety (18).

Demographic and clinic variables

Computer-assisted personal interviewing modules assessed respondents' demographics, occupational status, long-standing illness, alcohol consumption, and smoking habits. Height and weight were also measured for the calculation of body mass index, computed as weight (kilograms) divided by squared height (metres).

Statistical analyses

Participants were categorised into tertiles for sedentary and activity categories. We used multiple logistic regression to compute odds ratios (OR) with accompanying 95% confidence intervals (CI) for the association between sedentary time/activity and

psychological distress. The models were adjusted for potential confounding factors, including age, sex, smoking (never; previous; current), frequency of alcohol intake (at least 1/wk; monthly; rarely or never), BMI (normal weight, BMI<25; overweight, BMI 25 – 30; obese, BMI > 30 kg/m^2), social occupational group (professional and managerial occupations; skilled non-manual; routine and manual), highest educational qualification, (non mental health-related) long standing illness, and Actigraph wear time (for analyses involving accelerometry). Finally, the models were mutually adjusted for MVPA in the analyses using sedentary or light activity as the main exposure, or sedentary when using MVPA as the main exposure. Models were run for each main exposure including an interaction term between the main exposure and sex. This interaction term was not significant in any of the models, so analysis was sex-adjusted, but not sex stratified. The complex samples module in SPSS was used to take into account the survey design, which adjusted for uneven non-response and accounted for the clusters and stratum used in data collection. A sensitivity analysis was run for accelerometry-measured sedentary time, using a more conservative cut off of <100 CPM. Due to the large difference in sample size between accelerometry and self-reported outcomes, a second sensitivity analysis was conducted to test whether observed differences in results between accelerometry and self-reported exposures were due to differences between the accelerometry and non-accelerometry samples. Logistic regression models were run substituting sedentary/physical activity tertiles for sample type (accelerometry / non-accelerometry sample). All analyses were conducted using SPSS version 21.

Results

Descriptives

Of the self-report sample used in the analyses (11,658), 12.7% reported psychological distress (see Table 1). Respondents with psychological distress were more likely to be female, from a lower social class, have a lower educational qualification, be out of paid work, smoke, report a non-mental health longstanding illness, and have problems with usual activities than those without psychological distress (all $p<0.001$). Respondents with psychological distress were also more sedentary and spent on average 31 and 25 min/day more in TV and non-TV leisure-time sitting respectively, and 10 min/d less in self-reported MVPA ($p<0.001$).

Accelerometry-measured sedentary time and physical activity

Table 2 presents multivariable-adjusted associations between accelerometry-measured sedentary time and physical activity, with psychological distress. Sedentary time (<200 CPM) was directly associated with psychological distress after adjustment for all covariables including MVPA, although this was more apparent in the highest tertile (OR=1.74, 95% CI, 1.07, 2.83). Light activity (200 to 2018 CPM) was inversely associated with risk for psychological distress, although the association was not linear. MVPA, however, was not associated with psychological distress in any models.

Self-reported sedentary time and physical activity

Table 3 presents the associations between self-reported sedentary time and physical activity with psychological distress. Total sitting time was directly associated with risk of psychological distress, although only the highest tertile of sitting was different to the referent group (OR=1.34, 95% CI, 1.15, 1.56). This association was largely driven by 'non- TV viewing' sedentary time as the associations for TV viewing

demonstrated an inconsistent pattern. MVPA was inversely associated with risk of psychological distress in a dose-response manner ($p<0.001$ for all models).

Sensitivity analysis

In the sensitivity analysis using a different sedentary cut off of 100 CPM (Supplemental Table 1) similar results were found, (multivariate adjusted OR of psychological distress for the highest tertile of sedentary time compared to the lowest tertile = 2.04, 95% CI, 1.29, 3.21, p=0.005). We also examined if there were differences in prevalence of psychological distress between the accelerometry sample and main sample (Supplemental Table 2). Sample type (accelerometry vs non-accelerometry), however, was not a significant predictor of psychological distress, after adjusting for relevant covariates (age, sex, smoking, employment status, longstanding illness, and self-reported MVPA and TV time). Lastly, we examined the influence of number of valid Actigraph wear days but there were no associations found with psychological distress as the outcome.

Discussion

The aim of this study was to examine the association between objectively assessed and self reported sedentary time with mental health in a population sample of adults. Our findings consistently show an association between sedentary time and adverse mental health whether using objective or self reported measures of sedentary time. Nevertheless, in contrast to previous evidence (4,5,8,9) the associations between context specific sedentary time (TV viewing) and psychological distress were far less consistent. Given that subjective mental state is a complex measure comprising cognitive (depressed mood) and somatic symptoms (eg, lethargy, tiredness, lack of appetite, pain), this might partly influence an individual's assessment of context

specific sedentary time. Our findings are not consistent with data from NHANES that showed null associations between objectively assessed sedentary time and depressive symptoms in the main sample, although did find an association among overweight/ obese adults in sensitivity analyses (13). Nevertheless, our study used a composite measure of psychological distress consisting of items on anxiety and depression;, thus our data can not be directly compared to the measure of depressive symptoms used in NHANES.

There is mounting evidence to suggest detrimental effects of excess sedentary time on mental health, although plausible biological mechanisms are currently lacking. There are numerous data showing associations between sedentary time and cardio-metabolic risk factors (2,19,20), thus the links with mental health might act partly through these mechanisms. In particular, the role of low grade inflammation in depression has gained substantial attention (21), although in a recent study C-reactive protein did not explain the link between TV viewing and depressive symptoms in older adults (22). Psychosocial mechanisms might also be important. For example, passive sedentary activities such as TV viewing might encourage social isolation and limit the development of social networks.

We are not aware of any other studies that have compared associations of objective and self reported sedentary/MVPA in relation to mental health outcomes. There was a consistent association between sedentary time and adverse mental health whether using objective or self reported measures, albeit stronger with the objective measure. In contrast, we observed a discrepancy in results between self-reported and

objectively assessed MVPA in relation to psychological distress, showing associations only for self-reported measures. In our recent studies, where we also compared accelerometry and self-reported exposures but in relation to cardiometabolic outcomes (1,14), we found associations between MVPA and most outcomes for both self-reported and objective measures. Thus, one interpretation of the present results is that self reported mental health and MVPA might have conceptual overlap causing participants with poor mental health to mis-report their activity levels. For example, symptoms such as lethargy may cause individuals to under report their activity. -In addition, cognitive impairement that is sometimes associated with depression (23) could impair recall introducing bias into the results. Nevertheless, one might view objective and self reported activity as different measures since objective assessment cannot take context into account and, by definition, measure slightly different aspects of MVPA. In this regard, context might be extremely important as some of the effects of physical activity on mental health are most likely driven by factors such as social interaction whereas accelerometry is simply a measure of body movement and cannot capture contextual information such as 'where' and 'who with'. We did not, however, take contextual information into account in our analysis of self reported MVPA.

Few studies have examined associations between objectively assessed physical activity and mental health, and those that have reveal inconsistent findings. For example, in a small cohort of elderly Japanese participants, physical activity was assessed objectively over one year, and inverse associations of activity with depression and stressful life events were observed (24,25). In NHANES an inverse dose response association was observed between MVPA and depressive symptoms (18). In a sample of 40 healthy females who completed a once-a-day mood rating

scale for one week we found inverse associations of depressive symptoms with objectively assessed light and moderate intensity activity but not vigorous (26). Other evidence is also equivocal (27,28). The present findings suggested that only objectively assessed light intensity activity was associated with lower risk of psychological distress, which is consistent with prior evidence showing associations between objective light-intensity physical activity and self rated health in older adults (29). Data from randomised controlled trials also show that light/moderate intensity exercise has greater antidepressive effects (30), effects on positive mood (31), and on reducing symptoms of fatigue compared with vigorous intensity (32,33). Lighter intensity activity may be more beneficial for mental health as greater exertion during vigorous forms of exercise may produce discomfort and shortness of breath, thus feel less enjoyable. Our findings therefore suggest that modifying the balance between sedentary time and light intensity activity could be beneficial for mental health, as suggested by other recent studies (10, 29).

The main limitation of this study is the cross-sectional design, which precludes us from making any inferences about direction or causality. Sedentary behavior has been longitudinally associated with risk of future depression in some (7,8), but not all (9,11) studies; thus the issue of causality remains unclear. Second, since accelerometry measures were only collected over one week we do not know if this reflects habitual sedentary patterns in contrast to self-reported questions that enquired about activity over the last 4 weeks. However, strong test-retest reliability for MVPA (r=0.89 for men, r=0.76 in women) was demonstrated in our validation study of 106 British adults from the general population, who wore accelerometers for two non-consecutive weeks over a month period (34). Undoubtedly, controlled trials are the

best test of causality. However, studies of community samples have several advantages in that they are more representative. In the present study we aimed to minimise possible confounding by controlling for key covariables. Future studies are required to examine the biological plausibility of a possible association between sedentary behaviour and mental health which would further our understanding of this area.

Taken together, observational studies of representative community samples are an important approach for establishing links between sedentary behaviour and health outcomes, although further work is required to establish if the existing evidence reflects causal associations.

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Author contributions

MH had full access to the data, and takes responsibility for the integrity and accuracy of the results. NC performed all statistical analyses under supervision of ES. MH drafted the manuscript. All authors contributed to the concept and design of study, and critical revision of the manuscript.

Conflict of interest

None of the authors have any competing interests to declare.

Data sharing

There is no additional data available.

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Table 1: Sample characteristics in relation to psychological distress.

	GHQ<4			GHQ>=4			
Categorical variables		%	N		%	N	*p**
sex (% male)		48.1	10172		38.2	1486	*<0.001*
social class (% semi-skilled manual or lower)		21.7	10172		26.4	1486	*<0.001*
qualification (% secondary school or lower)		50.8	10172		58.1	1486	*<0.001*
% not in paid work		33.9	10172		53.6	1486	*<0.001*
smoking (% current)		20.6	10172		29.9	1486	*<0.001*
Alcohol consumption (% 5+ times a week)		18.5	10172		16.4	1486	*<0.001*
% with LSI** (non-mental health)		39.8	10172		57.3	1486	*<0.001*
% problems with usual activities		10.4	10172		40.5	1486	*<0.001*
Continuous variables	M	SD	N	M	SD	N	*p*
Age (years)	50.0	(17.6)	10172	48.3	(17.2)	1486	*0.149*
BMI (kg/m^2)	27.3	(5.0)	10172	27.8	(6.0)	1486	*0.046*
TV viewing (mins/day)	167.9	(99.6)	10172	199.3	(133.1)	1486	*<0.001*
non-TV leisure-time sitting (mins/day)	126.7	(92.0)	10172	152.0	(119.0)	1486	*<0.001*
Total leisure-time sitting (mins/day)	294.6	(136.8)	10172	351.3	(17.4)	1486	*<0.001*
Self-reported MVPA (mins/day)	45.7	(67.2)	10172	35.3	(63.7)	1486	*<0.001*
Accel sedentary time (mins/day)	578.5	(93.2)	1698	574.1	(98.1)	249	*0.386*
Accel light physical activity time (mins/day)	293.9	(85.3)	1698	288.6	(90.5)	249	*0.436*
Accel MVPA time (mins/day)	29.2	(25.5)	1698	25.7	(22.4)	249	*0.027*
Accel wear time per valid day (mins)	835.9	(74.7)	1698	822.8	(77.3)	249	*0.004*

*p calculated by chi-square for categorical, and by Mann-Whitney U test for continuous
**Longstanding illness

Table 2: Multivariable-adjusted associations between accelerometry-measured sedentary time, light intensity activity, and MVPA, with psychological distress.

	N	Model 1[a]	Model 2[b]	Model 3[c]
Tertiles of sedentary time				
Low	649	1.00	1.00	1.00
Med	649	1.00 (0.66, 1.53)	1.05 (0.68, 1.62)	1.09 (0.70, 1.71)
High	649	1.52 (0.98, 2.35)	1.59 (1.01, 2.51)	1.74 (1.07, 2.83)
p		*0.072*	*0.071*	*0.037*
Tertiles of light PA time				
Low	649	1.000	1.000	1.000
Med	649	0.62 (0.42, 0.92)	0.56 (0.37, 0.84)	0.56 (0.37, 0.84)
High	649	0.79 (0.53, 1.17)	0.74 (0.49, 1.12)	0.73 (0.48, 1.12)
p		*0.056*	*0.021*	*0.020*
Tertiles of MVPA				
Low	649	1.000	1.000	1.000
Med	649	0.67 (0.45, 0.99)	0.81 (0.54, 1.22)	0.90 (0.59, 1.37)
High	649	0.84 (0.55, 1.28)	1.05 (0.68, 1.62)	1.27 (0.80, 2.04)
p		*0.130*	*0.432*	*0.283*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of accel-measured MVPA (for sedentary and light PA exposures) or sedentary time (for MVPA exposure)

Table 3: Multivariable-adjusted associations between self-reported total sitting time, sedentary behaviours, and MVPA with psychological distress

	N	Model1	Model2	Model3
Tertiles of total sitting				
Low	3836	1.00	1.00	1.00
Med	3910	1.11 (0.95, 1.29)	0.99 (0.85, 1.16)	0.97 (0.83, 1.13)
High	3912	2.07 (1.79, 2.38)	1.41 (1.21, 1.64)	1.34 (1.15, 1.56)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of TV time				
Low	3304	1.00	1.00	1.00
Med	4432	0.89 (0.77, 1.03)	0.84 (0.72, 0.98)	0.83 (0.71, 0.97)
High	3922	1.56 (1.35, 1.80)	1.14 (1.00, 1.35)	1.11 (0.95, 1.30)
p		*<0.001*	*<0.001*	*<0.001*
Tertiles of non-TV leisure-time sitting				
Low	4208	1.00	1.00	1.00
Med	3673	0.99 (0.86, 1.15)	0.95 (0.82, 1.10)	0.95 (0.82, 1.10)
High	3777	1.55 (1.35, 1.77)	1.26 (1.09, 1.45)	1.23 (1.07, 1.42)
p		*<0.001*	*<0.001*	*0.001*
Tertiles of weekly MVPA				
Low	3876	1.000	1.000	1.000
Med	3864	0.56 (0.49, 0.65)	0.69 (0.59, 0.79)	0.70 (0.60, 0.81)
High	3918	0.52 (0.45, 0.60)	0.63 (0.54, 0.73)	0.65 (0.56, 0.76)
p		*<0.001*	*<0.001*	*<0.001*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of self-reported MVPA (for TV and sitting exposures) or total sitting time time (for MVPA exposure)

Supplemental Table 1: Multivariable-adjusted associations between accelerometry-measured sedentary time (100CPM cut-off) and psychological distress

	N	Model 1[a]	Model 2[b]	Model 3[c]
Tertiles of sedentary time (<100CPM)				
Low	649	1.00	1.00	1.00
Med	649	1.11 (0.74, 1.68)	1.19 (0.78, 1.82)	1.24 (0.81, 1.90)
High	649	1.71 (1.11, 2.61)	1.88 (1.21, 2.92)	2.04 (1.29, 3.21)
p		*0.027*	*0.012*	*0.005*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of accel-measured MVPA (for sedentary and light PA exposures) or sedentary time (for MVPA exposure)

Supplemental Table 2: Multivariable-adjusted associations between accelerometry/non accelerometry sample and psychological distress

	N	Model 1[a]	Model 2[b]	Model 3[c]
Sample				
Accelerometer sample	1944	1.00	1.00	1.00
Non-accelerometer sample	9714	0.99 (0.86, 1.15)	0.98 (0.84, 1.15)	0.97 (0.83, 1.13)
p		*0.927*	*0.830*	*0.684*

[a] Model 1 adjusted for age, sex, and accelerometry wear time
[b] Model 2 also adjusted for smoking, alcohol, education, BMI, social occupational group employment longstanding illness (non-mental only)
[c] Model 3 also adjusted for tertiles of self-reported MVPA and TV time

STROBE Statement— Associations between objectively assessed and self-reported sedentary time with mental health in adults Health Survey for England

	Page No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found
Introduction		
Background/rationale	4	Explain the scientific background and rationale for the investigation being reported
Objectives	4	State specific objectives, including any prespecified hypotheses
Methods		
Study design	5	Present key elements of study design early in the paper
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection
Participants	5	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case
Variables	5-6	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable
Data sources/ measurement	6	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group
Bias	6	Describe any efforts to address potential sources of bias
Study size	7	Explain how the study size was arrived at
Quantitative variables	7	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why
Statistical methods	7-8	(*a*) Describe all statistical methods, including those used to control for confounding
		(*b*) Describe any methods used to examine subgroups and interactions
		(*c*) Explain how missing data were addressed
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy
		(*e*) Describe any sensitivity analyses

Continued on next page

Results		
Participants	8	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed
		(b) Give reasons for non-participation at each stage
		(c) Consider use of a flow diagram
Descriptive data	8	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders
		(b) Indicate number of participants with missing data for each variable of interest
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)
Outcome data	9	*Cohort study*—Report numbers of outcome events or summary measures over time
		Case-control study—Report numbers in each exposure category, or summary measures of exposure
		Cross-sectional study—Report numbers of outcome events or summary measures
Main results	8-10	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included
		(*b*) Report category boundaries when continuous variables were categorized
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period
Other analyses	10	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	10	Summarise key results with reference to study objectives
Limitations	10	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias
Interpretation	10/13	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence
Generalisability	12	Discuss the generalisability (external validity) of the study results
Other information		
Funding	12	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.