BMJ Open

Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006034
Article Type:	Research
Date Submitted by the Author:	03-Jul-2014
Complete List of Authors:	Stamatakis, Emmanuel; University of Sydney, Exercise and Sport Sciences & Charles Perkins Centre Coombs, Ngaire; University of Southampton, Social Sciences Rowlands, Alex; University of South Australia, Division of Health Sciences Shelton, Nicola; University College London, Epidemiology and Public Health Hillsdon, Melvyn; University of Exeter, Sport and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health, Epidemiology, Sports and exercise medicine
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

Title: Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Running title: Sedentary time and socioeconomic status

Authors: Emmanuel Stamatakis[1 2 3], Ngaire Coombs[3 4], Alex Rowlands[5], Nicola Shelton[3], Melvyn Hillsdon[6].

[1] Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

[2]Charles Perkins Centre, University of Sydney, Australia

[3]PARG (Physical Activity Research Group), Department of Epidemiology and Public Health, University College London, London, UK

[4]Department of Social Sciences, University of Southampton, UK

[5] Division of Health Sciences, University of South Australia, Australia

[6] Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, UK

Correspondence: Emmanuel Stamatakis, Charles Perkins Centre, University of Sydney , Johns Hopkins Drive, Sydney, NSW 2050, Australia. Email: emmanuel.stamatakis@sydney.edu.au, Telephone: +61 293519668.

Wordcount:

Abstract: 242 words

Main text: 3455 words

Abstract

Objectives: To examine the associations between socioeconomic position (SEP) and multi-domain self-reported and objectively-assessed sedentary time (ST)**. Design**: cross-sectional; **Setting**: general population households in England. Participants: 2289 adults aged 16 and over who participated in the 2008 Health Survey for England. **Outcomes**: accelerometer-measured sedentary time, television time, non-television leisure-time sitting and occupational sitting/standing. We examined multivariable associations between household income, social class, education, area deprivation each SEP indicator (including a 5-point composite SEP score computed by aggregating individual SEP indicators) and each ST indicator using generalised linear models. **Results**: Accelerometry-measured total ST and occupational sitting/standing were positively associated with SEP score and most of its constituent SEP indicators, while television time was negatively associated with SEP score and education level. Area-level deprivation was largely unrelated to ST. Those in the lowest composite SEP group spent 64 (95% CIs: 52 to 76) and 72 (48 to 98), fewer minutes/day in total ST and occupational sitting/standing compared to those in the top SEP group, and an additional 48 (35 to 60) minutes/day watching television ($p<0.001$ for linear trend). Stratified analyses showed that these associations between composite SEP score and total ST were evident only among participants who were in employment. **Conclusions**: Occupational sitting seems to drive the positive association between socioeconomic position and total sedentary time. Lower socioeconomic position is linked to higher TV viewing times. TV viewing, but not overall sedentary time, may be a contributor to socioeconomic inequalities in health in England.

Article summary

Strengths and limitations of this study:

- First study of its kind to use objective sedentary behaviour measurements
- Broad range of self-reported sedentary behaviour types
- Broad set of socioeconomic status markers including are-level deprivation
- The main limitation is the cross-sectional design

Keywords

Socioeconomic status; television; sedentary behavior; inequality; physical activity; accelerometer;

Introduction

Recent studies show that sedentary time (defined as an energy expenditure rate below 1.5 metabolic equivalents[1], often characterised by activities involving sitting) is linked to increased all-cause [2-5] and cardiovascular [2 3] mortality risk independently of leisure-time physical activity participation. Television viewing, one of the most common sedentary time (ST) activities, has been specifically linked to all-cause and cardiovascular mortality and type 2 diabetes [6]. Objective data show that adults in England spend approximately nine to 10 hours a day being sedentary on average, out of which approximately 4 hours/day is TV watching [7 8] . Assuming that the average waking day lasts for 16 hrs, total sedentary time accounts for some 55-65% of total waking time. For working age adults a substantial proportion of total sedentary time takes place while at work, 56% of working English men and 50% of women report more than 5 hrs /day being sedentary while at work [7].

Socioeconomic position (SEP) is a broad term that encompasses a range of characteristics, including occupational type and employment status, purchasing capacity and ownership, educational level and deprivation. Accordingly, there are several SEP indices each of which measures different aspects of social standing. Overall, SEP is a strong predictor of premature mortality and chronic disease occurrence including cardiovascular disease (CVD) [9] and diabetes [10] with individuals in lower SEP being considerably more likely to fall ill and die prematurely. Although there is no consensus on the origins of the socioeconomic gradient in health, one of the suggested pathways involves higher prevalence of poor health behaviors (e.g. physical inactivity and smoking) among lower socioeconomic groups [11] .

We have previously shown that lower SEP is linked consistently with increased TV viewing and other recreational screen time in Scottish adults [12], a finding that has been confirmed by studies in other countries such as Belgium [12 13], Australia [14 15], and the US [16] that used TV as a

proxy for ST. However, these findings are not necessarily generalizable to overall sedentary or sitting time because TV viewing is a complex exposure that seems to be a poor index of overall ST [17]. In a recent study comparing associations between TV time and objectively measured sedentary time, associations were of fair magnitude, but were not consistent across population sub-groups [18]. The results of the few studies that looked at overall (self-reported) sitting in relation to SEP are inconsistent. Higher social position was linked to higher overall sitting time among Australian women [19] but education level was unrelated to sitting time among Portuguese adults [20]. Objective measuring methodologies such as accelerometers and inclinometers can give more comprehensive and complete estimates of total sedentary behavior than partial self-reported indices such as TV viewing, or self-reported total sitting time, which may be more difficult to recall than TV viewing and therefore be subject to more measurement error. Besides, SEP characteristics that relate to occupational class and income will naturally have an impact on work time sitting. For example, manual unskilled workers normally spend less time sitting during work than professionals in managerial office-based jobs [21]. Similarly, higher incomes and the associated spending capacity might impact on the time spent sitting driving a car or commuting. To our knowledge, no study has looked at the associations between SEP defined using education, occupational class, income and area deprivation indices, and SB estimated using self-reported sitting across different domains as well as objective methods.

The aim of this study was to look at the associations between multiple SEP indicators and self-reported indices of sitting time and SB as well as objectively-assessed total SB time. We used data from one of the largest European accelerometry general population studies, the 2008 Health Survey for England.

Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behavior. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere [8]. The household response rate was 64% for the main sample, and 73% for the accelerometer sub-sample [8]. We included adults aged 16 and over who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. An abridged methods section is presented here: the full methods section with more information can be found in supplementary file S1 (Unabridged Methods). Ethical approval was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102).

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height and weight were measured by the same fieldworkers using standard protocols that have been described in detail elsewhere [7] . Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class (of the household reference person) was determined using the Registrar General's classification and was grouped as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Equivalised household income was grouped into quintiles. Highest education qualification was coded as

no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD), a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. Consistent with previous epidemiological SB studies [22], the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero minutely counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Participants with at least one day of valid wear were included in these analyses. [22]

SR Sedentary time was assessed using a set of questions on the usual week/weekend day time spent on: a) TV (including DVDs and videos) viewing; and b) any other sitting during non-work times, including reading and computer use. For those participants who were economically active another set of questions assessed the average daily times spent sitting or standing while at work [17]. While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as accelerometers are unable to differentiate between time spent sitting or standing. Like previously [17] for the purposes of this study standing will be considered a measure of sedentary behavior.

Physical activity questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose, domestic physical activity [12 23], and any recreational sports and exercise including cycling for any purpose [24].

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods [12], we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high end of the score, the top SEP score was collapsed into five categories of comparable size.

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7. Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type [7 8] Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day. For the accelerometry data we used 0-99 counts/minute to

denote sedentary (<1.5 MET) [3] and ≥2,020 counts/minute to denote MVPA (>3 MET) [25]. Accelerometry-measured variables were converted to time (minutes) per valid day.

Missing data and multiple imputation

Outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses to improve normality. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2289 for accelerometry-measured ST, 2279 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Statistical analysis

Analyses were weighted for non-response to give a sample that was representative of adults living in England. The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometry-measured ST) were examined using generalised linear models, and by multiple

linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. We also repeated the SEP score analyses stratified by economic activity (employed/self-employed vs non-economically active). SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators (household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA or accelerometry-measured MVPA as appropriate, and average accelerometer wear time on valid days. Models 2 and 3 with accelerometry-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. This work conforms with the STROBE statement for observational studies. [26]

Results

Descriptives

2289 adults provided valid accelerometry data, with 2279 and 2253 also providing self-reported TV and non-TV time respectively. 1170 provided occupational sitting/standing time. Table 1 presents the sample characteristics of the accelerometry sample by SEP score group (prior to MI) with casewise deletion of missing values (N=1651). In total 628 participants in the accelerometry sample had at least one covariate imputed. The variables with the most imputed values were household income (361 imputed) and BMI (233 imputed). Participants from lower SEP groups were more likely to be female, older, have a higher BMI, spend less time sedentary overall and sitting at work, but spend more time watching TV than individuals

in higher SEP groups. Lower SEP individuals were also more likely to report a limiting longstanding illness and difficulties with usual daily activities, and be a current cigarette smoker, but less likely to be a heavy drinker and meet physical activity guidelines.

Table 1: Sample Characteristics by Socioeconomic Position Score

	SEP Score Group			
	1 (lowest) & 2 (N=521)*	3 (N=355)*	4 & 5 (highest) (N=775)*	
Categorical variables[a]	%	%	%	*p*
Sex (% male)	40.1	47.0	50.5	0.001
Limiting longstanding illness (%)	32.8	24.5	16.8	<0.001
Adherence to the physical activity guidelines (self-reported data) (%)	32.6	43.9	49.6	<0.001
Difficulty in performing usual activities (%)	21.5	14.9	7.8	<0.001
Car or van available (%)	73.9	89.9	94.7	<0.001
Drinking frequency (% ≥5 times /week)	15.9	23.1	24.9	<0.001
Smoking (% current)	27.1	23.9	15.5	<0.001
Employment status (% employed/self-employed)	35.2	64.8	76.3	<0.001
Continuous variables[b]	M (SD)	M (SD)	M (SD)	*P*
Age (years)	56.1 (18.5)	50.4 (16.6)	46.9 (15.9)	<0.001
BMI (kg/m^2)	28.0 (4.9)	27.4 (4.9)	26.8 (4.5)	<0.001
Sedentary time (accelerometry data) (Minutes/day))	505.6 (97.7)	499.4 (90.7)	528.7 (87.2)	<0.001
TV (Minutes/day)	218.6 (117.3)	175.8 (97.7)	145.0 (74.7)	<0.001
Non-TV sitting time (Minutes/day)	128.1 (86.4)	121.5 (90.6)	133.2 (86.3)	0.110
Occupational sitting/standing time (Minutes/day)	151.8 (116.5)	173.5 (120.9)	198.1 (121.9)	<0.001
MVPA time per day (accelerometry data) (Minutes/day)	24.7 (24.1)	29.7 (26.3)	32.0 (25.1)	<0.001

* Occupational sitting time SEP 1 N=152 SEP 2 N=214; SEP 3 N=549 for SEP 4 & 5

[a] Chi Square was used to test significance of association between categorical variables and social class

[b] Anova was used to test significance of association between continuous variables and social class

Composite Socioeconomic position and sedentary time

Figure 1 presents the GLM estimated marginal means and their 95% CIs describing the associations between composite SEP score and each measure of ST. SEP was positively associated with accelerometry-measured ST and occupational sitting/standing time, and inversely associated with TV time in all models. There were no associations between SEP and non-TV sitting time. Adjustments for potential confounders made no material difference to all above associations. Figure 2 presents associations between SEP score and accelerometry-measured ST, stratified by employment status. SEP score was positively associated with accelerometry-measured ST for those in employment only. SEP was inversely associated with TV time regardless of employment status, while non-TV leisure-time sitting was positively associated with SEP (SEP1 coefficient 134, 95% CI 125 to 145; SEP5 coefficient 177, 155 to 198), but only for those not in employment. However this association was not linear (data not shown).

Equivalised Household income and sedentary time

Figure 3 presents associations between household income and each measure of ST. Household income was positively associated with accelerometer-measured ST and occupational sitting time and these associations persisted following adjustments for MVPA and other confounders. Like with SEP score, household income was inversely associated with TV time, although this association was attenuated to the null following adjustments for potential confounders in models 2 and 3. Household income was not associated with non-TV sitting time.

Educational attainment and sedentary time

Figure 4 presents the associations between the highest educational qualification and each measure of ST. Educational attainment was positively associated with accelerometry-measured ST and inversely associated with TV time in all models. Occupational sitting/standing time was inversely associated with education but the association did not appear to be linear (it was evident across the lowest three educational levels only) and was attenuated to the null following adjustments for potential confounders. There was a weak positive association between education and non-TV sitting time, following adjustments for potential confounders in models 2 and 3.

Occupational social class and sedentary time

As shown in Figure 5, occupational social class was positively associated with accelerometry-measured ST and occupational sitting/standing. The initial inverse association with TV time (model 1) was attenuated to the null following adjustments for potential confounders. Similarly to SEP score and income, social class was not associated with non-TV sitting time.

Area deprivation and sedentary time

Area-level deprivation was positively associated with TV time (the lower the deprivation the lower the TV time) but these associations did not persist in the adjusted models (Figure 6). Area deprivation was not associated with any other measures of ST (Figure 6).

Differential associations between imputed and non-imputed data

There were no differences between the imputed and non-imputed models describing the associations between SEP score and ST indicators, although the 95% confidence intervals were slightly broader in the unimputed models due to the lower sample size (see supplementary Figure S2).

Differential associations in weekday Vs weekend days

There was no consistent pattern of differences in the associations of SEP and ST by weekend vs weekday (see supplementary Figures S3 and S4), time of the week-specific results showed broadly the same pattern as the whole week. The only notable difference was that a direct association between SEP and non-TV sitting time was observed on weekend days, but not on weekdays.

Discussion

Literature on the socio-economic gradient of sedentary behavior is very limited and has relied on partial sedentary behavior indicators, mostly TV viewing. To our knowledge, this study is the only one that considers four indicators of socioeconomic position in relation to four indicators of sedentary behavior, allowing a much more in-depth examination of the associations of interest than in previous studies. Our study suggests that occupational ST is what drives the positive association between overall SEP and total ST as there was no association among those not in employment (Figure 2). The difference between the lowest and highest SEP groups (Figure 1) is in the region of 60-70 minutes per day for both total accelerometry-measured sedentary time and occupational sitting/standing time and this is comparable with the difference between the extreme SEP group among the economically active part of the sample (~90 minutes/day). Our findings agree with an Australian study [19] which found that among women, full-time work, skilled occupations, and university education were all associated with high (self-reported) total sitting time. Our study also found that the inverse association between TV time and SEP was significant regardless of employment status. In a study of Dutch workers, sitting time at work varied considerably by type of occupation but not sitting during leisure time [27].

Previous studies of adults in Belgium [13] and Australia [14 15 28] have reported inverse associations between SEP indicators and TV time. We observed the same TV time pattern with SEP score and education but not with occupational class, household income or area deprivation. Although the occupational class and household income data were suggestive of a weak association with TV time, our current results somehow contradict our study in Scottish adults,[12] where all SEP indicators (occupational class, household income or area deprivation) as well as the composite SEP score were associated with recreational screen time (including TV time). Explanations for this might be that the Scottish study was three times larger in size (which might have made it easier for data patterns to emerge) and the inclusion of non-TV screen time as an outcome, although studies from other countries suggest no clear pattern between non-TV recreational screen time (e.g. computer use) and SEP [29 15]. Nevertheless, both our English and the Scottish studies demonstrate that when education, occupational social class and income are combined into a single measure (SEP score) they are a much more powerful predictor of sedentary time than any single indicator, perhaps because they collectively capture actual socioeconomic position more thoroughly than any single indicator. Composite SEP score showed a clear and consistent pattern with all ST outcomes, although each of the individual/household-level SEP indicators seemed to influence each ST outcome in various ways, suggesting there are complex, interacting, multi-dimensional influences of SEP on ST. Accelerometry-measured ST was the only sedentary behavior variable that showed clear and consistent (positive) associations with all SEP variables (except from area-level deprivation).

Strengths of our study include the availability of both objectively-measured and self-reported indicators of sedentary behavior which allowed us to be more thorough and detailed when examining the associations of interest. Accelerometers can capture total sedentary time more comprehensively than any partial self-reported indicator and as such are able to better

quantify the socioeconomic gradient of ST as a contributor to health inequalities, however a limitation is that accelerometers do not distinguish between sitting and standing which have different health implications, this also applies to occupational sitting/standing time. It has been argued that standing should not be considered a sedentary behavior [30]. Another limitation is that our study was limited to the accelerometry sample of HSE 2008 and this might have led to our sample being less representative of the target population. Although those in the subsample offered the accelerometer were older and more likely to be retired and to be less healthy than the rest of the adult Health Survey for England sample, those who refused to wear an accelerometer were similar in terms of employment status and area-level deprivation compared to those who wore the accelerometers for at least four days a week[31]. Higher SEP is linked to higher commuting by car [32] and this may partly explain the socioeconomic gradient but our data are limited in that there was no specific question on commuting-related sitting to examine this explanation.

Conclusions

Objectively-measured total sedentary time and occupational sedentary time are higher among economically active English adults in higher socioeconomic groups compared to less privileged groups. However, TV viewing is lower in higher socioeconomic groups regardless of economic activity. Combining different socioeconomic indicators appears to have composite power as a predictor of sedentary time. Although the cross-sectional design of this study precludes causal inferences, the pattern of the associations we observed suggests that it is unlikely that total sedentary behavior contributes to socioeconomic inequalities in health.

Funding: This work was funded by the National Institute for Health Research through a Career Development Fellowship (ES). NC is also funded by the National Institute for Health Research through the same source. The views expressed in this article are those of the authors and not the English Department of Health or the National Institute for Health Research.

Data Sharing: No additional data are available

Competing interests: None of the authors have any competing interests to declare

Authors' Contributions: All authors have contributed sufficiently, ES conceived the idea, prepared the dataset, drafted most of the manuscript and revised the manuscript several times. NC did the statistical analysis under the supervision of ES and prepared the Tables, Figures and Supplemental Online material. AR processed the accelerometry files. NS, MH and AR redrafted parts of the manuscript and critically evaluated the whole material. All authors approved the final version before submission.

References

1. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exercise and Sport Sciences Reviews 2008;**36**(4):173-78.
2. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
3. Matthews C, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 2012;**95**(2):437-45.
4. Patel AV, Bernstein L, Deka A, et al. Leisure Time Spent Sitting in Relation to Total Mortality in a Prospective Cohort of US Adults. Am J Epidemiol 2010;**172**(4):419-29.
5. van der Ploeg HP, Chey T, Korda RJ, et al. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. Arch Intern Med 2012;**172**(6):494-500.
6. Grøntved A, Hu FB. Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality. JAMA 2011;**305**(23):2448-55.
7. Joint Health Surveys Unit. The Health Survey for England 2008. Volume 1 Leeds, 2010:21-206.
8. Joint Health Surveys Unit. The Health Survey for England 2008, Volume 2. Leeds: , 2010:11.
9. Marmot MG, Shipley MJ, Hemingway H, et al. Biological and behavioural explanations of social inequalities in coronary heart disease: Whitehall II Study. Diabetologia 2008;**51**(11):1980-88.
10. Williams ED, Tapp RJ, Magliano DJ, et al. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia 2010;**53**:2538-45.
11. Stringhini S, Sabia S, Shipley M, et al. Association of Socioeconomic Position With Health Behaviors and Mortality. JAMA 2010;**303**(12):1159-66.
12. Stamatakis E, Hillsdon M, Mishra G, et al. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. Journal of epidemiology and community health 2009;**63**(9):734-40.
13. Van Dyck D, Cardon G, Deforche B, et al. Socio-demographic, psychosocial and home-environmental attributes associated with adults' domestic screen time. BMC Public Health 2011;**11**:668.
14. Teychenne M, Ball K, Salmon J. Correlates of socio-economic inequalities in women's television viewing: a study of intrapersonal, social and environmental mediators. Int J Behav Nutr Phy Act 2012;**9**:3.
15. Burton NW, Haynes M, van Uffelen JGZ, et al. Mid-Aged Adults' Sitting Time in Three Contexts. Am J Prev Med 2012;**42**(4):363-73.
16. Bowman SA. Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Preventing Chronic Disease 2006;**3**(2).
17. Stamatakis E, Hamer M, Tilling K, et al. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. Int J Epidemiol 2012;**41**:1328-37.
18. Clark BK, Healy GN, Winkler EAH, et al. Relationship of Television Time with Accelerometer-Derived Sedentary Time: NHANES Med Sci Sports Exerc 2011;**43**(5):822-28.
19. van Uffelen JGZ, Heesch KC, Brown W. Correlates of Sitting Time in Working Age Australian Women: Who Should Be Targeted With Interventions to Decrease Sitting Time? J Phys Act Health 2012;**9**(2):270-87.
20. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a portuguese sample of men: Results from the azorean physical activity and health study (APAHS). Int J Environ Res Publ Health 2010;**7**(4):1500-07.
21. Duncan MJ, HBadland HM, Mummery WK. Physical Activity Levels by Occupational Category in Non-Metropolitan Australian Adults. J Phys Act Health 2010;**7**(6):718-23.

22. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. Am J Epidemiol 2008;**167**(7):875-81.
23. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . Prev Med 2007;**45**:416-23.
24. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey Br J Sports Med 2008;**42**:601-08.
25. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;**40**(1):181-8.
26. Gallo V, Egger M, McCormack V, et al. STrengthening the Reporting of OBservational studies in Epidemiology--Molecular Epidemiology (STROBE-ME): an extension of the STROBE Statement. PLoS medicine 2011;**8**(10):e1001117.
27. Jans M, Proper K, Hildebrandt V. Sedentary Behavior in Dutch Workers: Differences between Occupations and Business Sectors. Am J Prev Med 2007;**33**:450-54.
28. Stamatakis E, Grunseit AC, Coombs N, et al. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: The Social, Economic, and Environmental Factor (SEEF) Study. Prev Med 2014;**63c**:72-80.
29. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior A Systematic Review. Am J Prev Med 2012;**42**(3):E3-E28.
30. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Research and Clinical Practice 2011;**93**(2):292-94.
31. Roth M, Mindell J. Who provides accelerometry data? Correlates of adherence to wearing an accelerometry motion sensor: the 2008 health survey for England. J Phys Act Health 2013;**10**(1):70-78.
32. Goodman A, Guell C, Panter J, et al. Healthy travel and the socio-economic structure of car commuting in Cambridge, UK: A mixed-methods analysis. Social Science & Medicine 2012;**74**(12):1929-38.

Figure Legends and footnotes

Figure 1: Multivariate-adjusted average daily sedentary time by SEP score

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates lowest income quartile (<=£13876),Q4 indicates the highest income quartile (>=£39001).

Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average

accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Education Level 1 represents NVQ1/CSE and NVQ2 GCE O Level equivalent; Level 2 represents NVQ3/GCE A Level equivalent; Level 3 represents higher education below Degree and NVQ4/NVQ5/Degree or higher.

Figure 5: Multivariate-adjusted average daily sedentary time[a] by occupational social class.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

Figure 6: Multivariate-adjusted sedentary time by area deprivation quintile.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates most deprived, Q5 indicates least deprived

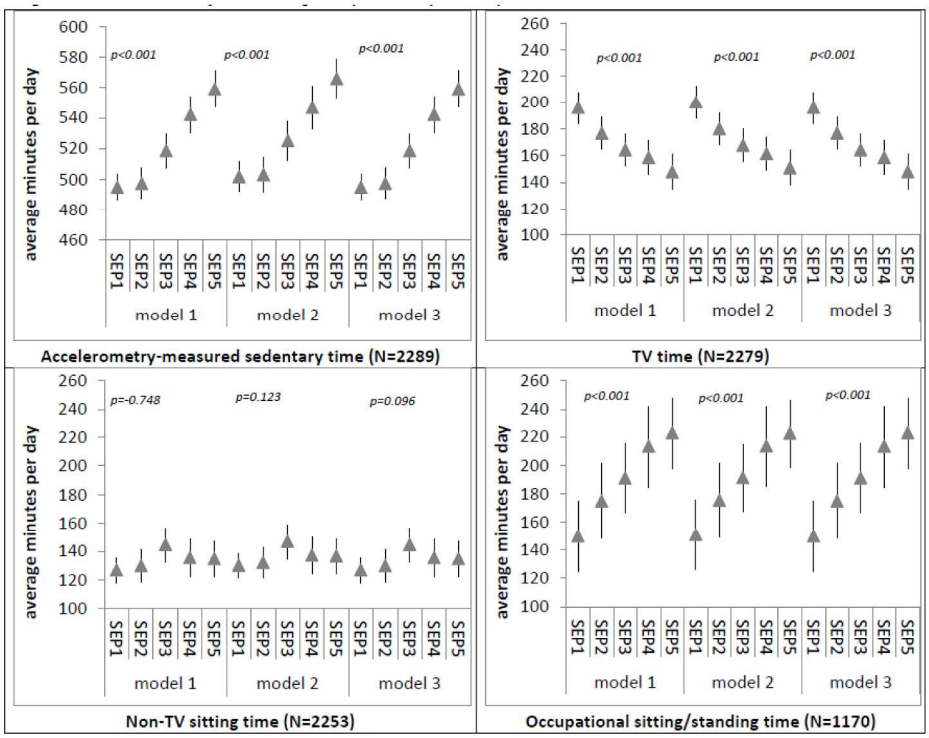


Figure 1: Multivariate-adjusted average daily sedentary time by SEP score
254x190mm (300 x 300 DPI)

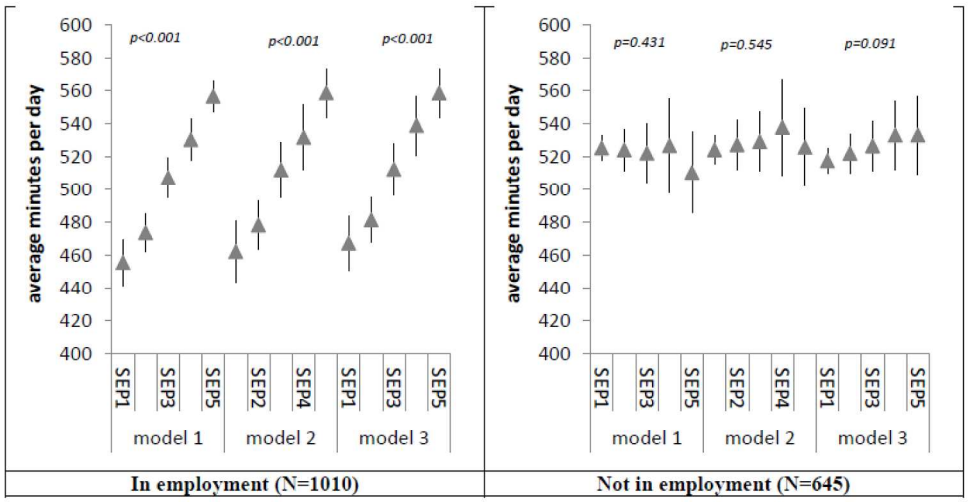


Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status
254x190mm (300 x 300 DPI)

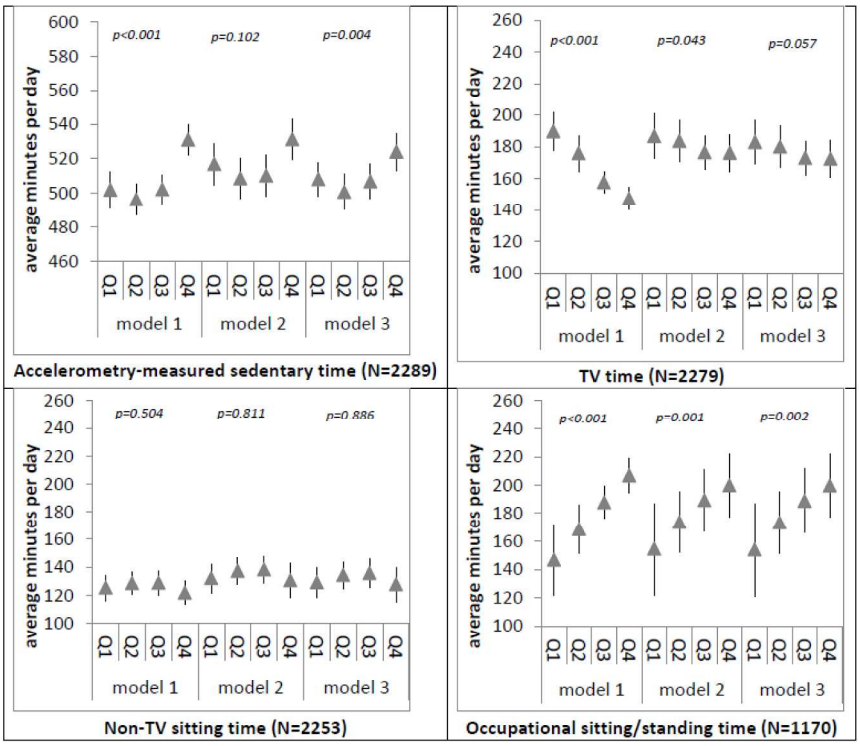


Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile
254x190mm (300 x 300 DPI)

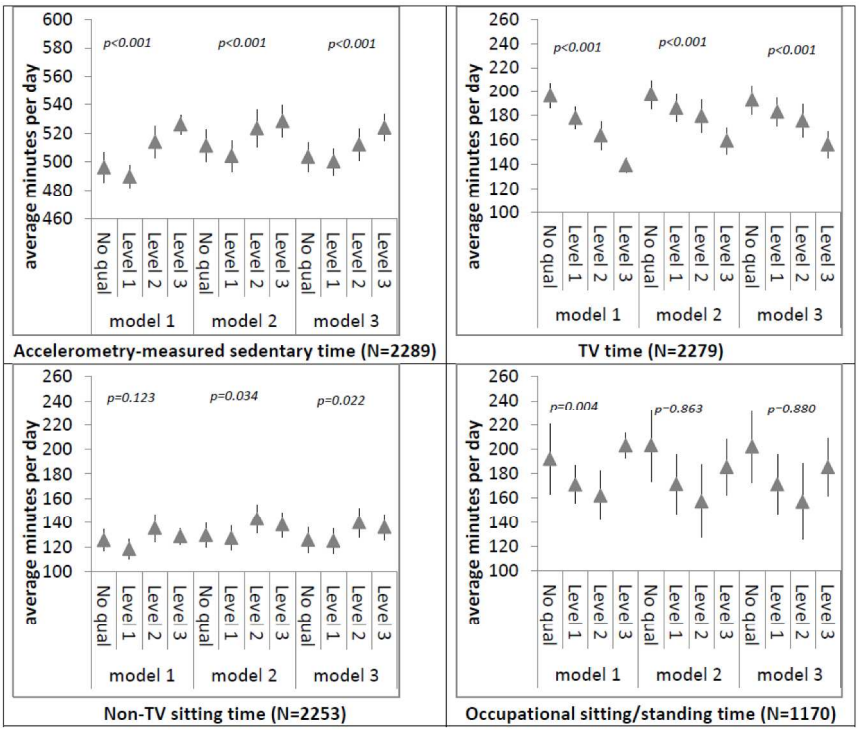


Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification
254x190mm (300 x 300 DPI)

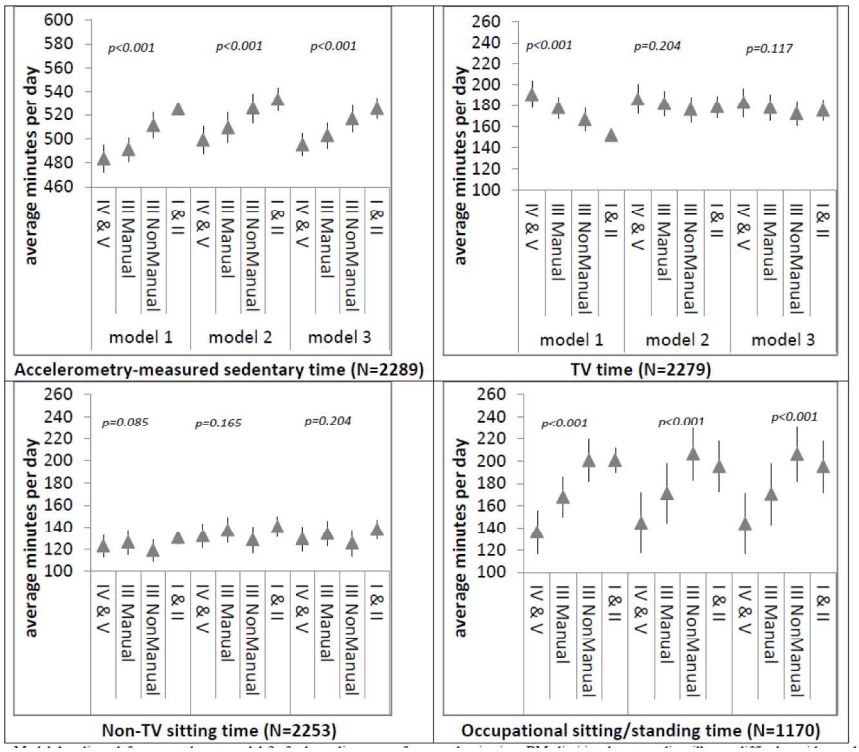


Figure 5: Multivariate-adjusted average daily sedentary timea by occupational social class
254x190mm (300 x 300 DPI)

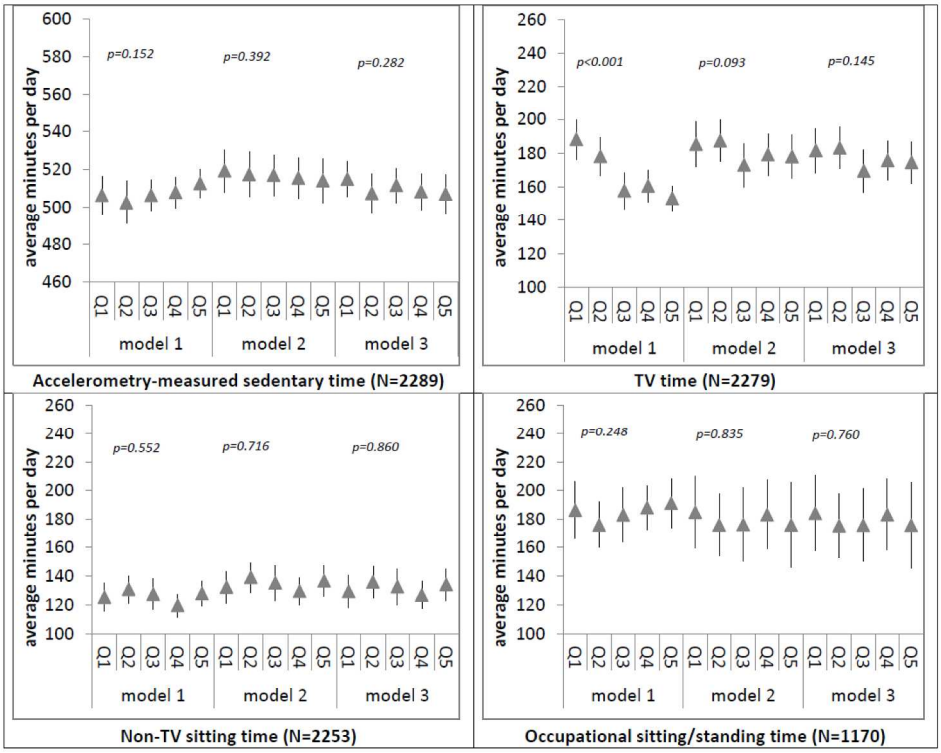


Figure 6: Multivariate-adjusted sedentary time by area deprivation quintiles
254x190mm (300 x 300 DPI)

Supplemental Digital Content 1

Unabridged Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere (2). The household response rate was 64% for the main sample, and 73% for the accelerometer sub-sample (3). Ethical approval for the 2008 HSE was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). We included adults aged 16 and over who had both valid accelerometry and self-reported SB data. Participants provided written informed consent.

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height and weight were measured by the same fieldworkers using standard protocols that have been described in detail elsewhere (5). Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class was determined using the Registrar General's classification and was grouped as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Household income was converted to equivalised annual household income that is adjusted for the number of persons in the household using the McClements scoring system (15). The

income data presented here are based on quartiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD) which provides a measure of area deprivation with deprivation based on measures in seven domains: income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, crime and living environment. IMD was initially a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

Objective measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. At the core addresses that were eligible for accelerometry, up to two adults in total were selected to wear the accelerometer (up to one adult in those households with eligible children). Full details of the accelerometry sample selection procedure can be found elsewhere (6). At the end of the initial HSE 2008 interview, interviewers obtained agreement for participation in the accelerometry study, provided the accelerometers and explained procedures. The accelerometry data were processed using specialist software (KineSoft, New Brunswick). In consistency with previous epidemiological SB studies (8), the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero counts, with allowance for up to 2 consecutive minutes of 1–99 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Like previously (7), participants with at least one day of valid wear were included in these analyses, although the majority (76%, N=1742) had between six

and seven days and 95% (N=2165) had at least three valid days. All physical activity and sedentary time variables were converted to time (in minutes) per valid day.

Self-reported measures

Sedentary time was assessed using a set of questions on the usual weekday time spent on: a) TV (including DVDs and videos) viewing ("In the last four weeks, how much time did you spend watching TV/videos) on an average week day?"); and b) any other sitting during non-work times, including reading and computer use ("In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekday? Please do not include time spent doing these activities while at work"). An equivalent set of questions assessed TV and non-TV sedentary time in the weekend days. For those participants who were economically 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/standing while at work ("On an average work day in the last four weeks, how much time did you usually spend sitting down or standing up?"). (14) While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as most accelerometers are unable to differentiate between time spent sitting or standing. For the purposes of this study, standing will be considered a measure of sedentary behaviour.

Physical activity was assessed using the long version of the Health Survey for England 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, domestic physical activity (12) (11) and any recreational exercise, (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports, racket sports) (9). Occupational activity was measured as average daily (per day at work) times spent on walking, climbing stairs or ladders, and lifting, carrying or moving loads (5). We calculated MVPA

using established metabolic equivalent tables (1). The criterion validity of the physical activity questionnaire has been demonstrated in a study of 106 English adults from the general population (45 men) where the output of accelerometers (worn for two non-consecutive weeks over a month period) was compared against the above questions (4, 13).

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods (10), we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, the second lowest category was given a SEP score of 1, and so on, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high and low end of the score, the SEP score was collapsed into five categories of comparable size (0 -3=SEP1; 4- 5=SEP2; 6- 7=SEP3; 8=SEP4; 9- 12=SEP5), with 1 representing the lowest SEP, and 5 the highest.

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7.

Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type (walking, cycling, and each other sport and exercise the questionnaire enquired about) (5, 6) Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day.

For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) (7); 200-2,019 counts/minute to denote light physical activity; and ≥2,020 counts/minute to denote MVPA (>3 MET) (16). Accelerometer-measured sedentary time and physical activity variables were converted to time (in minutes) per valid day.

Missing data and multiple imputation

To improve the normality of the residuals that are required for linear regression, outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2279 for accelerometry-measured ST, 2269 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Dealing with non-response

Analyses were weighted for non-response (5) to give a sample that was representative of adults living in England. In brief, the non-response weights were calculated by fitting a logistic regression model (weighted by a previously developed weighting factor)(5) for all adults with interview completion as the outcome and age group by sex, household type, geographical area, and household social class as covariates. The non-response weights, which were trimmed at the 1% tails to remove extreme values, were calculated as the inverse of the predicted probabilities of response.(5) The complex samples module in SPSS was used to account for clusters in the survey design.

Statistical analysis

The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometer-measured ST) was examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design.

All statistical models were run for each combination of dependent variable and main exposure. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators (household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA and accelerometer-measured MVPA, and average accelerometer wear

time on valid days Models with accelerometer-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. There was no evidence of colinearity in the multivariate model as no variance inflation factor value was higher than approximately 1.5, with most values just over 1. Residual statistics and plots for each model were checked for normality, independence of observations, homoscedasticity, and influential outliers.

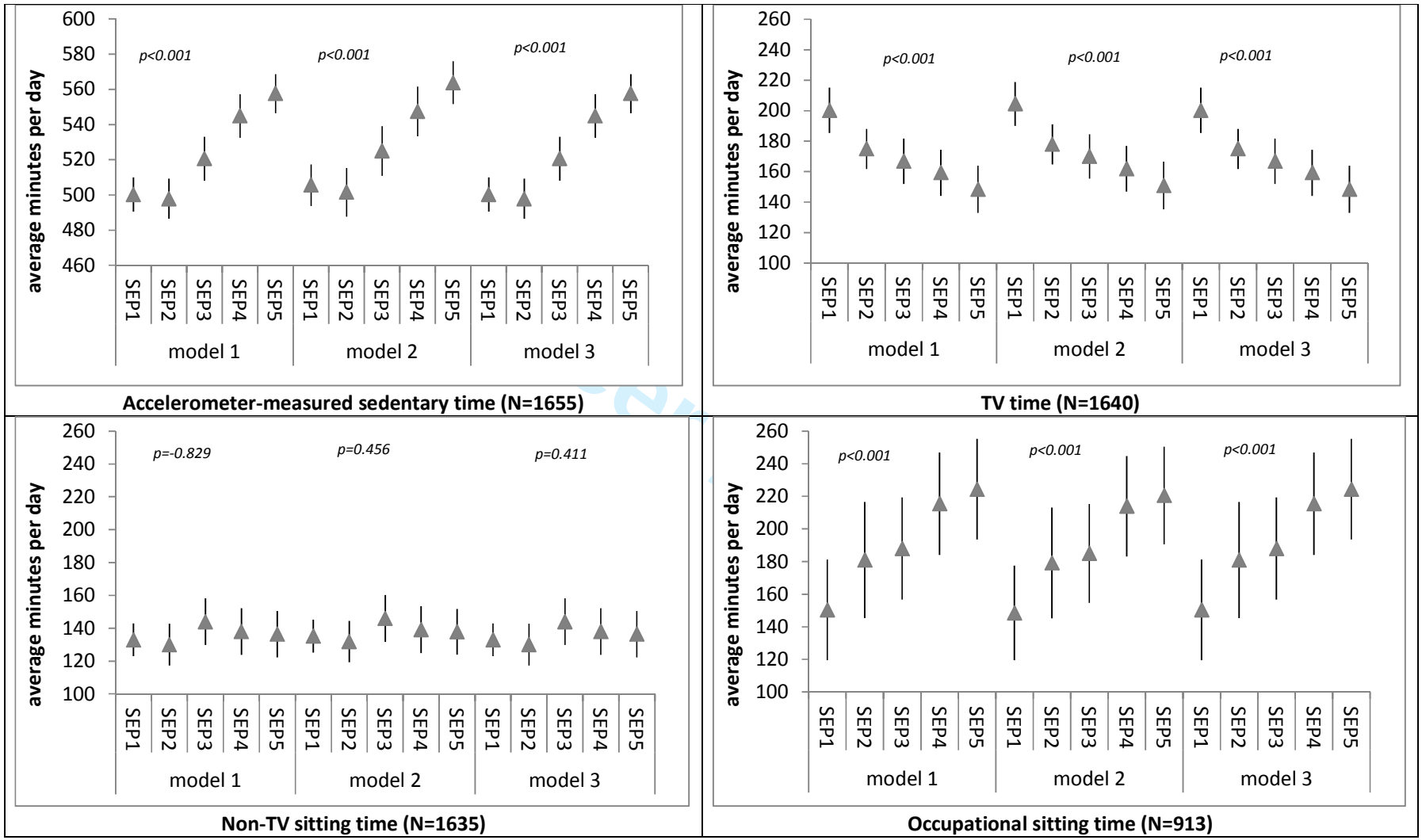
GLM coefficients indicate mean differences in sedentary time (in minutes) between the reference category and each of the other SEP categories. The lowest SEP category (<£10671 for household income, unskilled/ semi-skilled manual for social class, most deprived quintile for area deprivation, SEP1 (lowest socioeconomic position) for SEP score) is the reference category for the mean difference in the outcome (and associated confidence interval for the difference) in all CSGLMs.

References

1. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S498-504.
2. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 1* Leeds2010.
3. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 2* Leeds2010.
4. Joint Health Surveys Unit. *The Health Survey for England Physical Activity Validation Study: substantive report.* Leeds: Health and Social Care Information Centre; 2007.
5. Joint Health Surveys Unit. *The Health Survey for England 2008*. Leeds: The Information Centre for Health and Social Care; 2009.
6. Joint Health Surveys Unit. *The Health Survey for England 2008, Volume 2: Methods and Documentation*. Leeds: The Information Centre for Health and Social Care; 2009.
7. Matthews C, George SM, Moore SC et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *The American Journal of Clinical Nutrition*. 2012;95(2):437-45.
8. Matthews CE, Chen KY, Freedson PS et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. *Am J Epidemiol*. 2008;167(7):875-81.
9. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey *Br J Sports Med*. 2008;42:601-8.
10. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *J Epidemiol Commun Health*. 2009;63:734-40.
11. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . *Prev Med*. 2007;45:416-23.
12. Stamatakis E, Hamer M, Lawlor DA. Physical activity, mortality and cardiovascular disease: Is domestic physical activity beneficial? The Scottish Health Survey 1995, 1998 and 2003. . *Am J Epidemiol*. 2009;169:1191-200.

13. Stamatakis E, Hamer M, Primatesta P. Cardiovascular medication, physical activity and mortality: cross-sectional population study with ongoing mortality follow-up. *Heart*. 2009;95(6):448-53.
14. Stamatakis E, Hamer M, Tilling K, Lawlor DA. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. *Int J Epidemiol*. 2012.
15. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *Journal of Epidemiology and Community Health*. 2009;63(9):734-40.
16. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-8.

Supplementary Figure S2: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Unimputed, casewise-deleted data.

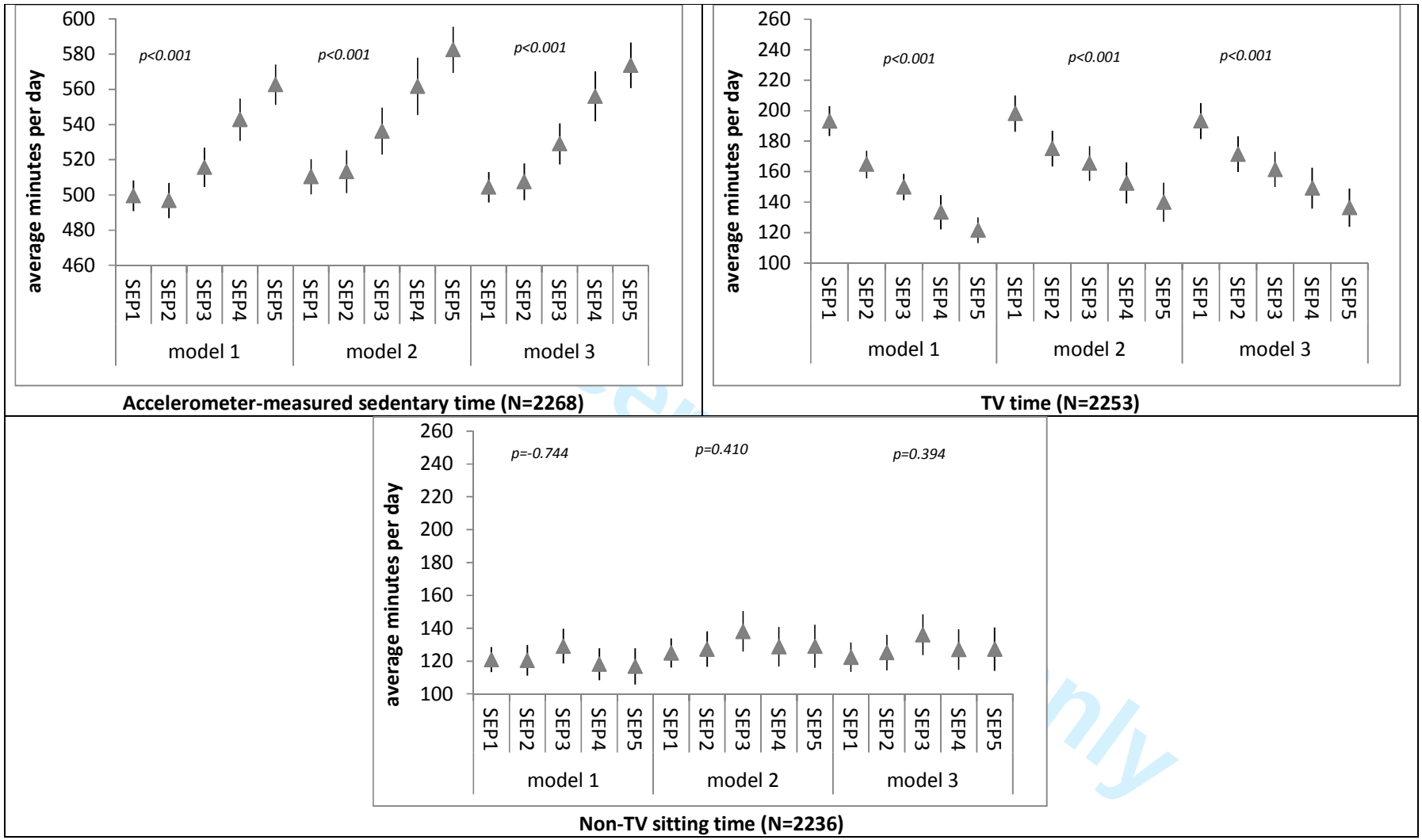


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S3: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekdays.

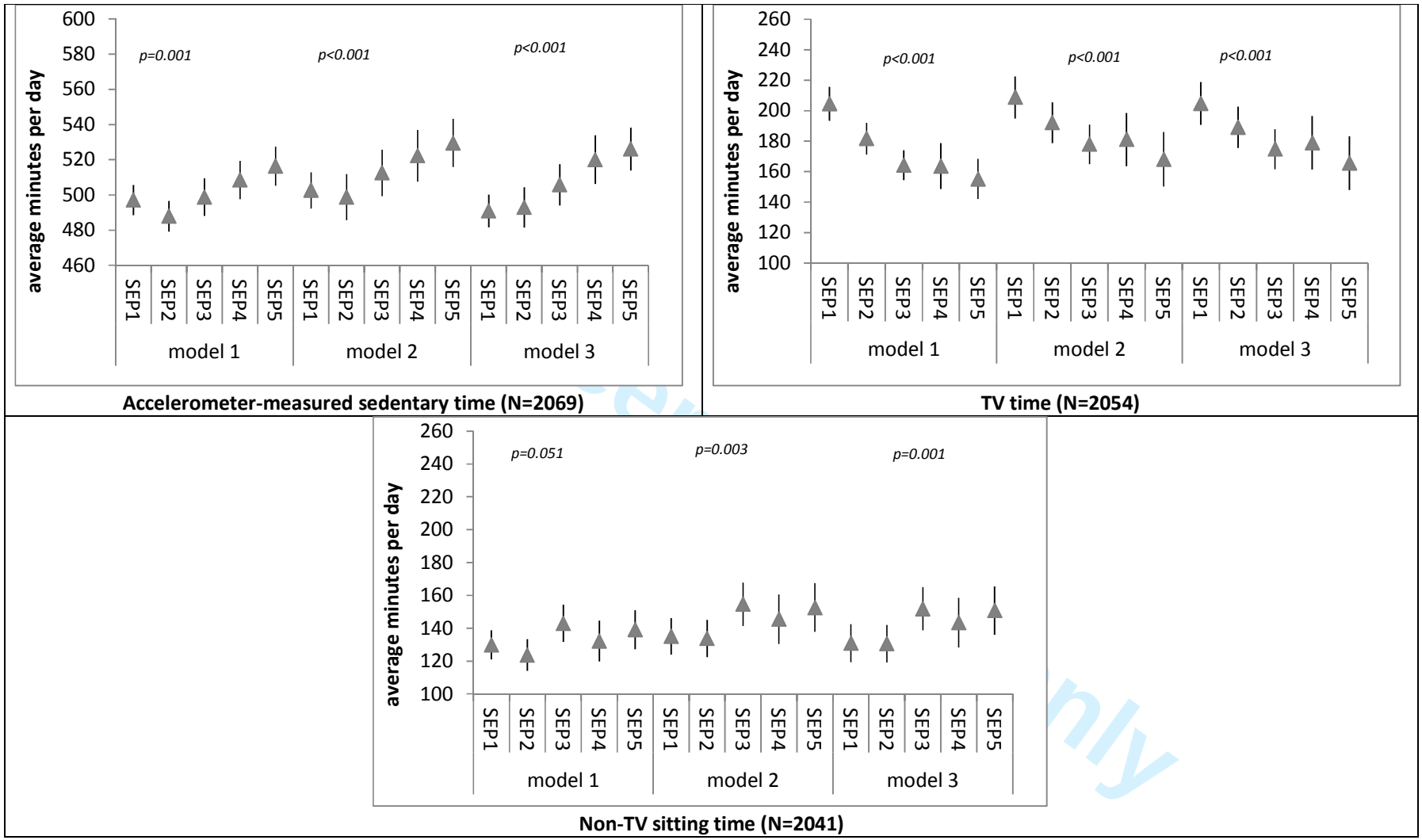


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S4: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekend days.



Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	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	6-8
Bias	9	Describe any efforts to address potential sources of bias	*8*
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(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	10-11
		(b) Give reasons for non-participation at each stage	10-11
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*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	12
		(*b*) Report category boundaries when continuous variables were categorized	7-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	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	18

*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.

BMJ Open

Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006034.R1
Article Type:	Research
Date Submitted by the Author:	17-Sep-2014
Complete List of Authors:	Stamatakis, Emmanuel; University of Sydney, Exercise and Sport Sciences & Charles Perkins Centre Coombs, Ngaire; University of Southampton, Social Sciences Rowlands, Alex; University of South Australia, Division of Health Sciences Shelton, Nicola; University College London, Epidemiology and Public Health Hillsdon, Melvyn; University of Exeter, Sport and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health, Epidemiology, Sports and exercise medicine
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

Title: Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Running title: Sedentary time and socioeconomic status

Authors: Emmanuel Stamatakis[1 2 3], Ngaire Coombs[3 4], Alex Rowlands[5], Nicola Shelton[3], Melvyn Hillsdon[6].

[1]Charles Perkins Centre, University of Sydney, Australia

[2] Discipline of Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

[3]PARG (Physical Activity Research Group), Department of Epidemiology and Public Health, University College London, London, UK

[4]Department of Social Sciences, University of Southampton, UK

[5] Division of Health Sciences, University of South Australia, Australia

[6] Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, UK

Correspondence: Emmanuel Stamatakis, Charles Perkins Centre, University of Sydney , Johns Hopkins Drive, Sydney, NSW 2050, Australia. Email: emmanuel.stamatakis@sydney.edu.au, Telephone: +61 293519668.

Wordcount:

Abstract: 245 words

Main text: 3693 words

Abstract

Objectives: To examine the associations between socioeconomic position (SEP) and multi-domain self-reported and objectively-assessed sedentary time (ST)**. Design**: cross-sectional; **Setting**: general population households in England. **Participants**: 2289 adults aged 16-96 years who participated in the 2008 Health Survey for England. **Outcomes**: accelerometer-measured sedentary time, and self-reported television time, non-television leisure-time sitting and occupational sitting/standing. We examined multivariable associations between household income, social class, education, area deprivation each SEP indicator (including a 5-point composite SEP score computed by aggregating individual SEP indicators) and each ST indicator using generalised linear models. **Results**: Accelerometry-measured total ST and occupational sitting/standing were positively associated with SEP score and most of its constituent SEP indicators, while television time was negatively associated with SEP score and education level. Area-level deprivation was largely unrelated to ST. Those in the lowest composite SEP group spent 64 (95% CIs: 52 to 76) and 72 (48 to 98), fewer minutes/day in total ST and occupational sitting/standing compared to those in the top SEP group, and an additional 48 (35 to 60) minutes/day watching television ($p<0.001$ for linear trend). Stratified analyses showed that these associations between composite SEP score and total ST were evident only among participants who were in employment. **Conclusions**: Occupational sitting seems to drive the positive association between socioeconomic position and total sedentary time. Lower socioeconomic position is linked to higher TV viewing times.

Article summary

Strengths and limitations of this study:

- First study of its kind to use objective sedentary behaviour measurements
- Broad range of self-reported sedentary behaviour types
- Broad set of socioeconomic status markers including are-level deprivation
- This is a cross-sectional design
- The occupational sedentary time question and accelerometry cannot differentiate between sitting and standing

Keywords

Socioeconomic status; television; sedentary behaviour; inequality; physical activity; accelerometer;

Introduction

Recent studies show that sedentary time (defined as an energy expenditure rate below 1.5 metabolic equivalents[1], often characterised by activities involving sitting) is linked to increased all-cause [2-5] and cardiovascular [2 3] mortality risk independently of leisure-time physical activity participation. Television viewing, one of the most common sedentary time (ST) activities, has been specifically linked to all-cause and cardiovascular mortality and type 2 diabetes [6]. Objective data show that adults in England spend approximately nine to 10 hours a day being sedentary on average, out of which approximately 4 hours/day is TV watching [7 8] . Assuming that the average waking day lasts for 16 hrs, total sedentary time accounts for some 55-65% of total waking time. For working age adults a substantial proportion of total sedentary time takes place while at work, 56% of working English men and 50% of women report more than 5 hrs /day being sedentary while at work [7].

Socioeconomic position (SEP) is a broad term that encompasses a range of characteristics, including occupational type and employment status, purchasing capacity and ownership, educational level and deprivation. Accordingly, there are several SEP indices each of which measures different aspects of social standing. Overall, SEP is a strong predictor of premature mortality and chronic disease occurrence including cardiovascular disease (CVD) [9] and diabetes [10] with individuals in lower SEP being considerably more likely to fall ill and die prematurely. Although there is no consensus on the origins of the socioeconomic gradient in health, one of the suggested pathways involves higher prevalence of poor health behaviours (e.g. physical inactivity and smoking) among lower socioeconomic groups [11] .

We have previously shown that lower SEP is linked consistently with increased TV viewing and other recreational screen time in Scottish adults [12], a finding that has been confirmed by studies in other countries such as Belgium [12 13], Australia [14 15], and the US [16] that used TV as a

proxy for ST. However, these findings are not necessarily generalizable to overall sedentary or sitting time because TV viewing is a complex exposure that seems to be a poor index of overall ST [17]. In a recent study comparing associations between TV time and objectively measured sedentary time, associations were of fair magnitude, but were not consistent across population sub-groups [18]. The results of the few studies that looked at overall (self-reported) sitting in relation to SEP are inconsistent. Higher social position was linked to higher overall sitting time among Australian women [19] but education level was unrelated to sitting time among Portuguese adults [20]. Objective measuring methodologies such as accelerometers and inclinometers can give more comprehensive and complete estimates of total sedentary behaviour than partial self-reported indices such as TV viewing, or self-reported total sitting time, which may be more difficult to recall than TV viewing and therefore be subject to more measurement error. Besides, SEP characteristics that relate to occupational class and income will naturally have an impact on work time sitting. For example, manual unskilled workers normally spend less time sitting during work than professionals in managerial office-based jobs [21]. Similarly, higher incomes and the associated spending capacity might impact on the time spent sitting driving a car or commuting. To our knowledge, no study has looked at the associations between SEP defined using education, occupational class, income and area deprivation indices, and SB estimated using self-reported sitting across different domains as well as objective methods.

The aim of this study was to look at the associations between multiple SEP indicators and self-reported indices of sitting time and SB as well as objectively-assessed total SB time. We used data from one of the largest European accelerometry general population studies, the 2008 Health Survey for England.

Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere [8]. The overall interview household response rate for the main sample of 15,102 adults was 64%, and for the accelerometer sub-sample of 4,507 adults was 73% [8]. In this analysis we included adults aged 16 and over (age range 16-96 years) who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. An abridged methods section is presented here: the full methods section with more information can be found in supplementary file S1 (Unabridged Methods). Ethical approval was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102).

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing.

Height was measured using a standard stadiometer with a sliding head plate, a base plate and three connecting rods marked with a metric measuring scale. Participants were asked to remove their shoes. One measurement was taken, with the participant stretching to the maximum height. Weight was measured using Tanita electronic scales with a digital display (Tanita Corporation, Japan). Participants were asked to remove their shoes and any bulky clothing and a single measurement was recorded to the nearest 100g. .[7] Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class (of the household reference person) was determined by asking questions on participants' occupation and using the Registrar General's classification to grouped them as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Equivalised household income was grouped into quintiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD), a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. Consistent with previous epidemiological SB studies [22], the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero minutely counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Participants with at least one day of valid wear were included in these analyses. [22]

Self-reported sedentary time was assessed using a set of questions on the usual week/weekend day in the last four weeks prior to the interview time spent on: a) TV (including DVDs and videos) viewing; and b) any other sitting during non-work times, including reading and computer use. For those participants who were economically active another set of questions assessed the average daily times spent sitting or standing while at work [17]. While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as accelerometers are unable to differentiate between time spent sitting or standing. Like previously [17] for the purposes of this study standing will be considered a measure of sedentary behaviour.

Physical activity questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose, domestic physical activity [12 23], and any recreational sports and exercise including cycling for any purpose [24]. Both the physical activity and the SB questions have been validated against accelerometry.[25]

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods [12], we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high end of

the score, the top SEP score was collapsed into five categories of comparable sample size: SEP1 consisted of the lowest two SEP categories (0 and 1), SEP2 comprised categories 2 and 3, SEP3 comprised categories 4 and 5, SEP4 comprised categories 6 and 7, and SEP5 comprised of categories 8 and 9 (the highest observed SEP category).

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7. Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type [7 8] Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day. For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) [3] and ≥2,020 counts/minute to denote MVPA (>3 MET) [26]. Accelerometry-measured variables were converted to time (minutes) per valid day.

Missing data and multiple imputation

Outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses to improve normality. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with

observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2289 for accelerometry-measured ST, 2279 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Statistical analysis

Analyses were weighted for non-response to give a sample that was representative of adults living in England. The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometry-measured ST) were examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. We also repeated the SEP score analyses stratified by economic activity (employed/self-employed vs non-economically active). SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators (household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA or accelerometry-measured MVPA as appropriate, and average

accelerometer wear time on valid days. Models 2 and 3 with accelerometry-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. This work conforms with the STROBE statement for observational studies. [27]

Results

Descriptives

2289 adults (1030 males) provided valid accelerometry data, with 2279 (1020 males) and 2253 (1014 males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time. Table 1 presents the sample characteristics of the accelerometry sample by SEP score group (prior to MI) with casewise deletion of missing values (N=1651). In total 628 participants in the accelerometry sample had at least one covariate imputed. The variables with the most imputed values were household income (361 imputed) and BMI (233 imputed). Participants from lower SEP groups were more likely to be female, older, have a higher BMI, spend less time sedentary overall and sitting at work, but spend more time watching TV than individuals in higher SEP groups. Lower SEP individuals were also more likely to report a limiting longstanding illness and difficulties with usual daily activities, and be a current cigarette smoker, but less likely to be a heavy drinker and meet physical activity guidelines. The mean wear time on valid days was 831 minutes. The mean number of valid days (for those with at least 1 valid day) was 6.0 days.

Table 1: Sample Characteristics by Socioeconomic Position Score

	SEP Score Group			
	1 (lowest) & 2 (N=521)*	3 (N=355)*	4 & 5 (highest) (N=775)*	
Categorical variables[a]	%	%	%	*p*
Sex (% male)	40.1	47.0	50.5	0.001
Limiting longstanding illness (%)	32.8	24.5	16.8	<0.001
Adherence to the physical activity guidelines (self-reported data) (%)	32.6	43.9	49.6	<0.001
Difficulty in performing usual activities (%)	21.5	14.9	7.8	<0.001
Car or van available (%)	73.9	89.9	94.7	<0.001
Drinking frequency (% ≥5 times /week)	15.9	23.1	24.9	<0.001
Smoking (% current)	27.1	23.9	15.5	<0.001
Employment status (% employed/self-employed)	35.2	64.8	76.3	<0.001
Continuous variables[b]	M (SD)	M (SD)	M (SD)	*P*
Age (years)	56.1 (18.5)	50.4 (16.6)	46.9 (15.9)	<0.001
BMI (kg/m^2)	28.0 (4.9)	27.4 (4.9)	26.8 (4.5)	<0.001
Sedentary time (accelerometry data) (Minutes/day))	505.6 (97.7)	499.4 (90.7)	528.7 (87.2)	<0.001
TV (Minutes/day)	218.6 (117.3)	175.8 (97.7)	145.0 (74.7)	<0.001
Non-TV sitting time (Minutes/day)	128.1 (86.4)	121.5 (90.6)	133.2 (86.3)	0.110
Occupational sitting/standing time (Minutes/day)	151.8 (116.5)	173.5 (120.9)	198.1 (121.9)	<0.001
MVPA time per day (accelerometry data) (Minutes/day)	24.7 (24.1)	29.7 (26.3)	32.0 (25.1)	<0.001

* Occupational sitting time SEP 1 N=152 SEP 2 N=214; SEP 3 N=549 for SEP 4 & 5

[a] Chi Square was used to test significance of association between categorical variables and social class

[b] Anova was used to test significance of association between continuous variables and social class

Composite Socioeconomic position and sedentary time

Figure 1 presents the GLM estimated marginal means and their 95% CIs describing the associations between composite SEP score and each measure of ST. SEP was positively associated with accelerometry-measured ST and occupational sitting/standing time, and inversely associated with TV time in all models. There were no associations between SEP and non-TV sitting time. Adjustments for potential confounders made no material difference to all above associations. Figure 2 presents associations between SEP score and accelerometry-measured ST, stratified by employment status. SEP score was positively associated with accelerometry-measured ST for those in employment only. SEP was inversely associated with TV time regardless of employment status, while non-TV leisure-time sitting was positively associated with SEP (SEP1 coefficient 134, 95% CI 125 to 145; SEP5 coefficient 177, 155 to 198), but only for those not in employment. However this association was not linear (data not shown).

Equivalised Household income and sedentary time

Figure 3 presents associations between household income and each measure of ST. Household income was positively associated with accelerometer-measured ST and occupational sitting time and these associations persisted following adjustments for MVPA and other confounders. Like with SEP score, household income was inversely associated with TV time, although this association was attenuated to the null following adjustments for potential confounders in models 2 and 3. Household income was not associated with non-TV sitting time.

Educational attainment and sedentary time

Figure 4 presents the associations between the highest educational qualification and each measure of ST. Educational attainment was positively associated with accelerometry-measured ST and inversely associated with TV time in all models. Occupational sitting/standing time was inversely associated with education but the association did not appear to be linear (it was evident across the lowest three educational levels only) and was attenuated to the null following adjustments for potential confounders. There was a weak positive association between education and non-TV sitting time, following adjustments for potential confounders in models 2 and 3.

Occupational social class and sedentary time

As shown in Figure 5, occupational social class was positively associated with accelerometry-measured ST and occupational sitting/standing. The initial inverse association with TV time (model 1) was attenuated to the null following adjustments for potential confounders. Similarly to SEP score and income, social class was not associated with non-TV sitting time.

Area deprivation and sedentary time

Area-level deprivation was positively associated with TV time (the lower the deprivation the lower the TV time) but these associations did not persist in the adjusted models (Figure 6). Area deprivation was not associated with any other measures of ST (Figure 6).

Differential associations between imputed and non-imputed data

There were no differences between the imputed and non-imputed models describing the associations between SEP score and ST indicators, although the 95% confidence intervals were slightly broader in the unimputed models due to the lower sample size (see supplementary Figure S2).

Differential associations in weekday Vs weekend days

There was no consistent pattern of differences in the associations of SEP and ST by weekend vs weekday (see supplementary Figures S3 and S4), time of the week-specific results showed broadly the same pattern as the whole week. The only notable difference was that a direct association between SEP and non-TV sitting time was observed on weekend days, but not on weekdays.

Discussion

Literature on the socio-economic gradient of sedentary behaviour is very limited and has relied on partial sedentary behaviour indicators, mostly TV viewing. To our knowledge, this study is the only one that considers four indicators of socioeconomic position in relation to four indicators of sedentary behaviour, allowing a much more in-depth examination of the associations of interest than in previous studies. Our study suggests that occupational ST is what drives the positive association between overall SEP and total ST as there was no association among those not in employment (Figure 2). The difference between the lowest and highest SEP groups (Figure 1) is in the region of 60-70 minutes per day for both total accelerometry-measured sedentary time and occupational sitting/standing time and this is comparable with the difference between the extreme SEP group among the economically active part of the sample (~90 minutes/day). Our findings agree with an Australian study [19] which found that among women, full-time work, skilled occupations, and university education were all associated with high (self-reported) total sitting time. Our study also found that the inverse association between TV time and SEP was significant regardless of employment status. In a study of Dutch workers, sitting time at work varied considerably by type of occupation but not sitting during leisure time [28].

Previous studies of adults in Belgium [13] and Australia [14 15 29] have reported inverse associations between SEP indicators and TV time. We observed the same TV time pattern with SEP score and education but not with occupational class, household income or area deprivation. Although the occupational class and household income data were suggestive of a weak association with TV time, our current results somehow contradict our study in Scottish adults,[12] where all SEP indicators (occupational class, household income or area deprivation) as well as the composite SEP score were associated with recreational screen time (including TV time). Explanations for this might be that the Scottish study was three times larger in size (which might have made it easier for data patterns to emerge) and the inclusion of non-TV screen time as an outcome, although studies from other countries suggest no clear pattern between non-TV recreational screen time (e.g. computer use) and SEP [30 15]. Nevertheless, both our English and the Scottish studies demonstrate that when education, occupational social class and income are combined into a single measure (SEP score) they are a much more powerful predictor of sedentary time than any single indicator, perhaps because they collectively capture actual socioeconomic position more thoroughly than any single indicator. Composite SEP score showed a clear and consistent pattern with all ST outcomes, although each of the individual/household-level SEP indicators seemed to influence each ST outcome in various ways, suggesting there are complex, interacting, multi-dimensional influences of SEP on ST. Accelerometry-measured ST was the only sedentary behaviour variable that showed clear and consistent (positive) associations with all SEP variables (except from area-level deprivation). Although the cross-sectional design of this study precludes causal inferences, the pattern of the accelerometry-based associations we observed suggests that it is unlikely that total sedentary behaviour contributes to the well-documented socioeconomic inequalities in health. [11]

Strengths of our study include the availability of both objectively-measured and self-reported indicators of sedentary behaviour which allowed us to be more thorough and detailed when examining the associations of interest. Accelerometers can capture total sedentary time more comprehensively than any partial self-reported indicator and as such are able to better quantify the socioeconomic gradient of ST as a contributor to health inequalities, however a limitation is that accelerometers do not distinguish between sitting and standing which have different health implications, this also applies to occupational sitting/standing time. It has been argued that standing should not be considered a sedentary behaviour [31]. This limitation is also pertinent to the self-reported ST assessment as standing time was included in the occupational ST question. Taken together, these limitations of the measurements may, to some extent, have confounded the associations of SEP with total and occupational ST we reported. Another limitation is that our study was limited to the accelerometry sample of HSE 2008 and this might have led to our sample being less representative of the target population. Although those in the subsample offered the accelerometer were older and more likely to be retired and to be less healthy than the rest of the adult Health Survey for England sample, those who refused to wear an accelerometer were similar in terms of employment status and area-level deprivation compared to those who wore the accelerometers for at least four days a week[32]. Higher SEP is linked to higher commuting by car [33] and this may partly explain the socioeconomic gradient but our data are limited in that there was no specific question on commuting-related sitting to examine this explanation.

Conclusions

Objectively-measured total sedentary time and occupational sedentary time are higher among economically active English adults in higher socioeconomic groups compared to less

privileged groups. However, TV viewing is lower in higher socioeconomic groups regardless of economic activity. Combining different socioeconomic indicators appears to have composite power as a predictor of sedentary time.

Funding: This work was funded by the National Institute for Health Research through a Career Development Fellowship (ES). NC is also funded by the National Institute for Health Research through the same source. The views expressed in this article are those of the authors and not the English Department of Health or the National Institute for Health Research.

Data Sharing: No additional data are available

Competing interests: None of the authors have any competing interests to declare

Authors' Contributions: All authors have contributed sufficiently, ES conceived the idea, prepared the dataset, drafted most of the manuscript and revised the manuscript several times. NC did the statistical analysis under the supervision of ES and prepared the Tables, Figures and Supplemental Online material. AR processed the accelerometry files. NS, MH and AR redrafted parts of the manuscript and critically evaluated the whole material. All authors approved the final version before submission.

References

1. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exercise and Sport Sciences Reviews 2008;**36**(4):173-78.
2. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
3. Matthews C, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 2012;**95**(2):437-45.
4. Patel AV, Bernstein L, Deka A, et al. Leisure Time Spent Sitting in Relation to Total Mortality in a Prospective Cohort of US Adults. Am J Epidemiol 2010;**172**(4):419-29.
5. van der Ploeg HP, Chey T, Korda RJ, et al. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. Arch Intern Med 2012;**172**(6):494-500.
6. Grøntved A, Hu FB. Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality. JAMA 2011;**305**(23):2448-55.
7. Joint Health Surveys Unit. The Health Survey for England 2008. Volume 1 Leeds, 2010:21-206.
8. Joint Health Surveys Unit. The Health Survey for England 2008, Volume 2. Leeds: , 2010:11.
9. Marmot MG, Shipley MJ, Hemingway H, et al. Biological and behavioural explanations of social inequalities in coronary heart disease: Whitehall II Study. Diabetologia 2008;**51**(11):1980-88.
10. Williams ED, Tapp RJ, Magliano DJ, et al. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia 2010;**53**:2538-45.
11. Stringhini S, Sabia S, Shipley M, et al. Association of Socioeconomic Position With Health Behaviors and Mortality. JAMA 2010;**303**(12):1159-66.
12. Stamatakis E, Hillsdon M, Mishra G, et al. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. Journal of epidemiology and community health 2009;**63**(9):734-40.
13. Van Dyck D, Cardon G, Deforche B, et al. Socio-demographic, psychosocial and home-environmental attributes associated with adults' domestic screen time. BMC Public Health 2011;**11**:668.
14. Teychenne M, Ball K, Salmon J. Correlates of socio-economic inequalities in women's television viewing: a study of intrapersonal, social and environmental mediators. Int J Behav Nutr Phy Act 2012;**9**:3.
15. Burton NW, Haynes M, van Uffelen JGZ, et al. Mid-Aged Adults' Sitting Time in Three Contexts. Am J Prev Med 2012;**42**(4):363-73.
16. Bowman SA. Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Preventing Chronic Disease 2006;**3**(2).
17. Stamatakis E, Hamer M, Tilling K, et al. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. Int J Epidemiol 2012;**41**:1328-37.
18. Clark BK, Healy GN, Winkler EAH, et al. Relationship of Television Time with Accelerometer-Derived Sedentary Time: NHANES Med Sci Sports Exerc 2011;**43**(5):822-28.
19. van Uffelen JGZ, Heesch KC, Brown W. Correlates of Sitting Time in Working Age Australian Women: Who Should Be Targeted With Interventions to Decrease Sitting Time? J Phys Act Health 2012;**9**(2):270-87.
20. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a portuguese sample of men: Results from the azorean physical activity and health study (APAHS). Int J Environ Res Publ Health 2010;**7**(4):1500-07.
21. Duncan MJ, HBadland HM, Mummery WK. Physical Activity Levels by Occupational Category in Non-Metropolitan Australian Adults. J Phys Act Health 2010;**7**(6):718-23.

22. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. Am J Epidemiol 2008;**167**(7):875-81.
23. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . Prev Med 2007;**45**:416-23.
24. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey Br J Sports Med 2008;**42**:601-08.
25. Scholes S, Coombs N, Pedisic Z, et al. Age- and sex-specific criterion validity of the health survey for England physical activity and sedentary behavior assessment questionnaire as compared with accelerometry. Am J Epidemiol 2014;**179**(12):1493-502.
26. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;**40**(1):181-8.
27. Gallo V, Egger M, McCormack V, et al. STrengthening the Reporting of OBservational studies in Epidemiology--Molecular Epidemiology (STROBE-ME): an extension of the STROBE Statement. PLoS medicine 2011;**8**(10):e1001117.
28. Jans M, Proper K, Hildebrandt V. Sedentary Behavior in Dutch Workers: Differences between Occupations and Business Sectors. Am J Prev Med 2007;**33**:450-54.
29. Stamatakis E, Grunseit AC, Coombs N, et al. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: The Social, Economic, and Environmental Factor (SEEF) Study. Prev Med 2014;**63c**:72-80.
30. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior A Systematic Review. Am J Prev Med 2012;**42**(3):E3-E28.
31. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Research and Clinical Practice 2011;**93**(2):292-94.
32. Roth M, Mindell J. Who provides accelerometry data? Correlates of adherence to wearing an accelerometry motion sensor: the 2008 health survey for England. J Phys Act Health 2013;**10**(1):70-78.
33. Goodman A, Guell C, Panter J, et al. Healthy travel and the socio-economic structure of car commuting in Cambridge, UK: A mixed-methods analysis. Social Science & Medicine 2012;**74**(12):1929-38.

Figure Legends and footnotes

Figure 1: Multivariate-adjusted average daily sedentary time by SEP score

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates lowest income quartile (<=£13876),Q4 indicates the highest income quartile (>=£39001).

Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average

accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Education Level 1 represents NVQ1/CSE and NVQ2 GCE O Level equivalent; Level 2 represents NVQ3/GCE A Level equivalent; Level 3 represents higher education below Degree and NVQ4/NVQ5/Degree or higher.

Figure 5: Multivariate-adjusted average daily sedentary time[a] by occupational social class.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

Figure 6: Multivariate-adjusted sedentary time by area deprivation quintile.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates most deprived, Q5 indicates least deprived

Title: Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Running title: Sedentary time and socioeconomic status

Authors: Emmanuel Stamatakis[1 2 3], Ngaire Coombs[3 4], Alex Rowlands[5], Nicola Shelton[3], Melvyn Hillsdon[6].

~~[1]~~[2][1]Charles Perkins Centre, University of Sydney, Australia

~~[1]~~[2] Discipline of Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

~~[2]Charles Perkins Centre, University of Sydney, Australia~~

[3]PARG (Physical Activity Research Group), Department of Epidemiology and Public Health, University College London, London, UK

[4]Department of Social Sciences, University of Southampton, UK

[5] Division of Health Sciences, University of South Australia, Australia

[6] Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, UK

Correspondence: Emmanuel Stamatakis, Charles Perkins Centre, University of Sydney , Johns Hopkins Drive, Sydney, NSW 2050, Australia. Email: emmanuel.stamatakis@sydney.edu.au, Telephone: +61 293519668.

Wordcount:

Abstract: ~~242~~ 245 words

Main text: ~~3455~~ 3693 words

Abstract

Objectives: To examine the associations between socioeconomic position (SEP) and multi-domain self-reported and objectively-assessed sedentary time (ST)**. Design**: cross-sectional; **Setting**: general population households in England. **Participants**: 2289 adults aged 16-96 years~~and over~~ who participated in the 2008 Health Survey for England. **Outcomes**: accelerometer-measured sedentary time, and self-reported television time, non-television leisure-time sitting and occupational sitting/standing. We examined multivariable associations between household income, social class, education, area deprivation each SEP indicator (including a 5-point composite SEP score computed by aggregating individual SEP indicators) and each ST indicator using generalised linear models. **Results**: Accelerometry-measured total ST and occupational sitting/standing were positively associated with SEP score and most of its constituent SEP indicators, while television time was negatively associated with SEP score and education level. Area-level deprivation was largely unrelated to ST. Those in the lowest composite SEP group spent 64 (95% CIs: 52 to 76) and 72 (48 to 98), fewer minutes/day in total ST and occupational sitting/standing compared to those in the top SEP group, and an additional 48 (35 to 60) minutes/day watching television ($p<0.001$ for linear trend). Stratified analyses showed that these associations between composite SEP score and total ST were evident only among participants who were in employment. **Conclusions**: Occupational sitting seems to drive the positive association between socioeconomic position and total sedentary time. Lower socioeconomic position is linked to higher TV viewing times. ~~TV viewing, but not overall sedentary time, may be a contributor to socioeconomic inequalities in health in England.~~

Article summary

Strengths and limitations of this study:

- First study of its kind to use objective sedentary behaviour measurements
- Broad range of self-reported sedentary behaviour types
- Broad set of socioeconomic status markers including are-level deprivation
- ~~The~~ This is ~~main limitation is the~~a cross-sectional design
- The occupational sedentary time question and accelerometry cannot differentiate between sitting and standing

Keywords

Socioeconomic status; television; sedentary ~~behavior~~behaviour; inequality; physical activity; accelerometer;

Introduction

Recent studies show that sedentary time (defined as an energy expenditure rate below 1.5 metabolic equivalents[1], often characterised by activities involving sitting) is linked to increased all-cause [2-5] and cardiovascular [2 3] mortality risk independently of leisure-time physical activity participation. Television viewing, one of the most common sedentary time (ST) activities, has been specifically linked to all-cause and cardiovascular mortality and type 2 diabetes [6]. Objective data show that adults in England spend approximately nine to 10 hours a day being sedentary on average, out of which approximately 4 hours/day is TV watching [7 8] . Assuming that the average waking day lasts for 16 hrs, total sedentary time accounts for some 55-65% of total waking time. For working age adults a substantial proportion of total sedentary time takes place while at work, 56% of working English men and 50% of women report more than 5 hrs /day being sedentary while at work [7].

Socioeconomic position (SEP) is a broad term that encompasses a range of characteristics, including occupational type and employment status, purchasing capacity and ownership, educational level and deprivation. Accordingly, there are several SEP indices each of which measures different aspects of social standing. Overall, SEP is a strong predictor of premature mortality and chronic disease occurrence including cardiovascular disease (CVD) [9] and diabetes [10] with individuals in lower SEP being considerably more likely to fall ill and die prematurely. Although there is no consensus on the origins of the socioeconomic gradient in health, one of the suggested pathways involves higher prevalence of poor health ~~behavior~~behaviours (e.g. physical inactivity and smoking) among lower socioeconomic groups [11] .

We have previously shown that lower SEP is linked consistently with increased TV viewing and other recreational screen time in Scottish adults [12], a finding that has been confirmed by

studies in other countries such as Belgium [12 13], Australia [14 15], and the US [16] that used TV as a proxy for ST. However, these findings are not necessarily generalizable to overall sedentary or sitting time because TV viewing is a complex exposure that seems to be a poor index of overall ST [17]. In a recent study comparing associations between TV time and objectively measured sedentary time, associations were of fair magnitude, but were not consistent across population sub-groups [18]. The results of the few studies that looked at overall (self-reported) sitting in relation to SEP are inconsistent. Higher social position was linked to higher overall sitting time among Australian women [19] but education level was unrelated to sitting time among Portuguese adults [20]. Objective measuring methodologies such as accelerometers and inclinometers can give more comprehensive and complete estimates of total sedentary ~~behavior~~behaviour than partial self-reported indices such as TV viewing, or self-reported total sitting time, which may be more difficult to recall than TV viewing and therefore be subject to more measurement error. Besides, SEP characteristics that relate to occupational class and income will naturally have an impact on work time sitting. For example, manual unskilled workers normally spend less time sitting during work than professionals in managerial office-based jobs [21]. Similarly, higher incomes and the associated spending capacity might impact on the time spent sitting driving a car or commuting. To our knowledge, no study has looked at the associations between SEP defined using education, occupational class, income and area deprivation indices, and SB estimated using self-reported sitting across different domains as well as objective methods.

The aim of this study was to look at the associations between multiple SEP indicators and self-reported indices of sitting time and SB as well as objectively-assessed total SB time. We used data from one of the largest European accelerometry general population studies, the 2008 Health Survey for England.

Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary ~~behavior~~behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere [8]. The overall interview household response rate for the main sample of 15,102 adults was 64% ~~for the main sample~~, and for the accelerometer sub-sample of 4,507 adults was 73% ~~for the accelerometer sub-sample~~ [8]. ~~We~~In this analysis ~~We~~ we included adults aged 16 and over (age range 16-96 years) who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. An abridged methods section is presented here: the full methods section with more information can be found in supplementary file S1 (Unabridged Methods). Ethical approval was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102).

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height was measured using a standard stadiometer with a sliding head plate, a base plate and three connecting rods marked with a metric measuring scale. Participants were asked to remove their shoes. One measurement was taken, with the participant stretching to the maximum height. Weight was measured using Tanita electronic scales with a digital display (Tanita Corporation, Japan). Participants were asked to remove their shoes and any bulky clothing and a single measurement was recorded to the nearest 100g. ~~Height and weight were~~

measured by the same fieldworkers using standard protocols that have been described in detail elsewhere.[7] . Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class (of the household reference person) was determined by asking questions on participants' occupation and using the Registrar General's classification and was to grouped them as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Equivalised household income was grouped into quintiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD), a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. Consistent with previous epidemiological SB studies [22], the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero minutely counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have

worn the accelerometer for a minimum of 600 minutes. Participants with at least one day of valid wear were included in these analyses. [22]

~~SR~~ Self-reported~~S~~ sedentary time was assessed using a set of questions on the usual week/weekend day ~~time~~ in the last four weeks prior to the interview time spent on: a) TV (including DVDs and videos) viewing; and b) any other sitting during non-work times, including reading and computer use. For those participants who were economically active another set of questions assessed the average daily times spent sitting or standing while at work [17]. While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as accelerometers are unable to differentiate between time spent sitting or standing. Like previously [17] for the purposes of this study standing will be considered a measure of sedentary ~~behavior~~behaviour.

Physical activity questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose, domestic physical activity [12 23], and any recreational sports and exercise including cycling for any purpose [24]. Both the physical activity and the SB questions have been validated against accelerometry.[25]

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods [12], we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, with the highest category given a

SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high end of the score, the top SEP score was collapsed into five categories of comparable sample size: SEP1 consisted of the lowest two SEP categories (0 and 1), SEP2 comprised categories 2 and 3, SEP3 comprised categories 4 and 5, SEP4 comprised categories 6 and 7, and SEP5 comprised of categories 8 and 9 (the highest observed SEP category).

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7. Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type [7 8] Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day. For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) [3] and ≥2,020 counts/minute to denote MVPA (>3 MET) [26]. Accelerometry-measured variables were converted to time (minutes) per valid day.

Missing data and multiple imputation

Outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses to improve normality. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the

exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2289 for accelerometry-measured ST, 2279 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Statistical analysis

Analyses were weighted for non-response to give a sample that was representative of adults living in England. The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometry-measured ST) were examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. We also repeated the SEP score analyses stratified by economic activity (employed/self-employed vs non-economically active). SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators

(household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA or accelerometry-measured MVPA as appropriate, and average accelerometer wear time on valid days. Models 2 and 3 with accelerometry-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. This work conforms with the STROBE statement for observational studies. [27]

Results

Descriptives

2289 adults (1030 males) provided valid accelerometry data, with 22767~~8~~9 (1020 males)~~2279~~ and 2253 (1014~~)~~ males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time. Table 1 presents the sample characteristics of the accelerometry sample by SEP score group (prior to MI) with casewise deletion of missing values (N=1651). In total 628 participants in the accelerometry sample had at least one covariate imputed. The variables with the most imputed values were household income (361 imputed) and BMI (233 imputed). Participants from lower SEP groups were more likely to be female, older, have a higher BMI, spend less time sedentary overall and sitting at work, but spend more time watching TV than individuals in higher SEP groups. Lower SEP individuals were also more likely to report a limiting longstanding illness and difficulties with usual daily activities, and be a current cigarette smoker, but less likely to be a heavy drinker and meet physical activity guidelines. The mean wear time on valid days was 831 minutes. The mean number of valid days (for those with at least 1 valid day) was 6.0 days.

Table 1: Sample Characteristics by Socioeconomic Position Score

	SEP Score Group			
	1 (lowest) & 2 (N=521)*	3 (N=355)*	4 & 5 (highest) (N=775)*	
Categorical variables[a]	%	%	%	*p*
Sex (% male)	40.1	47.0	50.5	0.001
Limiting longstanding illness (%)	32.8	24.5	16.8	<0.001
Adherence to the physical activity guidelines (self-reported data) (%)	32.6	43.9	49.6	<0.001
Difficulty in performing usual activities (%)	21.5	14.9	7.8	<0.001
Car or van available (%)	73.9	89.9	94.7	<0.001
Drinking frequency (% ≥5 times /week)	15.9	23.1	24.9	<0.001
Smoking (% current)	27.1	23.9	15.5	<0.001
Employment status (% employed/self-employed)	35.2	64.8	76.3	<0.001
Continuous variables[b]	M (SD)	M (SD)	M (SD)	*P*
Age (years)	56.1 (18.5)	50.4 (16.6)	46.9 (15.9)	<0.001
BMI (kg/m^2)	28.0 (4.9)	27.4 (4.9)	26.8 (4.5)	<0.001
Sedentary time (accelerometry data) (Minutes/day))	505.6 (97.7)	499.4 (90.7)	528.7 (87.2)	<0.001
TV (Minutes/day)	218.6 (117.3)	175.8 (97.7)	145.0 (74.7)	<0.001
Non-TV sitting time (Minutes/day)	128.1 (86.4)	121.5 (90.6)	133.2 (86.3)	0.110
Occupational sitting/standing time (Minutes/day)	151.8 (116.5)	173.5 (120.9)	198.1 (121.9)	<0.001
MVPA time per day (accelerometry data) (Minutes/day)	24.7 (24.1)	29.7 (26.3)	32.0 (25.1)	<0.001

* Occupational sitting time SEP 1 N=152 SEP 2 N=214; SEP 3 N=549 for SEP 4 & 5

[a] Chi Square was used to test significance of association between categorical variables and social class

[b] Anova was used to test significance of association between continuous variables and social class

Composite Socioeconomic position and sedentary time

Figure 1 presents the GLM estimated marginal means and their 95% CIs describing the associations between composite SEP score and each measure of ST. SEP was positively associated with accelerometry-measured ST and occupational sitting/standing time, and inversely associated with TV time in all models. There were no associations between SEP and non-TV sitting time. Adjustments for potential confounders made no material difference to all above associations. Figure 2 presents associations between SEP score and accelerometry-measured ST, stratified by employment status. SEP score was positively associated with accelerometry-measured ST for those in employment only. SEP was inversely associated with TV time regardless of employment status, while non-TV leisure-time sitting was positively associated with SEP (SEP1 coefficient 134, 95% CI 125 to 145; SEP5 coefficient 177, 155 to 198), but only for those not in employment. However this association was not linear (data not shown).

Equivalised Household income and sedentary time

Figure 3 presents associations between household income and each measure of ST. Household income was positively associated with accelerometer-measured ST and occupational sitting time and these associations persisted following adjustments for MVPA and other confounders. Like with SEP score, household income was inversely associated with TV time, although this association was attenuated to the null following adjustments for potential confounders in models 2 and 3. Household income was not associated with non-TV sitting time.

Educational attainment and sedentary time

Figure 4 presents the associations between the highest educational qualification and each measure of ST. Educational attainment was positively associated with accelerometry-measured ST and inversely associated with TV time in all models. Occupational sitting/standing time was inversely associated with education but the association did not appear to be linear (it was evident across the lowest three educational levels only) and was attenuated to the null following adjustments for potential confounders. There was a weak positive association between education and non-TV sitting time, following adjustments for potential confounders in models 2 and 3.

Occupational social class and sedentary time

As shown in Figure 5, occupational social class was positively associated with accelerometry-measured ST and occupational sitting/standing. The initial inverse association with TV time (model 1) was attenuated to the null following adjustments for potential confounders. Similarly to SEP score and income, social class was not associated with non-TV sitting time.

Area deprivation and sedentary time

Area-level deprivation was positively associated with TV time (the lower the deprivation the lower the TV time) but these associations did not persist in the adjusted models (Figure 6). Area deprivation was not associated with any other measures of ST (Figure 6).

Differential associations between imputed and non-imputed data

There were no differences between the imputed and non-imputed models describing the associations between SEP score and ST indicators, although the 95% confidence intervals were slightly broader in the unimputed models due to the lower sample size (see supplementary Figure S2).

Differential associations in weekday Vs weekend days

There was no consistent pattern of differences in the associations of SEP and ST by weekend vs weekday (see supplementary Figures S3 and S4), time of the week-specific results showed broadly the same pattern as the whole week. The only notable difference was that a direct association between SEP and non-TV sitting time was observed on weekend days, but not on weekdays.

Discussion

Literature on the socio-economic gradient of sedentary ~~behavior~~behaviour is very limited and has relied on partial sedentary ~~behavior~~behaviour indicators, mostly TV viewing. To our knowledge, this study is the only one that considers four indicators of socioeconomic position in relation to four indicators of sedentary ~~behavior~~behaviour, allowing a much more in-depth examination of the associations of interest than in previous studies. Our study suggests that occupational ST is what drives the positive association between overall SEP and total ST as there was no association among those not in employment (Figure 2). The difference between the lowest and highest SEP groups (Figure 1) is in the region of 60-70 minutes per day for both total accelerometry-measured sedentary time and occupational sitting/standing time and this is comparable with the difference between the extreme SEP group among the economically active part of the sample (~90 minutes/day). Our findings agree with an Australian study [19] which found that among women, full-time work, skilled occupations, and university education were all associated with high (self-reported) total sitting time. Our study also found that the inverse association between TV time and SEP was significant regardless of employment status. In a study of Dutch workers, sitting time at work varied considerably by type of occupation but not sitting during leisure time [28].

Previous studies of adults in Belgium [13] and Australia [14 15 29] have reported inverse associations between SEP indicators and TV time. We observed the same TV time pattern with SEP score and education but not with occupational class, household income or area deprivation. Although the occupational class and household income data were suggestive of a weak association with TV time, our current results somehow contradict our study in Scottish adults,[12] where all SEP indicators (occupational class, household income or area deprivation) as well as the composite SEP score were associated with recreational screen time (including TV time). Explanations for this might be that the Scottish study was three times larger in size (which might have made it easier for data patterns to emerge) and the inclusion of non-TV screen time as an outcome, although studies from other countries suggest no clear pattern between non-TV recreational screen time (e.g. computer use) and SEP [30 15]. Nevertheless, both our English and the Scottish studies demonstrate that when education, occupational social class and income are combined into a single measure (SEP score) they are a much more powerful predictor of sedentary time than any single indicator, perhaps because they collectively capture actual socioeconomic position more thoroughly than any single indicator. Composite SEP score showed a clear and consistent pattern with all ST outcomes, although each of the individual/household-level SEP indicators seemed to influence each ST outcome in various ways, suggesting there are complex, interacting, multi-dimensional influences of SEP on ST. Accelerometry-measured ST was the only sedentary ~~behavior~~behaviour variable that showed clear and consistent (positive) associations with all SEP variables (except from area-level deprivation). Although the cross-sectional design of this study precludes causal inferences, the pattern of the accelerometry-based associations we observed suggests that it is unlikely that total sedentary ~~behavior~~behaviour contributes to the well-documented[11] socioeconomic inequalities in health.[11]

Strengths of our study include the availability of both objectively-measured and self-reported indicators of sedentary ~~behavior~~behaviour which allowed us to be more thorough and detailed when examining the associations of interest. Accelerometers can capture total sedentary time more comprehensively than any partial self-reported indicator and as such are able to better quantify the socioeconomic gradient of ST as a contributor to health inequalities, however a limitation is that accelerometers do not distinguish between sitting and standing which have different health implications, this also applies to occupational sitting/standing time. It has been argued that standing should not be considered a sedentary ~~behavior~~behaviour [31]. This limitation is also pertinent to the self-reported ST assessment as standing time was included in the occupational ST question. Taken together, these limitations of the measurements may, to some extent, have confounded the associations of SEP with total and occupational ST we reported. Another limitation is that our study was limited to the accelerometry sample of HSE 2008 and this might have led to our sample being less representative of the target population. Although those in the subsample offered the accelerometer were older and more likely to be retired and to be less healthy than the rest of the adult Health Survey for England sample, those who refused to wear an accelerometer were similar in terms of employment status and area-level deprivation compared to those who wore the accelerometers for at least four days a week[32]. Higher SEP is linked to higher commuting by car [33] and this may partly explain the socioeconomic gradient but our data are limited in that there was no specific question on commuting-related sitting to examine this explanation.

Conclusions

Objectively-measured total sedentary time and occupational sedentary time are higher among economically active English adults in higher socioeconomic groups compared to less

privileged groups. However, TV viewing is lower in higher socioeconomic groups regardless of economic activity. Combining different socioeconomic indicators appears to have composite power as a predictor of sedentary time. ~~Although the cross-sectional design of this study precludes causal inferences, the pattern of the associations we observed suggests that it is unlikely that total sedentary behavior contributes to socioeconomic inequalities in health.~~

Funding: This work was funded by the National Institute for Health Research through a Career Development Fellowship (ES). NC is also funded by the National Institute for Health Research through the same source. The views expressed in this article are those of the authors and not the English Department of Health or the National Institute for Health Research.

Data Sharing: No additional data are available

Competing interests: None of the authors have any competing interests to declare

Authors' Contributions: All authors have contributed sufficiently, ES conceived the idea, prepared the dataset, drafted most of the manuscript and revised the manuscript several times. NC did the statistical analysis under the supervision of ES and prepared the Tables, Figures and Supplemental Online material. AR processed the accelerometry files. NS, MH and AR redrafted parts of the manuscript and critically evaluated the whole material. All authors approved the final version before submission.

References

1. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exercise and Sport Sciences Reviews 2008;**36**(4):173-78.
2. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
3. Matthews C, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 2012;**95**(2):437-45.
4. Patel AV, Bernstein L, Deka A, et al. Leisure Time Spent Sitting in Relation to Total Mortality in a Prospective Cohort of US Adults. Am J Epidemiol 2010;**172**(4):419-29.
5. van der Ploeg HP, Chey T, Korda RJ, et al. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. Arch Intern Med 2012;**172**(6):494-500.
6. Grøntved A, Hu FB. Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality. JAMA 2011;**305**(23):2448-55.
7. Joint Health Surveys Unit. The Health Survey for England 2008. Volume 1 Leeds, 2010:21-206.
8. Joint Health Surveys Unit. The Health Survey for England 2008, Volume 2. Leeds: , 2010:11.
9. Marmot MG, Shipley MJ, Hemingway H, et al. Biological and behavioural explanations of social inequalities in coronary heart disease: Whitehall II Study. Diabetologia 2008;**51**(11):1980-88.
10. Williams ED, Tapp RJ, Magliano DJ, et al. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia 2010;**53**:2538-45.
11. Stringhini S, Sabia S, Shipley M, et al. Association of Socioeconomic Position With Health Behaviors and Mortality. JAMA 2010;**303**(12):1159-66.
12. Stamatakis E, Hillsdon M, Mishra G, et al. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. Journal of epidemiology and community health 2009;**63**(9):734-40.
13. Van Dyck D, Cardon G, Deforche B, et al. Socio-demographic, psychosocial and home-environmental attributes associated with adults' domestic screen time. BMC Public Health 2011;**11**:668.
14. Teychenne M, Ball K, Salmon J. Correlates of socio-economic inequalities in women's television viewing: a study of intrapersonal, social and environmental mediators. Int J Behav Nutr Phy Act 2012;**9**:3.
15. Burton NW, Haynes M, van Uffelen JGZ, et al. Mid-Aged Adults' Sitting Time in Three Contexts. Am J Prev Med 2012;**42**(4):363-73.
16. Bowman SA. Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Preventing Chronic Disease 2006;**3**(2).
17. Stamatakis E, Hamer M, Tilling K, et al. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. Int J Epidemiol 2012;**41**:1328-37.
18. Clark BK, Healy GN, Winkler EAH, et al. Relationship of Television Time with Accelerometer-Derived Sedentary Time: NHANES Med Sci Sports Exerc 2011;**43**(5):822-28.
19. van Uffelen JGZ, Heesch KC, Brown W. Correlates of Sitting Time in Working Age Australian Women: Who Should Be Targeted With Interventions to Decrease Sitting Time? J Phys Act Health 2012;**9**(2):270-87.
20. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a portuguese sample of men: Results from the azorean physical activity and health study (APAHS). Int J Environ Res Publ Health 2010;**7**(4):1500-07.
21. Duncan MJ, HBadland HM, Mummery WK. Physical Activity Levels by Occupational Category in Non-Metropolitan Australian Adults. J Phys Act Health 2010;**7**(6):718-23.

22. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. Am J Epidemiol 2008;**167**(7):875-81.
23. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . Prev Med 2007;**45**:416-23.
24. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey Br J Sports Med 2008;**42**:601-08.
25. Scholes S, Coombs N, Pedisic Z, et al. Age- and sex-specific criterion validity of the health survey for England physical activity and sedentary behavior assessment questionnaire as compared with accelerometry. Am J Epidemiol 2014;**179**(12):1493-502.
26. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;**40**(1):181-8.
27. Gallo V, Egger M, McCormack V, et al. STrengthening the Reporting of OBservational studies in Epidemiology--Molecular Epidemiology (STROBE-ME): an extension of the STROBE Statement. PLoS medicine 2011;**8**(10):e1001117.
28. Jans M, Proper K, Hildebrandt V. Sedentary Behavior in Dutch Workers: Differences between Occupations and Business Sectors. Am J Prev Med 2007;**33**:450-54.
29. Stamatakis E, Grunseit AC, Coombs N, et al. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: The Social, Economic, and Environmental Factor (SEEF) Study. Prev Med 2014;**63c**:72-80.
30. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior A Systematic Review. Am J Prev Med 2012;**42**(3):E3-E28.
31. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Research and Clinical Practice 2011;**93**(2):292-94.
32. Roth M, Mindell J. Who provides accelerometry data? Correlates of adherence to wearing an accelerometry motion sensor: the 2008 health survey for England. J Phys Act Health 2013;**10**(1):70-78.
33. Goodman A, Guell C, Panter J, et al. Healthy travel and the socio-economic structure of car commuting in Cambridge, UK: A mixed-methods analysis. Social Science & Medicine 2012;**74**(12):1929-38.

Figure Legends and footnotes

Figure 1: Multivariate-adjusted average daily sedentary time by SEP score

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates lowest income quartile (<=£13876),Q4 indicates the highest income quartile (>=£39001).

Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average

accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Education Level 1 represents NVQ1/CSE and NVQ2 GCE O Level equivalent; Level 2 represents NVQ3/GCE A Level equivalent; Level 3 represents higher education below Degree and NVQ4/NVQ5/Degree or higher.

Figure 5: Multivariate-adjusted average daily sedentary time[a] by occupational social class.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

Figure 6: Multivariate-adjusted sedentary time by area deprivation quintile.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates most deprived, Q5 indicates least deprived

Supplemental Digital Content 1

Unabridged Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere (2). The household response rate was 64% for the main sample, and 73% for the accelerometer sub-sample (3). Ethical approval for the 2008 HSE was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). We included adults aged 16 and over who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. In total, 2289 adults (1030 males) provided valid accelerometry data, with 227679 (1020 males) and 2253 (1014) males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height and weight were measured by the same fieldworkers using standard protocols that have been described in detail elsewhere (5). Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class was determined using the Registrar General's classification and was grouped as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and

unskilled manual). Household income was converted to equivalised annual household income that is adjusted for the number of persons in the household using the McClements scoring system (15). The income data presented here are based on quartiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD) which provides a measure of area deprivation with deprivation based on measures in seven domains: income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, crime and living environment. IMD was initially a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

Objective measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. At the core addresses that were eligible for accelerometry, up to two adults in total were selected to wear the accelerometer (up to one adult in those households with eligible children). Full details of the accelerometry sample selection procedure can be found elsewhere (6). At the end of the initial HSE 2008 interview, interviewers obtained agreement for participation in the accelerometry study, provided the accelerometers and explained procedures. The accelerometry data were processed using specialist software (KineSoft, New Brunswick). In consistency with previous epidemiological SB studies (8), the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero counts, with allowance for up to 2 consecutive minutes of 1–99 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Like previously (7), participants with at least one day

of valid wear were included in these analyses, although the majority (76%, N=1742) had between six and seven days and 95% (N=2165) had at least three valid days. All physical activity and sedentary time variables were converted to time (in minutes) per valid day.

Self-reported measures

Sedentary time was assessed using a set of questions on the usual weekday time spent on: a) TV (including DVDs and videos) viewing ("In the last four weeks, how much time did you spend watching TV/videos) on an average week day?"); and b) any other sitting during non-work times, including reading and computer use ("In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekday? Please do not include time spent doing these activities while at work"). An equivalent set of questions assessed TV and non-TV sedentary time in the weekend days. For those participants who were economically 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/standing while at work ("On an average work day in the last four weeks, how much time did you usually spend sitting down or standing up?"). (14) While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as most accelerometers are unable to differentiate between time spent sitting or standing. For the purposes of this study, standing will be considered a measure of sedentary behaviour.

Physical activity was assessed using the long version of the Health Survey for England 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, domestic physical activity (12) (11) and any recreational exercise, (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports, racket sports) (9). Occupational activity was measured as average daily (per day at work) times spent on

walking, climbing stairs or ladders, and lifting, carrying or moving loads (5). We calculated MVPA using established metabolic equivalent tables (1). The criterion validity of the physical activity questionnaire has been demonstrated in a study of 106 English adults from the general population (45 men) where the output of accelerometers (worn for two non-consecutive weeks over a month period) was compared against the above questions (4, 13).

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods (10), we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, the second lowest category was given a SEP score of 1, and so on, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high and low end of the score, the SEP score was collapsed into five categories of comparable size (0 -3=SEP1; 4- 5=SEP2; 6- 7=SEP3; 8=SEP4; 9- 12=SEP5), with 1 representing the lowest SEP, and 5 the highest.

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7.

Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type (walking, cycling, and each other sport and exercise the questionnaire enquired about) (5, 6) Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day.

For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) (7); 200-2,019 counts/minute to denote light physical activity; and ≥2,020 counts/minute to denote MVPA (>3 MET) (16). Accelerometer-measured sedentary time and physical activity variables were converted to time (in minutes) per valid day.

Missing data and multiple imputation

To improve the normality of the residuals that are required for linear regression, outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2279 for accelerometry-measured ST, 2269 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Dealing with non-response

Analyses were weighted for non-response (5) to give a sample that was representative of adults living in England. In brief, the non-response weights were calculated by fitting a logistic regression model (weighted by a previously developed weighting factor)(5) for all adults with interview completion as the outcome and age group by sex, household type, geographical area, and household social class as covariates. The non-response weights, which were trimmed at the 1% tails to remove extreme values, were calculated as the inverse of the predicted probabilities of response.(5) The complex samples module in SPSS was used to account for clusters in the survey design.

Statistical analysis

The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometer-measured ST) was examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design.

All statistical models were run for each combination of dependent variable and main exposure. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators (household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA and accelerometer-measured MVPA, and average accelerometer wear

time on valid days Models with accelerometer-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. There was no evidence of colinearity in the multivariate model as no variance inflation factor value was higher than approximately 1.5, with most values just over 1. Residual statistics and plots for each model were checked for normality, independence of observations, homoscedasticity, and influential outliers.

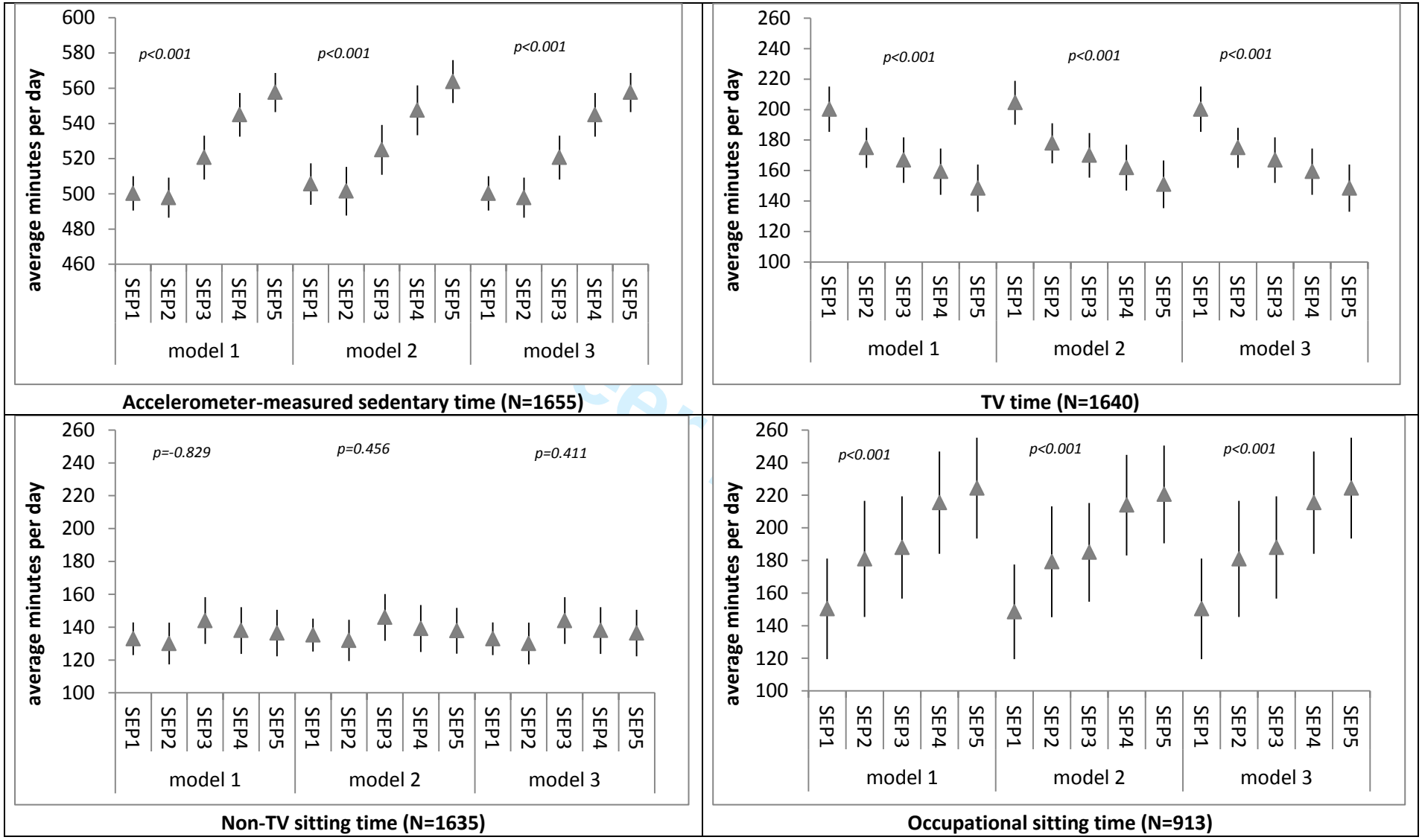
GLM coefficients indicate mean differences in sedentary time (in minutes) between the reference category and each of the other SEP categories. The lowest SEP category (<£10671 for household income, unskilled/ semi-skilled manual for social class, most deprived quintile for area deprivation, SEP1 (lowest socioeconomic position) for SEP score) is the reference category for the mean difference in the outcome (and associated confidence interval for the difference) in all CSGLMs.

References

1. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S498-504.
2. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 1* Leeds2010.
3. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 2* Leeds2010.
4. Joint Health Surveys Unit. *The Health Survey for England Physical Activity Validation Study: substantive report.* Leeds: Health and Social Care Information Centre; 2007.
5. Joint Health Surveys Unit. *The Health Survey for England 2008*. Leeds: The Information Centre for Health and Social Care; 2009.
6. Joint Health Surveys Unit. *The Health Survey for England 2008, Volume 2: Methods and Documentation*. Leeds: The Information Centre for Health and Social Care; 2009.
7. Matthews C, George SM, Moore SC et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *The American Journal of Clinical Nutrition*. 2012;95(2):437-45.
8. Matthews CE, Chen KY, Freedson PS et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. *Am J Epidemiol*. 2008;167(7):875-81.
9. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey *Br J Sports Med*. 2008;42:601-8.
10. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *J Epidemiol Commun Health*. 2009;63:734-40.
11. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . *Prev Med*. 2007;45:416-23.
12. Stamatakis E, Hamer M, Lawlor DA. Physical activity, mortality and cardiovascular disease: Is domestic physical activity beneficial? The Scottish Health Survey 1995, 1998 and 2003. . *Am J Epidemiol*. 2009;169:1191-200.

13. Stamatakis E, Hamer M, Primatesta P. Cardiovascular medication, physical activity and mortality: cross-sectional population study with ongoing mortality follow-up. *Heart*. 2009;95(6):448-53.
14. Stamatakis E, Hamer M, Tilling K, Lawlor DA. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. *Int J Epidemiol*. 2012.
15. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *Journal of Epidemiology and Community Health*. 2009;63(9):734-40.
16. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-8.

Supplementary Figure S2: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Unimputed, casewise-deleted data.

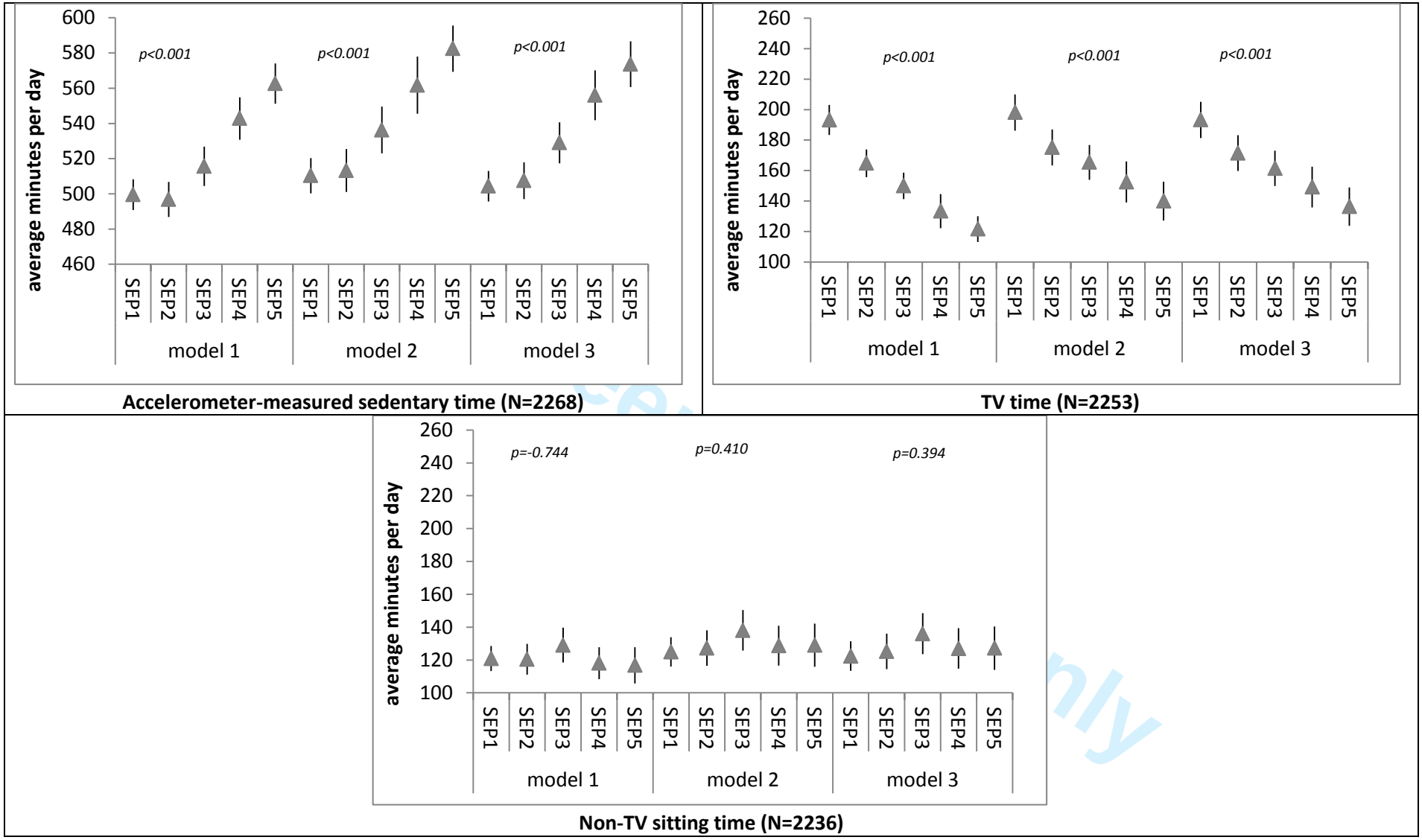


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S3: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekdays.

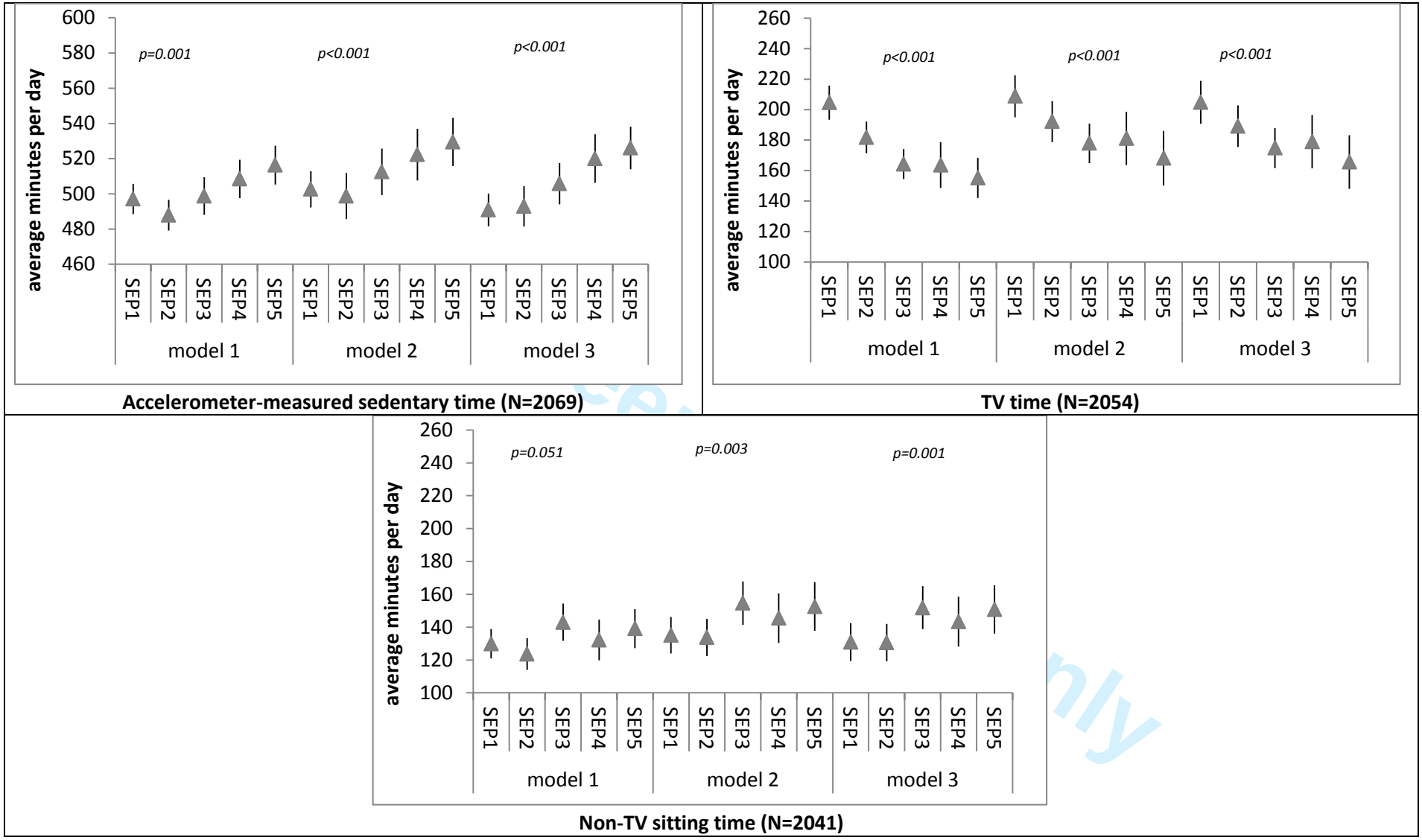


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S4: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekend days.



Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

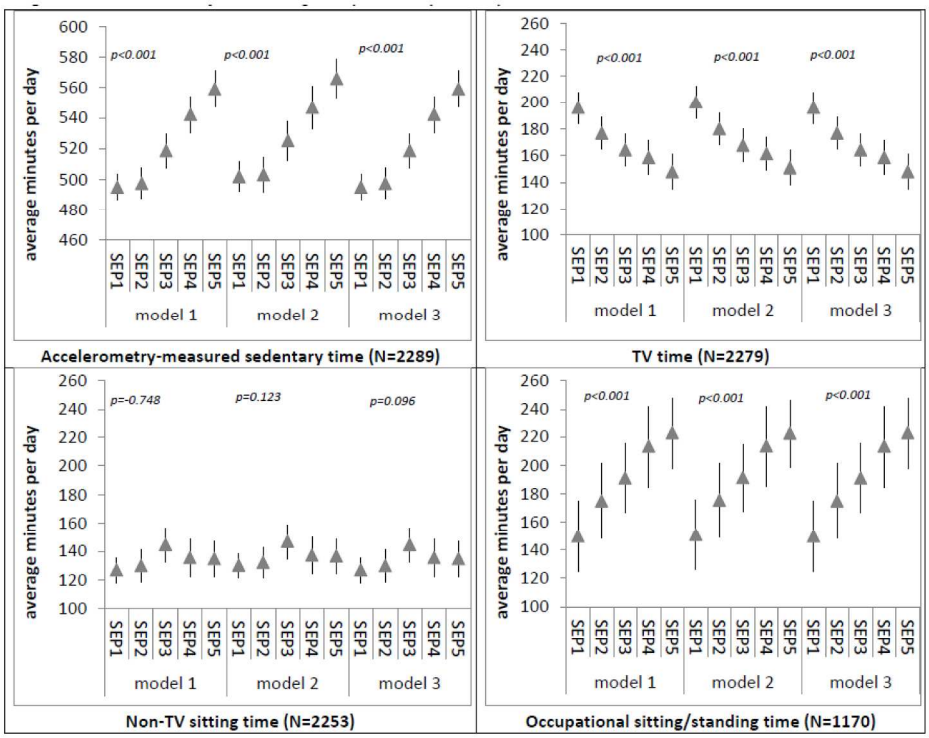


Figure 1: Multivariate-adjusted average daily sedentary time by SEP score
254x190mm (300 x 300 DPI)

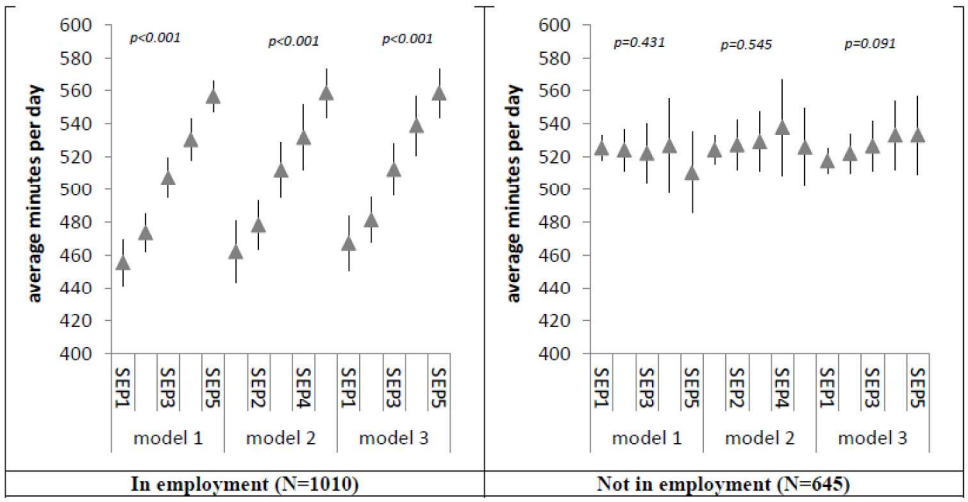


Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status
254x190mm (300 x 300 DPI)

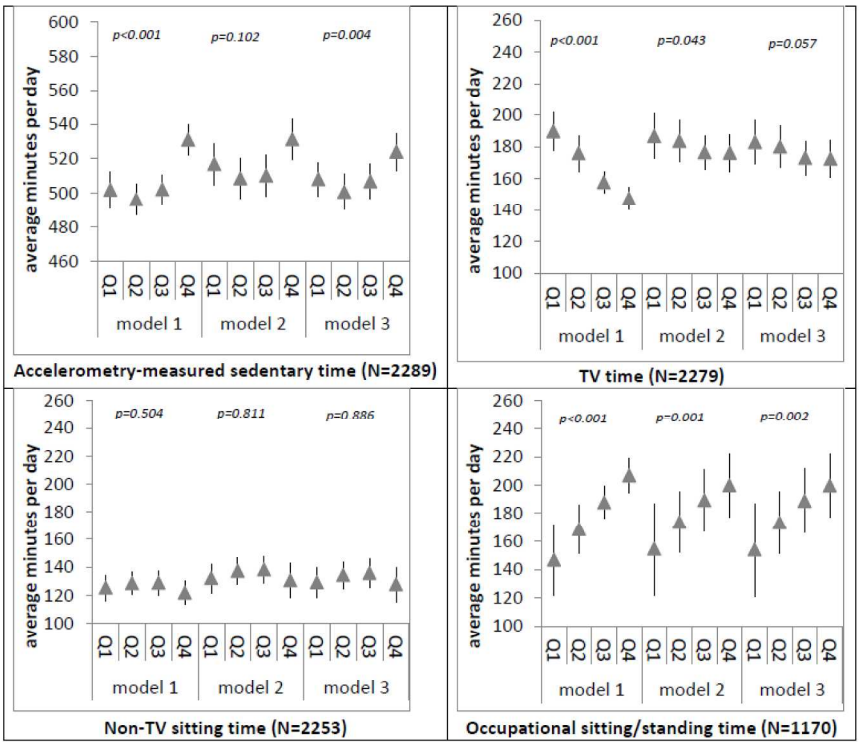


Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile
254x190mm (300 x 300 DPI)

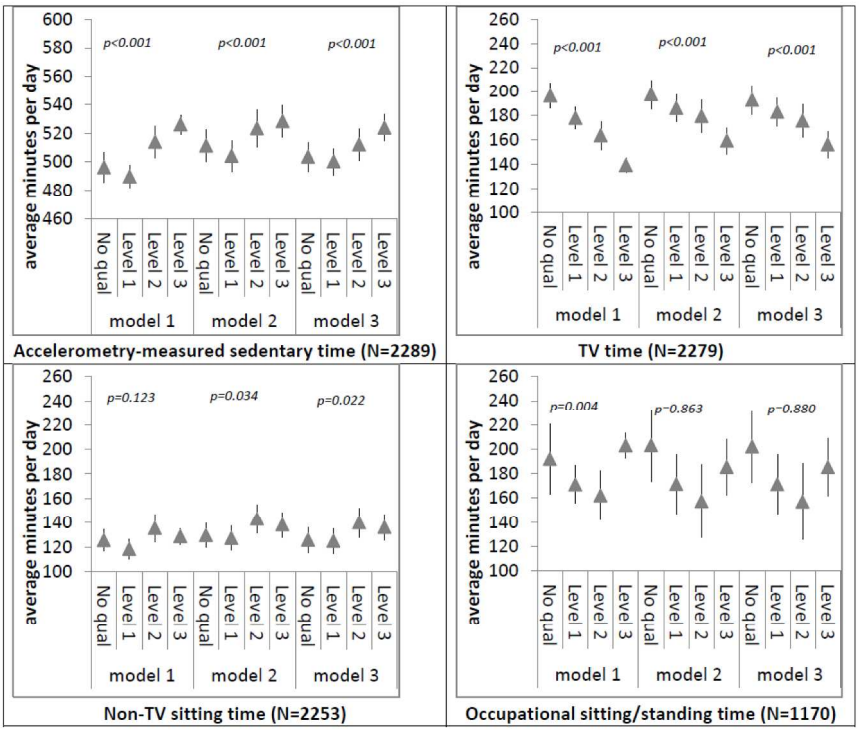


Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification
254x190mm (300 x 300 DPI)

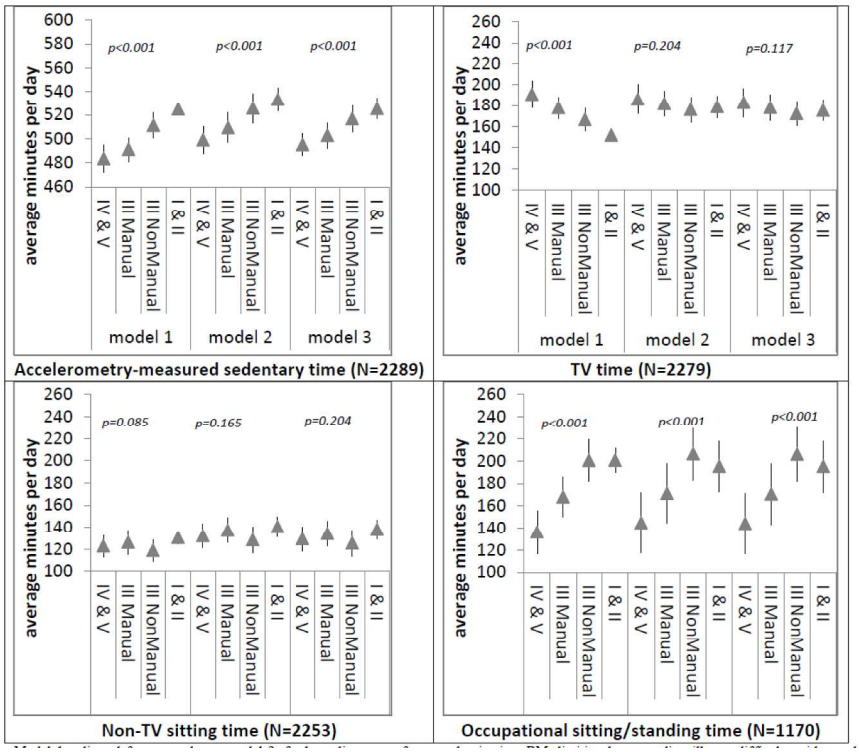


Figure 5: Multivariate-adjusted average daily sedentary timea by occupational social class
254x190mm (300 x 300 DPI)

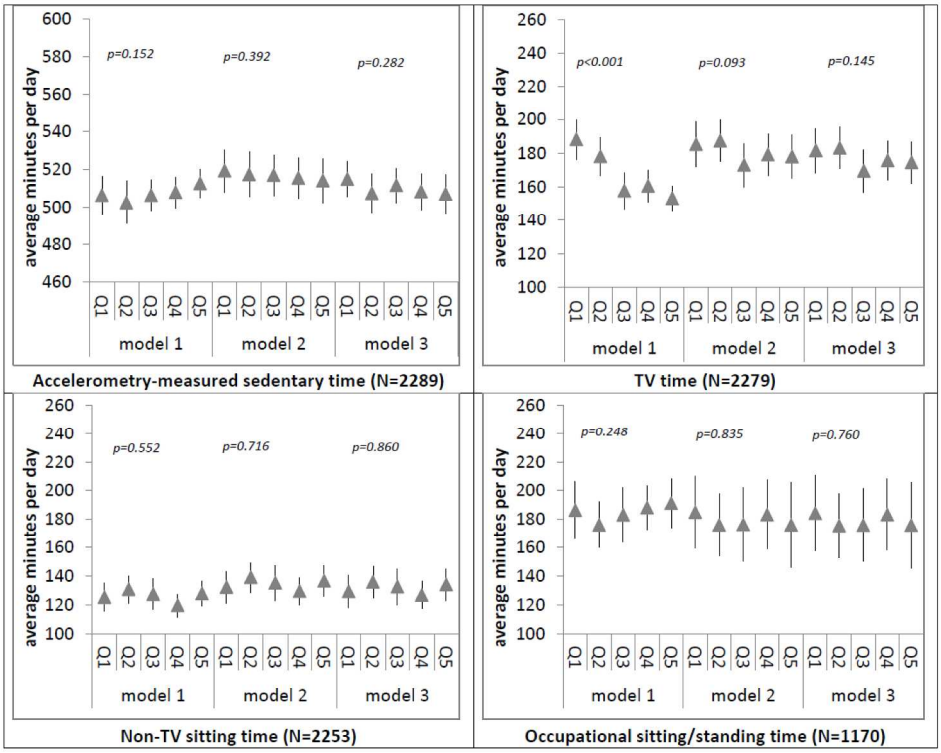


Figure 6: Multivariate-adjusted sedentary time by area deprivation quintiles
254x190mm (300 x 300 DPI)

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	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	6-8
Bias	9	Describe any efforts to address potential sources of bias	*8*
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(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	10-11
		(b) Give reasons for non-participation at each stage	10-11
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*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	12
		(*b*) Report category boundaries when continuous variables were categorized	7-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	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	18

*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.

BMJ Open

Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England: a cross-sectional study

Journal:	*BMJ Open*
Manuscript ID:	bmjopen-2014-006034.R2
Article Type:	Research
Date Submitted by the Author:	02-Oct-2014
Complete List of Authors:	Stamatakis, Emmanuel; University of Sydney, Exercise and Sport Sciences & Charles Perkins Centre Coombs, Ngaire; University of Southampton, Social Sciences Rowlands, Alex; University of South Australia, Division of Health Sciences Shelton, Nicola; University College London, Epidemiology and Public Health Hillsdon, Melvyn; University of Exeter, Sport and Health Sciences
Primary Subject Heading:	Epidemiology
Secondary Subject Heading:	Public health, Epidemiology, Sports and exercise medicine
Keywords:	EPIDEMIOLOGY, PUBLIC HEALTH, SOCIAL MEDICINE

Title: Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England: a cross-sectional study

Running title: Sedentary time and socioeconomic status

Authors: Emmanuel Stamatakis[1 2 3], Ngaire Coombs[3 4], Alex Rowlands[5], Nicola Shelton[3], Melvyn Hillsdon[6].

[1]Charles Perkins Centre, University of Sydney, Australia

[2] Discipline of Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

[3]PARG (Physical Activity Research Group), Department of Epidemiology and Public Health, University College London, London, UK

[4]Department of Social Sciences, University of Southampton, UK

[5] Division of Health Sciences, University of South Australia, Australia

[6] Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, UK

Correspondence: Emmanuel Stamatakis, Charles Perkins Centre, University of Sydney , Johns Hopkins Drive, Sydney, NSW 2050, Australia. Email: emmanuel.stamatakis@sydney.edu.au, Telephone: +61 293519668.

Wordcount:

Abstract: 245 words

Main text: 3693 words

Abstract

Objectives: To examine the associations between socioeconomic position (SEP) and multi-domain self-reported and objectively-assessed sedentary time (ST)**. Design**: cross-sectional; **Setting**: general population households in England. **Participants**: 2289 adults aged 16-96 years who participated in the 2008 Health Survey for England. **Outcomes**: accelerometer-measured sedentary time, and self-reported television time, non-television leisure-time sitting and occupational sitting/standing. We examined multivariable associations between household income, social class, education, area deprivation for each SEP indicator (including a 5-point composite SEP score computed by aggregating individual SEP indicators) and each ST indicator using generalised linear models. **Results**: Accelerometry-measured total ST and occupational sitting/standing were positively associated with SEP score and most of its constituent SEP indicators, while television time was negatively associated with SEP score and education level. Area-level deprivation was largely unrelated to ST. Those in the lowest composite SEP group spent 64 (95% CIs: 52 to 76) and 72 (48 to 98), fewer minutes/day in total ST and occupational sitting/standing compared to those in the top SEP group, and an additional 48 (35 to 60) minutes/day watching television ($p<0.001$ for linear trend). Stratified analyses showed that these associations between composite SEP score and total ST were evident only among participants who were in employment. **Conclusions**: Occupational sitting seems to drive the positive association between socioeconomic position and total sedentary time. Lower socioeconomic position is linked to higher TV viewing times.

Article summary

Strengths and limitations of this study:

- First study of its kind to use objective sedentary behaviour measurements
- Broad range of self-reported sedentary behaviour types
- Broad set of socioeconomic status markers including area-level deprivation
- This is a cross-sectional design
- The occupational sedentary time question and accelerometry cannot differentiate between sitting and standing

Keywords

Socioeconomic status; television; sedentary behaviour; inequality; physical activity; accelerometer;

Introduction

Recent studies show that sedentary time (defined as an energy expenditure rate below 1.5 metabolic equivalents[1], often characterised by activities involving sitting) is linked to increased all-cause [2-5] and cardiovascular [2 3] mortality risk independently of leisure-time physical activity participation. Television viewing, one of the most common sedentary time (ST) activities, has been specifically linked to all-cause and cardiovascular mortality and type 2 diabetes [6]. Objective data show that adults in England spend approximately nine to 10 hours a day being sedentary on average, out of which approximately 4 hours/day is TV watching [7 8] . Assuming that the average waking day lasts for 16 hrs, total sedentary time accounts for some 55-65% of total waking time. For working age adults a substantial proportion of total sedentary time takes place while at work, 56% of working English men and 50% of women report more than 5 hrs /day being sedentary while at work [7].

Socioeconomic position (SEP) is a broad term that encompasses a range of characteristics, including occupational type and employment status, purchasing capacity and ownership, educational level and deprivation. Accordingly, there are several SEP indices each of which measures different aspects of social standing. Overall, SEP is a strong predictor of premature mortality and chronic disease occurrence including cardiovascular disease (CVD) [9] and diabetes [10] with individuals in lower SEP being considerably more likely to fall ill and die prematurely. Although there is no consensus on the origins of the socioeconomic gradient in health, one of the suggested pathways involves higher prevalence of poor health behaviours (e.g. physical inactivity and smoking) among lower socioeconomic groups [11] .

We have previously shown that lower SEP is linked consistently with increased TV viewing and other recreational screen time in Scottish adults [12], a finding that has been confirmed by studies in other countries such as Belgium [12 13], Australia [14 15], and the US [16] that used TV as a

proxy for ST. However, these findings are not necessarily generalizable to overall sedentary or sitting time because TV viewing is a complex exposure that seems to be a poor index of overall ST [17]. In a recent study comparing associations between TV time and objectively measured sedentary time, associations were of fair magnitude, but were not consistent across population sub-groups [18]. The results of the few studies that looked at overall (self-reported) sitting in relation to SEP are inconsistent. Higher social position was linked to higher overall sitting time among Australian women [19] but education level was unrelated to sitting time among Portuguese adults [20]. Objective measuring methodologies such as accelerometers and inclinometers can give more comprehensive and complete estimates of total sedentary behaviour than partial self-reported indices such as TV viewing, or self-reported total sitting time, which may be more difficult to recall than TV viewing and therefore be subject to more measurement error. Besides, SEP characteristics that relate to occupational class and income will naturally have an impact on work time sitting. For example, manual unskilled workers normally spend less time sitting during work than professionals in managerial office-based jobs [21]. Similarly, higher incomes and the associated spending capacity might impact on the time spent sitting driving a car or commuting. To our knowledge, no study has looked at the associations between SEP defined using education, occupational class, income and area deprivation indices, and SB estimated using self-reported sitting across different domains as well as objective methods.

The aim of this study was to look at the associations between multiple SEP indicators and self-reported indices of sitting time and SB as well as objectively-assessed total SB time. We used data from one of the largest European accelerometry general population studies, the 2008 Health Survey for England.

Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere [8]. The overall interview household response rate for the main sample of 15,102 adults was 64%, and for the accelerometer sub-sample of 4,507 adults was 73% [8]. In this analysis we included adults aged 16 and over (age range 16-96 years) who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. An abridged methods section is presented here: the full methods section with more information can be found in supplementary file S1 (Unabridged Methods). Ethical approval was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102).

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height was measured using a standard stadiometer with a sliding head plate, a base plate and three connecting rods marked with a metric measuring scale. Participants were asked to remove their shoes. One measurement was taken, with the participant stretching to the maximum height. Weight was measured using Tanita electronic scales with a digital display (Tanita Corporation, Japan). Participants were asked to remove their shoes and any bulky clothing and a single measurement was recorded to the nearest 100g. .[7] Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class (of the household reference person) was determined by asking questions on participants' occupation and using the Registrar General's classification to group them as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Equivalised household income was grouped into quintiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD), a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. Consistent with previous epidemiological SB studies [22], the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero minutely counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Participants with at least one day of valid wear were included in these analyses. [22]

Self-reported sedentary time was assessed using a set of questions on the usual week/weekend day in the last four weeks prior to the interview time spent on: a) TV (including DVDs and videos) viewing; and b) any other sitting during non-work times, including reading and computer use. For those participants who were economically active another set of questions assessed the average daily times spent sitting or standing while at work [17]. While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as accelerometers are unable to differentiate between time spent sitting or standing. Like previously [17] for the purposes of this study standing will be considered a measure of sedentary behaviour.

Physical activity questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose, domestic physical activity [12 23], and any recreational sports and exercise including cycling for any purpose [24]. Both the physical activity and the SB questions have been validated against accelerometry.[25]

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods [12], we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high end of

the score, the top SEP score was collapsed into five categories of comparable sample size: SEP1 consisted of the lowest two SEP categories (0 and 1), SEP2 comprised categories 2 and 3, SEP3 comprised categories 4 and 5, SEP4 comprised categories 6 and 7, and SEP5 comprised of categories 8 and 9 (the highest observed SEP category).

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7. Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type [7 8] Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day. For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) [3] and ≥2,020 counts/minute to denote MVPA (>3 MET) [26]. Accelerometry-measured variables were converted to time (minutes) per valid day and daily ST time was calculated as the sum of the average ST minutes per valid day divided by the number of valid days.

Missing data and multiple imputation

Outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses to improve normality. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the

exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2289 for accelerometry-measured ST, 2279 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Statistical analysis

Analyses were weighted for non-response to give a sample that was representative of adults living in England. The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometry-measured ST) were examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. We also repeated the SEP score analyses stratified by economic activity (employed/self-employed vs non-economically active). SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators

(household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA or accelerometry-measured MVPA as appropriate, and average accelerometer wear time on valid days. Models 2 and 3 with accelerometry-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. This work conforms with the STROBE statement for observational studies. [27]

Results

Descriptives

2289 adults (1030 males) provided valid accelerometry data, with 2279 (1020 males) and 2253 (1014 males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time. Table 1 presents the sample characteristics of the accelerometry sample by SEP score group (prior to MI) with casewise deletion of missing values (N=1651). In total 628 participants in the accelerometry sample had at least one covariate imputed. The variables with the most imputed values were household income (361 imputed) and BMI (233 imputed). Participants from lower SEP groups were more likely to be female, older, have a higher BMI, spend less time sedentary overall and sitting at work, but spend more time watching TV than individuals in higher SEP groups. Lower SEP individuals were also more likely to report a limiting longstanding illness and difficulties with usual daily activities, and be a current cigarette smoker, but less likely to be a heavy drinker and meet physical activity guidelines. The mean wear time on valid days was 831 minutes. The mean number of valid days (for those with at least 1 valid day) was 6.0 days.

Table 1: Sample Characteristics by Socioeconomic Position Score

	SEP Score Group			
	1 (lowest) & 2 (N=521)*	3 (N=355)*	4 & 5 (highest) (N=775)*	
Categorical variables[a]	%	%	%	*p*
Sex (% male)	40.1	47.0	50.5	0.001
Limiting longstanding illness (%)	32.8	24.5	16.8	<0.001
Adherence to the physical activity guidelines (self-reported data) (%)	32.6	43.9	49.6	<0.001
Difficulty in performing usual activities (%)	21.5	14.9	7.8	<0.001
Car or van available (%)	73.9	89.9	94.7	<0.001
Drinking frequency (% ≥5 times /week)	15.9	23.1	24.9	<0.001
Smoking (% current)	27.1	23.9	15.5	<0.001
Employment status (% employed/self-employed)	35.2	64.8	76.3	<0.001
Continuous variables[b]	M (SD)	M (SD)	M (SD)	*P*
Age (years)	56.1 (18.5)	50.4 (16.6)	46.9 (15.9)	<0.001
BMI (kg/m^2)	28.0 (4.9)	27.4 (4.9)	26.8 (4.5)	<0.001
Sedentary time (accelerometry data) (Minutes/day))	505.6 (97.7)	499.4 (90.7)	528.7 (87.2)	<0.001
TV (Minutes/day)	218.6 (117.3)	175.8 (97.7)	145.0 (74.7)	<0.001
Non-TV sitting time (Minutes/day)	128.1 (86.4)	121.5 (90.6)	133.2 (86.3)	0.110
Occupational sitting/standing time (Minutes/day)	151.8 (116.5)	173.5 (120.9)	198.1 (121.9)	<0.001
MVPA time per day (accelerometry data) (Minutes/day)	24.7 (24.1)	29.7 (26.3)	32.0 (25.1)	<0.001

* Occupational sitting time SEP 1 N=152 SEP 2 N=214; SEP 3 N=549 for SEP 4 & 5

[a] Chi Square was used to test significance of association between categorical variables and social class

[b] Anova was used to test significance of association between continuous variables and social class

Composite Socioeconomic position and sedentary time

Figure 1 presents the GLM estimated marginal means and their 95% CIs describing the associations between composite SEP score and each measure of ST. SEP was positively associated with accelerometry-measured ST and occupational sitting/standing time, and inversely associated with TV time in all models. There were no associations between SEP and non-TV sitting time. Adjustments for potential confounders made no material difference to all above associations. Figure 2 presents associations between SEP score and accelerometry-measured ST, stratified by employment status. SEP score was positively associated with accelerometry-measured ST for those in employment only. SEP was inversely associated with TV time regardless of employment status, while non-TV leisure-time sitting was positively associated with SEP (SEP1 coefficient 134, 95% CI 125 to 145; SEP5 coefficient 177, 155 to 198), but only for those not in employment. However this association was not linear (data not shown).

Equivalised Household income and sedentary time

Figure 3 presents associations between household income and each measure of ST. Household income was positively associated with accelerometer-measured ST and occupational sitting time and these associations persisted following adjustments for MVPA and other confounders. Like with SEP score, household income was inversely associated with TV time, although this association was attenuated to the null following adjustments for potential confounders in models 2 and 3. Household income was not associated with non-TV sitting time.

Educational attainment and sedentary time

Figure 4 presents the associations between the highest educational qualification and each measure of ST. Educational attainment was positively associated with accelerometry-measured ST and inversely associated with TV time in all models. Occupational sitting/standing time was inversely associated with education but the association did not appear to be linear (it was evident across the lowest three educational levels only) and was attenuated to the null following adjustments for potential confounders. There was a weak positive association between education and non-TV sitting time, following adjustments for potential confounders in models 2 and 3.

Occupational social class and sedentary time

As shown in Figure 5, occupational social class was positively associated with accelerometry-measured ST and occupational sitting/standing. The initial inverse association with TV time (model 1) was attenuated to the null following adjustments for potential confounders. Similarly to SEP score and income, social class was not associated with non-TV sitting time.

Area deprivation and sedentary time

Area-level deprivation was positively associated with TV time (the lower the deprivation the lower the TV time) but these associations did not persist in the adjusted models (Figure 6). Area deprivation was not associated with any other measures of ST (Figure 6).

Differential associations between imputed and non-imputed data

There were no differences between the imputed and non-imputed models describing the associations between SEP score and ST indicators, although the 95% confidence intervals were slightly broader in the unimputed models due to the lower sample size (see supplementary Figure S2).

Differential associations in weekday Vs weekend days

There was no consistent pattern of differences in the associations of SEP and ST by weekend vs weekday (see supplementary Figures S3 and S4), time of the week-specific results showed broadly the same pattern as the whole week. The only notable difference was that a direct association between SEP and non-TV sitting time was observed on weekend days, but not on weekdays.

Discussion

Literature on the socio-economic gradient of sedentary behaviour is very limited and has relied on partial sedentary behaviour indicators, mostly TV viewing. To our knowledge, this study is the only one that considers four indicators of socioeconomic position in relation to four indicators of sedentary behaviour, allowing a much more in-depth examination of the associations of interest than in previous studies. Our study suggests that occupational ST is what drives the positive association between overall SEP and total ST as there was no association among those not in employment (Figure 2). The difference between the lowest and highest SEP groups (Figure 1) is in the region of 60-70 minutes per day for both total accelerometry-measured sedentary time and occupational sitting/standing time and this is comparable with the difference between the extreme SEP group among the economically active part of the sample (~90 minutes/day). As low SEP is more likely to involve fixed length shift-based work one possible explanation is that these occupational ST differences reflect the longer working hours of professionals in higher SEP groups, although we had no information on work times to examine this hypothesis or make statistical adjustments. Our findings agree with an Australian study [19] which found that among women, full-time work, skilled occupations, and university education were all associated with high (self-reported)

total sitting time. Our study also found that the inverse association between TV time and SEP was significant regardless of employment status. In a study of Dutch workers, sitting time at work varied considerably by type of occupation but not sitting during leisure time [28].

Previous studies of adults in Belgium [13] and Australia [14 15 29] have reported inverse associations between SEP indicators and TV time. We observed the same TV time pattern with SEP score and education but not with occupational class, household income or area deprivation. Although the occupational class and household income data were suggestive of a weak association with TV time, our current results somehow contradict our study in Scottish adults,[12] where all SEP indicators (occupational class, household income or area deprivation) as well as the composite SEP score were associated with recreational screen time (including TV time). Explanations for this might be that the Scottish study was three times larger in size (which might have made it easier for data patterns to emerge) and the inclusion of non-TV screen time as an outcome, although studies from other countries suggest no clear pattern between non-TV recreational screen time (e.g. computer use) and SEP [30 15]. Nevertheless, both our English and the Scottish studies demonstrate that when education, occupational social class and income are combined into a single measure (SEP score) they are a much more powerful predictor of sedentary time than any single indicator, perhaps because they collectively capture actual socioeconomic position more thoroughly than any single indicator. Composite SEP score showed a clear and consistent pattern with all ST outcomes, although each of the individual/household-level SEP indicators seemed to influence each ST outcome in various ways, suggesting there are complex, interacting, multi-dimensional influences of SEP on ST. Accelerometry-measured ST was the only sedentary behaviour variable that showed clear and consistent (positive) associations with all SEP variables (except from area-level deprivation). Although the cross-sectional design of this study precludes causal inferences, the pattern of the accelerometry-based associations we observed

suggests that it is unlikely that total sedentary behaviour contributes to the well-documented socioeconomic inequalities in health. [11]

Strengths of our study include the availability of both objectively-measured and self-reported indicators of sedentary behaviour which allowed us to be more thorough and detailed when examining the associations of interest. Accelerometers can capture total sedentary time more comprehensively than any partial self-reported indicator and as such are able to better quantify the socioeconomic gradient of ST as a contributor to health inequalities, however a limitation is that accelerometers do not distinguish between sitting and standing which have different health implications, this also applies to occupational sitting/standing time. It has been argued that standing should not be considered a sedentary behaviour [31]. This limitation is also pertinent to the self-reported ST assessment as standing time was included in the occupational ST question. The lack of information on work times did not allow us to examine the possibility that ST differences between SEP groups are partly due to longer work hours in higher SEP groups. Taken together, these limitations of the measurements may, to some extent, have confounded the associations of SEP with total and occupational ST we reported. Another limitation is that our study was limited to the accelerometry sample of HSE 2008 and this might have led to our sample being less representative of the target population. Although those in the subsample offered the accelerometer were older and more likely to be retired and to be less healthy than the rest of the adult Health Survey for England sample, those who refused to wear an accelerometer were similar in terms of employment status and area-level deprivation compared to those who wore the accelerometers for at least four days a week[32]. Higher SEP is linked to higher commuting by car [33] and this may partly explain the socioeconomic gradient but our data are limited in that there was no specific question on commuting-related sitting to examine this explanation.

Conclusions

Objectively-measured total sedentary time and occupational sedentary time are higher among economically active English adults in higher socioeconomic groups compared to less privileged groups. However, TV viewing is lower in higher socioeconomic groups regardless of economic activity. Combining different socioeconomic indicators appears to have composite power as a predictor of sedentary time.

Funding: This work was funded by the National Institute for Health Research through a Career Development Fellowship (ES). NC is also funded by the National Institute for Health Research through the same source. The views expressed in this article are those of the authors and not the English Department of Health or the National Institute for Health Research.

Data Sharing: No additional data are available

Competing interests: None of the authors have any competing interests to declare

Authors' Contributions: All authors have contributed sufficiently, ES conceived the idea, prepared the dataset, drafted most of the manuscript and revised the manuscript several times. NC did the statistical analysis under the supervision of ES and prepared the Tables, Figures and Supplemental Online material. AR processed the accelerometry files. NS, MH and AR redrafted parts of the manuscript and critically evaluated the whole material. All authors approved the final version before submission.

References

1. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exercise and Sport Sciences Reviews 2008;**36**(4):173-78.
2. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
3. Matthews C, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 2012;**95**(2):437-45.
4. Patel AV, Bernstein L, Deka A, et al. Leisure Time Spent Sitting in Relation to Total Mortality in a Prospective Cohort of US Adults. Am J Epidemiol 2010;**172**(4):419-29.
5. van der Ploeg HP, Chey T, Korda RJ, et al. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. Arch Intern Med 2012;**172**(6):494-500.
6. Grøntved A, Hu FB. Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality. JAMA 2011;**305**(23):2448-55.
7. Joint Health Surveys Unit. The Health Survey for England 2008. Volume 1 Leeds, 2010:21-206.
8. Joint Health Surveys Unit. The Health Survey for England 2008, Volume 2. Leeds: , 2010:11.
9. Marmot MG, Shipley MJ, Hemingway H, et al. Biological and behavioural explanations of social inequalities in coronary heart disease: Whitehall II Study. Diabetologia 2008;**51**(11):1980-88.
10. Williams ED, Tapp RJ, Magliano DJ, et al. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia 2010;**53**:2538-45.
11. Stringhini S, Sabia S, Shipley M, et al. Association of Socioeconomic Position With Health Behaviors and Mortality. JAMA 2010;**303**(12):1159-66.
12. Stamatakis E, Hillsdon M, Mishra G, et al. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. Journal of epidemiology and community health 2009;**63**(9):734-40.
13. Van Dyck D, Cardon G, Deforche B, et al. Socio-demographic, psychosocial and home-environmental attributes associated with adults' domestic screen time. BMC Public Health 2011;**11**:668.
14. Teychenne M, Ball K, Salmon J. Correlates of socio-economic inequalities in women's television viewing: a study of intrapersonal, social and environmental mediators. Int J Behav Nutr Phy Act 2012;**9**:3.
15. Burton NW, Haynes M, van Uffelen JGZ, et al. Mid-Aged Adults' Sitting Time in Three Contexts. Am J Prev Med 2012;**42**(4):363-73.
16. Bowman SA. Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Preventing Chronic Disease 2006;**3**(2).
17. Stamatakis E, Hamer M, Tilling K, et al. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. Int J Epidemiol 2012;**41**:1328-37.
18. Clark BK, Healy GN, Winkler EAH, et al. Relationship of Television Time with Accelerometer-Derived Sedentary Time: NHANES Med Sci Sports Exerc 2011;**43**(5):822-28.
19. van Uffelen JGZ, Heesch KC, Brown W. Correlates of Sitting Time in Working Age Australian Women: Who Should Be Targeted With Interventions to Decrease Sitting Time? J Phys Act Health 2012;**9**(2):270-87.
20. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a portuguese sample of men: Results from the azorean physical activity and health study (APAHS). Int J Environ Res Publ Health 2010;**7**(4):1500-07.
21. Duncan MJ, HBadland HM, Mummery WK. Physical Activity Levels by Occupational Category in Non-Metropolitan Australian Adults. J Phys Act Health 2010;**7**(6):718-23.

22. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. Am J Epidemiol 2008;**167**(7):875-81.
23. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . Prev Med 2007;**45**:416-23.
24. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey Br J Sports Med 2008;**42**:601-08.
25. Scholes S, Coombs N, Pedisic Z, et al. Age- and sex-specific criterion validity of the health survey for England physical activity and sedentary behavior assessment questionnaire as compared with accelerometry. Am J Epidemiol 2014;**179**(12):1493-502.
26. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;**40**(1):181-8.
27. Gallo V, Egger M, McCormack V, et al. STrengthening the Reporting of OBservational studies in Epidemiology--Molecular Epidemiology (STROBE-ME): an extension of the STROBE Statement. PLoS medicine 2011;**8**(10):e1001117.
28. Jans M, Proper K, Hildebrandt V. Sedentary Behavior in Dutch Workers: Differences between Occupations and Business Sectors. Am J Prev Med 2007;**33**:450-54.
29. Stamatakis E, Grunseit AC, Coombs N, et al. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: The Social, Economic, and Environmental Factor (SEEF) Study. Prev Med 2014;**63c**:72-80.
30. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior A Systematic Review. Am J Prev Med 2012;**42**(3):E3-E28.
31. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Research and Clinical Practice 2011;**93**(2):292-94.
32. Roth M, Mindell J. Who provides accelerometry data? Correlates of adherence to wearing an accelerometry motion sensor: the 2008 health survey for England. J Phys Act Health 2013;**10**(1):70-78.
33. Goodman A, Guell C, Panter J, et al. Healthy travel and the socio-economic structure of car commuting in Cambridge, UK: A mixed-methods analysis. Social Science & Medicine 2012;**74**(12):1929-38.

Figure Legends and footnotes

Figure 1: Multivariate-adjusted average daily sedentary time by SEP score

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates lowest income quartile (<=£13876),Q4 indicates the highest income quartile (>=£39001).

Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average

accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Education Level 1 represents NVQ1/CSE and NVQ2 GCE O Level equivalent; Level 2 represents NVQ3/GCE A Level equivalent; Level 3 represents higher education below Degree and NVQ4/NVQ5/Degree or higher.

Figure 5: Multivariate-adjusted average daily sedentary time[a] by occupational social class.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

Figure 6: Multivariate-adjusted sedentary time by area deprivation quintile.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates most deprived, Q5 indicates least deprived

Title: Objectively-assessed and self-reported sedentary time in relation to multiple socioeconomic status indicators among adults in England

Running title: Sedentary time and socioeconomic status

Authors: Emmanuel Stamatakis[1 2 3], Ngaire Coombs[3 4], Alex Rowlands[5], Nicola Shelton[3], Melvyn Hillsdon[6].

[1]Charles Perkins Centre, University of Sydney, Australia

[2] Discipline of Exercise and Sport Sciences, Faculty of Health Sciences, University of Sydney, Sydney, Australia

[3]PARG (Physical Activity Research Group), Department of Epidemiology and Public Health, University College London, London, UK

[4]Department of Social Sciences, University of Southampton, UK

[5] Division of Health Sciences, University of South Australia, Australia

[6] Sport and Health Sciences, College of Life and Environmental Sciences, University of Exeter, UK

Correspondence: Emmanuel Stamatakis, Charles Perkins Centre, University of Sydney , Johns Hopkins Drive, Sydney, NSW 2050, Australia. Email: emmanuel.stamatakis@sydney.edu.au, Telephone: +61 293519668.

Wordcount:

Abstract: 245 words

Main text: 3693 words

Abstract

Objectives: To examine the associations between socioeconomic position (SEP) and multi-domain self-reported and objectively-assessed sedentary time (ST)**. Design**: cross-sectional; **Setting**: general population households in England. **Participants**: 2289 adults aged 16-96 years who participated in the 2008 Health Survey for England. **Outcomes**: accelerometer-measured sedentary time, and self-reported television time, non-television leisure-time sitting and occupational sitting/standing. We examined multivariable associations between household income, social class, education, area deprivation for each SEP indicator (including a 5-point composite SEP score computed by aggregating individual SEP indicators) and each ST indicator using generalised linear models. **Results**: Accelerometry-measured total ST and occupational sitting/standing were positively associated with SEP score and most of its constituent SEP indicators, while television time was negatively associated with SEP score and education level. Area-level deprivation was largely unrelated to ST. Those in the lowest composite SEP group spent 64 (95% CIs: 52 to 76) and 72 (48 to 98), fewer minutes/day in total ST and occupational sitting/standing compared to those in the top SEP group, and an additional 48 (35 to 60) minutes/day watching television ($p<0.001$ for linear trend). Stratified analyses showed that these associations between composite SEP score and total ST were evident only among participants who were in employment. **Conclusions**: Occupational sitting seems to drive the positive association between socioeconomic position and total sedentary time. Lower socioeconomic position is linked to higher TV viewing times.

Article summary

Strengths and limitations of this study:

- First study of its kind to use objective sedentary behaviour measurements
- Broad range of self-reported sedentary behaviour types
- Broad set of socioeconomic status markers including area-level deprivation
- This is a cross-sectional design
- The occupational sedentary time question and accelerometry cannot differentiate between sitting and standing

Keywords

Socioeconomic status; television; sedentary behaviour; inequality; physical activity; accelerometer;

Introduction

Recent studies show that sedentary time (defined as an energy expenditure rate below 1.5 metabolic equivalents[1], often characterised by activities involving sitting) is linked to increased all-cause [2-5] and cardiovascular [2 3] mortality risk independently of leisure-time physical activity participation. Television viewing, one of the most common sedentary time (ST) activities, has been specifically linked to all-cause and cardiovascular mortality and type 2 diabetes [6]. Objective data show that adults in England spend approximately nine to 10 hours a day being sedentary on average, out of which approximately 4 hours/day is TV watching [7 8] . Assuming that the average waking day lasts for 16 hrs, total sedentary time accounts for some 55-65% of total waking time. For working age adults a substantial proportion of total sedentary time takes place while at work, 56% of working English men and 50% of women report more than 5 hrs /day being sedentary while at work [7].

Socioeconomic position (SEP) is a broad term that encompasses a range of characteristics, including occupational type and employment status, purchasing capacity and ownership, educational level and deprivation. Accordingly, there are several SEP indices each of which measures different aspects of social standing. Overall, SEP is a strong predictor of premature mortality and chronic disease occurrence including cardiovascular disease (CVD) [9] and diabetes [10] with individuals in lower SEP being considerably more likely to fall ill and die prematurely. Although there is no consensus on the origins of the socioeconomic gradient in health, one of the suggested pathways involves higher prevalence of poor health behaviours (e.g. physical inactivity and smoking) among lower socioeconomic groups [11] .

We have previously shown that lower SEP is linked consistently with increased TV viewing and other recreational screen time in Scottish adults [12], a finding that has been confirmed by studies in other countries such as Belgium [12 13], Australia [14 15], and the US [16] that used TV as a

proxy for ST. However, these findings are not necessarily generalizable to overall sedentary or sitting time because TV viewing is a complex exposure that seems to be a poor index of overall ST [17]. In a recent study comparing associations between TV time and objectively measured sedentary time, associations were of fair magnitude, but were not consistent across population sub-groups [18]. The results of the few studies that looked at overall (self-reported) sitting in relation to SEP are inconsistent. Higher social position was linked to higher overall sitting time among Australian women [19] but education level was unrelated to sitting time among Portuguese adults [20]. Objective measuring methodologies such as accelerometers and inclinometers can give more comprehensive and complete estimates of total sedentary behaviour than partial self-reported indices such as TV viewing, or self-reported total sitting time, which may be more difficult to recall than TV viewing and therefore be subject to more measurement error. Besides, SEP characteristics that relate to occupational class and income will naturally have an impact on work time sitting. For example, manual unskilled workers normally spend less time sitting during work than professionals in managerial office-based jobs [21]. Similarly, higher incomes and the associated spending capacity might impact on the time spent sitting driving a car or commuting. To our knowledge, no study has looked at the associations between SEP defined using education, occupational class, income and area deprivation indices, and SB estimated using self-reported sitting across different domains as well as objective methods.

The aim of this study was to look at the associations between multiple SEP indicators and self-reported indices of sitting time and SB as well as objectively-assessed total SB time. We used data from one of the largest European accelerometry general population studies, the 2008 Health Survey for England.

Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere [8]. The overall interview household response rate for the main sample of 15,102 adults was 64%, and for the accelerometer sub-sample of 4,507 adults was 73% [8]. In this analysis we included adults aged 16 and over (age range 16-96 years) who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. An abridged methods section is presented here: the full methods section with more information can be found in supplementary file S1 (Unabridged Methods). Ethical approval was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102).

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing.

Height was measured using a standard stadiometer with a sliding head plate, a base plate and three connecting rods marked with a metric measuring scale. Participants were asked to remove their shoes. One measurement was taken, with the participant stretching to the maximum height. Weight was measured using Tanita electronic scales with a digital display (Tanita Corporation, Japan). Participants were asked to remove their shoes and any bulky clothing and a single measurement was recorded to the nearest 100g. .[7] Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class (of the household reference person) was determined by asking questions on participants' occupation and using the Registrar General's classification to -group~~ed~~ them as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and unskilled manual). Equivalised household income was grouped into quintiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD), a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. Consistent with previous epidemiological SB studies [22], the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero minutely counts, with allowance for up to 2 consecutive minutes of 1–100 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Participants with at least one day of valid wear were included in these analyses. [22]

Self-reported sedentary time was assessed using a set of questions on the usual week/weekend day in the last four weeks prior to the interview time spent on: a) TV (including DVDs and videos) viewing; and b) any other sitting during non-work times, including reading and computer use. For those participants who were economically active another set of questions assessed the average daily times spent sitting or standing while at work [17]. While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as accelerometers are unable to differentiate between time spent sitting or standing. Like previously [17] for the purposes of this study standing will be considered a measure of sedentary behaviour.

Physical activity questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose, domestic physical activity [12 23], and any recreational sports and exercise including cycling for any purpose [24]. Both the physical activity and the SB questions have been validated against accelerometry.[25]

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods [12], we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high end of

the score, the top SEP score was collapsed into five categories of comparable sample size: SEP1 consisted of the lowest two SEP categories (0 and 1), SEP2 comprised categories 2 and 3, SEP3 comprised categories 4 and 5, SEP4 comprised categories 6 and 7, and SEP5 comprised of categories 8 and 9 (the highest observed SEP category).

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7. Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type [7 8] Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day. For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) [3] and ≥2,020 counts/minute to denote MVPA (>3 MET) [26]. Accelerometry-measured variables were converted to time (minutes) per valid day and daily ST time was calculated as the sum of the average ST minutes per valid day divided by the number of valid days.

Missing data and multiple imputation

Outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses to improve normality. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the

exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2289 for accelerometry-measured ST, 2279 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Statistical analysis

Analyses were weighted for non-response to give a sample that was representative of adults living in England. The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometry-measured ST) were examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. We also repeated the SEP score analyses stratified by economic activity (employed/self-employed vs non-economically active). SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators

(household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA or accelerometry-measured MVPA as appropriate, and average accelerometer wear time on valid days. Models 2 and 3 with accelerometry-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. This work conforms with the STROBE statement for observational studies. [27]

Results

Descriptives

2289 adults (1030 males) provided valid accelerometry data, with 2279 (1020 males) and 2253 (1014 males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time. Table 1 presents the sample characteristics of the accelerometry sample by SEP score group (prior to MI) with casewise deletion of missing values (N=1651). In total 628 participants in the accelerometry sample had at least one covariate imputed. The variables with the most imputed values were household income (361 imputed) and BMI (233 imputed). Participants from lower SEP groups were more likely to be female, older, have a higher BMI, spend less time sedentary overall and sitting at work, but spend more time watching TV than individuals in higher SEP groups. Lower SEP individuals were also more likely to report a limiting longstanding illness and difficulties with usual daily activities, and be a current cigarette smoker, but less likely to be a heavy drinker and meet physical activity guidelines. The mean wear time on valid days was 831 minutes. The mean number of valid days (for those with at least 1 valid day) was 6.0 days.

Table 1: Sample Characteristics by Socioeconomic Position Score

	SEP Score Group			
	1 (lowest) & 2 (N=521)*	3 (N=355)*	4 & 5 (highest) (N=775)*	
Categorical variables[a]	%	%	%	*p*
Sex (% male)	40.1	47.0	50.5	0.001
Limiting longstanding illness (%)	32.8	24.5	16.8	<0.001
Adherence to the physical activity guidelines (self-reported data) (%)	32.6	43.9	49.6	<0.001
Difficulty in performing usual activities (%)	21.5	14.9	7.8	<0.001
Car or van available (%)	73.9	89.9	94.7	<0.001
Drinking frequency (% ≥5 times /week)	15.9	23.1	24.9	<0.001
Smoking (% current)	27.1	23.9	15.5	<0.001
Employment status (% employed/self-employed)	35.2	64.8	76.3	<0.001
Continuous variables[b]	M (SD)	M (SD)	M (SD)	*P*
Age (years)	56.1 (18.5)	50.4 (16.6)	46.9 (15.9)	<0.001
BMI (kg/m^2)	28.0 (4.9)	27.4 (4.9)	26.8 (4.5)	<0.001
Sedentary time (accelerometry data) (Minutes/day))	505.6 (97.7)	499.4 (90.7)	528.7 (87.2)	<0.001
TV (Minutes/day)	218.6 (117.3)	175.8 (97.7)	145.0 (74.7)	<0.001
Non-TV sitting time (Minutes/day)	128.1 (86.4)	121.5 (90.6)	133.2 (86.3)	0.110
Occupational sitting/standing time (Minutes/day)	151.8 (116.5)	173.5 (120.9)	198.1 (121.9)	<0.001
MVPA time per day (accelerometry data) (Minutes/day)	24.7 (24.1)	29.7 (26.3)	32.0 (25.1)	<0.001

* Occupational sitting time SEP 1 N=152 SEP 2 N=214; SEP 3 N=549 for SEP 4 & 5

[a] Chi Square was used to test significance of association between categorical variables and social class

[b] Anova was used to test significance of association between continuous variables and social class

Composite Socioeconomic position and sedentary time

Figure 1 presents the GLM estimated marginal means and their 95% CIs describing the associations between composite SEP score and each measure of ST. SEP was positively associated with accelerometry-measured ST and occupational sitting/standing time, and inversely associated with TV time in all models. There were no associations between SEP and non-TV sitting time. Adjustments for potential confounders made no material difference to all above associations. Figure 2 presents associations between SEP score and accelerometry-measured ST, stratified by employment status. SEP score was positively associated with accelerometry-measured ST for those in employment only. SEP was inversely associated with TV time regardless of employment status, while non-TV leisure-time sitting was positively associated with SEP (SEP1 coefficient 134, 95% CI 125 to 145; SEP5 coefficient 177, 155 to 198), but only for those not in employment. However this association was not linear (data not shown).

Equivalised Household income and sedentary time

Figure 3 presents associations between household income and each measure of ST. Household income was positively associated with accelerometer-measured ST and occupational sitting time and these associations persisted following adjustments for MVPA and other confounders. Like with SEP score, household income was inversely associated with TV time, although this association was attenuated to the null following adjustments for potential confounders in models 2 and 3. Household income was not associated with non-TV sitting time.

Educational attainment and sedentary time

Figure 4 presents the associations between the highest educational qualification and each measure of ST. Educational attainment was positively associated with accelerometry-measured ST and inversely associated with TV time in all models. Occupational sitting/standing time was inversely associated with education but the association did not appear to be linear (it was evident across the lowest three educational levels only) and was attenuated to the null following adjustments for potential confounders. There was a weak positive association between education and non-TV sitting time, following adjustments for potential confounders in models 2 and 3.

Occupational social class and sedentary time

As shown in Figure 5, occupational social class was positively associated with accelerometry-measured ST and occupational sitting/standing. The initial inverse association with TV time (model 1) was attenuated to the null following adjustments for potential confounders. Similarly to SEP score and income, social class was not associated with non-TV sitting time.

Area deprivation and sedentary time

Area-level deprivation was positively associated with TV time (the lower the deprivation the lower the TV time) but these associations did not persist in the adjusted models (Figure 6). Area deprivation was not associated with any other measures of ST (Figure 6).

Differential associations between imputed and non-imputed data

There were no differences between the imputed and non-imputed models describing the associations between SEP score and ST indicators, although the 95% confidence intervals were slightly broader in the unimputed models due to the lower sample size (see supplementary Figure S2).

Differential associations in weekday Vs weekend days

There was no consistent pattern of differences in the associations of SEP and ST by weekend vs weekday (see supplementary Figures S3 and S4), time of the week-specific results showed broadly the same pattern as the whole week. The only notable difference was that a direct association between SEP and non-TV sitting time was observed on weekend days, but not on weekdays.

Discussion

Literature on the socio-economic gradient of sedentary behaviour is very limited and has relied on partial sedentary behaviour indicators, mostly TV viewing. To our knowledge, this study is the only one that considers four indicators of socioeconomic position in relation to four indicators of sedentary behaviour, allowing a much more in-depth examination of the associations of interest than in previous studies. Our study suggests that occupational ST is what drives the positive association between overall SEP and total ST as there was no association among those not in employment (Figure 2). The difference between the lowest and highest SEP groups (Figure 1) is in the region of 60-70 minutes per day for both total accelerometry-measured sedentary time and occupational sitting/standing time and this is comparable with the difference between the extreme SEP group among the economically active part of the sample (~90 minutes/day). As low SEP is more likely to involve fixed length shift-based work one possible explanation is that these occupational ST differences reflect the longer working hours of professionals in higher SEP groups, although we had no information on work times to examine this hypothesis or make statistical adjustments. Our findings agree with an Australian study [19] which found that among women, full-time work, skilled occupations, and university education were all associated with high (self-reported)

total sitting time. Our study also found that the inverse association between TV time and SEP was significant regardless of employment status. In a study of Dutch workers, sitting time at work varied considerably by type of occupation but not sitting during leisure time [28].

Previous studies of adults in Belgium [13] and Australia [14 15 29] have reported inverse associations between SEP indicators and TV time. We observed the same TV time pattern with SEP score and education but not with occupational class, household income or area deprivation. Although the occupational class and household income data were suggestive of a weak association with TV time, our current results somehow contradict our study in Scottish adults,[12] where all SEP indicators (occupational class, household income or area deprivation) as well as the composite SEP score were associated with recreational screen time (including TV time). Explanations for this might be that the Scottish study was three times larger in size (which might have made it easier for data patterns to emerge) and the inclusion of non-TV screen time as an outcome, although studies from other countries suggest no clear pattern between non-TV recreational screen time (e.g. computer use) and SEP [30 15]. Nevertheless, both our English and the Scottish studies demonstrate that when education, occupational social class and income are combined into a single measure (SEP score) they are a much more powerful predictor of sedentary time than any single indicator, perhaps because they collectively capture actual socioeconomic position more thoroughly than any single indicator. Composite SEP score showed a clear and consistent pattern with all ST outcomes, although each of the individual/household-level SEP indicators seemed to influence each ST outcome in various ways, suggesting there are complex, interacting, multi-dimensional influences of SEP on ST. Accelerometry-measured ST was the only sedentary behaviour variable that showed clear and consistent (positive) associations with all SEP variables (except from area-level deprivation). Although the cross-sectional design of this study precludes causal inferences, the pattern of the accelerometry-based associations we observed

suggests that it is unlikely that total sedentary behaviour contributes to the well-documented socioeconomic inequalities in health. [11]

Strengths of our study include the availability of both objectively-measured and self-reported indicators of sedentary behaviour which allowed us to be more thorough and detailed when examining the associations of interest. Accelerometers can capture total sedentary time more comprehensively than any partial self-reported indicator and as such are able to better quantify the socioeconomic gradient of ST as a contributor to health inequalities, however a limitation is that accelerometers do not distinguish between sitting and standing which have different health implications, this also applies to occupational sitting/standing time. It has been argued that standing should not be considered a sedentary behaviour [31]. This limitation is also pertinent to the self-reported ST assessment as standing time was included in the occupational ST question. The lack of information on work times did not allow us to examine the possibility that ST differences between SEP groups are partly due to longer work hours in higher SEP groups. Taken together, these limitations of the measurements may, to some extent, have confounded the associations of SEP with total and occupational ST we reported. Another limitation is that our study was limited to the accelerometry sample of HSE 2008 and this might have led to our sample being less representative of the target population. Although those in the subsample offered the accelerometer were older and more likely to be retired and to be less healthy than the rest of the adult Health Survey for England sample, those who refused to wear an accelerometer were similar in terms of employment status and area-level deprivation compared to those who wore the accelerometers for at least four days a week[32]. Higher SEP is linked to higher commuting by car [33] and this may partly explain the socioeconomic gradient but our data are limited in that there was no specific question on commuting-related sitting to examine this explanation.

Conclusions

Objectively-measured total sedentary time and occupational sedentary time are higher among economically active English adults in higher socioeconomic groups compared to less privileged groups. However, TV viewing is lower in higher socioeconomic groups regardless of economic activity. Combining different socioeconomic indicators appears to have composite power as a predictor of sedentary time.

Funding: This work was funded by the National Institute for Health Research through a Career Development Fellowship (ES). NC is also funded by the National Institute for Health Research through the same source. The views expressed in this article are those of the authors and not the English Department of Health or the National Institute for Health Research.

Data Sharing: No additional data are available

Competing interests: None of the authors have any competing interests to declare

Authors' Contributions: All authors have contributed sufficiently, ES conceived the idea, prepared the dataset, drafted most of the manuscript and revised the manuscript several times. NC did the statistical analysis under the supervision of ES and prepared the Tables, Figures and Supplemental Online material. AR processed the accelerometry files. NS, MH and AR redrafted parts of the manuscript and critically evaluated the whole material. All authors approved the final version before submission.

References

1. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". Exercise and Sport Sciences Reviews 2008;**36**(4):173-78.
2. Katzmarzyk PT, Church TS, Craig CL, et al. Sitting Time and Mortality from All Causes, Cardiovascular Disease, and Cancer. Med Sci Sports Exerc 2009;**41**(5):998-1005.
3. Matthews C, George SM, Moore SC, et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. Am J Clin Nutr 2012;**95**(2):437-45.
4. Patel AV, Bernstein L, Deka A, et al. Leisure Time Spent Sitting in Relation to Total Mortality in a Prospective Cohort of US Adults. Am J Epidemiol 2010;**172**(4):419-29.
5. van der Ploeg HP, Chey T, Korda RJ, et al. Sitting Time and All-Cause Mortality Risk in 222 497 Australian Adults. Arch Intern Med 2012;**172**(6):494-500.
6. Grøntved A, Hu FB. Television Viewing and Risk of Type 2 Diabetes, Cardiovascular Disease, and All-Cause Mortality. JAMA 2011;**305**(23):2448-55.
7. Joint Health Surveys Unit. The Health Survey for England 2008. Volume 1 Leeds, 2010:21-206.
8. Joint Health Surveys Unit. The Health Survey for England 2008, Volume 2. Leeds: , 2010:11.
9. Marmot MG, Shipley MJ, Hemingway H, et al. Biological and behavioural explanations of social inequalities in coronary heart disease: Whitehall II Study. Diabetologia 2008;**51**(11):1980-88.
10. Williams ED, Tapp RJ, Magliano DJ, et al. Health behaviours, socioeconomic status and diabetes incidence: the Australian Diabetes Obesity and Lifestyle Study (AusDiab). Diabetologia 2010;**53**:2538-45.
11. Stringhini S, Sabia S, Shipley M, et al. Association of Socioeconomic Position With Health Behaviors and Mortality. JAMA 2010;**303**(12):1159-66.
12. Stamatakis E, Hillsdon M, Mishra G, et al. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. Journal of epidemiology and community health 2009;**63**(9):734-40.
13. Van Dyck D, Cardon G, Deforche B, et al. Socio-demographic, psychosocial and home-environmental attributes associated with adults' domestic screen time. BMC Public Health 2011;**11**:668.
14. Teychenne M, Ball K, Salmon J. Correlates of socio-economic inequalities in women's television viewing: a study of intrapersonal, social and environmental mediators. Int J Behav Nutr Phy Act 2012;**9**:3.
15. Burton NW, Haynes M, van Uffelen JGZ, et al. Mid-Aged Adults' Sitting Time in Three Contexts. Am J Prev Med 2012;**42**(4):363-73.
16. Bowman SA. Television-viewing characteristics of adults: correlations to eating practices and overweight and health status. Preventing Chronic Disease 2006;**3**(2).
17. Stamatakis E, Hamer M, Tilling K, et al. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. Int J Epidemiol 2012;**41**:1328-37.
18. Clark BK, Healy GN, Winkler EAH, et al. Relationship of Television Time with Accelerometer-Derived Sedentary Time: NHANES Med Sci Sports Exerc 2011;**43**(5):822-28.
19. van Uffelen JGZ, Heesch KC, Brown W. Correlates of Sitting Time in Working Age Australian Women: Who Should Be Targeted With Interventions to Decrease Sitting Time? J Phys Act Health 2012;**9**(2):270-87.
20. Santos R, Soares-Miranda L, Vale S, et al. Sitting time and body mass index, in a portuguese sample of men: Results from the azorean physical activity and health study (APAHS). Int J Environ Res Publ Health 2010;**7**(4):1500-07.
21. Duncan MJ, HBadland HM, Mummery WK. Physical Activity Levels by Occupational Category in Non-Metropolitan Australian Adults. J Phys Act Health 2010;**7**(6):718-23.

22. Matthews CE, Chen KY, Freedson PS, et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. Am J Epidemiol 2008;**167**(7):875-81.
23. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . Prev Med 2007;**45**:416-23.
24. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey Br J Sports Med 2008;**42**:601-08.
25. Scholes S, Coombs N, Pedisic Z, et al. Age- and sex-specific criterion validity of the health survey for England physical activity and sedentary behavior assessment questionnaire as compared with accelerometry. Am J Epidemiol 2014;**179**(12):1493-502.
26. Troiano RP, Berrigan D, Dodd KW, et al. Physical activity in the United States measured by accelerometer. Med Sci Sports Exerc 2008;**40**(1):181-8.
27. Gallo V, Egger M, McCormack V, et al. STrengthening the Reporting of OBservational studies in Epidemiology--Molecular Epidemiology (STROBE-ME): an extension of the STROBE Statement. PLoS medicine 2011;**8**(10):e1001117.
28. Jans M, Proper K, Hildebrandt V. Sedentary Behavior in Dutch Workers: Differences between Occupations and Business Sectors. Am J Prev Med 2007;**33**:450-54.
29. Stamatakis E, Grunseit AC, Coombs N, et al. Associations between socio-economic position and sedentary behaviour in a large population sample of Australian middle and older-aged adults: The Social, Economic, and Environmental Factor (SEEF) Study. Prev Med 2014;**63c**:72-80.
30. Rhodes RE, Mark RS, Temmel CP. Adult Sedentary Behavior A Systematic Review. Am J Prev Med 2012;**42**(3):E3-E28.
31. Yates T, Wilmot EG, Khunti K, et al. Stand up for your health: Is it time to rethink the physical activity paradigm? Diabetes Research and Clinical Practice 2011;**93**(2):292-94.
32. Roth M, Mindell J. Who provides accelerometry data? Correlates of adherence to wearing an accelerometry motion sensor: the 2008 health survey for England. J Phys Act Health 2013;**10**(1):70-78.
33. Goodman A, Guell C, Panter J, et al. Healthy travel and the socio-economic structure of car commuting in Cambridge, UK: A mixed-methods analysis. Social Science & Medicine 2012;**74**(12):1929-38.

Figure Legends and footnotes

Figure 1: Multivariate-adjusted average daily sedentary time by SEP score

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b SEP1 indicates most deprived, SEP 5 indicates least deprived
c Any paid work in the last four weeks.

Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates lowest income quartile (<=£13876),Q4 indicates the highest income quartile (>=£39001).

Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average

accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Education Level 1 represents NVQ1/CSE and NVQ2 GCE O Level equivalent; Level 2 represents NVQ3/GCE A Level equivalent; Level 3 represents higher education below Degree and NVQ4/NVQ5/Degree or higher.

Figure 5: Multivariate-adjusted average daily sedentary time[a] by occupational social class.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

Figure 6: Multivariate-adjusted sedentary time by area deprivation quintile.

Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometry-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.
a Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.
b Q1 indicates most deprived, Q5 indicates least deprived

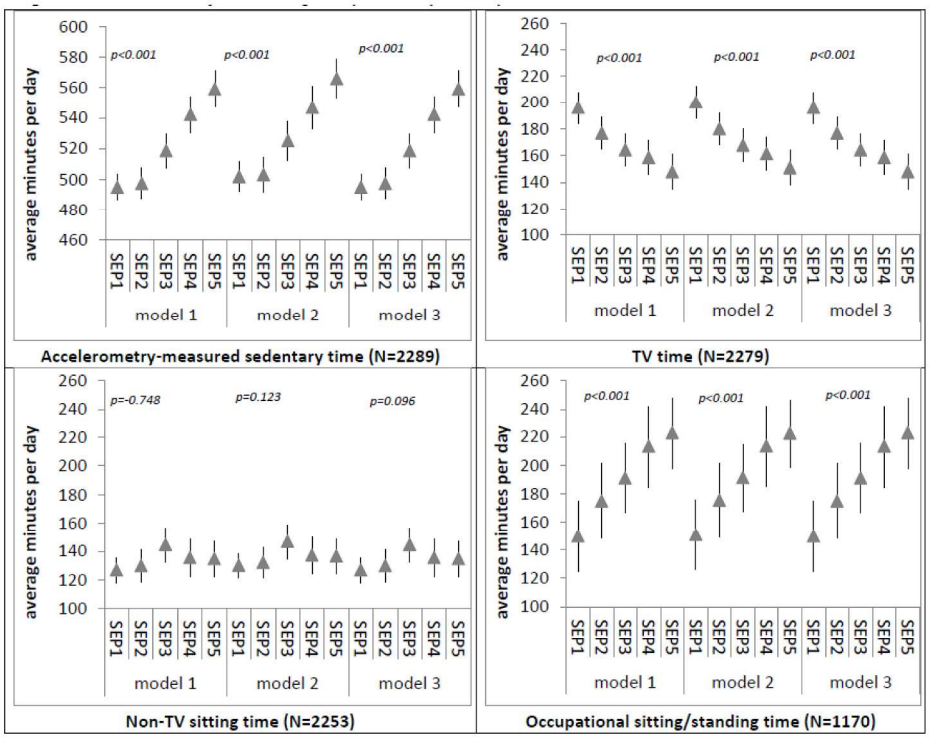


Figure 1: Multivariate-adjusted average daily sedentary time by SEP score
254x190mm (300 x 300 DPI)

Supplemental Digital Content 1

Unabridged Methods

Study Sample

The Health Survey for England (HSE) is a repeated nationally representative study of individuals living in private households in England. We drew our sample from the 2008 HSE which had a special focus on physical activity and sedentary behaviour. The sample is drawn using multi-stage stratified probability sampling with postcode sectors as the primary sampling unit. More details of the sample design are available elsewhere (2). The household response rate was 64% for the main sample, and 73% for the accelerometer sub-sample (3). Ethical approval for the 2008 HSE was obtained from the Oxford A Research Ethics Committee (reference number 07/H0604/102). We included adults aged 16 and over who had both valid accelerometry and self-reported SB data. Participants provided written informed consent. In total, 2289 adults (1030 males) provided valid accelerometry data, with 2279 (1020 males) and 2253 (1014) males) also providing self-reported TV and non-TV time respectively. 1170 (576 males) provided occupational sitting/standing time

Demographics and contextual variables

Trained fieldworkers assessed participants' demographics, self-rated health, long standing illness, alcohol consumption and smoking using Computer Assisted Personal Interviewing. Height and weight were measured by the same fieldworkers using standard protocols that have been described in detail elsewhere (5). Body mass index (BMI) was computed as weight (kilograms) divided by squared height (metres).

Socioeconomic position measures

Social class was determined using the Registrar General's classification and was grouped as I&II (professional and managerial/technical), III Non-manual, III manual, IV&V (semi-skilled manual and

unskilled manual). Household income was converted to equivalised annual household income that is adjusted for the number of persons in the household using the McClements scoring system (15). The income data presented here are based on quartiles. Highest education qualification was coded as no qualification and three levels: Level 1 represents secondary school or below (NVQ1/CSE and NVQ2/GCE O Level equivalent); Level 2 represents post-compulsory secondary school (NVQ3/GCE A Level equivalent) and Level 3 represents higher education (higher education below Degree and NVQ4/NVQ5/Degree or higher). Area deprivation was assessed using the 2004 Index of Multiple Deprivation (IMD) which provides a measure of area deprivation with deprivation based on measures in seven domains: income, employment, health deprivation and disability, education, skills and training, barriers to housing and services, crime and living environment. IMD was initially a continuous score that we grouped into quintiles (1 representing the most deprived quintile, and 5 representing the least deprived).

Sedentary time and physical activity measures

Objective measures

A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, Florida) during waking hours for seven consecutive days. At the core addresses that were eligible for accelerometry, up to two adults in total were selected to wear the accelerometer (up to one adult in those households with eligible children). Full details of the accelerometry sample selection procedure can be found elsewhere (6). At the end of the initial HSE 2008 interview, interviewers obtained agreement for participation in the accelerometry study, provided the accelerometers and explained procedures. The accelerometry data were processed using specialist software (KineSoft, New Brunswick). In consistency with previous epidemiological SB studies (8), the sampling epoch was one minute and non-wear time was defined as periods of at least 60 consecutive minutes of zero counts, with allowance for up to 2 consecutive minutes of 1–99 counts/minute. For a day to be 'valid' for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 minutes. Like previously (7), participants with at least one day

of valid wear were included in these analyses, although the majority (76%, N=1742) had between six and seven days and 95% (N=2165) had at least three valid days. All physical activity and sedentary time variables were converted to time (in minutes) per valid day.

Self-reported measures

Sedentary time was assessed using a set of questions on the usual weekday time spent on: a) TV (including DVDs and videos) viewing ("In the last four weeks, how much time did you spend watching TV/videos) on an average week day?"); and b) any other sitting during non-work times, including reading and computer use ("In the last 4 weeks, how much time did you spend sitting down doing any other activity on an average weekday? Please do not include time spent doing these activities while at work"). An equivalent set of questions assessed TV and non-TV sedentary time in the weekend days. For those participants who were economically 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/standing while at work ("On an average work day in the last four weeks, how much time did you usually spend sitting down or standing up?"). (14) While it is not ideal to include standing as a measure of sedentary time, it is often necessitated by the unavailability of sitting-specific data, and standing is routinely included in objectively measured sedentary data as most accelerometers are unable to differentiate between time spent sitting or standing. For the purposes of this study, standing will be considered a measure of sedentary behaviour.

Physical activity was assessed using the long version of the Health Survey for England 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, domestic physical activity (12) (11) and any recreational exercise, (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports, racket sports) (9). Occupational activity was measured as average daily (per day at work) times spent on

walking, climbing stairs or ladders, and lifting, carrying or moving loads (5). We calculated MVPA using established metabolic equivalent tables (1). The criterion validity of the physical activity questionnaire has been demonstrated in a study of 106 English adults from the general population (45 men) where the output of accelerometers (worn for two non-consecutive weeks over a month period) was compared against the above questions (4, 13).

Data handling/Statistical analysis

Regrouping the Socioeconomic position variables

Due to small numbers of observations, the top and bottom two categories of social class were collapsed, resulting in four categories: unskilled /semi-skilled manual; skilled manual; skilled non-manual; and managerial/technical/ professional. Using existing methods (10), we derived a composite Socioeconomic Position (SEP) score using household income, individual education, and occupational social class of the head of household. The lowest category of each component variable was assigned a SEP score of 0, the second lowest category was given a SEP score of 1, and so on, with the highest category given a SEP score of 4. The scores for each individual SEP indicator were then aggregated, resulting in a SEP score ranging from 0 to 12. Due to small numbers of observations in the high and low end of the score, the SEP score was collapsed into five categories of comparable size (0 -3=SEP1; 4- 5=SEP2; 6- 7=SEP3; 8=SEP4; 9- 12=SEP5), with 1 representing the lowest SEP, and 5 the highest.

Deriving sedentary time and physical activity variables

Week- and weekend day-specific TV and non-TV leisure time sitting were converted to all-week time (minutes) using the following formula: (weekday time × 5) + (weekend day time × 2) / 7. Occupational sitting/standing time (minutes) per day was calculated by multiplying the number of days worked per week by the average time spent sitting/standing at work on a work day, and dividing by 7.

Weekly self-reported MVPA hours/week were calculated as number of days of participation multiplied by time per day in each activity type (walking, cycling, and each other sport and exercise the questionnaire enquired about) (5, 6) Due to the large number of participants and the very skewed distribution, self-reported MVPA was categorised in to none, less than 30 minutes, 30 minutes to 1 hour, 1 to 2 hours, and more than 2 hours of MVPA per day.

For the accelerometry data we used 0-99 counts/minute to denote sedentary (<1.5 MET) (7); 200-2,019 counts/minute to denote light physical activity; and ≥2,020 counts/minute to denote MVPA (>3 MET) (16). Accelerometer-measured sedentary time and physical activity variables were converted to time (in minutes) per valid day.

Missing data and multiple imputation

To improve the normality of the residuals that are required for linear regression, outliers outside 3 standard deviations of the mean for all continuous variables apart from age were removed from the analyses. This excluded 1.3% to 2.2% of cases from each continuous variable. Due to a substantial proportion of cases with at least one missing value in at least one covariable or exposure variable (22% to 28% depending on the exposure variable) we performed multiple imputation. IBM SPSS v20 was used to conduct the multiple imputation, missing values were imputed for all covariables and exposures, with observed maximum and minimum values used as constraints. Outcome variables did not have missing values imputed, but were included in the imputation models to predict missing values in other variables. Linear regression was used as the type of imputation, and 5 cycles of imputation were conducted resulting in 5 imputed datasets. Results from these 5 datasets were combined using the multiple imputation module in SPSS to provide pooled results. The imputed sample size is limited to the number of valid observations for each outcome variable (2279 for accelerometry-measured ST, 2269 for TV time, 2253 for non-TV sitting time, and 1170 for occupational sitting time). Non-imputed results are presented in the appendix.

Dealing with non-response

Analyses were weighted for non-response (5) to give a sample that was representative of adults living in England. In brief, the non-response weights were calculated by fitting a logistic regression model (weighted by a previously developed weighting factor)(5) for all adults with interview completion as the outcome and age group by sex, household type, geographical area, and household social class as covariates. The non-response weights, which were trimmed at the 1% tails to remove extreme values, were calculated as the inverse of the predicted probabilities of response.(5) The complex samples module in SPSS was used to account for clusters in the survey design.

Statistical analysis

The associations between each of the socioeconomic indicators (household income, social class, education, SEP score, and area deprivation,) and each individual ST indicator (TV time, non-TV sitting tine, occupational sitting/standing, and accelerometer-measured ST) was examined using generalised linear models, and by multiple linear regression to determine linear trend p values. Results are presented for the whole week, the weekday/weekend day-specific results can be found in the online appendix. SPSS version 21 was used for all analyses. For all multivariate analyses we used the complex samples generalised linear models (GLM) procedure to take into account the complex survey design.

All statistical models were run for each combination of dependent variable and main exposure. Different models were adjusted for: 1) age and sex; 2) additionally for BMI, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, smoking status, and other socioeconomic indicators (household income, social class, area deprivation); 3) additionally for time spent in self-reported MVPA and accelerometer-measured MVPA, and average accelerometer wear

time on valid days Models with accelerometer-measured ST as the outcome were also adjusted for average accelerometer wear time on each valid day. There was no evidence of colinearity in the multivariate model as no variance inflation factor value was higher than approximately 1.5, with most values just over 1. Residual statistics and plots for each model were checked for normality, independence of observations, homoscedasticity, and influential outliers.

GLM coefficients indicate mean differences in sedentary time (in minutes) between the reference category and each of the other SEP categories. The lowest SEP category (<£10671 for household income, unskilled/ semi-skilled manual for social class, most deprived quintile for area deprivation, SEP1 (lowest socioeconomic position) for SEP score) is the reference category for the mean difference in the outcome (and associated confidence interval for the difference) in all CSGLMs.

References

1. Ainsworth BE, Haskell WL, Whitt MC et al. Compendium of physical activities: an update of activity codes and MET intensities. *Med Sci Sports Exerc*. 2000;32(9 Suppl):S498-504.
2. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 1* Leeds2010.
3. Joint Health Surveys Unit. *The Health Survey for England 2008. Volume 2* Leeds2010.
4. Joint Health Surveys Unit. *The Health Survey for England Physical Activity Validation Study: substantive report.* Leeds: Health and Social Care Information Centre; 2007.
5. Joint Health Surveys Unit. *The Health Survey for England 2008*. Leeds: The Information Centre for Health and Social Care; 2009.
6. Joint Health Surveys Unit. *The Health Survey for England 2008, Volume 2: Methods and Documentation*. Leeds: The Information Centre for Health and Social Care; 2009.
7. Matthews C, George SM, Moore SC et al. Amount of time spent in sedentary behaviors and cause-specific mortality in US adults. *The American Journal of Clinical Nutrition*. 2012;95(2):437-45.
8. Matthews CE, Chen KY, Freedson PS et al. Amount of time spent in sedentary behaviors in the united states, 2003-2004. *Am J Epidemiol*. 2008;167(7):875-81.
9. Stamatakis E, Chaudhury M. Temporal trends in adults' sports participation patterns in England between 1997 and 2006: the Health Survey *Br J Sports Med*. 2008;42:601-8.
10. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *J Epidemiol Commun Health*. 2009;63:734-40.
11. Stamatakis E, Ekelund U, Wareham N. Temporal trends in physical activity in England. The Health Survey for England 1991 to 2004. . *Prev Med*. 2007;45:416-23.
12. Stamatakis E, Hamer M, Lawlor DA. Physical activity, mortality and cardiovascular disease: Is domestic physical activity beneficial? The Scottish Health Survey 1995, 1998 and 2003. . *Am J Epidemiol*. 2009;169:1191-200.

13. Stamatakis E, Hamer M, Primatesta P. Cardiovascular medication, physical activity and mortality: cross-sectional population study with ongoing mortality follow-up. *Heart*. 2009;95(6):448-53.
14. Stamatakis E, Hamer M, Tilling K, Lawlor DA. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. *Int J Epidemiol*. 2012.
15. Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey 2003. *Journal of Epidemiology and Community Health*. 2009;63(9):734-40.
16. Troiano RP, Berrigan D, Dodd KW, Masse LC, Tilert T, McDowell M. Physical activity in the United States measured by accelerometer. *Med Sci Sports Exerc*. 2008;40(1):181-8.

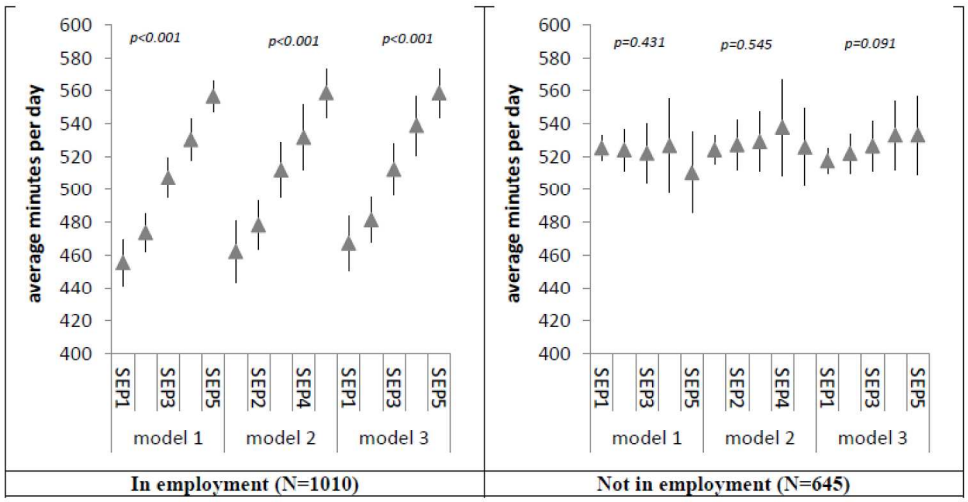


Figure 2: Multivariate-adjusted accelerometer-measured sedentary time by SEP Score for individuals stratified by employment status
254x190mm (300 x 300 DPI)

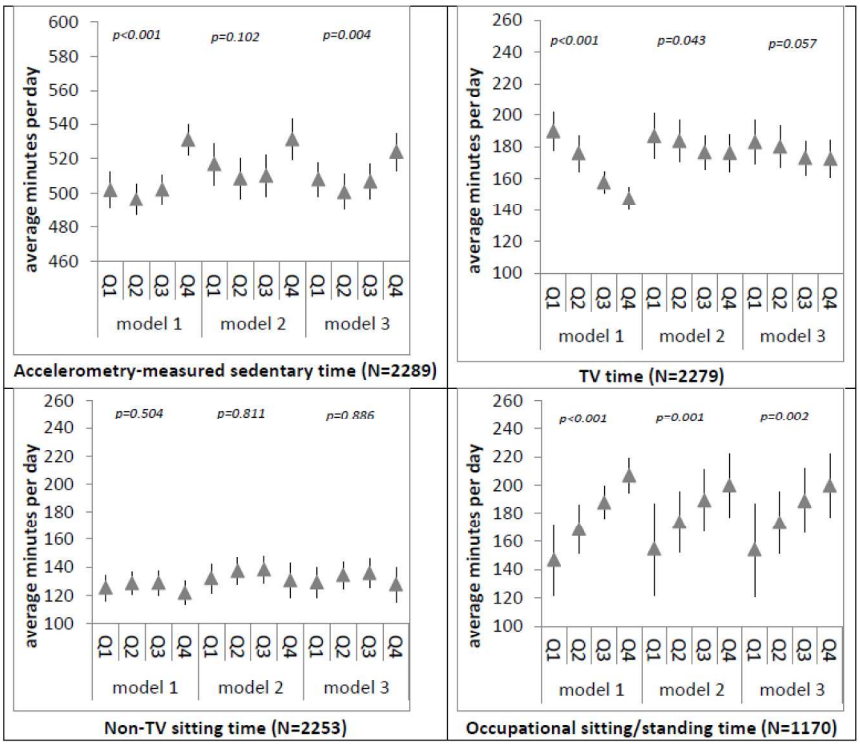


Figure 3: Multivariate-adjusted average daily sedentary time by household income quartile
254x190mm (300 x 300 DPI)

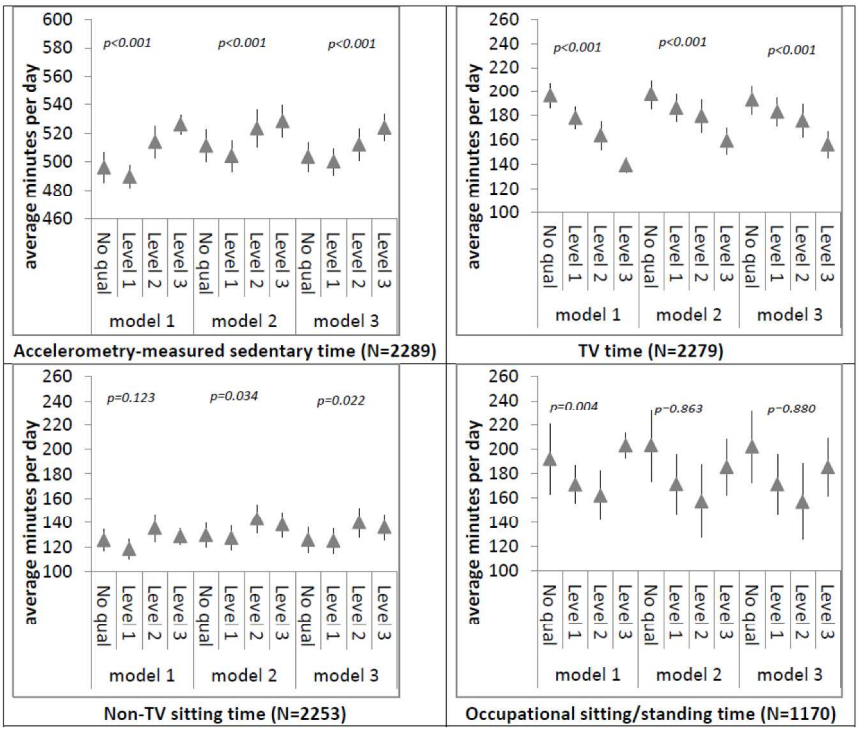


Figure 4: Multivariate-adjusted difference average daily sedentary time by highest qualification
254x190mm (300 x 300 DPI)

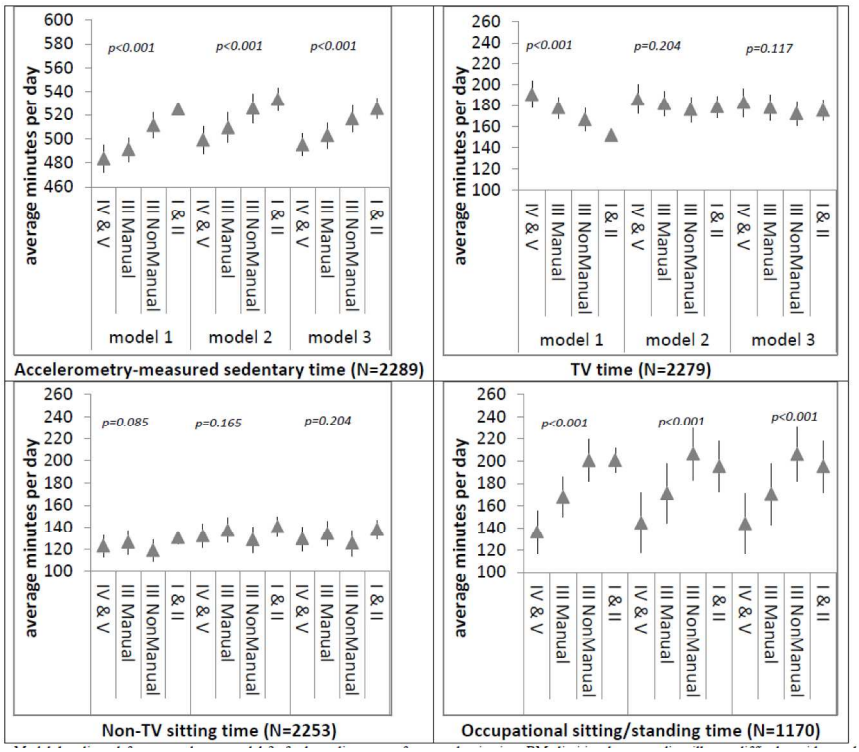


Figure 5: Multivariate-adjusted average daily sedentary timea by occupational social class
254x190mm (300 x 300 DPI)

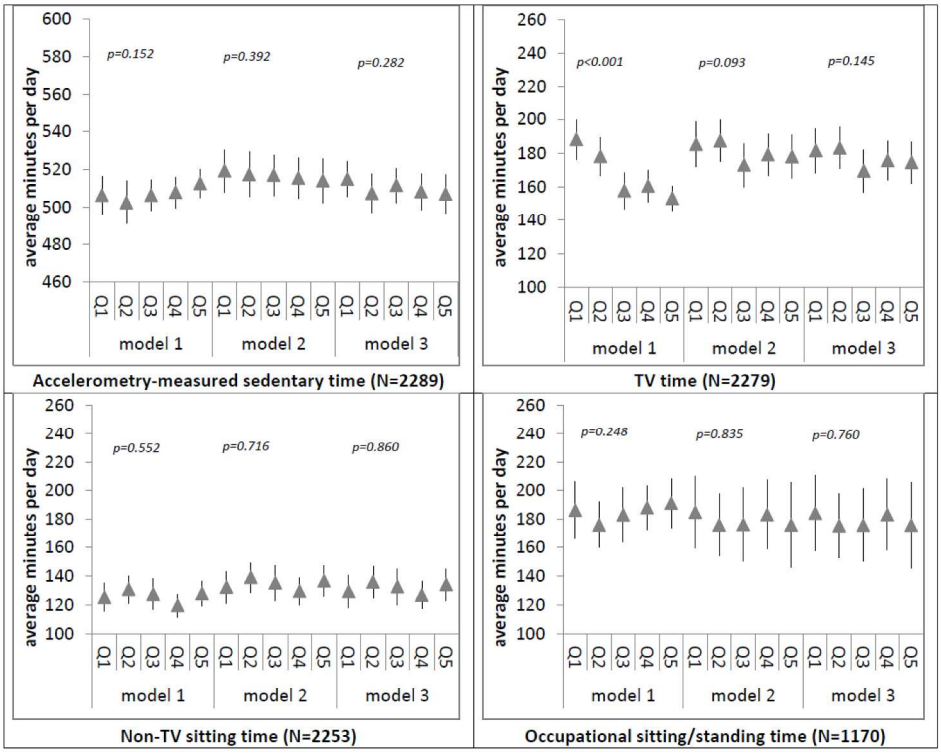
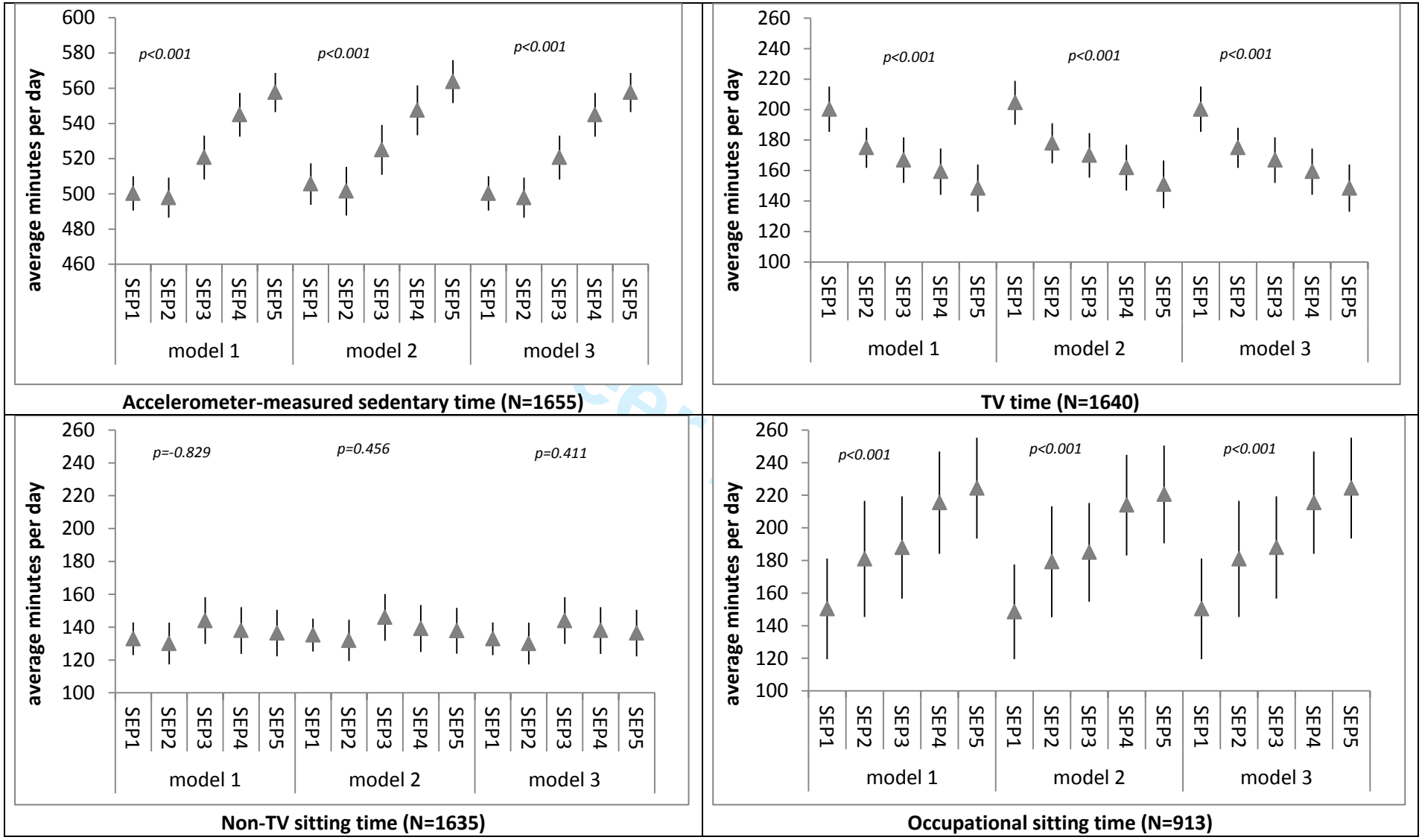


Figure 6: Multivariate-adjusted sedentary time by area deprivation quintiles
254x190mm (300 x 300 DPI)

Supplementary Figure S2: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Unimputed, casewise-deleted data.

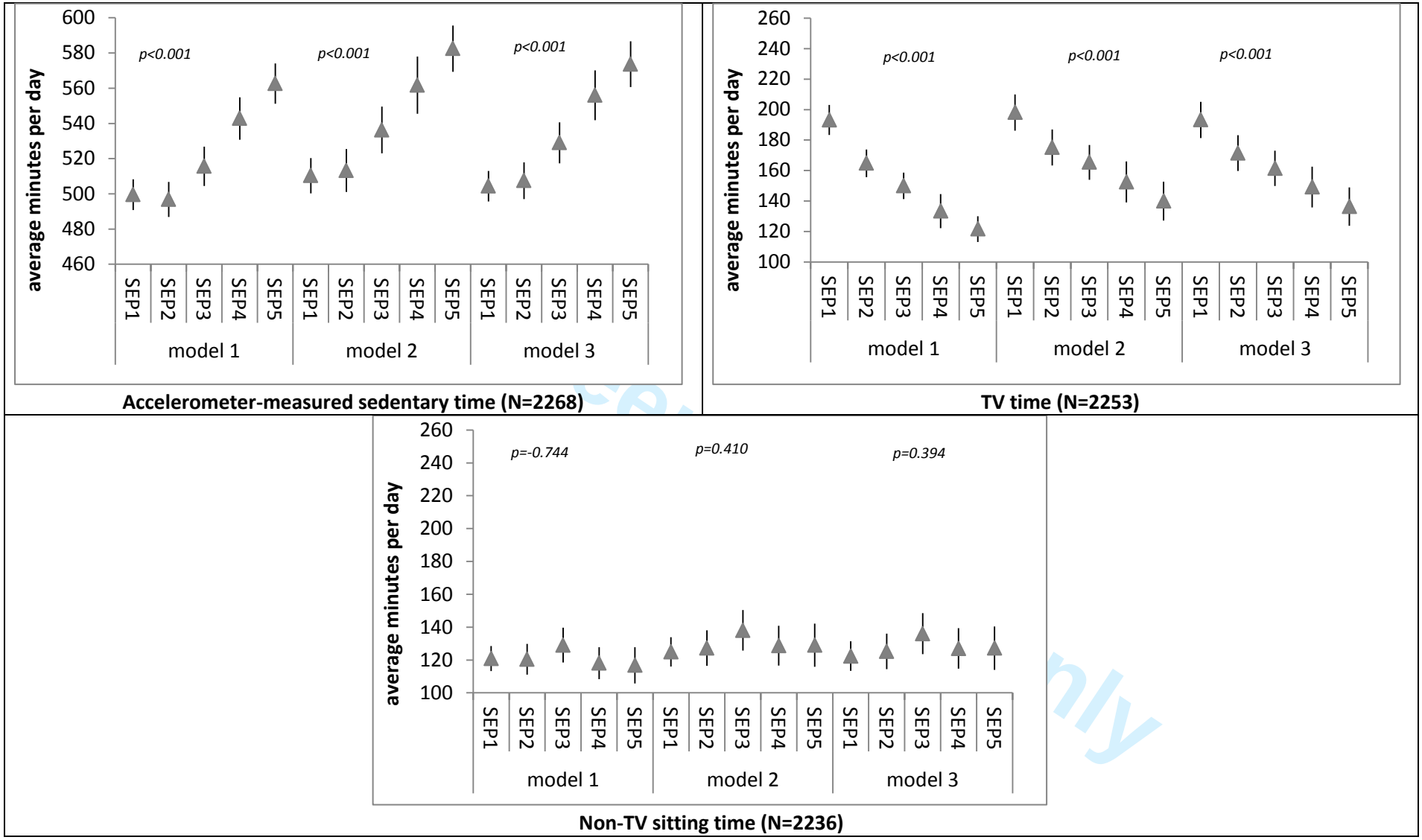


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S3: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekdays.

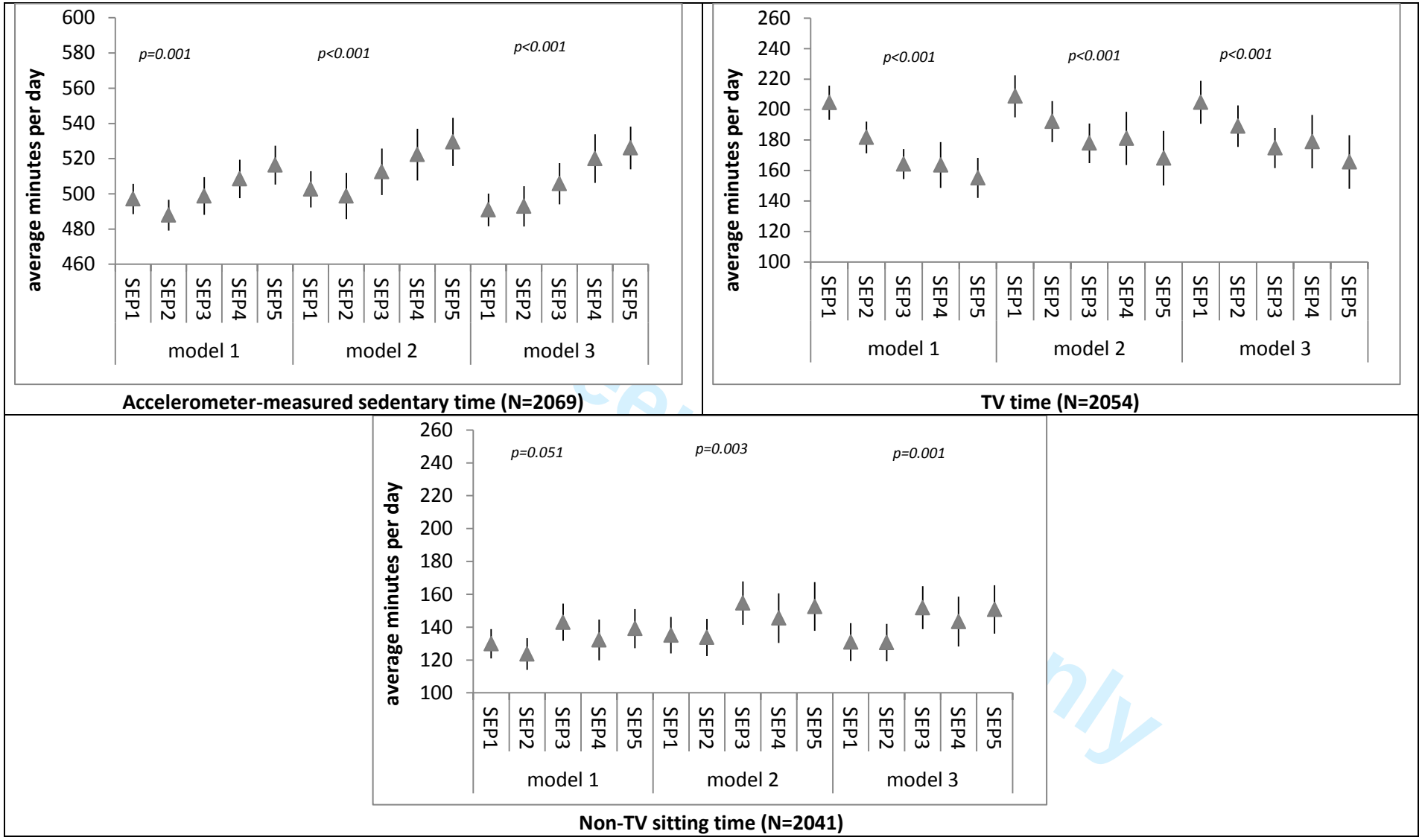


Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

Supplementary Figure S4: Multivariate-adjusted average daily sedentary time[a] by SEP score[b]. Weekend days.



Model 1: adjusted for age and sex; model 2: further adjustments for area deprivation, BM, limiting long standing illness, difficulty with usual activities, car ownership, drinking frequency, and smoking status; model 3: further adjustments for self-reported time spent in MVPA, accelerometer-measured MVPA time, and average accelerometer wear time on valid days. Models with accelerometer sedentary time as the outcome were also adjusted for average accelerometer wear time on valid days.

[a] Coefficients represent estimated marginal means from generalised linear models, with 95% confidence intervals. Linear trend p values were obtained from linear regression.

[b] SEP1 indicates most deprived, SEP 5 indicates least deprived

STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	3-4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	6
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	6
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-8
Data sources/ measurement	8*	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	6-8
Bias	9	Describe any efforts to address potential sources of bias	*8*
Study size	10	Explain how the study size was arrived at	10
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	9-10
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9-10
		(*b*) Describe any methods used to examine subgroups and interactions	9-10
		(*c*) Explain how missing data were addressed	9
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	10
		(*e*) Describe any sensitivity analyses	9-10
Results			

Participants	13*	(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	10-11
		(b) Give reasons for non-participation at each stage	10-11
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10-12
		(b) Indicate number of participants with missing data for each variable of interest	9
Outcome data	15*	Report numbers of outcome events or summary measures	
Main results	16	(*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	12
		(*b*) Report category boundaries when continuous variables were categorized	7-10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	n/a
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	14-15
Discussion			
Key results	18	Summarise key results with reference to study objectives	15
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	16-17
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	16-17
Generalisability	21	Discuss the generalisability (external validity) of the study results	17
Other information			
Funding	22	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	18

*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.