Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults

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Background Sedentary behaviour has been proposed to be detrimentally associated with cardio-metabolic risk independently of moderate to vigorous physical activity (MVPA). However, it is unclear how the choice of sedentary time (ST) indicator may influence such associations. The main objectives of this study were to examine the associations between ST and a set of cardio-metabolic risk factors [waist, body mass index (BMI), systolic and diastolic blood pressure, total and high-density lipoprotein cholesterol, glycated haemoglobin] and whether these associations differ depending upon whether ST is assessed by self-report or objectively by accelerometry.

Methods Multiple linear regression was used to examine the above objectives in a cross-sectional study of 5948 adults (2669 men) aged 16–65 years with self-reported measures of television time, other recreational sitting and occupational sitting or standing. In all, 1150 (521 men) participants had objective (accelerometry) data on ST as well.

Results Total self-reported ST showed multivariable-adjusted (including for MVPA) associations with BMI [(unstandardized beta coefficients corresponding to the mean difference per 10 min/day greater ST: 0.035 kg/m²; 95% CI: 0.027–0.044), waist circumference (0.083 cm; 0.062–0.105), systolic (0.024 mmHg; 0.000–0.049) and diastolic blood pressure (0.023 mmHg; 0.006–0.040) and total cholesterol (0.010 mmol/l; 0.001–0.018)]. Similar associations were observed for TV time, whereas non-TV self-reported ST showed consistent associations with the two adiposity proxies (BMI/waist circumference) and total cholesterol. Accelerometry-assessed ST was only associated with total cholesterol (0.010 mmol/l; 0.001–0.018).

Conclusions In this study, ST was associated consistently with cardio-metabolic risk only when it was measured by self-report.
**Introduction**

An emerging body of evidence consistently suggests that excessive sedentary behaviour, as characterized by activities involving sitting, may be linked to increased risk for obesity, dyslipidemia and impaired glucose metabolism, independently of moderate to vigorous physical activity (MVPA) participation.

Recent prospective studies have shown associations between greater amounts of time spent in activities involving sitting and increased incidence of cardiovascular disease and overall mortality. Greater time spent in television (TV) viewing or other screen-based recreation has gained particular attention. A recent meta-analysis concluded that prolonged TV viewing is associated with increased risk of cardio-metabolic disease and death. Nevertheless, TV viewing behaviour remains poorly understood, and its associations with adverse outcomes might be due to a true causal effect of sedentary behaviour, an association with other unhealthy behaviours (e.g. unhealthy food snacking) that are commonly related to TV viewing or the influence of TV advertisements for unhealthy foods. In a sample of Australian adults, TV viewing was a robust marker of overall sedentary time (ST) assessed by self-report in women, but not in men. Greater time spent watching TV has been associated with obesity in many studies, and it is possible that this association explains associations with other cardio-metabolic risk factors and events. We have previously found that body mass index of unhealthy eating that was based on the average weekly consumption frequency of cheese, red meat, fried food, chocolate, crisps, nuts, biscuits and cakes (range 0–32).

To date, the majority of studies looking at the associations between markers of ST and cardio-metabolic outcomes have relied solely on self-reported measures. In order to better understand the association between ST and cardio-metabolic risk, it is valuable to combine both self-reported (which can provide contextual information, such as whether the individual is watching TV when sedentary, which is not possible to obtain with accelerometry) and objective measures (using movement sensors, which can provide an accurate assessment of total time being inactive—primarily sitting). We are unaware of any studies that have compared associations for cardio-metabolic outcomes using both of these methods.

The aim of this study was to investigate the associations between ST and cardio-metabolic risk in working age adults. The specific objectives were to examine: (i) whether any observed associations differ between self-report and objectively assessed ST, (ii) whether any observed associations between self-reported ST and the examined cardio-metabolic outcomes differ by ST indicator (TV, other leisure time sitting, etc.), (iii) whether any observed associations are independent of MVPA and (iv) whether any observed associations between ST and (non-adiposity) cardio-metabolic outcomes are independent of BMI and waist circumference.

**Methods**

**Sample and design**

The Health Survey for England (HSE) draws annually a nationally representative general population sample of adults living in households. The sample is drawn using multistage stratified probability sampling with postcode sectors as the primary sampling unit. In the present analysis, we used data from HSE 2008, which had a special focus on physical activity and fitness. In HSE 2008, the household response rate for the core sample was 64%. Ethical approval for the 2008 survey was obtained from the Oxford Research Ethics Committee (reference number 07/H0604/102). Only participants aged 16–65 years were included in the analyses because the sedentary behaviour patterns of those aged >65 years were distinctively different. We included only participants who reported no cardiovascular long-standing illness (stroke, angina or coronary heart disease).

**Measurements**

**Demographics and contextual variables**

Computer-assisted personal interviewing modules assessed participants’ demographics, occupational status, long-standing illness, education, eating habits, fruit and vegetable consumption, alcohol and smoking. In a separate visit, qualified nurses collected and coded information on prescribed medication.

The eating habits information was used to derive an index of unhealthy eating that was based on the average weekly consumption frequency of cheese, red meat, fried food, chocolate, crisps, nuts, biscuits and cakes (range 0–32).

**Biological cardio-metabolic risk factors**

Height and weight were measured during home visits by trained interviewers using standard protocols that have been described in detail elsewhere. BMI was computed as weight (kilograms) divided by squared height (metres). In a subsequent home visit, the survey nurses measured waist circumference (defined...
ST and physical activity
Self-reported measures. ST was assessed using a set of questions on the usual weekday time spent on (i) TV (including DVDs and videos) viewing (‘In the last 4 weeks, how much time did you spend watching TV/videos on an average weekday?’) and (ii) 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 ST in the weekend days. For those participants who were professionally active [i.e., those who answered ‘yes’ to the question ‘In the last 4 weeks, did you do any paid or unpaid work either as an employee or as self-employed (including voluntary or part time work)?’], another set of questions assessed the average daily times spent sitting or standing while at work (‘On an average workday in the last 4 weeks, how much time did you usually spend sitting down or standing up?’).

Physical activity was assessed using the long version of the HSE questionnaire that was used in the 1997 survey for the first time and was repeated in the 1998, 2006 and 2008 surveys. Questions included frequency (number of days in the last 4 weeks) and duration (minutes per day) of participation in walking for any purpose and any recreational exercise (e.g. cycling, swimming, aerobics, gym exercises, dancing, team sports or racket sports). Occupational activity was measured as average daily (per day at work) time spent on walking, climbing stairs or ladders and lifting, carrying or moving loads. We calculated MVPA using established metabolic equivalent tables, but we excluded domestic physical activity (such as housework, DIY and gardening) as we have previously shown that this type of activity is not related to CVD risk factors or CVD fatal or non-fatal events. 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 2 non-consecutive weeks over a month) was compared with the above questions.

Objective measures. A random sub-sample of HSE 2008 participants were selected to wear a uniaxial accelerometer (Actigraph model GT1M, Pensacola, FL, USA) during waking hours for 7 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 and are summarized in Supplementary Appendix 1 available as Supplementary data at IJE online.

Data handling
Dealing with non-response
Analyses were weighted for non-response to give a sample that was representative of adults living in the UK. In brief, the non-response weights were calculated by fitting a logistic regression model (weighted by a previously developed weighting factor) 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.

Deriving ST and physical activity variables
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). For the accelerometry data, we used 0–199 counts/min to denote sedentary (<1.5 MET). For time spent in physical activity, we used the following cutoff points to calculate daily times: light (1.5–3 MET) 200–2019 counts/min; MVPA (≥3 MET) ≥2020 counts/min. The sampling epoch was 1 min 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 1–199 counts/min. For a day to be ‘valid’ for inclusion in the analyses, participants had to have worn the accelerometer for a minimum of 600 min/day. Although participants with at least 1 day of valid wear have been included in these analyses, the majority (70%, n = 815) had between 6 and 7 days and 84% (n = 978)
had at least 3 valid days. All physical activity and ST variables were converted to time (in minutes) per valid day.

Exposures, outcomes and potential confounders

The exposures considered were total and domain-specific self-reported ST and accelerometer-assessed ST, all as continuous variables. The outcomes of the analyses were BMI (kg/m²), waist circumference (cm), SBP (mmHg), DBP (mmHg), total cholesterol (mmol/l), HDLC (mmol/l) and HbA1c (% of total haemoglobin). Multivariable analyses were adjusted for age, sex, social class, employment status, alcohol consumption in the past week, fruit and vegetable consumption, unhealthy eating index, psychological distress (General Health Questionnaire²¹), cardiovascular or diabetes medication, occupational physical activity and self-reported or accelerometer-assessed MVPA, as appropriate. Accelerometry analyses were also adjusted for average accelerometer wear time.

Statistical analysis

All analyses were carried out with SPSS version 18 (IBM, Chicago, IL). Since all exposures and outcomes were continuous variables, linear regression was used for all analyses. First, we examined associations between total self-reported ST and each outcome (Analysis 1). Second, we examined the associations between each domain of self-reported ST separately (TV time, any other leisure-time sitting, occupational sitting/standing and combined non-TV sitting) and the cardio-metabolic outcomes (Analysis 2). Third, we examined the associations between accelerometer-assessed ST and the above outcomes (Analysis 3). All linear regression analyses took into account the study sampling design using the SPSS 18 Complex Samples module. We assessed multicollinearity between independent variables by performing variance inflation factor (VIF) tests. Generally, VIF values exceeding 10 indicate the presence of multicollinearity. ²² In our models, VIF values were no greater than 1.22 for any exposure or confounder variable. Interactions between the main exposures and sex were examined by entering the centred interaction terms in the age- or sex-adjusted models for each outcome variable. ²³ We also repeated all regression models of non-adiposity-related outcomes (SBP, DBP, HDLC, total cholesterol and HbA1c) where in addition to all other covariables described above we additionally adjusted for waist circumference or BMI (in two sets of different models).

Results

HSE 2008 recruited a total of 11,851 participants aged 16–65 (5347 men) years who were considered for inclusion in Analyses 1 and 2 (self-reported ST). Among those, 2415 participated in the accelerometer sub-study and were considered for Analysis 3 (accelerometer-assessed ST). One hundred forty-eight participants reported cardiovascular long-standing illness and were excluded from analyses. Another 5755 participants were excluded from Analysis 1 and Analysis 2 due to missing data in at least one exposure, outcome or covariable. The accelerometer files of 541 participants were unusable due to non-specific fieldwork errors and another 609 participants were excluded from Analysis 3 due to missing data or not meeting the minimum accelerometer wear time criteria. The variables with most missing values were the blood analytes (n=6661 with missing data in at least one analyte), blood pressure (n=4945) and waist (n=3758). After all exclusions, Analyses 1 and 2 included 5948 participants and Analysis 3 included 1150 participants. For the analyses involving blood biomarkers, these numbers were reduced to 4970 and 971, respectively. Participants included in Analyses 1 and 2 were older and less likely to be smokers, non-drinkers, from manual social class or on CVD medication and more likely to eat fruits and vegetables than those excluded for any reason (Supplementary Table 1, available as Supplementary data at IJE online). Participants included in Analysis 3 were older and less likely to be smokers, non-drinkers or from manual social class and more likely to be on CVD medication and to eat fruits and vegetables than those excluded for any reason (Supplementary Table 2, available as Supplementary data at IJE online). Overall, the sample entered in Analyses 1 and 2 was younger and less likely to eat fruits and vegetables or to be on CVD medication than the sample entered in Analysis 3 but not different in any other characteristics (Supplementary Table 3, available as Supplementary data at IJE online).

In the sub-sample with data on accelerometer and questionnaire measurements of ST (n=1772), the Spearman ρ coefficient for total self-reported vs accelerometer-assessed ST was 0.28 (P<0.0001), for TV alone was 0.02 (P=0.3), for non-TV leisure-time sitting was 0.11 (P<0.001) and for occupational sitting or standing was 0.19 (P<0.001).

Baseline characteristics

Table 1 presents the characteristics of the sample entered in Analyses 1 and 2 (self-reported measures of ST) and Analysis 3 (accelerometry) by tertiles of daily ST. Men reported a mean of 441±164 min/day and women 380±155 min/day of ST and had 582±99 and 558±82 sedentary min/day recorded by the accelerometers. Men also reported more MVPA than women (33±50 vs 29±49) and had more daily MVPA minutes recorded by accelerometers (39±29 vs 28±22) (all P<0.001). The correlations between total ST and MVPA were weak for both self-reported
Table 1 Characteristics of the samples included in the analyses involving self-reported and objective measures of sedentary behaviour

<table>
<thead>
<tr>
<th></th>
<th>Tertiles of daily ST (min/day)</th>
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<tbody>
<tr>
<td></td>
<td>Self-reported</td>
<td>Accelerometry-assessed</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bottom (&lt;325)</td>
<td>Middle (325–470)</td>
<td>Top (&gt;470)</td>
<td>Bottom (&lt;525 min/day)</td>
</tr>
<tr>
<td>n</td>
<td>1998</td>
<td>1936</td>
<td>2014</td>
<td>358</td>
</tr>
<tr>
<td>Sex (% men)</td>
<td>34.9</td>
<td>44.0</td>
<td>55.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Smoking (% current smoker)</td>
<td>19.0</td>
<td>18.1</td>
<td>20.3</td>
<td>0.289</td>
</tr>
<tr>
<td>Social class (% manual)</td>
<td>39.6</td>
<td>34.0</td>
<td>31.5</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Alcohol (% ≥8 units/day in men and ≥6 units/day in women)</td>
<td>19.3</td>
<td>23.1</td>
<td>25.7</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Fruit and vegetable (% ≥5/day)</td>
<td>30.3</td>
<td>30.2</td>
<td>26.9</td>
<td>0.004</td>
</tr>
<tr>
<td>Cardiovascular medication (%)</td>
<td>13.6</td>
<td>15.5</td>
<td>14.6</td>
<td>0.228</td>
</tr>
<tr>
<td>Mean (SD)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>44.0 (13.3)</td>
<td>43.9 (13.5)</td>
<td>42.4 (13.0)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Self-reported MVPAa (min/day)</td>
<td>35.4</td>
<td>32.7 (48.5)</td>
<td>28.6 (43.8)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Accelerometry-assessed MVPAa (min/day)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>Valid accelerometer wear time (min/valid day)</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td></td>
</tr>
<tr>
<td>BMI (kg/m²)</td>
<td>26.4 (4.9)</td>
<td>27.1 (5.1)</td>
<td>27.7 (5.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>89.0 (13.5)</td>
<td>90.8 (13.8)</td>
<td>93.5 (14.3)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>122.9</td>
<td>124.5 (15.3)</td>
<td>124.7 (14.9)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>73.1</td>
<td>74.0 (10.9)</td>
<td>74.3 (10.5)</td>
<td>0.001</td>
</tr>
<tr>
<td>HDLc (mmol/l)</td>
<td>1.53 (0.40)</td>
<td>1.49 (0.37)</td>
<td>1.44 (0.35)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Total cholesterol (mmol/l)</td>
<td>5.45</td>
<td>5.40 (1.11)</td>
<td>5.44 (1.10)</td>
<td>0.472</td>
</tr>
<tr>
<td>HbA1c (%)</td>
<td>5.54 (0.63)</td>
<td>5.50 (0.61)</td>
<td>5.52 (0.66)</td>
<td>0.274</td>
</tr>
</tbody>
</table>

*Based on likelihood ratio chi-square test (categorical variables) or one-way analysis of variance (continuous variables); testing null hypothesis of no difference between tertiles.

aMVPA.

(Spearman ρ = −0.05, P < 0.001) and accelerometry-assessed variables (ρ = −0.28, P < 0.001).

Analysis 1: associations between total self-reported ST and cardio-metabolic risk markers

Table 2 presents the results of the regression models for Analysis 1. With the exception of HbA1c and HDLC, self-report ST was adversely associated with all cardio-metabolic outcomes in the fully adjusted models.

Analysis 2: associations between individual domains of self-reported ST and cardio-metabolic risk markers

As shown in Supplementary Table 4 (available as Supplementary data at IJE online), TV time was associated with all outcomes but not with HDLC or HbA1c. Total non-TV leisure ST was associated with BMI, waist circumference and total cholesterol. Occupational sitting or standing time was associated with BMI, waist circumference, total cholesterol and DBP.
Analysis 3: associations between accelerometry-assessed ST and cardio-metabolic risk markers

Table 3 shows the results of the regression models of accelerometry-assessed ST (Analysis 3). In age- and sex-adjusted models, ST was associated with BMI, waist circumference and total cholesterol, but once analyses were adjusted for MVPA and other potential confounders it was only associated with total cholesterol.

The role of adiposity markers in the associations observed in Analyses 1 and 2

When Analyses 1 and 2 (non-adiposity-related outcomes only) were adjusted for BMI or waist circumference, all associations were attenuated to the null, except for total cholesterol (adjusting for waist, 0.003 mmol/l; 0.001–0.005). In Analysis 2, with TV time as the exposure, adjustments for waist or BMI attenuated the associations with DBP and total cholesterol to the null but not those for SBP (adjusting for waist, 0.047 mmHg; 0.005–0.088). In Analysis 2 with work sitting or standing as the exposure, all associations were attenuated to the null apart from cholesterol (adjusting for waist, 0.0033 mmol/l; 0.0002–0.0064). In analyses with total non-TV time (non-TV leisure time sitting plus work sitting/standing) as the exposure, all associations were attenuated to the null. A full analysis of the role of adiposity in explaining the observed associations between self-reported ST and cardio-metabolic risk markers can be found in another study of ours.24

Sensitivity analyses

To address the possibility that this lack of evidence for an association was due to insufficient statistical power, we carried out the following sensitivity analyses:

(i) We repeated all Analysis 3 models with the maximum available number of participants with valid accelerometry data for each outcome (n range: 1251–2123). All associations were attenuated to the null after adjustments for MVPA (Supplementary Table 5, available as Supplementary data at IJE online).

(ii) In the core sample of Analysis 3 (n = 1150), we examined the multivariable-adjusted associations between accelerometry-assessed MVPA and risk factors. There is less controversy about the association of MVPA with risk factors and if the null association of accelerometer-assessed ST with risk factors was explained largely by lack of statistical power, we might expect that similarly the association of accelerometer-
assessed MVPA would be null. MVPA was associated with all risk factors in the expected direction (data not shown).

(iii) To address the possibility that the different results between the analyses involving self-reported and accelerometry measures were not driven by the different samples, we restricted the analyses 1 and 2 to the accelerometry sample ($n = 1150$). Total self-reported ST was associated with BMI, waist circumference and total cholesterol. TV time was associated with BMI and waist circumference (Supplementary Table 6, available as Supplementary data at IJE online).

(iv) We repeated the analyses of self-reported ST, but instead of adjusting for self-reported MVPA we used accelerometer-assessed MVPA. The results were concordant with those described above in point (iii) (Supplementary Table 7, available as Supplementary data at IJE online).

Interaction tests

As there were interactions between self-reported ST and sex for SBP ($P < 0.001$), we carried out sex-stratified SBP analyses. There was evidence for an association between ST and SBP in women (0.007 mmHg, 0.003–0.010), and to a lesser extent in men (0.013 mmHg, −0.047–0.020).

### Discussion

In this study of a representative sample of the UK population, we observed associations between self-reported ST and a number of cardio-metabolic risk factors, which confirms previous findings.\(^1\)\(^–\)\(^3\) ST domain-specific analyses suggested that these associations were more consistent for TV time than for other domains. Importantly, these associations were not attenuated by adjustments for self-reported and objectively assessed MVPA. We did not, however, confirm most of these associations when using objective (accelerometry-based) measures of ST. These findings suggest that associations of TV viewing with adverse cardio-metabolic risk factors may not represent a causal association between ST and these outcomes, but might reflect the association of TV viewing with other behavioural risk factors, such as consuming high-energy snack foods and/or the influence of TV advertisements on unhealthy behaviours.\(^10\) In the present analyses, we were only able to adjust for simple measurements of diet and hence residual confounding from these characteristics might remain. Besides behavioural residual confounding, we\(^25\) and others\(^26\) have reported TV viewing to be associated with adverse psychological outcomes. Given that cardio-metabolic risk is associated with psychological factors,\(^27\)\(^,\)\(^28\) this may be another potential pathway through which TV viewing adversely affects cardio-metabolic risk profile.

### Table 3

Multivariable associations (unstandardized beta\(^a\) coefficients and 95% CI) between accelerometry-assessed sedentary time and cardiovascular risk factors ($n = 1150$)

<table>
<thead>
<tr>
<th></th>
<th>Model 1(^b)</th>
<th>Model 2(^c)</th>
<th>Model 3(^d)</th>
</tr>
</thead>
<tbody>
<tr>
<td>BMI (kg/m(^2))</td>
<td>0.016 (−0.019, 0.050)</td>
<td>0.029 (0.012, 0.070)</td>
<td>−0.025 (−0.064, 0.014)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.08</td>
<td>0.09</td>
<td>0.02</td>
</tr>
<tr>
<td>Waist (cm)</td>
<td>0.084 (0.003, 0.164)</td>
<td>0.144 (0.048, 0.240)</td>
<td>0.007 (−0.088, 0.101)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.28</td>
<td>0.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Systolic blood pressure (mmHg)</td>
<td>−0.022 (−0.064, 0.109)</td>
<td>0.033 (−0.064, 0.130)</td>
<td>−0.021 (−0.089, 0.101)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.15</td>
<td>0.02</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>Diastolic blood pressure (mmHg)</td>
<td>0.036 (−0.038, 0.111)</td>
<td>0.054 (−0.032, 0.139)</td>
<td>0.061 (−0.036, 0.158)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.08</td>
<td>0.02</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>HDL(^c) (mmol/l)</td>
<td>−0.001 (−0.003, 0.002)</td>
<td>−0.003 (−0.006, 0.000)</td>
<td>−0.001 (−0.004, 0.002)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.14</td>
<td>0.09</td>
<td>0.01</td>
</tr>
<tr>
<td>Total cholesterol(^e) (mmol/l)</td>
<td>0.002 (−0.003, 0.008)</td>
<td>0.009 (0.001, 0.016)</td>
<td>0.010 (0.001, 0.018)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.23</td>
<td>0.02</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>HbA1c(^e) (%)</td>
<td>0.001 (−0.003, 0.005)</td>
<td>0.003 (−0.002, 0.007)</td>
<td>−0.002 (−0.006, 0.002)</td>
</tr>
<tr>
<td>$R^2$ change</td>
<td>0.10</td>
<td>0.06</td>
<td>0.02</td>
</tr>
</tbody>
</table>

\(^a\)Represents the mean difference in each cardiovascular risk factor per 10 min greater time spent in sedentary behaviour.

\(^b\)Adjusted for age and sex.

\(^c\)Also adjusted for smoking, social class, alcohol consumption, depression (GHQ12), occupational status, fruit and vegetable consumption, cardiovascular medication (diabetes medication for HbA1c), accelerometer wear time per valid day and frequency of unhealthy foods.

\(^d\)Also adjusted for accelerometer-assessed MVPA (log-transformed).

\(^e\)For the analyses involving blood biomarkers, $n = 971$ due to missing data.
The associations between TV viewing and cardio-metabolic risk we observed are consistent with several cross-sectional\textsuperscript{1,2,29,30} and some longitudinal\textsuperscript{8,31} studies that have found deleterious associations with adiposity markers\textsuperscript{1,2,8,29–31}, blood lipids\textsuperscript{2,8,29–31} or clustered cardio-metabolic risk profiles\textsuperscript{8,31}. On the other hand, our results showing limited associations between accelerometry-assessed ST and the cardio-metabolic risk outcomes partly contrast with another recent cross-sectional analysis among 4757 US adults who participated in the 2003–06 National Health and Nutrition Examination Survey and who were also given an Actigraph accelerometer to wear for 7 days\textsuperscript{32}. In this study by Healy \textit{et al.}, accelerometry-assessed ST showed adverse associations with waist circumference and HDLC but, as in our study, there was no evidence for associations with systolic or diastolic blood pressure. In addition, Healy \textit{et al.} reported detrimental associations between accelerometry-assessed ST and a number of cardio-metabolic risk factors that were not available to us (C-reactive protein and fasting triglycerides). In terms of glycaemic status markers, Healy \textit{et al.} found an association with fasting insulin but we did not find any association with Hba1c\textsuperscript{32}. We examined whether the differential associations in the overlapping outcomes and glycaemic status markers were due to the different accelerometry cutoff (200 counts/min vs 100 counts/min used by Healy \textit{et al.}) by repeating all our analyses using a ST cutoff of 100 counts/min. As with the main analysis (Table 3), we found evidence only for an association between ST and total cholesterol (data not shown). Another smaller study among obese individuals\textsuperscript{33} failed to find evidence for an association between accelerometry-assessed ST and glucose metabolism.

The discrepancy observed between self-reported and objectively assessed ST might also be explained by other methodological issues. For example, our self-report measure enquired about ST in the past 28 days, whereas objective measures were collected over a 7-day period. Nevertheless, one might expect TV viewing and occupational ST (the likely major contributors to total ST) to be relatively stable over time, particularly within the same season\textsuperscript{34}. It is possible that self-reported TV time is able to better capture prolonged periods of sitting compared with the currently available methods of objective assessment. Sitting, rather than standing, is thought to be potentially detrimental to cardio-metabolic health\textsuperscript{35} but this idea is far from verified as it is only based on animal models\textsuperscript{36,37}. Like in previous studies\textsuperscript{3,32}, the accelerometry device participants wore could not distinguish between sitting and standing and one could argue that this has diluted the associations between objectively assessed ST and risk factors. However, it is far more likely that low accelerometer counts will represent sitting rather than standing (especially in office-based occupations\textsuperscript{38,39}) as few occupations involve standing still for more than a few seconds. According to the UK Time Use Survey 2005\textsuperscript{40}, the activities taking up most adults’ waking time are employment, housework, watching TV/DVD, travelling and eating\textsuperscript{40}. Despite the fact that accelerometers and self-report differ in their ability to capture MVPA, both of these MVPA measures were associated with cardio-metabolic risk in our study (data not shown), providing further evidence that methodological differences are unlikely to explain all of the differential associations of self-reported and accelerometer-assessed ST with these risk factors.

The key strength of this study is that, to our knowledge, it is the first to examine the associations between both self-reported and objectively assessed ST and cardio-metabolic risk markers in a sample of working age adults. Our study is one of the largest to date looking at the associations of objectively assessed ST with cardio-metabolic risk. We were able to adjust for objectively measured MVPA in our analyses, and the sample is roughly representative of the population of England, which adds to the ecological validity of our results. The main limitation of this study is the cross-sectional design, which precludes us from making any inferences about causality or examining the meaning of the attenuation of associations after adjustment for BMI/waist.

Conclusion
Self-report (in particular TV viewing), but not accelerometry-assessed ST, was consistently associated with cardio-metabolic risk factors. These findings suggest either that TV viewing is a proxy of other behavioural and psychological risk factors or that accelerometers cannot measure ST better than self-report. Future research requires large prospective studies with both self-report measures and movement sensors that are feasible for use in large-scale studies.

Supplementary Data
Supplementary Data are available at IJE online.

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KEY MESSAGES

- Previous research shows that sedentary time (ST) is associated with cardio-metabolic outcomes.
- It is unclear what the role of choice of ST indicator is when such associations are examined as only a few studies have used multiple indicators or type of measurement.
- Self-reported ST is associated with most cardio-metabolic outcomes but associations are consistent for TV viewing only.
- Objectively assessed ST was only associated with total cholesterol in this study.

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Conflict of interest: None declared.


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