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RESEARCH ARTICLE

Socioeconomic correlates of sedentary time during pregnancy among women at risk of gestational diabetes in the UK

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Abstract

Little is known about the relationship between socioeconomic position (SEP) and duration and patterning of objectively measured sedentary time (ST) among adults, especially adults at high risk of diabetes. The aim of this study was to examine cross-sectional associations of SEP with ST (total, prolonged ST, breaks in ST) and self-reported TV time among pregnant women at risk of gestational diabetes in the UK. At 20 weeks' gestation, pregnant women (n=174) wore an activPAL accelerometer and reported their usual TV time. Generalized linear mixed models were used to test associations of education, household income and area-level deprivation (separately and with mutual adjustment) with total ST, prolonged ST and breaks in ST. Logistic regression models were used to test associations between SEP indicators and high (≥2h/day) TV time. Those with the lowest education, lowest household income and highest area-level deprivation had the lowest ST and lowest prolonged ST. After mutual adjustment, area-level deprivation remained associated with total ST (β=0.10 [0.01, 0.20]). There was an inverse association between area-level deprivation and breaks in sedentary time (exp(b)=1.11 [1.01, 1.22]). Education was the only SEP correlate of high TV time, with more of those with least education reporting high TV time; this association persisted after adjustment for household income and area-level deprivation. The association between SEP and total and prolonged ST (positive) was the opposite of the association between education and high TV time (negative) in this sample of high-risk pregnant women. These findings should inform interventions to reduce sedentary time.

Keywords: Sedentary time; Socioeconomic position; Pregnancy

Introduction

Sedentary time, defined as time spent in a sitting or reclining posture with low energy expenditure during waking hours (Sedentary Behaviour Research Network, 2012), has been linked to the development of poor health outcomes, including all-cause mortality and incident type 2 diabetes, after adjustment for physical activity (Patterson *et al.*, 2018). Sedentary time (ST) is also associated with biomarkers indicative of cardiometabolic risk, including higher levels of plasma glucose, insulin and triglycerides (Powell *et al.*, 2018). The way in which ST is accumulated throughout the day may also be important, as evidence suggests that prolonged ST (i.e. uninterrupted periods of sitting lasting ≥30 minutes) is more strongly associated with higher glucose levels than total ST (Wagnild *et al.*, 2019), while breaks in ST have been linked to lower glucose levels (Healy *et al.*, 2008; Carson *et al.*, 2014). Television time, which is one source of ST, has been shown to have a stronger association with incident type 2 diabetes (Patterson *et al.*, 2018) and gestational diabetes (Wagnild *et al.*, 2019) than total ST. It is therefore important to identify sociodemographic correlates of ST (in total, prolonged and breaks) and television time to understand their distribution within the population and inform interventions.

Socioeconomic position (SEP), which refers to the 'social and economic factors that influence what positions individuals or groups hold within the structure of a society' (Galobardes *et al.*, 2006a), is strongly linked to health outcomes (Braveman *et al.*, 2011). Socioeconomic position may therefore be one of the most important determinants of sedentary time to understand. While the complexity of SEP makes it difficult to quantitatively operationalize, various indicators offer insights into specific facets of SEP in adult populations. For example, at the individual level, educational attainment may reflect childhood SEP and potential employment and income, while household income is an indicator of material living standards (Galobardes *et al.*, 2006a). Area-level SEP reflects the socioeconomic conditions of the neighbourhoods in which people live, which may have an impact on health beyond individual and household SEP (Galobardes *et al.*, 2006b).

The relationship between SEP and television time among adults has been extensively explored, with consistent evidence suggesting that lower SEP groups have higher television time in countries such as the UK (Stamatakis *et al.*, 2014) and Australia (Clark *et al.*, 2010). It has been suggested that interventions to reduce ST should target those with high television time, including low SEP groups (Clark *et al.*, 2010). However, there is evidence to suggest (based on the 2008 Health Survey for England) that, when total objectively measured ST is considered, those in the lowest SEP groups actually have the lowest total sedentary time (Stamatakis *et al.*, 2014). It is therefore critical to improve our understanding of the relationship between SEP and objectively measured ST to ensure that interventions are targeted correctly. It is also important to explore the relationship between SEP and the way in which ST is accumulated throughout the day (prolonged, breaks), which to the authors' knowledge has not yet been done. Those at high risk of cardiometabolic disease such as diabetes are regularly targeted for interventions and prevention programmes, including interventions to reduce sedentary time (Biddle *et al.*, 2015). It is therefore especially important to understand the relationships between SEP and ST duration and pattern among high-risk groups to tailor interventions effectively.

The primary aim of this study was to examine the relationship of SEP (measured as education, household income and area-level deprivation) with measurements of ST (total, prolonged, breaks) using a gold-standard measurement that accounts for posture in a sample of pregnant women at high risk for gestational diabetes in the UK. This study also aimed to examine socioeconomic correlates of television time within the same sample.

Methods

Participants

Participants were recruited from antenatal clinics in two hospitals in the North East of England when they attended for their dating scan around 12 weeks' gestation in 2017. All participants had at least one risk factor for gestational diabetes (BMI $\geq$30 kg/m^2, first-degree relative with diabetes, previous gestational diabetes, minority ethnic origin with a high prevalence of diabetes, or previous macrosomic baby) (National Institute for Health and Care Excellence, 2015) as this was part of a study examining associations between ST and gestational diabetes risk (Wagnild *et al.*, 2019). Participants also had to be at least 18 years old, fluent in English with a singleton pregnancy to be eligible for the study. All participants provided written consent prior to engagement in any research activities. The study was granted ethical approval by the South Central Oxford B NHS Research Ethics Committee (REC reference: 16/SC/0355).

Measurement of sedentary time

The measurement of ST in this study has been detailed elsewhere (Wagnild *et al.*, 2019). Briefly, ST was measured by the activPAL3 (PAL Technologies, Glasgow, UK), which is considered to be the gold standard for the measurement of ST in free-living contexts (Kozey-Keadle *et al.*, 2011) and has been validated for the measurement of sit-to-stand transitions ('breaks') (Lyden *et al.*, 2012). The activPAL was affixed to the anterior midline of the right thigh with waterproof adhesive by a trained member of the research team when the participant attended the hospital for an ultrasound scan at 20 weeks' gestation (second trimester). Participants were asked to wear the device 24 hours per day and were instructed to record the start and end times of all instances of sleep and non-wear during the activPAL wear period on provided diaries.

The activPAL data were downloaded using the proprietary software and were processed using a validated algorithm (Winkler *et al.*, 2016) using the algorithm's default criteria for identifying sleep and non-wear with manual corrections against the sleep diaries (Wagnild *et al.*, 2019). Only 24-hour days of wear were included in analyses; the first and last days of wear were removed from the dataset, as well as any days that registered $<$10 hours of waking wear (Bellettiere *et al.*, 2017). Accelerometry data sets were considered valid if participants provided at least four complete (24-hour) days of measurement (Bellettiere *et al.*, 2017). Sedentary time (minutes per day), prolonged ST (uninterrupted sedentary time in bouts lasting $\geq$30 minutes) (Bellettiere *et al.*, 2017) and breaks in ST on each valid measurement day were included in analyses.

Measurement of television time

At the time of the accelerometer fitting (20 weeks' gestation), participants reported the amount of time they spent watching television on a usual day in the second trimester. Responses were dichotomized as less than or more than 2 hours per day (Oken *et al.*, 2006).

Measurement of SEP and covariates

Participants provided basic information about themselves on an enrolment form at their 12-week scan, including highest educational qualification and annual household income category (categories shown in Table 1). Area-level deprivation was determined by looking up the residential postcode on the 2015 Index of Multiple Deprivation (IMD). The IMD category is typically reported in quintiles; however, because the distribution of this sample was skewed towards higher deprivation (reflecting the relatively deprived geographical areas in which the study was conducted), tertiles were used here with the bottom tertile being the most deprived. While occupational category and employment status are also important components of SEP (Galobardes *et al.*, 2006b), these were not included in analyses because specific information was not available as to how or whether working hours or working conditions may have changed for each participant between completion of the enrolment form (12 weeks' gestation) and when the activPAL was worn (20 weeks' gestation).

Participants' BMI recorded at their booking appointment (~8 weeks' gestation) was extracted from antenatal medical records.

Statistical analysis

All statistical analyses were conducted using R. Generalized linear mixed models were used to examine associations between SEP correlates and activPAL-assessed ST with measurement day nested within participant. Total ST was normally distributed, thus a linear model was used. Prolonged ST was not normally distributed; a linear model was used to generate estimated marginal means for plotting, but the formal model used a binary variable (dichotomized at the median) with high versus low prolonged ST as the outcome. As breaks in sedentary time are

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Table 1. Characteristics of the study sample ($N=174$)

Characteristic	Mean (SD) or *n* (%)
Age (years)	31.2 (5.1)
BMI (kg/m^2)	34.6 (5.6)
Highest educational qualification[a]	
GCSEs or equivalent	78 (44.8%)
A-levels or equivalent	29 (16.7%)
University/postgraduate	67 (38.5%)
Household income category	
<£20,000	57 (32.8%)
£20–40,000	66 (37.9%)
>£40,000	51 (29.3%)
Neighbourhood deprivation	
Most deprived	107 (61.5%)
Middle	33 (19.0%)
Least deprived	34 (19.5%)
Number of children at home	
None	66 (37.9%)
One or more	108 (62.1%)
Working status at 12 weeks' gestation	
Full time	94 (54.0%)
Part time	49 (28.2%)
Not in paid work (including full-time students)	31 (17.8%)
Marital status	
Married/cohabiting	151 (86.8%)
Single or living apart	23 (13.2%)
Smoking status	
No smoking during this pregnancy	142 (81.6%)
Any smoking during this pregnancy	32 (18.4%)
Ethnicity	
White British	166 (95.4%)
Other	8 (4.6%)
Sedentary time (min/day)	577 (97)
Prolonged sedentary time (min/day)[b]	137.1 (80.3, 198.3)
Breaks in sedentary time (*n*/day)	53 (14)
TV time ≥2h/day ($n=167$)	60 (35.9%)

[a]GCSEs and A-levels are age 16 and 18 qualifications, respectively.
[b]Median (interquartile range).

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effectively counts (but never zero), zero-truncated Poisson models with log links were used. Logistic regression models were used to examine SEP correlates of high (≥2hours/day) television time; a mixed model was not used here because there were not repeated measurements of television time. Models of the associations between SEP variables and ST variables or television time were constructed: 1) separately by SEP indicator, 2) with mutual adjustment for education and household income, and 3) additional adjustment for area-level deprivation. All models controlled for age, BMI, whether any children lived at home, marital status, recruitment site and smoking status (which has been previously linked to ST during pregnancy) (Evenson & Wen, 2011). Recruitment site was not included as an additional level in the mixed models because two sites is too few to robustly estimate the random effect. Waking wear time was also controlled in all accelerometry models. Lack of multicollinearity was confirmed in all models using variance inflation factor and tolerance statistics.

Results

Sample participants

Of those who were approached to take part in the study and were eligible, 326 consented to take part in the study (55% response rate). No information about those who declined to take part is available. Sixty-six (20.2%) of those who initially consented to the study withdrew prior to wearing the accelerometer, and a further 68 participants did not provide sufficient accelerometry data. Data for various SEP variables were missing for 18 participants, leaving a final analytical sample of 174 (Table 1) for accelerometry outcomes and 167 for TV time. Most participants (n=108, 62%) provided at least six 24-hour days of accelerometry data. There was a moderate correlation between total ST and prolonged ST (Spearman's ρ=0.46, p<0.001) but weak correlations between total ST and breaks in ST (Spearman's ρ=0.09, p<0.01) and prolonged ST and breaks (Spearman's ρ=–0.06, p=0.06).

Socioeconomic correlates of objectively measured sedentary time

Spearman correlations between the socioeconomic indicators were moderate: education and household income (ρ=0.40, p<0.001), education and area-level deprivation (ρ=0.19, p=0.01), household income and area-level deprivation (ρ=0.31, p<0.001).

Education, household income and area-level deprivation were each associated with ST when examined separately (Table 2, Model 1). Estimated marginal means indicated that higher education and higher income were associated with higher ST (Figure 1a); those in the highest education and income groups had approximately 40 and 64 minutes more ST per day than those in the lowest education and income groups, respectively. The association between area-level deprivation and ST was non-linear (Figure 1a). Those living in the most deprived tertile had the lowest ST, which was 53 minutes less per day than those in the middle tertile; the ST of those living in the least deprived tertile did not significantly differ from those living in the most deprived tertile (Table 2, Model 1). When both education and household income were mutually adjusted, associations were attenuated but income remained significantly associated with ST (Table 2, Model 2). When area-level deprivation was added to the model, associations were further attenuated but the association between area-level deprivation and ST remained significant (Table 2, Model 3), following a similar pattern to that shown in Figure 1.

The socioeconomic patterning of prolonged ST was similar to the patterning of total ST (Figure 1b). When assessed separately, education, household income and area-level deprivation were each associated with higher likelihood of high prolonged ST (Table 2, Model 1). However, the associations between each SEP indicator and prolonged ST were fully attenuated after mutual adjustment (Table 2, Models 2–3).

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Table 2. Associations between indicators of socioeconomic position and activPAL-measured sedentary time (N=174)

	Model 1[a]	Model 2[b]	Model 3[c]
Total sedentary time	β (95% CI)	β (95% CI)	β (95% CI)
Highest educational qualification			
GCSEs or below	Referent	Referent	Referent
A-levels or equivalent	0.03 (–0.07, 0.14)	0.03 (–0.07, 0.14)	0.03 (–0.07, 0.14)
University/postgraduate	0.13 (0.02, 0.24)*	0.09 (–0.03, 0.20)	0.08 (–0.03, 0.19)
Household income category			
<£20,000	Referent	Referent	Referent
£20–40,000	0.07 (–0.06, 0.19)	0.05 (–0.08, 0.17)	0.03 (–0.09, 0.16)
>£40,000	0.20 (0.07, 0.33)**	0.17 (0.03, 0.30)*	0.13 (0.00, 0.27)
Area-level deprivation			
Most deprived	Referent	N/A	Referent
Middle	0.14 (0.04, 0.24)**		0.10 (0.01, 0.20)*
Least deprived	0.09 (–0.01, 0.19)		0.05 (–0.05, 0.15)
High prolonged sedentary time[d]	OR (95% CI)	OR (95% CI)	OR (95% CI)
Highest educational qualification			
GCSEs or below	Referent	Referent	Referent
A-levels or equivalent	1.02 (0.61, 1.69)	1.03 (0.62, 1.70)	1.01 (0.62, 1.67)
University/postgraduate	1.50 (1.01, 2.23)*	1.32 (0.88, 1.99)	1.32 (0.88, 1.98)
Household income category			
<£20,000	Referent	Referent	Referent
£20–40,000	1.10 (0.70, 1.74)	1.03 (0.65, 1.64)	1.03 (0.65, 1.63)
>£40,000	1.87 (1.14, 3.09)*	1.65 (0.98, 2.80)	1.62 (0.95, 2.76)
Area-level deprivation			
Most deprived	Referent	N/A	Referent
Middle	1.58 (1.00, 2.47)*		1.35 (0.86, 2.12)
Least deprived	0.95 (0.61, 1.50)		0.82 (0.52, 1.29)
Breaks in sedentary time	exp(b) (95% CI)	exp(b) (95% CI)	exp(b) (95% CI)
Highest educational qualification			
GCSEs or below	Referent	Referent	Referent
A-levels or equivalent	1.08 (0.96, 1.20)	1.07 (0.96, 1.20)	1.08 (0.97, 1.20)
University/postgraduate	1.04 (0.95, 1.13)	1.03 (0.94, 1.13)	1.03 (0.94, 1.12)
Household income category			
<£20,000	Referent	Referent	Referent
£20–40,000	1.04 (0.94, 1.14)	1.03 (0.93, 1.14)	1.02 (0.92, 1.13)
>£40,000	1.03 (0.93, 1.15)	1.03 (0.92, 1.15)	1.01 (0.90, 1.13)

(*Continued*)

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Table 2. (*Continued*)

Breaks in sedentary time	exp(*b*) (95% CI)	exp(*b*) (95% CI)	exp(*b*) (95% CI)
Area-level deprivation			
Most deprived	Referent	N/A	Referent
Middle	1.02 (0.92, 1.12)		1.02 (0.92, 1.12)
Least deprived	1.11 (1.01, 1.22)*		1.11 (1.01, 1.22)*

All models adjusted for age, BMI, children at home, marital status, smoking status, recruitment site and waking wear time.[a]Each socioeconomic indicator included separately.
[b]Both education and household income included in the model.
[c]Area-level deprivation added to the model.
[d]Outcome is dichotomized at the median (137.1 minutes per day).
*$p<0.05$; **$p<0.01$.

There were no associations between education or household income and breaks in ST in this sample (Table 2, Model 1). Only area-level deprivation was associated with breaks, such that those living in the least deprived tertile had significantly more daily breaks in ST than those in the most deprived tertile (Table 2, Model 1; Figure 1c). This association persisted after adjustment for education and household income (Table 2, Model 3).

Socioeconomic correlates of self-reported television time

Only education was associated with television time, with those educated to A-level significantly less likely than those with GCSEs or below to watch ≥2 hours of television per day (Table 3, Model 1). The association between income and television time approached significance ($p=0.06$), such that those in the highest income category were less likely to have high television time compared with those in the lowest income category. Area-level deprivation was not associated with television time (Table 3, Model 1). When education and income were mutually adjusted, the effect of education remained significant and income remained non-significant (Table 3, Model 2). The association between education and high television time remained significant after additional adjustment for area-level deprivation (Table 3, Model 3).

Discussion

In this sample of pregnant women at high risk of gestational diabetes, the relationship between SEP and ST was positive, with those of the lowest SEP having the lowest total and prolonged ST. Education, household income and area-level deprivation were each associated with total ST, but after mutual adjustment, only the association between area-level deprivation and ST remained significant. The relationship between SEP and high prolonged ST was similar, except that all associations were attenuated when all SEP indicators were mutually adjusted. Only area-level deprivation was associated with breaks, with those in less deprived areas accumulating more sit–stand transitions. In contrast, high television time (≥2 hours per day) was most prevalent in the lowest education group, but was not significantly predicted by either household income or area-level deprivation.

Education and household income were positively associated with total ST when considered separately, but only income remained significant after mutual adjustment. In a much larger sample, Stamatakis *et al.* (2014) found that both education and income were associated with objectively measured ST independently of each other. The positive association between income and ST has been suggested to be driven by higher occupational sitting (Stamatakis *et al.*, 2014). Higher income has consistently been linked with higher occupational sitting, with those in the highest income groups sitting at work for 1 to 2 hours more per day than those in the lowest income

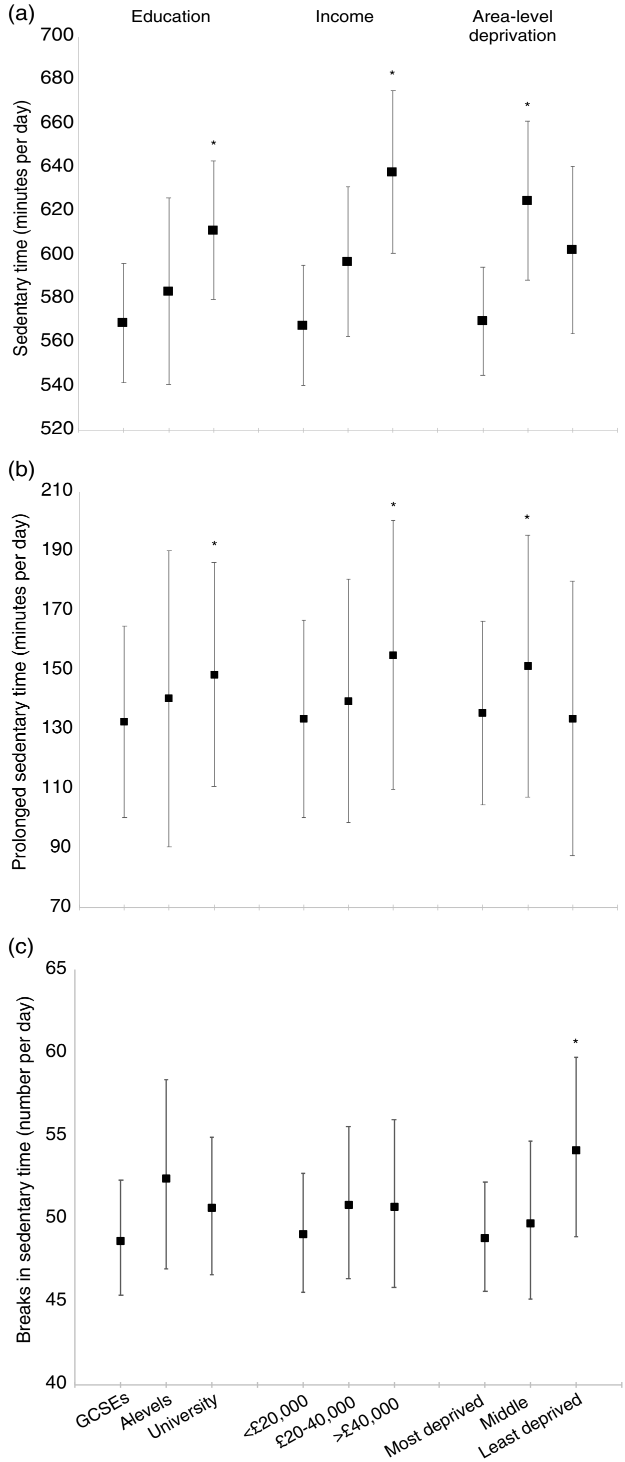

Figure 1. Associations between indicators of socioeconomic position and a) total sedentary time, b) prolonged sedentary time, and c) breaks in sedentary time.

Table 3. Associations between indicators of socioeconomic position and high (≥2h/day) television time (*N*=167)

	Model 1[a]	Model 2[b]	Model 3[c]
	OR (95% CI)	OR (95% CI)	OR (95% CI)
Highest educational qualification			
GCSEs or below	Referent	Referent	Referent
A-levels or equivalent	0.26 (0.08, 0.76)*	0.24 (0.07, 0.72)*	0.23 (0.07, 0.70)*
University/postgraduate	0.50 (0.23, 1.06)	0.60 (0.27, 1.35)	0.58 (0.25, 1.29)
Household income category			
<£20,000	Referent	Referent	Referent
£20–40,000	1.01 (0.43, 2.40)	1.18 (0.47, 3.00)	1.12 (0.44, 2.89)
>£40,000	0.39 (0.14, 1.02)	0.48 (0.16, 1.40)	0.42 (0.13, 1.30)
Area-level deprivation			
Most deprived	Referent	N/A	Referent
Middle	1.28 (0.55, 2.95)		1.92 (0.76, 4.94)
Least deprived	0.88 (0.35, 2.15)		1.09 (0.41, 2.86)

All models adjusted for age, BMI, children at home, marital status, smoking status and recruitment site.[a]Each socioeconomic indicator included separately.
[b]Both education and household income included in the model.
[c]Area-level deprivation added to the model.
*$p<0.05$.

groups (De Cocker *et al.*, 2014; Wallmann-Sperlich *et al.*, 2014). Socioeconomic differences in childcare demands may also be relevant here. Women with higher education and household incomes tend to spend less time in domestic and childcare activities than women with lower education and incomes (Cusatis & Garbarski, 2019; Jonsson *et al.*, 2020), which may result in higher sedentary time (van Uffelen *et al.*, 2012).

In this sample, those living in the most deprived neighbourhoods had the lowest ST, and this association was independent of education and household income. The only other study, to the authors' knowledge, to test an association between area-level deprivation and objectively measured ST did not find an association (Stamatakis *et al.*, 2014). The low ST of pregnant women living in more deprived neighbourhoods in this sample may be linked to differences in built environment and transport mode. For example, individuals who live in more deprived areas have been shown to rely more heavily on walking rather than sitting in a vehicle as a primary mode of transportation than those in less deprived areas, independently of education and household income (Rachele *et al.*, 2015). This has been suggested to be due to characteristics of the built environment of more deprived neighbourhoods that may facilitate walking, such as higher street connectivity, as well as limited access to a car (Turrell *et al.*, 2013).

To date, no other studies have examined associations between SEP and the patterning of ST. In this sample, the relationships between each SEP indicator and prolonged ST were similar to the relationship between SEP and total ST, while low area-level deprivation was associated with more breaks in ST in this sample. Further research is needed to clarify possible differences in ST accumulation patterns across SEP groups.

Education was the only SEP indicator that was associated with television time in this sample, such that those in the lowest education group were the most likely to have high (≥2h/day) television time. This is similar to other studies, which have consistently shown an inverse relationship between education and television time (after adjustment for household income) but no association between household income and television time (Clark *et al.*, 2010; Burton *et al.*, 2012; Stamatakis *et al.*, 2014). The effect of education on television time independently of household income suggests the general link between low SEP and high television time is not necessarily due to material or financial constraints. As educational attainment reflects childhood SEP (Galobardes *et al.*, 2006a), childhood socioeconomic conditions may play a role here. This is supported by the findings of Smith *et al.* (2015) based on the 1970 British Cohort Study, in which they showed that childhood television time and father's occupational class during childhood were each significantly associated with television time in adulthood (at age 42) independently of each other and independently of participants' own educational attainment.

Taken together, these findings have important implications for the development of interventions aimed at the reduction of sedentary time among high-risk groups. While many behavioural interventions tend to target low SEP groups because practices linked to poor health (e.g. smoking, poor diet) tend to be more prevalent at the lower end of the socioeconomic spectrum (Bull *et al.*, 2014), interventions to reduce sedentary time ought to be aimed at high SEP groups. Low SEP groups do, however, tend to have higher television time, as seen in our sample and those of others (Stamatakis *et al.*, 2014). Television time is consistently linked with poor health outcomes (Patterson *et al.*, 2018), which might suggest that targeting the reduction of television time in low SEP groups would seem a logical step. However, the mechanism(s) by which television time affects health have yet to be identified (Wagnild & Pollard, 2021), and there is a possibility that the observed effects of television time reflect residual confounding by SEP (Stamatakis *et al.*, 2018); thus, interventions to reduce television time could be ineffective. Further research is needed to understand how television time is linked to cardiometabolic health outcomes before any interventions aimed at its reduction are implemented.

This study has several strengths. It used a gold-standard method for the measurement of free-living ST. It is also the first to test associations between various SEP indicators and ST among a high-risk group. This study also has limitations that must be acknowledged. First, television time was self-reported, as is standard practice, and may thus be subject to reporting bias. The sample size for this study was powered for testing associations with GDM (Wagnild *et al.*, 2019) and may thus be underpowered for detecting associations with SEP. Finally, the results of this study are based on pregnant women at risk of gestational diabetes from relatively disadvantaged areas of the UK (although there was variation in SEP) and may therefore not necessarily be generalizable to other populations.

In conclusion, findings from this study suggest that indicators of SEP may be important correlates of ST and television time among pregnant women at risk of gestational diabetes. In this sample, those of higher SEP had higher ST and prolonged ST, while those with lower education had higher television time (but lower ST). These findings suggest that interventions aimed at reducing sedentary time among high-risk women might be aimed at higher SEP groups. Further research is needed on the mechanism(s) by which television time affects cardiometabolic health before interventions to reduce television time can be recommended.

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Conflicts of Interest. The authors have no conflicts of interest to declare.

Ethical Approval. The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Declaration of Helsinki of 1975, as revised in 2008. The study was granted ethical approval by the South Central Oxford B NHS Research Ethics Committee (REC reference: 16/SC/0355). All participants provided written consent prior to engagement in any research activities.

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