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Sedentary behaviour and chronic stress in old age: A cross-sectional analysis of TV viewing and hair cortisol concentrations

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A R T I C L E I N F O

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A B S T R A C T

Purpose: Several studies have reported a positive association between sedentary behaviour and perceived stress, but none using a population-based sample has examined this relationship using an objective measure of stress exposure. The aim of this study was therefore to analyse the association between sedentary behaviour (operationalised as daily TV viewing time) and levels of cortisol in hair (an objective measure of chronic stress) using data from a large population-based sample of older adults.
Method: Analyses used cross-sectional data from older adults (≥50 years) participating in Wave 6 (2012/13) of the English Longitudinal Study of Ageing. Hair cortisol concentrations were determined from the scalp-nearest 2 cm hair segment. TV viewing time was self-reported and categorised as < 2, 2 < 4, 4 < 6, or ≥6 h/day. Covariates included age, sex, ethnicity, education, wealth, limiting long-standing illness, cardiovascular disease, diabetes, smoking status, alcohol intake, physical activity, body mass index, and depressive symptoms.
Results: The sample comprised 3555 men and women, of whom 284 (8.0%) reported watching less than 2 h of TV per day, 1160 (32.6%) 2–4 h, 1079 (30.4%) 4–6 h, and 1032 (29.0%) ≥6 h. Mean hair cortisol concentrations for those spending < 2, 2 < 4, 4 < 6, and ≥6 h per day watching TV were 0.862, 0.880, 0.889, and 0.934 log pg/mg, respectively. Differences between groups were not statistically significant in unadjusted (p = .088) or adjusted (p = .663) models.
Conclusion: In a large sample of older adults in England, self-reported sedentary behaviour was not associated with a biomarker of chronic stress.

1. Introduction

In the UK and other developed countries, population levels of sedentary behaviour (defined as an energy expenditure ≤1.5 metabolic equivalents of task while in a sitting or reclining posture during waking behaviour (Tremblay et al., 2017)) are high (Loyen et al., 2016). This is of concern as excessive sedentary time is an important health risk, known to be associated with a wide range of adverse physical (Biswas et al., 2015; Chau et al., 2015) and mental (Allen et al., 2019; Zhai et al., 2015) health outcomes. Specifically, TV viewing time (one

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domain of sedentary behaviour) has been identified as an important driving force for many of the observed associations (Hamer et al., 2015; Madhav et al., 2017; Smith et al., 2015; Smith and Hamer, 2014).

A handful of studies across different populations have indicated that greater sedentary time may be associated with increased levels of perceived stress (An et al., 2015; Ashdown-Franks et al., 2018; Ellingson et al., 2018; Fang et al., 2014; Lee and Kim, 2018; Mouchacca et al., 2013), although there have been inconsistent findings (Rosenberg et al., 2016). With stress demonstrated to be associated with several physical health conditions (Blanc-Lapierre et al., 2017; Redmond et al., 2013; Song et al., 2017) and a precursor to chronic mental health conditions such as depression (Iwata et al., 2013), this may be an important pathway underlying associations between sedentary time and poor health. However, the majority of the studies that have documented an association between sedentary behaviour and stress have relied on self-reports. Even though perceived stress does not always correlate with physiological markers of stress such as cortisol (Milam et al., 2014; O'Brien et al., 2013; Olstad et al., 2016), these markers are still associated with the development of various diseases and cardiometabolic risk (Anagnostis et al., 2009). Thus, there is a need to validate these findings with an objective measure of stress exposure.

Biological assessments of stress exposure have traditionally relied on measurements of cortisol obtained from saliva, urine, or blood. However, natural fluctuations in cortisol due to the circadian rhythm, pulsatile secretion, and situation factors (e.g. illness, diet, external stressors) mean that these methods are not well suited for capturing longer-term stress levels. A relatively novel technique that has been used increasingly frequently over the last decade involves analysing cortisol concentrations in hair. Scalp hair incorporates unbound cortisol and other lipophilic substances, and grows at an average rate of 1 cm per month (Kintz et al., 2006), which means a scalp-proximal hair sample of 1 cm can be used to infer mean exposure to free cortisol over the last month. The validity and reliability of hair cortisol concentration as a marker of long-term cortisol exposure is well established (Dettenborn et al., 2012; Kirschbaum et al., 2009; Manenschijn et al., 2011; Stalder et al., 2012; Thomson et al., 2010). As such, hair cortisol assessment provides an objective measure of stress that can be used to examine the relationship with sedentary behaviour.

While TV viewing may be considered to be a relaxing, stress-relieving activity, there are potential mechanisms linking sedentary behaviour in general, and TV viewing specifically, to higher levels of chronic stress. For example, sedentary behaviour, particularly TV viewing time (often used in the literature as a proxy for total sedentary time), has been shown to be associated with an unfavourable inflammatory profile (Hamer et al., 2015) and low-grade inflammation has been shown to be associated with stress (Shimanoe et al., 2014).

To our knowledge, just one study to date has examined the association between sedentary time and an objective marker of stress, using hair cortisol measurements as described above. This was a small study in a sample of 72 women from socially disadvantaged neighbourhoods (Teychenne et al., 2018). Results showed no significant association, but whether this was due to lack of effect or lack of statistical power due to the small sample size is not clear. The aim of this study was therefore to analyse the association between sedentary behaviour (operationalised as daily TV viewing time, a proxy for total sedentary time (Clark et al., 2010; Sugiyama et al., 2008)) and hair cortisol concentration using data from a large population-based sample of older adults.

2. Method

2.1. Study population

Data were from the English Longitudinal Study of Ageing (ELSA), a longitudinal panel study of men and women aged ≥50 years living in England. The study started in 2002, with participants recruited from an annual cross-sectional survey of households and followed up every two years. The sample is periodically refreshed to ensure that the full age range is maintained, and comparisons of sociodemographic characteristics with the national census indicate that the sample is broadly representative of the English population (Steptoe et al., 2013). The general methods of data collection are detailed at www.elsa-project.ac.uk. At each assessment, participants complete an interview and questionnaires, and in alternate (even) waves, nurse visits are conducted to obtain objective measurements of health status, such as height and weight, blood samples, and blood pressure. The present analyses used data collected at wave 6 (2010-11) as this is the only occasion that hair samples have been taken for measurement of cortisol. Hair analysis was carried out on a subset of the 9169 core participants who took part in wave 6, selected at random, because of financial constraints. We restricted our sample to those with complete data on hair cortisol, TV viewing, and covariates, resulting in a final sample for analysis of 3555 men and women. Participants gave full informed consent and ethical approval was obtained from the National Research Ethics Service.

2.2. Measurement of exposure: TV viewing time

TV viewing time was assessed with two questions: "*How many hours of television do you watch on an ordinary day or evening, that is, Monday to Friday?" and "How many hours of television do you normally watch in total over the weekend, that is, Saturday and Sunday*?" Average daily time spent watching TV was calculated as [(weekday TV time x 5) + (weekend TV time)]/7. Daily TV time was categorised into four groups (< 2 h/day; 2 to < 4 h/day; 4 to < 6 h/day; ≥6 h/day), as has been done in previous investigations (Smith et al., 2015; Smith and Hamer, 2014).

2.3. Measurement of outcome: hair cortisol concentration

A lock of hair measuring at least 2 cm in length and weighing at least 10 mg was collected from the posterior vertex of all consenting participants, cut as close to the scalp as possible. Exclusion criteria for hair sampling included certain scalp conditions, pregnancy, breastfeeding, inability to sit with head remaining still, and having less than 2 cm of hair length in the posterior vertex scalp area. Full details of the hair sampling process are provided at http://www.elsa-project.ac.uk/uploads/elsa/docs_w6/project_instructions_nurse.pdf. The wash procedure and steroid extraction were undertaken using high performance liquid chromatography–mass spectrometry, as described by Gao et al. (2013). Assuming an average hair growth of approximately 1 cm per month (Kintz et al., 2006), the scalp-nearest hair segment of 2 cm represents average cortisol accumulated over an approximate time span of two months prior to sampling.

2.4. Measurement of potential confounders

Demographic information collected included age, sex, ethnicity (white/non-white), education (no qualifications/below degree/degree or higher), and socio-economic status (SES). SES was based on household non-pension wealth, because it has been identified as particularly relevant to health outcomes in this age group (Banks et al., 2003), categorised into quintiles across all ELSA participants who took part in wave 6. Health-related questions included self-reports of limiting longstanding illness, diagnosed CVD (hypertension, angina, myocardial infarction, or stroke), diagnosed diabetes, current smoking status (smoker/non-smoker), and frequency of alcohol intake (daily, 5–6/week, 3–4/week, 1–2/week, 1–2/month, once every couple of months, 1–2/year, never). Physical activity was assessed with items that asked participants how often they took part in vigorous and moderate activities (more than once a week, once a week, 1–3 times a month, hardly ever/never) (Hamer et al., 2014). Physical activity was further categorised into three categories: inactive (no moderate/vigorous activity on a weekly basis); moderate activity at least once a week; and vigorous activity at least once a week. Nurses measured weight using portable electronic scales and height using a portable stadiometer, and recorded any factors that might have compromised the reliability of the measurements (e.g., participant was stooped/unwilling to remove shoes). Body mass index (BMI) was calculated as weight in kilograms divided by the square of height in metres, with any cases with unreliable measurements excluded from the sample. Depressive symptoms were assessed using the 8-item Centre of Epidemiological Studies Depression (CES-D) scale, highly validated for use in older adults (Steffick, 2000).

2.5. Statistical analyses

Analyses were performed using IBM SPSS Statistics 24. Hair cortisol data were log transformed to correct skewness. We tested associations between sample characteristics and TV viewing time using one-way independent analyses of variance (ANOVAs) for continuous variables and χ^2 tests for categorical variables, and used one-way independent ANOVA and analysis of covariance (ANCOVA) to examine the association between TV viewing time (< 2 h, 2 < 4 h, 4 < 6 h, ≥6 h) and hair cortisol concentration (continuous), with and without adjustment for relevant covariates. We did two sensitivity analyses, which involved: (i) testing the adjusted model with depressive symptoms excluded from the list of covariates, to check for potential over-adjustment; and (ii) using linear regression models to test the association between TV viewing time as a continuous variable and hair cortisol concentration.

3. Results

The sample comprised 3555 men and women, of whom 284 (8.0%) reported watching less than 2 h of TV per day, 1160 (32.6%) 2–4 h, 1079 (30.4%) 4–6 h, and 1032 (29.0%) ≥6 h. Compared with those who were excluded on the basis of missing data, the analysed sample was slightly older and overrepresented female, white, more educated, more wealthy, and more healthy participants (all $p < .001$). The analysed sample also had a significantly higher mean hair cortisol concentration ($p = .042$), but did not differ significantly from excluded participants in terms of TV viewing ($p = .660$).

Table 1 presents sample characteristics overall and in relation to TV viewing time. The mean age was 68.34 years and the sample was predominantly female, white, and educated, with the upper quintiles of wealth overrepresented. The majority were free of limiting long-standing illness, CVD, and diabetes, were non-smokers, and engaged in regular physical activity, but more than half were regular drinkers and the mean BMI was in the overweight range. Participants who watched more TV tended to be older, female, less educated, and more socio-economically deprived. They were generally less healthy in terms of chronic illness, smoking, lower physical activity, higher BMI, and more depressive symptoms, although fewer were regular alcohol drinkers.

Table 2 presents the results of one-way ANOVAs testing for differences in mean hair cortisol concentration by TV viewing. In the unadjusted analysis, there was a small but non-significant difference in hair cortisol concentration across groups, with hair cortisol increasing with increasing TV viewing time ($p = .088$). The mean hair cortisol concentration of the group watching ≥6 h/day (0.934 log pg/mg) was 8.4% higher than that of the group watching < 2 h/day (0.862 log pg/mg). After adjustment for age, sex, ethnicity, education, wealth, limiting long-standing illness, CVD, diabetes, smoking status, alcohol intake, physical activity, BMI, and depressive symptoms, these minimal differences were attenuated, such that the difference in mean hair cortisol concentration between the groups watching the least vs. the most TV per daily was just 3.6% ($p = .663$).

Removing depressive symptoms from the list of covariates did not alter the results ($F = 0.61$, $p = .608$). When TV viewing time was analysed as a continuous variable, there was a significant association with hair cortisol concentration in the unadjusted ($B = 0.007$, 95% CI 0.002–0.011, $p = .004$), but not the adjusted model ($B = 0.004$, 95% CI 0.000–0.009, $p = .072$).

4. Discussion

A positive association between sedentary time and perceived stress has been documented in several studies (An et al., 2015; Ashdown-Franks et al., 2018; Ellingson et al., 2018; Fang et al., 2014; Lee and Kim, 2018; Mouchacca et al., 2013). We aimed to replicate this using an objective measure of stress (hair cortisol) in a large, representative sample of older adults. However, we found no evidence of an association between TV viewing time (an established indicator of sedentary behaviour) as a categorical exposure and hair cortisol concentration in unadjusted or adjusted models. While there was a very small increase in hair cortisol concentration with increasing TV viewing time, differences were not statistically significant and attenuated substantially after adjustment for relevant confounders. In a sensitivity analysis of TV viewing time as a continuous exposure, the association with hair

Table 1
Sample characteristics in relation to TV viewing time.

	Whole sample (n = 3555)	< 2 h/day (n = 284)	2 < 4 h/day (n = 1160)	4 < 6 h/day (n = 1079)	≥6 h/day (n = 1032)	p[*]
Age (mean [SD] years)	68.34 (7.86)	66.74 (7.97)	67.39 (7.72)	69.08 (7.75)	69.06 (7.94)	< .001
Men	33.4	46.1	37.9	31.3	26.8	< .001
Non-white	1.9	2.5	2.1	1.0	2.6	.050
No qualifications	22.3	6.3	12.2	24.9	35.3	< .001
Lowest social status[a]	12.8	3.5	8.4	11.1	22.0	< .001
Limiting long-standing illness	32.1	24.6	26.6	31.8	40.7	< .001
Cardiovascular disease	44.6	32.4	38.9	47.5	51.3	< .001
Diabetes	10.3	6.7	7.8	9.9	14.3	< .001
Current smoker	9.4	6.0	8.0	8.5	12.8	< .001
Regular alcohol intake[b]	57.2	64.1	65.1	56.0	47.7	< .001
Physical activity[c]	80.8	88.7	86.3	81.9	71.4	< .001
BMI (mean [SD] kg/m^2)	28.25 (5.29)	26.05 (4.35)	27.51 (4.75)	28.42 (5.11)	29.51 (5.92)	< .001
Depressive symptoms (0-8) (mean [SD])	1.19 (1.76)	0.89 (1.54)	0.91 (1.49)	1.18 (1.71)	1.60 (2.06)	< .001

Note: all values presented as percentages unless otherwise stated.
SD = standard deviation; BMI = body mass index.
* p value for bivariate association with TV viewing time (< 2, 2 < 4, 4 < 6, ≥6 h/day).
a Defined as the lowest quintile of household non-pension wealth.
b Defined as alcohol intake at least once per week.
c Defined as moderate or vigorous physical activity at least once per week.

Table 2
Unadjusted and adjusted associations between TV viewing time and mean hair cortisol concentration.

	Mean (95% CI) hair cortisol concentration (log pg/mg)				F	p
	< 2 h/day (n = 284)	2 < 4 h/day (n = 1160)	4 < 6 h/day (n = 1079)	≥6 h/day (n = 1032)		
Unadjusted	0.862 (0.795–0.928)	0.880 (0.847–0.913)	0.889 (0.855–0.923)	0.934 (0.899–0.969)	2.18	.088
Fully adjusted[a]	0.885 (0.817–0.954)	0.892 (0.858–0.925)	0.887 (0.853–0.922)	0.917 (0.880–0.953)	0.53	.663

CI = confidence interval.
[a] Fully adjusted model controlled for age, sex, ethnicity, education, wealth, limiting long-standing illness, cardiovascular disease, diabetes, smoking status, alcohol intake, physical activity, body mass index and depressive symptoms.

cortisol concentration was significant before but not after adjustment.

These results are inconsistent with the majority of previous studies of perceived stress, although these have typically used broader measures of sedentary behaviour, rather than focusing on TV viewing time specifically (An et al., 2015; Ashdown-Franks et al., 2018; Ellingson et al., 2018; Fang et al., 2014; Lee and Kim, 2018; Mouchacca et al., 2013). However, they are in line with one small-scale study of older adults in residential care, which observed no significant associations between accelerometer-measured sedentary time, self-reported sedentary behaviours, or TV viewing time and perceived stress scores (Rosenberg et al., 2016). They are also consistent with results of a small study of women living in socioeconomically deprived neighbourhoods, which found no significant association between sitting time (TV viewing, computer use, overall sitting time) and hair cortisol concentration (Teychenne et al., 2018). Discordant results across the various studies cannot be attributed to the age of the samples, given one of the studies that reported a significant association with perceived stress was also conducted in the over-50 s and observed consistent results across six different countries (Ashdown-Franks et al., 2018). It is possible that other characteristics of the samples may be important, however, two of the previous studies reported significant results in less socioeconomically advantaged groups (Ashdown-Franks et al., 2018; Mouchacca et al., 2013).

It is more likely that differences between the findings of the present study and the majority of the extant literature are attributable to the assessment of objective vs. perceived stress. A number of studies have examined concordance between hair cortisol concentration and ratings of perceived stress and found no significant correlation (Milam et al., 2014; O'Brien et al., 2013; Olstad et al., 2016). This lack of "psychoendocrine covariance" (Dettenborn et al., 2010; Schlotz et al., 2008) could be due to differences between the responsiveness of the neural circuitry controlling the hypothalamic-pituitary-adrenal axis and the circuitry mediating the subjective experience of stress (Meyer and Novak, 2012); that is, two people experiencing the same physiological stress response may perceive very different levels of stress. However, because subjective stress was not measured in the present study, we cannot confirm this. It is possible that even if subjective measures of stress had been included, they may have also not been significantly associated with TV viewing, and therefore there would have been no inconsistencies between the measures. This is currently unknown and further research incorporating both subjective and objective measures of stress within the same sample is required to shed further light on this issue. An alternative explanation for the inconsistent findings is that survey measures of perceived stress reflect acute perceptions of stress, whereas hair cortisol captures stress exposure over a longer period. Recall bias may also affect accuracy of self-reports.

Strengths of the present study include the large representative sample and use of hair cortisol as an objective measure of stress. However, there were several limitations. First, the cross-sectional design meant we were unable to draw causal inferences on the impact of TV viewing time on changes in objective stress over time. There was also potential for reverse causality if certain characteristics of stressed individuals made them more likely to be sedentary. Future studies using a longitudinal or experimental design are needed to establish the direction of causation. Secondly, TV viewing time was self-reported, introducing scope for recall or social desirability bias. Thus, future studies must examine whether cortisol and other objective markers are associated with objective measures of TV viewing (i.e. using accelerometery). However, the measure in the present study has strong criterion validity and has been shown to be associated with a range of health outcomes (Hamer et al., 2015; Madhav et al., 2017; Smith et al., 2015; Smith and Hamer, 2014). Thirdly, we did not adjust for hair-related factors such as dyeing and washing, or for the season in which hair samples were collected, which have been shown to influence level of hair cortisol (Abell et al., 2016). In addition, our analyses did not take into account use of medications that might influence cortisol concentration, such as steroids or hormone replacement therapies. Fourthly, participants were not asked about the content of their TV viewing. It is plausible that certain content (e.g. the news, horror movies) may be more stress-inducing than other content (e.g. cooking channels, comedy movies), thus differentially affecting hair cortisol concentrations. Fifthly, we only investigated one domain of sedentary behaviour, TV viewing time. It is possible that other domains (e.g. motorised travel, desk-based work) are associated with objective stress. Further research investigating such associations could help shed light on any differences across domains of sedentary behaviour. Finally, while our participants were drawn from a representative sample, there was a substantial amount of missing data and our analysed sample was older, healthier, and more socioeconomically advantaged than those who were excluded, but had slightly higher hair cortisol levels. As such, our findings may not generalise beyond the study sample. Further work is necessary to examine the relationship between sedentary behaviour and hair cortisol concentrations in other populations.

In conclusion, our results do not support an association between TV viewing time and chronic stress in older adults. Further research is needed to confirm or refute this finding using longitudinal or experimental designs, objective measures of sedentary behaviour, and investigating different domains of sedentary behaviour.

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