



# Associations between mentally-passive and mentally-active sedentary behaviours during adolescence and psychological distress during adulthood

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## ABSTRACT

It is unclear if different types of sedentary behaviour during the adolescence are differentially associated with psychological distress during adolescence and adulthood. It is also unknown what may mediate this potential proposed association. The current study aimed to analyse the association of mentally-active and mentally-passive sedentary behaviours during adolescence (16y) with subsequent psychological distress during adulthood (42y), and to examine the role of potential mediators (42y). Data from the 1970 British Cohort Study was used ( $N = 1787$ ). At age 16y participants reported time and frequency in mentally-passive (TV-viewing and watching movies) and mentally-active (reading books, doing homework and playing computer games) sedentary behaviours, psychological distress and organized sports participation. At 42y, participants reported cognition (vocabulary test), TV-viewing, psychological distress, self-rated health, body mass index and employment status. Education was collected throughout the follow-up years. Logistic regression and mediation models assessed associations. Multiple imputation using chained equations was used to assess the impact of missing data. Mentally-passive sedentary behaviour in adolescence was a risk factor for psychological distress during adulthood in complete-cases analysis [OR:1.44(95%CI:1.09–1.90)], which was confirmed by the model with multiple imputation. Mentally-active sedentary behaviour at 16y was not associated with psychological distress at 42y. Adult TV-viewing during weekends (24.7%), and self-rated health (19.0%) mediated the association between mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood. However, the mediation was not clear in the models with multiple imputation. Mentally-passive sedentary behaviour during adolescence was associated with elevated psychological distress during adulthood and this association was mediated TV-viewing and self-rated health in adulthood.

## 1. Introduction

Depression is highly prevalent and is estimated to affect 4.4% of global population (Ferrari et al., 2013). Moreover, depressive symptoms are associated an reduced life expectancy (Chang et al., 2011), including the development of cardiovascular disease among patients with depression (Correll et al., 2017). There is large variation in the underlying risk and protective factors for depression, and there has been

increased attention on lifestyle behaviours as potential modifiable factors for prevention, management and treatment of common mental disorders (Köhler et al., 2018). Psychological distress is related to depressive symptoms and therefore is of interest in mental health research for the prevention of depression (Bell et al., 2015; Rutter et al., 1970). Low physical activity is associated with increased incidence of depression, especially among adults (Schuch et al., 2018).

Also, sedentary behaviour during adolescence has been associated

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with later depressive symptoms (Hamer et al., 2016; Kandola et al., 2020). Inflammation has been suggested as a biological mechanisms linking sedentary behaviour and depressive symptoms among adults (Endrighi et al., 2016). However, it is plausible that mentally active sedentary behaviours may provide stimulation and other protective benefits that may not be achieved through mentally passive sedentary behaviours. Thus the type of sedentary behaviour, as opposed to duration of time spent sedentary, which is of primary interest for physical chronic diseases, is of particular interest for mental health outcomes (Hallgren et al., 2020; Hallgren et al., 2018; Kikuchi et al., 2014).

Indeed, previous studies found that the association between sedentary behaviour and depressive symptoms is possibly domain-dependent. Specifically, mentally-passive (e.g. watching TV) sedentary behaviours were associated with depressive symptoms, while mentally-active (e.g. reading, working) sedentary behaviours had no association or were protective of depressive symptoms (Hallgren et al., 2019; Hallgren et al., 2018). However, previous studies have primarily emerged from adult samples and the association between different types of sedentary behaviour during adolescence and mental health in adulthood is still unclear. This is highlighted due to the importance of adolescence for the long-term adoption of health behaviours (Hayes et al., 2019), and a longer period presenting higher sedentary behaviour can be differently associated with the outcome, considering the higher latency period. Also, the onset of mental disorders as depression occurs during adolescence, which can be a critical period for the development of health behaviours (Kessler et al., 2007).

Considering that sedentary behaviour, especially in mentally-passive activities, is independently associated with depressive symptoms (Hallgren et al., 2018), previous research also has identified several potential physical, psychological and behavioural mediators of the association between overall sedentary behaviour and depressive symptoms (Stubbs et al., 2018). However, mediators of mentally-active and mentally-passive sedentary behaviours have not been examined and may differ because mentally-active and mentally-passive sedentary behaviours have potential distinct associations with health indicators (Hallgren et al., 2018).

Considering tracking of sedentary behaviour (Busschaert et al., 2015), it is possible that higher levels of sedentary behaviour during adolescence may be associated with higher levels of sedentary behaviour during adulthood, and consequently associated with adult depressive symptoms (Hamer et al., 2016; Vancampfort et al., 2017). Similarly, sedentary behaviour can also be associated with other risk behaviours such as physical inactivity (Koyanagi et al., 2018), which is also associated with depressive symptoms and could be potential mediators of the association between in the association between sedentary behaviours and psychological distress (Stubbs et al., 2018; Werneck et al., 2019). Considering that mentally-passive sedentary behaviour is associated with minimal cognitive demands, cognition can also be a potential mediator of the association between mentally-passive sedentary behaviour and psychological distress (Horowitz-Kraus and Hutton, 2018; Kaser et al., 2017). In addition, sedentary behaviour is associated with self-rated health (Rosenkranz et al., 2013), which is a general perception of health and is closely associated with several indicators of physical health as chronic diseases and mobility that can also be influenced by higher sedentary behaviour (Gyasi and Phillips, 2018; Mantyselka et al., 2003) and self-rated health can be associated with depressive symptoms, acting as a potential mediator (Uchino et al., 2019).

Therefore, we aimed to examine the association between mentally-passive and mentally-active sedentary behaviours during adolescence with psychological distress during adulthood and investigate the role of potential mediators in the association between adolescent sedentary behaviours and adult psychological distress.

## 2. Methods

### 2.1. Cohort design and sample

The 1970 British Birth Cohort (BCS70) is a multidisciplinary longitudinal study (Elliott and Shepherd, 2006). Initially, BCS70 was designed as the British Births Survey and included all individuals from England, Scotland, Wales and Northern Ireland who were born in a specific week of 1970 (Elliott and Shepherd, 2006). The sample was followed-up in 1975 (5y), 1980 (10y), 1986 (16y), 1996 (26y), 2000 (30y), 2004 (34y), 2008 (38y), 2012 (42y) and 2016 (46y). The present study analysed data from 1986 and 2012 waves. All questionnaire data were collected through face-to-face interviews, including self-reported questions. All procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by a internal committee for the 1986 wave and London-Central MREC (11/LO/1560) for the 2012 wave. Participants provided informed consent and all procedures.

The initial study sample included 17,284 people (at 1970). However, there are substantial missing data in the adolescence wave (1986–16 years), due to a teacher's strike; 6350 participants did not complete the self-completion module during adolescence, with 4393 adolescents with valid data for the main exposures. When also considering the 2012 wave, our final sample was composed of 1787 participants with complete data (706 men).

### 2.2. Exposures: sedentary behaviour during adolescence

Mentally-active and mentally-passive sedentary behaviours were used as our main exposures. Sedentary behaviour during adolescence was assessed using questions covering several domains. Questions about time spent in sedentary behaviour during the previous day were asked regarding reading books, doing homework, watching films, playing computer games and TV-viewing. For all these questions, possible answers were: a) not at all, b) less than 1 h, c) more than 1 h, d) more than 2 h, e) more than 3 h or f) more than 4 h.

Sedentary behaviours were divided into two sub-groups, mentally-passive sedentary behaviour (TV-viewing and watching movies) and mentally-active sedentary behaviours (reading books, doing homework and playing computer games) as per previous research (Hallgren et al., 2019; Hallgren et al., 2018) (Supplementary Fig. A). We then summed the number of hours reported watching TV and movies (for mentally-passive sedentary behaviour) and the number of hours reported reading books, doing homework and playing computer games (for mentally-active sedentary behaviour) and dichotomised using the cut-off point of more than 3 h was used as in previous studies (high:  $\geq 3$  h/day and low:  $< 3$  h/day) (Rezende et al., 2016). Magazine and newspaper reading were also assessed, but we were unable to include in our indicators as they were on a different scale.

### 2.3. Outcome: adult psychological distress

Psychological distress was evaluated using the Malaise Inventory at both time-points, which asks questions regarding depressive moods, lack of energy, anxiety and stress (Rutter et al., 1970). During adolescence, the 24-item scale was used, excluding the "rheumatism and fibrosis" and "nervous breakdown" questions. A score of 15 or higher was considered as elevated. During adulthood, the 9-item version was applied. A score of 4 or more was considered as elevated, as adopted in previous analyses (Ploubidis et al., 2017). Aiming to improve the comparability between the measures, we also considered the same 9 items of the adult scale in the adolescent measurement, with a score of 4 or more considered as elevated. The Malaise inventory of 24 items presented good reliability (Cronbach alpha = 0.80) in a previous study among the UK adult

population (Rodgers et al., 1999) and the 9-item version have a high correlation with the 24-item questionnaire (Ploubidis et al., 2017). However, the reliability among adolescents is unknown.

#### 2.4. Potential mediators

Potential mediators were identified from the existing evidence base (Hamer et al., 2016; Kaser et al., 2017; Koyanagi et al., 2018; Stubbs et al., 2018; Vancampfort et al., 2017; Werneck et al., 2019). Cognition was estimated using the vocabulary test, which used 20 words and cohort members were asked to select which of the five words next to it had a similar meaning to the original word. Vocabulary test was categorized according the mean (below mean and equal or superior to mean). Self-rated health was also assessed using a 5-item Likert scale; responses “good”, “very good” and “excellent” were considered as “good” self-rated health. During adulthood, participants were asked about the time spent watching television during weekdays and weekends. Possible answers were a) none, b) less than an hour, c) between 1 and 3 h, d) between 3 and 5 h and e) 5 h or more. More than 3 h of TV-viewing, considering the weighted average of TV-viewing during weekdays and weekends, was considered as elevated as used in previous studies (Rezende et al., 2016). For physical activity assessment during adulthood, participants were asked about the frequency of physical exercise participation; participants who reported at least 5 days/week were considered as active, based on proposed threshold from the World Health Organization (World Health Organization, 2010). We used self-rated health and physical activity at 34 years as mediators for a post-hoc analysis, aiming to explore the temporal sequence in the association. The question for self-rated health at 34y was similar to the question at 42y, while physical activity at 34y was assessed through a question regarding the frequency of physical exercise practice and we adopted the cut-off point of 5 days/week.

#### 2.5. Covariates

Education and employment status were inserted as covariates given their well-known associations with depressive symptoms (Bjelland et al., 2008; Perreault et al., 2017). Education (highest qualification achieved) was categorized into three groups: None (no formal education or incomplete secondary education), at least high school and more than high school. Employment status was assessed during adulthood (having a full-time job versus not having a full time job). Physical activity during adolescence was evaluated through two questions asking about the frequency of sports participation on the street/park or in a club/sports centre. Possible answers were a) Rarely/never, b) Less than once a week, c) once a week or d) More than once a week. Participants that answered “More than once a week” were considered as active. Also, body mass index during adulthood was estimated through self-reported stature and body mass and classified using the cut-off points of 25 kg/m<sup>2</sup> for overweight and 30 kg/m<sup>2</sup> for obesity.

#### 2.6. Statistics

Frequencies and logistic estimated 95% confidence intervals were used to describe the sample. Chi-square test and Cramer’s V were used for the comparison between included and excluded sample in the attrition analysis. Logistic regression models, reporting odds ratio (OR) were used to analyse the association between different types of sedentary behaviour during adolescence and psychological distress.

Dependent on finding an association between types of sedentary behaviour (16y) and psychological distress (42y), the potential mediation of cognition, physical activity, sedentary behaviour and self-rated health in adulthood (42y) was tested using the methods proposed by Valeri and Vanderweele (Valeri and Vanderweele, 2013). For this, the total effect was decomposed into total effect (i.e. the effect of types of sedentary behaviour on psychological distress), controlled direct effects

(i.e. the effect of types of sedentary behaviour on psychological distress that was not explained by the mediators), reference interaction (i.e. the effect of types of sedentary behaviour due to the interaction with the mediators), mediated interaction (i.e. the effect of types of sedentary behaviour due to both mediation and interaction with the mediators), and pure indirect effects (i.e. mediation effect). We created separate models for each mediator and we used command “med4way” on Stata 15.1 to undertake these analyses. All models were adjusted for the other type of sedentary behaviour (e.g. mentally-active sedentary behaviour for mentally-passive sedentary behaviour analysis), organized sports practice and psychological distress symptoms (Malaise Inventory with 9 items) at 16y, education, body mass index and employment status at 42y. As post-hoc analysis, we created models with self-rated health and physical activity at 34y, aiming to explore the temporal sequence in the association. The bias of potential unobserved/unmeasured confounders in the main analyses was estimated through the “E-value” (VanderWeele and Ding, 2017), which is defined as the minimum strength of association (risk ratio scale) that an unmeasured confounder would need to have with both exposure and the outcome to fully explain the specific exposure-outcome association, conditional on the measured covariates. The proposed theoretical model of mediation in the association between type of sedentary behaviour and psychological distress is presented on Fig. 1.

#### 2.7. Missing data

There was a high number of missing observations for all variables along the follow-up of the BCS70. Specifically for the present analyses, the wave of 16y was problematic due to a teacher’s strike, which affected the collection of data independently of sociodemographic factors as gender, social class and region of residency. For example, considering the participants with valid data for mentally-passive and mentally-active sedentary behaviour at 16y and participants with missing data, the basics sociodemographic data from the initial wave were similar: Age of mother at birth: Included: 26.1 ± 5.3 vs. excluded: 25.9 ± 5.6; Father’s social class (manual work): Included: 42.2% vs. excluded: 45.0%; Country of residency (England): Included: 83.1% vs. Excluded: 81.5%; Region of residency (Southeast): Included: 27.6% vs. Excluded: 29.7%. However, in the posterior waves (34y and 42y), there was a classical pattern of missing data, with a collected sample composed of participants with higher education, women and from other regions than Southeast (Mostafa and Wiggins, 2014). To handle missing data, we conducted sensitivity analysis with multiple imputation. Considering that there was no clear pattern of missing at 16y, and the lack of strong predictors of mentally-active and mentally-passive

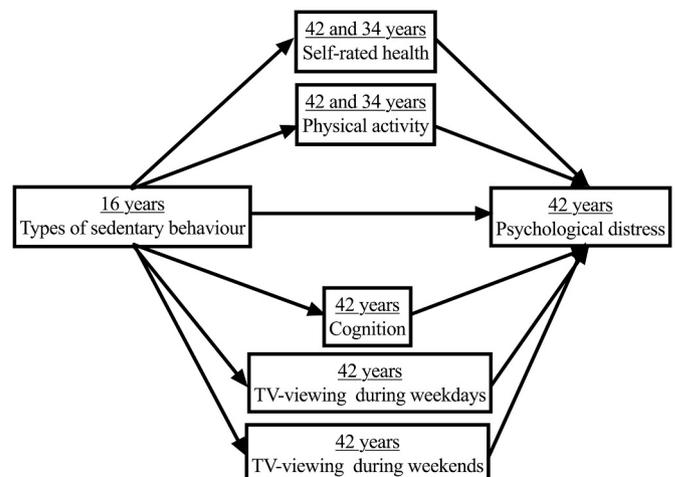


Fig. 1. Theoretical model. Note. SB, sedentary behaviour.

sedentary behaviours that could guide the imputations, we considered the initial sample of 4393 adolescents conducted multiple imputation methods for the mediators and outcomes at 34y and 42y, using chained equations with 20 imputations to optimize the validity of the findings. Considering missing data for the initial wave (social class, age of mother and sex were used to guide the multiple imputation models), 4043 were included in the analysis with imputed values. The logistic regression models were conducted in each of the 20 imputed dataset and the mean of the estimated from each imputed datasets was calculated for the overall odds ratio.

### 3. Results

From the initial sample, 1787 participants composed the final sample (706 men, 40%). Characteristics of the sample are presented in Table 1. The prevalence of at least 3 h/day of mentally-passive sedentary behaviour was 53.8%, while the prevalence of at least 3 h/day of mentally-active sedentary behaviour was 16.4%. Also, the prevalence of elevated psychological distress during adulthood was 15.3%. Attrition analysis of variables measured at 42 years according to included and excluded sample at 16 years are presented in Table 2. There were slight differences, especially regarding education, in which included sample presented higher prevalence of participants with more than high school.

Cross-sectional and longitudinal associations between adolescent mentally-active and mentally-passive sedentary behaviours and psychological distress during adolescence and adulthood, respectively are presented on Table 3. In cross-sectional analyses, neither mentally-active and mentally-passive sedentary behaviour were associated with psychological distress. Participants reporting greater mentally-passive sedentary behaviour during adolescence were 44% [OR: 1.44 (95%CI: 1.09 to 1.90)] more likely to present elevated psychological distress during adulthood, independent of mentally-active sedentary behaviour, organized sports practice and psychological distress symptoms (Malaise Inventory with 9 items) at 16 years, education, body mass index and employment status at 42 years. This model had an e-value of RRR: 1.69, suggesting that for a potential mediator to fully mediate this association is necessary to have relative risk of 1.69 with both mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood. However, potential mediators reduced the association between mentally-passive sedentary behaviour and psychological distress when inserted in the model.

**Table 1**  
Characteristics of the sample (n = 1787).

	% (95%CI)
<b>16 years</b>	
Sex (female)	60.7 (58.4 to 62.9)
Mentally-active sedentary behaviour (at least 3 h/day)	53.8 (51.5 to 56.1)
Mentally-passive sedentary behaviour (at least 3 h/day)	16.4 (14.7 to 18.2)
Organized sports practice at club (more than once a week)	17.4 (15.7 to 19.2)
Elevated psychological distress (malaise inventory - 22 items)	14.5 (13.0 to 16.3)
Elevated psychological distress (malaise inventory - 9 items)	52.7 (50.3 to 55.0)
<b>42 years</b>	
Screen time at weekdays (at least 3 h/day)	20.4 (18.6 to 22.4)
Screen time at weekends (at least 3 h/day)	41.7 (39.2 to 43.8)
Elevated psychological distress symptoms (malaise inventory)	15.3 (13.7 to 17.1)
Cognition (below average vocabulary test)	40.5 (38.3 to 42.8)
Physical activity (at least 5 days/week)	19.7 (17.9 to 21.6)
Self-rated health (regular to poor)	34.9 (32.7 to 37.2)
Employment status (yes)	75.4 (73.3 to 77.3)
<b>Education</b>	
None	16.6 (14.9 to 18.4)
Up to high school	45.4 (43.1 to 47.8)
More than high school	38.0 (35.7 to 40.3)

Note. Values are presented in frequencies (estimated 95% confidence interval). p-values refers to the chi-square test. \*n = 1577.

**Table 2**

Attrition analysis of variables measured at 42 years according to complete data at 16 years.

	Included (n = 1787)	Excluded (n = 6125)	p-value	Cramer's V
Sex (male)	60.7	50.8	<0.001	0.083
<b>Education</b>				
None	16.6	30.1	<0.001	0.163
Up to high school	45.4	47.0		
More than high school	38.0	23.0		
Elevated psychological distress (malaise inventory)	15.3	18.8	0.001	0.038
TV-viewing during weekdays (at least 3 h/day)	20.5	27.3	<0.001	0.064
TV-viewing during weekends (at least 3 h/day)	41.7	47.5	<0.001	0.049

Note. Values are presented in frequencies.

**Table 3**

Association between sedentary behaviour at adolescence and elevated psychological distress symptoms (Malaise Inventory) at adolescence (cross-sectional) and adulthood (prospective).

	Psychological distress (malaise inventory)		
	16 years		42 years
	22 items	9 items	9 items
	OR (95%CI)	OR (95%CI)	OR (95%CI)
<b>Base model</b>			
Mentally-active SB	0.99 (0.69 to 1.42)	1.11 (0.86 to 1.44)	1.09 (0.76 to 1.57)
Mentally-passive SB	0.97 (0.74 to 1.27)	1.15 (0.95 to 1.40)	1.44 (1.09 to 1.90)
<b>Cognition</b>			
Mentally-active SB	-	-	1.15 (0.79 to 1.66)
Mentally-passive SB	-	-	1.42 (1.07 to 1.87)
<b>Lifestyle potential mediators</b>			
Mentally-active SB	-	-	1.12 (0.77 to 1.61)
Mentally-passive SB	-	-	1.33 (1.00 to 1.77)
<b>Self-rated health</b>			
Mentally-active SB	-	-	1.07 (0.74 to 1.56)
Mentally-passive SB	-	-	1.37 (1.03 to 1.82)

Note. Base model: adjusted for sex, other sedentary behaviour pattern (e.g. mentally-active SB adjusting the model of mentally-passive SB) (for 16 years analysis) plus employment status, education, weight status and psychological distress symptoms at 16 years (with 9 items) for 42 years analysis. Cognition model: Base model + vocabulary test (below average vocabulary). Lifestyle potential mediators: Base model + physical activity and TV-viewing during weekdays and weekends. Physical and psychological potential mediators: Base model + self-rated health. OR, odds ratio. 95%CI, 95% confidence interval. SB, sedentary behaviour.

Table 4 shows the cross-sectional and longitudinal associations between adolescent mentally-active and mentally-passive sedentary behaviours and psychological distress during adolescence and adulthood with multiple imputation for missing values at 34y and 42y. Similar to the complete-cases analysis, mentally-passive was prospectively associated with higher psychological distress at 42y in all models. However, differently from the complete-cases analysis, cognition, lifestyle behaviours or self-rated health did not changed the association between mentally-passive sedentary behaviour and psychological distress, highlighting a direct association.

**Table 4**

Association between sedentary behaviour at adolescence and elevated psychological distress symptoms (Malaise Inventory) at adolescence (cross-sectional) and adulthood (prospective), using chained multiple imputation for missing values at 34y and 42y (n = 4043).

	Psychological distress (malaise inventory)		
	16 years		42 years
	22 items	9 items	9 items
	OR (95%CI)	OR (95%CI)	OR (95%CI)
<b>Base model</b>			
Mentally-active SB	0.90 (0.62 to 1.32)	0.90 (0.59 to 1.37)	1.01 (0.76 to 1.35)
Mentally-passive SB	1.26 (0.96 to 1.67)	1.01 (0.73 to 1.39)	1.25 (1.02 to 1.53)
<b>Potential mediators at 42 years</b>			
<b>Cognition</b>			
Mentally-active SB	–	–	1.04 (0.77 to 1.40)
Mentally-passive SB	–	–	1.24 (1.01 to 1.51)
<b>Lifestyle potential mediators</b>			
Mentally-active SB	–	–	1.08 (0.81 to 1.45)
Mentally-passive SB	–	–	1.39 (1.11 to 1.74)
<b>Self-rated health</b>			
Mentally-active SB	–	–	1.04 (0.77 to 1.39)
Mentally-passive SB	–	–	1.30 (1.04 to 1.63)
<b>Potential mediators at 34 years</b>			
<b>Physical activity</b>			
Mentally-active SB	–	–	1.01 (0.76 to 1.35)
Mentally-passive SB	–	–	1.25 (1.02 to 1.53)
<b>Self-rated health</b>			
Mentally-active SB	–	–	1.02 (0.76 to 1.37)
Mentally-passive SB	–	–	1.24 (1.01 to 1.52)

Note. Base model: adjusted for sex, other sedentary behaviour pattern (e.g. mentally-active SB adjusting the model of mentally-passive SB) (for 16 years analysis) plus employment status, education, weight status and psychological distress symptoms at 16 years (with 9 items) for 42 years analysis. Cognition model: Base model + vocabulary test (below average vocabulary). Lifestyle potential mediators: Base model + physical activity and TV-viewing during weekdays and weekends. Physical and psychological potential mediators: Base model + self-rated health. OR, odds ratio. 95%CI, 95% confidence interval. SB, sedentary behaviour.

Results of mediation models, considering the complete-cases analysis, for the association between mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood are presented in Table 5. TV-viewing during weekends and self-rated health

**Table 5**

Mediation models of lifestyle potential mediators and physical / psychological potential mediators of the association between mentally-passive sedentary behaviour at adolescence and elevated psychological distress symptoms at adulthood (Malaise Inventory).

Potential mediators	Total effect	Controlled direct effect	Reference interaction	Mediated interaction	Pure indirect effect
<b>Cognition</b>					
Cognition (vocabulary test)	0.44 (0.04 to 0.84)	0.41 (–0.03 to 0.85)	0.01 (–0.24 to 0.26)	0.01 (–0.05 to 0.05)	0.02 (–0.01 to 0.06)
<b>Lifestyle potential mediators</b>					
<b>Physical activity</b>					
TV-viewing during weekdays	0.44 (0.04 to 0.84)	0.36 (–0.06 to 0.78)	0.08 (–0.09 to 0.26)	–0.01 (–0.05 to 0.02)	0.01 (–0.01 to 0.03)
TV-viewing during weekends	0.44 (0.04 to 0.84)	0.46 (0.04 to 0.87)	–0.06 (–0.20 to 0.08)	–0.05 (–0.17 to 0.07)	0.09 (–0.01 to 0.19)
<b>Self-rated health</b>					
Self-rated health	0.44 (0.04 to 0.84)	0.38 (0.01 to 0.83)	–0.04 (–0.30 to 0.23)	–0.01 (–0.05 to 0.04)	0.08 (0.01 to 0.15)

Note. Values are presented in β (95% confidence interval). Adjusted for mentally-active sedentary behaviour, organized sports practice and psychological distress symptoms (Malaise Inventory with 9 items) at 16 years, education, body mass index and employment status at 42 years. % of mediation: TV-viewing during weekends: 24.7%; Self-rated health: 19.0%.

at 42 years mediated the association between mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood, explaining 24.7% (TV-viewing during weekends) and 19.0% (self-rated health) of the association. In the sensitivity analysis including self-rated health and physical activity at 34y as mediators of the association between mentally-passive sedentary behaviour during adolescence (16y) and psychological distress during adulthood (42y), we found that self-rated health at 34 years mediated 26.0% of the association (Table 6).

**4. Discussion**

The main findings of the present study were that adolescent mentally-passive sedentary behaviour was associated with elevated psychological distress during adulthood. This association was mediated by adult TV-viewing during weekends and self-rated health during adulthood in complete-cases analysis, but the evidence of mediation was not supported in the analysis with multiple imputation procedures for missing data. Adult cognition, physical activity and TV-viewing during weekdays did not emerge as mediators. Adolescent mentally-active sedentary behaviour was not associated with adult psychological distress. Our findings confirm previous research that different types of sedentary behaviour can have different associations with health outcomes (Hallgren et al., 2018).

Sedentary behaviour has been reported to be consistently negatively associated with depressive symptoms during adolescence (Vancampfort et al., 2018), however, previous studies have adopted single indicators of sedentary behaviour such as total sitting time, screen time or TV-viewing (Hoare et al., 2016; Vancampfort et al., 2018) and have not examined both mentally-active and mentally-passive sedentary

**Table 6**

Mediation models of physical activity and self-rated health at 34 years of the association between between mentally-passive sedentary behaviour at adolescence (16 years) and elevated psychological distress at adulthood (42 years) (n = 1577).

Potential mediators	Total effect	Controlled direct effect	Reference interaction	Mediated interaction	Pure indirect effect
Physical activity	0.38 (–0.03 to 0.79)	0.42 (–0.05 to 0.89)	–0.05 (–0.27 to 0.18)	0.01 (–0.03 to 0.18)	–0.01 (–0.02 to 0.02)
Self-rated health	0.37 (–0.04 to 0.78)	0.30 (–0.08 to 0.68)	–0.02 (–0.19 to 0.15)	–0.01 (–0.10 to 0.08)	0.10 (0.01 to 0.18)

Note. Values are presented in β (95% confidence interval). Adjusted for mentally-active SB, organized sports practice and psychological distress symptoms (Malaise Inventory with 9 items) at 16 years, education and employment status at 42 years. % mediated was only estimated for significant indirect effects. % of mediation: Self-rated health: 26.0%.

behaviours as done here. A possible explanation for the non-association between mentally-active sedentary behaviour during adolescence and psychological distress during adulthood is that mentally-active sedentary activities increase cognitive demand and brain connectivity (Blacker and Curby, 2013; Horowitz-Kraus and Hutton, 2018), making it plausible that more time spent in mentally-active activities could be associated with better cognitive development (Blacker and Curby, 2013; Sullivan and Brown, 2015), which is associated with mental health (Orchard and Reynolds, 2018). Moreover, as studying is a common behaviour during adolescence, more reading could indicate a higher satisfaction with school environment and relationships, which are also associated with mental health (Oberle, 2018). Conversely, mentally-passive sedentary behaviours could present lower cognitive demand and possibly need a higher latency period for exhibiting associations with psychological distress.

To our knowledge, this is the first study to assess the association between mentally-passive and mentally-active sedentary behaviours during adolescence and psychological distress during adulthood. Our results agree with previous studies conducted among adults in that mentally-passive sedentary behaviours were negatively associated with psychological distress, while mentally-active sedentary behaviours were unlikely to have harmful effects (Hallgren et al., 2019; Hallgren et al., 2018). Using the same cohort, Hamer et al. (2016) found no association between total screen time during adolescence and psychological distress during adulthood, possibly due to the inclusion of playing computer games (which is considered a mentally-active behaviour in our study as previous research found that playing games presents an elevated brain stimulation and can improve cognition (Blacker and Curby, 2013; Richlan et al., 2017)) in the score. The exact pathways of effect are unknown, but this finding may suggest a cognition pathway, in which more mentally-passive sedentary behaviour is associated with a lower activation of brain functional connectivity (Horowitz-Kraus and Hutton, 2018), which could be associated with depression in the long-term (Scully et al., 2017). However, we only found that cognition did not mediate the association between mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood.

We explored potential mediation pathways between mentally-passive sedentary behaviour and psychological distress in adulthood and we found that TV-viewing during weekends as well as self-rated health during adulthood mediated the association. It is possible that TV-viewing during weekends may be more detrimental for mental health than weekday TV-viewing as there is usually more discretionary time at weekends so the absolute exposure to TV-viewing may be higher than on weekdays (Khouja et al., 2019). It is also possible that choosing to watch TV rather than participating in other, potentially more 'active' behaviours could be associated with psychological distress through a lack of motivation and energy (Firth et al., 2016). In addition, this finding indicates a possible association of mentally-passive sedentary behaviour maintenance on psychological distress. Sedentary behaviour during adolescence can predict self-rated health in adulthood (Burdette et al., 2017), which can consequently affect mental health (Uchino et al., 2019). Moreover, self-rated health can be influenced by the presence of other chronic diseases such as cardiovascular disease which can also be promoted by highly sedentary lifestyles and can also be associated with depressive symptoms (Correll et al., 2017). However, we highlight that the mediation analysis should be inferred with caution, considering the we did not find that lifestyle behaviours or self-rated health reduced the association between mentally-passive sedentary behaviour and psychological distress in the models with multiple imputation for missing values.

Limitations of the present study should be recognized. Firstly, the number of missing data at 16 years was high; when including data from both 16 years and 42 years, the number of missing data is even more substantial, presenting a potential bias and precluding further stratified analyses. Also, attrition analysis revealed slight differences in the included sample when comparing with the excluded sample, especially

concerning education. For this, multiple imputation was used to reduce the bias caused by the differential dropout considering specific socio-demographic factors. All measures were self-reported, which can present potential recall bias as well as limited reliability and validity, although our exposures were based on contexts of sedentary behaviour and our outcome was psychological distress, which we currently still do not have an objective measure. Moreover, the measure of sedentary behaviour was different during adolescence and adulthood, separate domains of mentally-active and mentally-passive behaviour were not available in adulthood. Also, there were no time-points between 16 years and 42 years at which sedentary behaviour data were measured. However, sensitivity analysis using self-rated health and physical activity at 34 years as mediator confirmed our main results (with self-rated health and physical activity at 42 years). It is also plausible that part of the adolescents TV-viewing could be watching educational programs, which can be a mentally-active activity, stimulating cognition. Despite the limitations, to our knowledge, this is the first study to prospectively investigate the association between adolescent mentally-passive and mentally-active sedentary behaviours with sedentary behaviour and mental health in mid-adulthood, and also to explore potential mediators.

Mentally-passive sedentary behaviour during adolescence was associated with psychological distress during adulthood, while mentally-active sedentary behaviour during adolescence was not associated with psychological distress during adulthood. The association between mentally-passive sedentary behaviour during adolescence and psychological distress during adulthood was mediated by TV-viewing and self-rated health in adulthood. Potential interventions targeting sedentary behaviours could focus on reducing mentally-passive sedentary behaviours instead of total sitting time. Future studies could investigate this association with more time-points and could explore a greater range of potential mediators.

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## Availability of data

Cohort data comply with ESRC data sharing policies, readers can access data via the UK Data Archive ([www.data-archive.ac.uk](http://www.data-archive.ac.uk)).

## Ethics approval and consent to participate

Ethical approval was given for all waves, including internal review of London Multi-Centre Research on 1970, 1975, 1980, 1986, 1996 and

2004 waves and approval from London MREC (98/2/120) for the 2000 wave, Southampton & South West Hampshire (08/H0504/144) for the 2008 wave and London-Central (11/LO/1560) for the 2012 wave. Informed consent was obtained for all waves.

### Consent for publication

Not applicable.

### Conflict of interests

None.

### Author contribution

AWO: Analysis, interpretation of data and writing. KC and EH: Interpretation of data and writing. BS and EMFvS: Revision of the draft with substantial improvements.

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