

# BMJ Open Does meeting physical activity recommendations ameliorate association between television viewing with cardiovascular disease risk? A cross-sectional, population-based analysis

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## ABSTRACT

**Objectives** As a common form of sedentary behaviour, television viewing is associated with an increase in body mass index (BMI) as well as overall cardiovascular disease (CVD) risk. This study examined the extent to which meeting the recommended volume of weekly physical activity (PA) reduced the association between television viewing with the outcomes of BMI and CVD risk. A second aim was to determine the number of hours (ie, cut-point) of daily television viewing that conferred a higher BMI and CVD risk for a large population-based sample of adults.

**Design** Population-based, cross-sectional study.

**Setting** UK Biobank recruited across 35 centres in the UK between 2006 and 2010.

**Primary outcome** CVD risk, as measured by the 30-year Framingham risk score.

**Results** Linear regression models indicated that every additional hour of television viewing per day was associated with a 3% increase in CVD risk (aCoeff=0.03, d=0.16, p<0.0001); the interaction between television viewing with meeting PA guidelines was marginally associated with CVD risk (aCoeff=0.0010, d=0.01, p=0.014). Each additional hour of television viewing per day was associated with a 0.54 increase in BMI (aCoeff=0.54, d=0.13, p<0.0001); the interaction between television viewing with meeting PA guidelines was not significantly associated with BMI. Regression tree models of the study outcomes revealed that 2.5 hours of television viewing was associated with pronounced increases in BMI and CVD risk.

**Conclusions** These data underscore the independent association between television viewing with cardiovascular risk and suggest that reducing television viewing to less than 2.5 hours per day, even in physically active adults, is a clinical and public health priority.

## INTRODUCTION

Cardiovascular disease (CVD) is a global health problem and for which deaths exceed those caused by cancer, infectious disease and trauma combined.<sup>1</sup> In the USA, CVD is attributed to one in every three deaths.<sup>2</sup> The

## Strengths and limitations of this study

- The study used baseline data from the large population cohort assembled by the UK Biobank.
- In assessing whether meeting physical activity recommendations reduced the association between television viewing with body mass index and cardiovascular disease (CVD) risk, a comprehensive array of covariates were considered.
- The cross-sectional and self-reported study assessments precludes an objective and temporal assessment of the relationship between the study variables.
- The response rate for the UK Biobank is approximately 5%, thus, selection bias is a possibility in this sample.
- We report that viewing television for ≥2.5 hours/day may be a risk factor for CVD, even among physically active adults, which may have implications for clinicians.

clinical and public health burden of CVD is only expected to grow as population shifts in developed countries include more older,<sup>3</sup> and lower-income adults,<sup>4</sup> who are high risk for poor cardiovascular health. Sedentary behaviour, particularly in the form of television (TV) viewing, has emerged a well-documented determinant of CVD morbidity and mortality.<sup>5</sup> However, the modifying role of physical activity (PA) on the relationship between sedentary behaviour and CVD risk factors such as body mass index (BMI), and overall CVD risk remains unclear.

Sedentary behaviour is defined as any waking behaviour that results in an energy expenditure ≤1.5 metabolic equivalents (METs) while sitting or reclining.<sup>6</sup> American adults spend upwards of 55% of their day being sedentary,<sup>7 8</sup> with approximately

8% of adults accruing nine or more hours of total sitting time per day (outside of work).<sup>9</sup> High levels of sedentary behaviour in children/adolescents and elderly adults are particularly worrisome trends.<sup>10 11</sup> A positive association between increased sedentary time and CVD outcomes has been consistently reported. For example, each additional hour of sitting time has been shown to increase the odds of fatal and non-fatal CVD's by 6%.<sup>12</sup> Likewise, more than 12 vs <5.76 hours/day of sedentary time has been associated with a 20%–25% increased risk of mortality,<sup>13</sup> while 10 or more vs 5 or fewer hours of sedentary time increased CVD risk by 18%–38%.<sup>14 15</sup>

While the main effect of excessive sedentary time on poor CVD risk factors and outcomes is clear, the modifying effect of PA level is less consistently documented in the literature. Some studies show that the negative effects of increased sedentary time on poor cardiovascular health are independent of PA level,<sup>5 12 16</sup> while others show that the risk of CVD and all-cause mortality in highly sedentary adults may be ameliorated through moderate-vigorous PA.<sup>15 17</sup> As a common and highly prevalent behaviour related to CVD, sedentary behaviour, particularly in its common form of TV viewing, has much potential to be leveraged as a behavioural target to promote heart health. Limiting this potential is a clear understanding of the extent to which sedentary time is associated with cardiovascular risk in adults with varying levels of PA.<sup>18</sup> Although meta-analytical studies have reported between 3 hours<sup>19</sup> and 7 hours of TV viewing per day<sup>9</sup> as the cut-point beyond which cardiovascular, and all-cause mortality in adults is significantly increased, the TV viewing cut-point for more proximal outcomes such as BMI, is less clear.

To address these gaps, the current study used the UK Biobank population sample to assess: (1) the extent to which meeting recommended PA levels mitigates the association between TV viewing with a composite CVD risk score and BMI and (2) the cut-point of hours of daily TV viewing that conferred a higher CVD risk and BMI. Results from this study will add to our understanding of the relationships between sedentary behaviour, PA and CVD risk in a population setting.<sup>18</sup> We hypothesised that the relationship between sedentary behaviour and BMI would be ameliorated in adults who met recommended levels of PA.

## METHODS

### Study design and participants

Population data from the UK Biobank (application # 16153) were analysed. The UK Biobank is a prospective cohort study that began in 2005. Using patient registers from the UK National Health Service, adults aged 40–69 years who live within a 10 mile radius of one of the UK Biobank's 35 assessment centres are invited to participate. At a baseline visit, participants provided written informed consent and completed a touch screen questionnaire that assessed sociodemographic, lifestyle and health behaviour

variables. Between 2006 and 2010, 502 656 eligible and consenting adults provided baseline data and these data were used in the current analysis. More expansive details about the rationale, design and survey methods for UK Biobank have been described elsewhere<sup>20 21</sup> and information on data available and access procedures are given on the study website.<sup>22</sup>

## Measures

### Dependent variables

**BMI:** BMI was calculated using measured height (m) and weight (kg) with the formula:  $\text{kg/m}^2$ .<sup>23</sup>

**Thirty-year CVD risk:** The 30-year risk of CVD was calculated using the Framingham-30 composite risk score.<sup>24</sup> The computed risk score predicts the likelihood of experiencing 'hard' cardiovascular events (coronary death, myocardial infarction and fatal or non-fatal stroke) or coronary insufficiency, angina, transient ischaemic attack, intermittent claudication or congestive heart failure) in 30 years. The Framingham-30 risk score is computed based on the cardiovascular risk factors of male sex, age ( $\geq 45$  years), measured systolic blood pressure ( $\geq 140$  mm Hg), antihypertensive treatment (yes), BMI ( $\geq 30$   $\text{kg/m}^2$ ), smoking status (self-reported current smoker: yes/no) and diabetes mellitus (self-reported yes/no). While the resulting 30-year risk score is continuous and presented as a proportion, values  $<12\%$  are indicative of low risk,  $\geq 12\%$  and  $<40\%$  intermediate risk, and  $\geq 40\%$ , high risk.<sup>24</sup>

### Independent variable: TV viewing

Participants estimated how many hours per day they spend watching TV viewing.

### Moderating variable: meeting PA recommendations

Participants reported the number of days in a typical week that they engaged in walking as well as time spent in moderate and vigorous activities lasting 10 or more minutes.<sup>25</sup> Minutes per week spent in each activity (walking, moderate, vigorous) were calculated. Those who reported at least 150 min per week of moderate intensity, or 75 min per week of vigorous-intensity PA<sup>26</sup> were classified as meeting PA recommendations; all other participants were classified as not meeting recommendations.

## Covariates

### Sleep duration

Sleep duration was assessed with the survey item 'About how many hours sleep do you get in every 24 hours? (Please include naps.)' Responses were coded in integers and categorised into the following categories for analysis: short ( $\leq 6$  hours), adequate (7–8 hours) and long ( $\geq 9$  hours).<sup>27</sup>

### Fruit and vegetable Intake

Fruit and vegetable intake was reported using the Food Frequency Questionnaire.<sup>28</sup> Information on fresh fruit, salad and cooked/raw vegetables was combined to examine the number of servings per day.

### Alcohol Intake

Alcohol intake frequency was assessed with the survey item 'About how often do you drink alcohol?' Participants self-classified their alcohol consumption using these categories: alcohol daily or almost daily, alcohol on 3 or 4 days/week, alcohol once or twice a week, alcohol one to three times per month, special occasions only, never drinkers, and prefer not to answer. Due to the small number of participants who drank on special occasions only and never drinkers, these categories were combined for analysis.

### Bipolar and major depression status

Mental health diagnoses queried included bipolar and major depression. Only participants that had full information available to accurately assess their mental health status were classified as having or not having bipolar or major depressive disorder (yes/no); all other participants were classified as unknown.<sup>29</sup> Validity for these self-report assessments have been reported (Cohen's  $\kappa=0.28$  for bipolar disorder, 0.46 for depression).<sup>30</sup> Poor mental health (ie, clinical depression) is strongly correlated with higher levels of sedentary behaviour and lower levels of PA.<sup>31</sup>

### Sociodemographic variables

Race/ethnicity (coded as Asian/Asian British/Chinese, black/black British, mixed/other, white, and do not know/prefer not to answer), education (coded as college/no college/prefer not to answer), shift work (yes/no/do not know or prefer not to answer) were self-reported.

### Analysis

Baseline data from 502 623 cohort participants were obtained. Participants who withdrew from the study ( $n=4$ ) were initially excluded, leaving 502 619 participants. Further, participants with missing data for any of the study variables were excluded ( $n=162\ 473$ ), leaving 340 146 participants in the final analytic sample. Although significant differences were observed for all study variables between participants with and without complete data (table 1), this finding was attributed to the large sample size and robust power. As a result, we generated effect sizes that would provide an indicator of the relationship magnitude. The effect size metrics of Cohen's  $d$  (small: 0.20, medium: 0.50, large: 0.80) and Cramer's  $V$  (small: 0.10–0.30, medium: 0.40–0.50, large:  $>0.50$ ) were calculated, as appropriate, and were deemed either very small or small in size for all study variables, indicating negligible differences between participants with complete and incomplete data.<sup>32–34</sup>

Descriptive statistics were generated to characterise all variables. Frequencies and percentages were used to describe categorical variables. Since all continuous variables were normally distributed, means and SD were used to describe these variables. Unadjusted and adjusted linear regression models of the outcomes of the 30-year Framingham risk score and BMI were generated to

examine the simple and independent associations with TV viewing and meeting PA recommendations. The moderating effects of meeting PA recommendations on the relationship between TV viewing with the outcomes relied on their interaction (TV viewing X meeting PA recommendations). In the adjusted linear regression models BMI (30-year Framingham risk model only), age (BMI model only), sex, race/ethnicity, education, shift work, sleep duration, alcohol intake frequency, daily fruit and vegetable intake, current smoking, and bipolar/major depression status were included. To account for multiplicity, statistical significance was considered at the  $0.05/2=0.025$  level.<sup>35</sup>

A regression tree was subsequently generated for each study outcome in order to determine the cut-point for the number of hours of daily TV viewing that conferred greater BMI and 30-year CVD risk, as well as to clarify the relative contribution of TV viewing and meeting PA recommendations to the outcomes. Using the Classification and Regression Trees (CART) growing method, data were split into binary segments that were as homogeneous as possible with respect to the outcome until no predictors could improve the homogeneity of the nodes given a complexity parameter of 0.005 for all decision tree models.<sup>36</sup> The between-group sum of squares (or R-squared) for the models was maximised by splitting nodes and pruning the tree. If the increase in R-squared was less than the complexity parameter, splitting was stopped. The analytical sample was split into 60% training ( $n=204\ 087$ ) and 40% testing sets ( $n=136\ 059$ ). Regression trees were constructed using the training data and were validated using 10-fold cross validation. The splitting or cut-point for each variable, as well as the mean and SD for each homogeneous group is provided. Descriptive statistics and linear regression models were generated using SAS V.9.4 (SAS) and regression tree analyses were conducted using the rpart package in R V.3.4.3.

### Patient and public involvement

This study did not involve patients and the public.

## RESULTS

### Sample characteristics

The analytical sample for this study was comprised of 340 146 adults (table 1). The majority of the sample were female (53.85%), white (95.08%), did not attend college (63.74%) and had a mean age of 56.55 years ( $SD=8.17$ ). Participants reported watching a mean 2.64 hours ( $SD=1.52$ ) of TV per day and 61.78% of the sample met the recommended 150 min of moderate intensity or 75 vigorous-intensity PA per week. This proportion of meeting PA guidelines is comparable with previous work.<sup>37</sup> The overall sample means for BMI and 30-year cardiovascular risk score were  $27.05\text{ kg/m}^2$  ( $SD=4.47$ ) and 0.46 ( $SD=0.19$ ), respectively.

### Association between TV viewing and PA with outcomes

TV viewing and meeting PA levels were associated with 30-year cardiovascular risk in both bivariate and

**Table 1** Participant characteristics

Variable	Complete data (n=340 146)	Incomplete data (n=162 473)	P value*	Effect size†
Age in years, mean (SD)	56.55 (8.17)	56.49 (7.93)	0.0121	0.01
Sex, n (%)			<0.0001	0.02
Female	183 152 (53.85)	90 303 (55.58)		
Male	156 994 (46.15)	72 170 (44.42)		
Race/ethnicity, n (%)			<0.0001	0.07
Asian	6640 (1.95)	4816 (2.96)		
Black	4742 (1.39)	3322 (2.04)		
Mixed/other	4436 (1.30)	3082 (1.90)		
White	323 420 (95.08)	149 383 (91.94)		
Do not know/prefer not to answer	908 (0.27)	1870 (1.15)		
Education, n (%)			<0.0001	0.12
College	121 235 (35.64)	39 965 (24.60)		
No college	216 826 (63.74)	114 451 (70.44)		
Prefer not to answer	2085 (0.61)	3410 (2.10)		
Missing	0	4647 (2.86)		
Shift work, n (%)			<0.0001	0.02
Yes	35 253 (10.36)	14 311 (8.81)		
No	304 522 (89.53)	113 282 (69.72)		
Do not know/prefer not to answer	371 (0.11)	348 (0.21)		
Missing	0	34 532 (21.25)		
Sleep duration, n (%)			<0.0001	0.11
Short (≤6 hours)	79 013 (23.23)	44 265 (27.24)		
Adequate (7–8 hours)	237 359 (69.78)	99 407 (61.18)		
Long (≥9 hours)	23 131 (6.80)	15 227 (9.37)		
Do not know/prefer not to answer	643 (0.19)	2686 (1.65)		
Missing	0	888 (0.55)		
Alcohol intake frequency, n (%)			<0.0001	0.12
Daily or almost daily	73 429 (21.59)	28 358 (17.45)		
Three or four times a week	84 036 (24.71)	31 422 (19.34)		
Once or twice a week	88 897 (26.13)	40 419 (24.88)		
One to three times a month	36 801 (10.82)	19 069 (11.74)		
Special occasions only/never	56 876 (16.72)	41 806 (25.73)		
Prefer not to answer	107 (0.03)	498 (0.31)		
Missing	0	901 (0.55)		
Daily fruit and vegetable intake (portions/day), mean (SD)	3.96 (2.14)	3.61 (2.27)	<0.0001	0.16
Bipolar and major depression, n (%)			<0.0001	0.08
Yes	24 671 (7.25)	8787 (5.41)		
No	66 924 (19.68)	22 609 (13.92)		
Unknown	248 551 (73.07)	131 077 (80.68)		
Television viewing (hours/day), mean (SD)	2.64 (1.52)	3.14 (1.94)	<0.0001	0.30
Meeting physical activity recommendations, n (%)			<0.0001	0.02
Yes	210 152 (61.78)	29 600 (18.22)		
No	129 994 (38.22)	20 270 (12.48)		
Missing	0	112 603 (69.31)		
Body mass index, mean (SD)	27.05 (4.47)	28.24 (5.36)	<0.0001	0.25
30-year Framingham Cardiovascular Risk Score, mean (SD)	0.46 (0.19)	0.49 (0.20)	<0.0001	0.18

Continued



**Table 1** Continued

Variable	Complete data (n=340 146)	Incomplete data (n=162 473)	P value*	Effect size†
Use of cardiovascular medication, n (%)			<0.0001	0.15
Yes	88 053 (25.89)	50 217 (30.91)		
No	252 093 (74.11)	103 659 (63.80)		
Do not know/prefer not to answer	0	3889 (2.39)		
Missing	0	4708 (2.90)		

\*P values based on  $\chi^2$  tests for categorical variables and two-sample t-tests for continuous variables.

†Effect sizes based on Cohen's d (small: 0.20, medium: 0.50, large: 0.80) for continuous variables and Cramer's V (small: 0.10-0.30, medium: 0.40-0.50, large: >0.50) for categorical variables: effect sizes are deemed very small or small for all variables.

multivariable adjusted models (table 2A). In adjusted models, every additional hour of TV viewing was associated with a 3% increase in 30-year CVD risk (adjusted Coefficient (aCoeff)=0.03, Cohen's d (d)=0.16,  $p<0.001$ ), while meeting PA recommendations was associated with a 0.2% decrease in 30 year CVD risk (aCoeff=-0.002,  $d=0.01$ ,  $p<0.01$ ) (table 2A).

When BMI was considered an outcome variable, results from the adjusted models indicated that every additional hour of TV viewing was associated with a 0.54 increase

in BMI (aCoeff=0.54,  $d=0.13$ ,  $p<0.001$ ), while meeting PA recommendations was associated with a 0.75 decrease in BMI (aCoeff=-0.75,  $d=0.17$ ,  $p<0.001$ ) (table 2B).

### Interactive effects between TV viewing and PA on study outcomes

When examining the extent to which meeting PA recommendations ameliorated the association between TV viewing with study outcomes (ie, TV viewing  $\times$  meeting PA recommendations interaction), marginal effects were

**Table 2** A: associations\* between television viewing and meeting physical activity recommendations with 30-year Framingham risk score (n=340 146). B: associations\* between television viewing and meeting physical activity recommendations with BMI (n=340 146)

#### A: Associations\* between television viewing and meeting physical activity recommendations with 30-year Framingham Risk Score (n=340 146)

Independent variable	Unadjusted				Adjusted*			
	Estimate (SE)	95% CI	P value	Effect size†	Estimate (SE)	95% CI	P value	Effect size†
Television viewing (hours/day)	0.0326 (0.0002)	0.0322 to 0.0330	<0.0001	0.18	0.0294 (0.0002)	0.0290 to 0.0298	<0.0001	0.16
Meeting physical activity recommendations (reference=not meeting)	0.0017 (0.0007)	0.0004 to 0.0030	0.0102	0.01	-0.0018 (0.0007)	-0.0031 to -0.0005	0.0054	0.01

#### B: Associations\* between television viewing and meeting physical activity recommendations with BMI (n=340 146)

Independent variable	Unadjusted				Adjusted*			
	Estimate (SE)	95% CI	P value	Effect size†	Estimate (SE)	95% CI	P value	Effect size†
Television viewing (hours/day)	0.6226 (0.0049)	0.6129 to 0.6322	<0.0001	0.14	0.5443 (0.0052)	0.5341 to 0.5545	<0.0001	0.13
Meeting physical activity recommendations (reference=not meeting)	-0.6278 (0.0157)	-0.6587 to -0.5970	<0.0001	0.14	-0.7494 (0.0154)	-0.7797 to -0.7191	<0.0001	0.17

\*All models were adjusted for race/ethnicity, education, shift work, sleep duration, alcohol intake frequency, daily fruit and vegetable intake, and bipolar/major depression status. All models were adjusted for age, sex, race/ethnicity, education, shift work, sleep duration, alcohol intake frequency, daily fruit and vegetable intake, bipolar/major depression status and current smoking.

†Effect sizes based on Cohen's d (small: 0.20, medium: 0.50, large: 0.80). Effect sizes based on Cohen's d (small: 0.20, medium: 0.50, large: 0.80).

BMI, body mass index.

**Table 3** A: Associations\* between television viewing with 30-year Framingham risk score moderated by meeting physical activity recommendations (n=3 40 146). B: Associations\* between television viewing with BMI moderated by meeting physical activity recommendations (n=340 146)

Independent variable	Estimate (SE)	95% CI	P value	Effect size†
Television viewing (hours/day)	0.0288 (0.0003)	0.0281 to 0.0294	<0.0001	0.16
Meeting physical activity recommendations (reference=not meeting)	-0.0028 (0.0013)	-0.0053 to 0.0003	0.0274	0.02
Television viewing x meeting physical activity recommendations (reference=not meeting)	0.0010 (0.0004)	0.0002 to 0.0018	0.0142	0.01

Independent variable	Estimate (SE)	95% CI	P value	Effect size†
Television viewing (hours/day)	0.5381 (0.0079)	0.5227 to 0.5535	<0.0001	0.13
Meeting physical activity recommendations (reference=not meeting)	-0.7098 (0.0302)	-0.7691 to 0.6506	<0.0001	0.17
Television viewing x meeting physical activity recommendations (reference=not meeting)	0.0002 (0.0099)	-0.0192 to 0.0195	0.9867	<0.01

\*Model was adjusted for race/ethnicity, education, shift work, sleep duration, alcohol intake frequency, daily fruit and vegetable intake, and bipolar/major depression status. All models were adjusted for age, sex, race/ethnicity, education, shift work, sleep duration, alcohol intake frequency, daily fruit and vegetable intake, bipolar/major depression status and current smoking.

†Effect sizes based on Cohen's d (small: 0.20, medium: 0.50, large: 0.80). Effect sizes based on Cohen's d (small: 0.20, medium: 0.50, large: 0.80). BMI, body mass index.

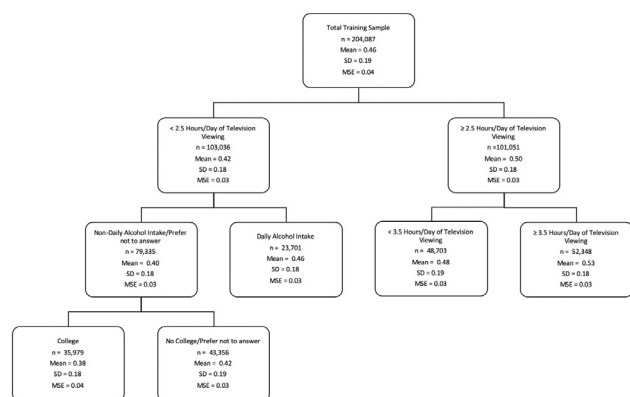
found (table 3A and B). Specifically, for every additional hour increase of TV viewing per day, those meeting the PA recommendations had a 0.1% higher cardiovascular risk score than those not meeting PA recommendations (aCoeff=0.001, d=0.01, p=0.01). While these effect sizes are very small, it may be relevant to note that the risk for CVD went from 3% for each additional hour of TV alone to 0.1% for each additional hour of TV viewed among those who met PA guidelines compared with those not meeting PA guidelines. For every additional hour increase of TV viewing per day, those who met PA recommendations had a 0.0002 higher BMI than those not meeting PA recommendations (aCoeff=0.0002, d<0.01, p=0.99). Thus, meeting PA guidelines was marginally associated with a reduction in CVD risk, but not associated with a lower BMI, in adults who watched more TV.

### Assessment of TV viewing cut-point for higher CVD risk and BMI

In a regression tree model of 30-year CVD risk that included all study variables except for those used to generate the risk score outcome (ie, TV viewing, meeting PA recommendations, race/ethnicity, education, shift work, alcohol intake frequency, sleep duration, daily fruit and vegetable intake, bipolar/major depression status), TV viewing emerged as the most proximal variable, with  $\geq 2.5$  hours of TV viewing conferring the greatest cardiovascular risk. Specifically, in the training sample of 204 087 adults, those accruing 2.5 or more hours of TV viewing had a mean cardiovascular risk score of 0.5 (SD=0.18; indicating a 50% risk for a full cardiovascular event in the next 30 years) vs 0.42 (SD=0.18) for adults accruing less than 2.5 hours of TV (figure 1).

In a second decision-tree model of BMI that included all study variables (ie, TV viewing, meeting PA recommendations, age, sex, race/ethnicity, education, shift work, alcohol intake frequency, sleep duration, daily fruit and vegetable intake, bipolar/major depression status, current smoking), TV viewing emerged as the most proximal variable, with  $\geq 2.5$  hours of TV viewing being associated with mean BMI of 27.86 (SD=4.60) as compared with 26.26 (SD=4.20) recorded in adults who reported watching fewer than 2.5 hours of TV (figure 2).

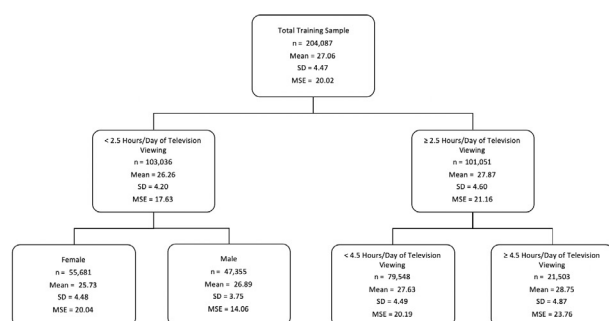
A bivariate examination of the relationship between TV viewing and meeting PA recommendations showed no significant association between the two variables ( $X^2=0.09$ ; p=0.76). Half of adults (49.5%) who reported meeting PA recommendations also reported watching 2.5 hours or more of TV in a typical day.



**Figure 1** Decision tree model of 30-year Framingham risk score (n=204 087). MSE, mean SE.

### DISCUSSION

An expansive, but incomplete, literature has documented that sedentary behaviour, in the form of TV viewing, is



**Figure 2** Decision tree model of body mass index (n=204 087). MSE, mean SE.

associated with CVD risk.<sup>9 19</sup> Results from the current population study extends this knowledge by showing that meeting PA recommendations may marginally ameliorate the association between TV viewing and cardiovascular risk, and that accumulating 2.5 hours of TV viewing per day confers a higher cardiovascular risk as indicated by a higher mean BMI and mean 30-year Framingham risk score. These data underscore the importance of addressing TV viewing as a risk factor for CVD, even among physically active adults.

Previous studies examining the moderating role of PA on the association between sedentary behaviours and health outcomes have generally shown that increased sitting time and/or TV viewing determines all-cause mortality and CVD, independent of PA levels. In one of the most comprehensive, harmonised meta-analyses investigating the association between TV viewing and all-cause mortality, data showed that watching TV for three or more hours per day was associated with earlier death, regardless of PA levels.<sup>17</sup> Other population studies that used CVD events as an outcome have had similar results: data from the Women's Health Initiative study (n=71 018) showed that total sitting time of ten or more hours per day as compared with 5 or fewer hours per day was associated with an 18% increased risk of CVD, independent of PA.<sup>14</sup> Where the relationship becomes more nuanced is in the case of highly active adults: in this group (ie, >35.5 MET-hours per week), the effects of prolonged sitting becomes significantly ameliorated. It is important to note, however, that this is only apparent in highly active adults.<sup>15 17</sup> Our work adds to this literature by showing that among our large population sample, the association for each additional hour of TV viewing went from 3% in the general sample, to 0.1% in adults who met PA guidelines. Although the effect size of this interaction between TV viewing and meeting PA guidelines was very small (d=0.01), the implications may be that while meeting PA guidelines may confer some protection over CVD risk among those who watch television daily, the protection is marginal.

One of the key findings from this study was that 2.5 hours or more per day of television viewing conferred greater cardiovascular risk. This cut-point was found using a regression tree approach and is potentially informative at the population and clinical level. For example, Kim *et al* showed

that 10 or more hours per day versus less than 5 hours of sitting was associated with a 19% increased odds of cardiovascular mortality in women, while five or more hours per day versus one or fewer hours per day of television viewing was associated with a 32% increase in cardiovascular mortality in women.<sup>8</sup> The consideration of television viewing time as part of the overall proportion of daily sedentary behaviour is potentially a more useful population health target than focusing on total sitting time since, unlike commuting to work, or sitting at one's desk to work, television viewing is likely a more modifiable leisure-time activity. From a clinical perspective, prior studies such as the one described by Kim *et al* that have compared the association between high versus low hours of sedentary time on cardiovascular metrics have largely relied on relatively arbitrary categories. The use of classification and regression tree methodologies extends this work to use repeated binary splits within the sample to generate a definitive cut-point that confers the greatest risk of outcome. Thus, the identification of 2.5 hours of television viewing time as the risk threshold for poor cardiovascular health, could be clinically significant.

Findings from the current study should be interpreted with consideration of several limitations. First, the cross-sectional and self-report nature of the study assessments precludes an objective and temporal assessment of the relationship between the study variables, and makes findings vulnerable to recall bias. Moreover, given that the response rate for the UK Biobank is approximately 5%, selection bias is a possibility in this sample. Second, work place sedentary behaviour and PA was not considered in the analysis. Duration of diabetes, use of medications (eg, anticholesterol pharmacotherapies), and season were not considered in this analysis, and may have altered results. Future steps for this work include verification of these findings using objective assessments (ie, accelerometers), consideration of a broader context of sedentary behaviour including workplace sitting, and use of smartphones, as well as the inclusion of a more heterogeneous sample (ie, a greater proportion of male respondents and non-Caucasian groups). Despite these limitations, these population data make a considerable contribution to the literature by demonstrating the independent association between television viewing and poor cardiovascular health, and that 2.5 hours or more of television per day confers considerable risk for cardiovascular health.

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**Patient consent for publication** Not required.

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**Data availability statement** Data are available on reasonable request. Data from UK Biobank (<https://www.ukbiobank.ac.uk/>) are available to bona fide researchers on application. An anonymised dataset received from the UK Biobank under application 16153 was used to conduct the current research study.

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