Mortality Risk Reductions from Substituting Screen-Time by Discretionary Activities

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Abstract

Purpose—Leisure-screen-time, including TV viewing, is associated with increased mortality risk. We estimated the all-cause mortality risk reductions associated with substituting leisure-screen-time with different discretionary physical activity types, and the change in mortality incidence associated with different substitution scenarios.

Methods—423,659 UK Biobank participants, without stroke, myocardial infarction or cancer history, were followed for 7.6 (1.4) (median (IQR)) years. They reported leisure-screen-time (TV watching and home computer use) and leisure/home activities, categorised as daily-life activities (walking for pleasure; light DIY; heavy DIY) and structured exercise (strenuous sports; other exercises). Iso-temporal substitution modelling in Cox regression provided hazard ratios (95% confidence intervals) for all-cause mortality when substituting screen-time (30 minutes/day) with different discretionary activity types of the same duration. Potential impact fractions (PIFs) estimated the proportional change in mortality incidence associated with different substitution scenarios.

Results—During 3,202,105 person-years of follow-up, 8,928 participants died. Each 30 minute/day difference in screen-time was associated with lower mortality hazard when modelling substitution of screen-time by an equal amount of daily-life activities (0.95 (0.94-0.97)), as well as structured exercise (0.87 (0.84-0.90)). Re-allocations from screen-time into specific activity subtypes suggested different reductions in mortality hazard (walking for pleasure (0.95 (0.92-0.98)), light DIY (0.97 (0.94-1.00)), heavy DIY (0.93 (0.90-0.96)), strenuous sports (0.87 (0.79-0.95)), other exercises (0.88 (0.84-0.91))). The lowest hazard estimates were found when modelling replacement of TV viewing. PIFs ranged from 4.3% (30 minute/day substitution of screen-time into light DIY) to 14.9% (TV viewing into strenuous sports).

Conclusion—Substantial public health benefits could be gained by replacing small amounts of screen-time with daily-life activities and structured exercise. Daily-life activities may provide feasible screen-time alternatives, if structured exercise is initially too ambitious.

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Conflict of Interest

The results of the present study do not constitute endorsement by the American College of Sports Medicine. The authors declare that they have no conflict of interest.

Introduction

Physical activity is well-established as a lifestyle component contributing to longevity (22). Sedentary behaviour (i.e. awake time sitting/reclining with low energy expenditure (31)) is increasingly recognised as an additional risk factor for chronic disease (39). TV viewing in particular has been most strongly and consistently associated with incident diabetes, cardiovascular disease, specific cancers and premature mortality from a multitude of causes in adults, irrespective of levels of moderate-to-vigorous intensity physical activity (MVPA) (10, 20, 21, 29, 38). Consequently, separate public health guidelines focusing on TV viewing in adults have been advocated (20, 35, 38). Early intervention work focusing on recreational sedentary screen-time has shown promising results (27). Nevertheless, at a population-level, this behaviour still amounts to a substantial proportion of people's time. English adults, for example, on average watch TV for 3 hours/day, making it the single most prevalent leisure-time pursuit (similar to the US (8)); and although total sedentary time has shown a slight decrease in recent years, TV viewing has not declined (30). This high prevalence together with reasonably strong associations with premature mortality has resulted in sizeable estimates of public health impact (14, 21, 35, 38).

Recommendations on reducing screen-time should involve replacement by non-sitting rather than other sitting activities. The most feasible behavioural change options likely involve replacement of screen-time by non-sitting activities in the home and leisure-time domain (i.e. discretionary time), rather than by non-sitting activities at work or during transportation (i.e. non-discretionary time). It is however largely unknown which types of such discretionary activities would be healthy alternatives. This is partially because current estimates for mortality risk have only considered the potential *additive* impact of screen-time reductions per se, i.e. while keeping all other activities constant. Total discretionary time is however fairly constant in this age-group and mortality risk reductions from decreasing screen-time depend on the activity that displaces screen-time (25). Higher intensity physical activities are associated with greater longevity but are generally less amenable to change (19, 28). Activities which can be easily incorporated into daily life (e.g. home maintenance and improvement activities) are perceived as more attractive compared to activities which require more organisation and costs (e.g. sports) (19).

Iso-temporal substitution modelling allows the estimation of the mortality benefits of replacing screen-time with another specific type of activity for the same duration, while keeping other activities constant (25). This approach, therefore, provides a more realistic insight into the potential impact of behavioural change using observational data (39), which is of interest given the lack of intervention studies with mortality as an outcome. We therefore aimed to estimate the differential mortality risk reductions associated with substituting leisure-screen-time with different discretionary physical activity types, in a large

sample of UK middle-aged adults, by means of iso-temporal substitution modelling. To further inform public health guidance, we also estimated the proportional reduction in all-cause mortality incidence associated with each of these behavioural change scenarios.

Methods

Participants

UK Biobank is a large-scale prospective cohort study of half a million middle-aged UK adults, established with a main aim to determine the aetiological role of various genetic and lifestyle factors in the development of chronic disease (1, 37). Eligible individuals aged 40-69 years and living within a convenient distance (up to ≈25 miles) from one of 22 assessment centres located throughout the UK were identified from NHS registers and invited to participate in a baseline assessment visit (2006-2010) (1, 34). Those who reported a history of stroke, myocardial infarction or cancer at baseline were excluded from the current analyses (n=55,401), as well as those with missing data for any of the covariates (n=26,960). As a result, 423,659 participants were included in the present analysis (45.3 % men). The UK Biobank was approved by the North West Research Ethics Committee and is monitored by the UK Biobank Ethics and Governance Council. All procedures performed were in accordance with the 1964 Helsinki declaration and its later amendments. Informed consent was obtained from all individual participants included in the study.

Measurement methods

Mortality ascertainment—All UK Biobank participants were followed up for vital status by linkage to national datasets (NHS Information Centre and Scottish Morbidity Record) until September 2016. This resulted in a median (IQR) follow-up time of included participants of 7.6 (1.4) years.

Screen-time and discretionary physical activity—As part of an electronic touchscreen questionnaire, participants were asked to indicate how many hours they spend watching TV and subsequently how many hours they spend using the computer (not including occupational computer use) on a typical day. The sum of both estimates was calculated to estimate average daily screen-time (hours/day). Questions were open-ended and screen time was truncated at 9 hour/day.

Participants were also asked about their participation in the last four weeks in five different types of activities in their leisure-time or at home. Activities included walking for pleasure (not as a means of transport), light do-it-yourself (DIY, i.e. home maintenance and improvement and gardening) activities (e.g. pruning) and heavy DIY (e.g. digging, carpentry), strenuous sports that make you sweat or breathe hard, and other exercises (e.g. swimming). Average time (minutes/day) spent in each of these activities was calculated by multiplying the reported frequency and average session duration. All frequency and duration questions were categorical. Strenuous sports and other exercises were combined into an indicator of structured exercise, and time spent in walking for pleasure, light and heavy DIY were combined into an indicator of daily-life activities, indicating the greater ease of embedding these activities into daily life. A screenshot with the exact wording for each of

the screen time and discretionary activity questions can be found online (e.g. TV viewing: http://biobank.ctsu.ox.ac.uk/crystal/refer.cgi?id=100277).

Covariates—The Townsend deprivation index, an indicator of material deprivation, was included as a proxy for socio-economic status. It was calculated at recruitment, based on the location of participants' postcode relative to the national census output areas, with higher scores indicating higher levels of deprivation. Ethnicity (White; Mixed; Asian; Black; Chinese; other) and employment status (unemployed; in paid employment or self-employed) were self-reported through the electronic questionnaire.

Participants also reported their alcohol intake (never; former; current <3 times/week; current 3 times/week), smoking status (never; former; current), salt adding behaviour (never/rarely; sometimes; usually; always), oily fish consumption (never; <1 time/week; 1 time/week; >1 time/week), fruit and vegetable intake (score ranging from 0-4 based on fresh and dried fruit intake and raw and cooked vegetable intake), processed and red meat intake (n days/week), and sleep duration (categorised as <7 hours/night; 7-8 hours/night; >8 hours/night). Sleep time was not included in the iso-temporal framework due to non-linearity of the association between sleep time and all-cause mortality; this is similar to the approach taken by others (17).

They were also asked about their chronic disease status at baseline. This included doctor diagnosis of stroke (yes; no), myocardial infarction (yes; no) and cancer (yes; no) and intake of anti-hypertensive (yes; no) and lipid-lowering medication (yes; no). They were considered to have diabetes (yes; no) if they reported a physician confirmed diagnosis and/or treatment with insulin. Finally, parental history of cardiovascular disease or diabetes (yes; no) was defined as self-reported paternal or maternal history of heart disease, stroke, hypertension or diabetes. A similar definition was employed for parental history of cancer (yes; no) based on bowel, lung, paternal prostate or maternal breast cancer.

Participants with baseline history of stroke, myocardial infarction or cancer were excluded from analyses (as described above) and all other covariates were included as confounders in the models, chosen a priori based on the relevant literature.

Statistical analysis

Baseline characteristics were summarised by vital status, and by screen-time and discretionary physical activity tertiles. Cox regression with age as the underlying timescale was used to estimate the association between screen-time, activity types and all-cause mortality. Linearity of the associations between all exposures and all-cause mortality was assessed by fitting cubic spline regression models with 5 knots. As no substantial deviations from linearity were suggested, all exposures were modelled linearly as continuous variables and hazard ratios and 95% confidence intervals (HR (95% CIs)) were estimated for 30 minute/day increments, deemed to be feasible changes for both sedentary and activity behaviours. The proportional hazards assumption for each covariate was examined using Schoenfeld residuals and graphical checks, and found to be appropriate. Partition models were fitted first, which estimate the *additive* effect of screen-time and each type of activity on all-cause mortality risk, holding all other exposures constant (25). Multiplicative

interactions between sex and screen-time and physical activity were tested by including the relevant parameters in the models.

We then estimated the effect of *substituting* screen-time by each of the physical activity types using iso-temporal substitution models. The resulting HR (95%CIs) for each physical activity type from this model provides an estimate of the potential effect on mortality of increasing that type of activity by 30 minutes/day while decreasing screen-time by the same duration, and holding other activity types constant (25).

To examine the potential public health impact of these substitutional effect estimates on all-cause mortality, we then calculated potential impact fractions (PIFs) using the "distribution shift" method described by Barendregt et al. (3), based on a normal distribution for screen-time. The 95% CIs were derived from bootstrap analysis with 1,000 replications. Each PIF represents the proportionate change in the incidence of mortality in the population if average screen-time in that population decreased by 30 minutes/day, while average physical activity (of the type being examined) increased by the same amount. For calculation of the PIF, the mean and SD of the screen-time variables was estimated from the UK Biobank sample. In a sensitivity analysis, prevalence estimates of TV viewing time from the nationally representative Health Survey for England 2012 (HSE 2012 (30)) were used, to overcome any potential selection bias of the UK Biobank sample. Questions for television viewing time in HSE 2012 data closely resembled those asked in UK Biobank, with the only difference that HSE 2012 questions were interview-based with a reference frame of the last 4 weeks, and asked for week- and weekend days separately. We calculated average daily television viewing estimates from the separate estimates for week- and weekend days (30 minutes/day).

To examine the possibility of reverse causality (i.e. when participants are on the chronic disease pathway but not yet diagnosed at baseline and therefore show or report high levels of screen time and/or low levels of discretionary activity) influencing the estimated HRs (95%CIs), we performed a second sensitivity analysis excluding those who died in the first 2 years of follow-up (in addition to exclusion of those who reported baseline history of stroke, myocardial infarction or cancer). All analyses were performed using Stata version 14 (*Stata Statistical Software.* College Station, TX: StataCorp LP. 2015).

Results

Descriptive characteristics

During 3,202,105 person-years of follow-up, 8,928 participants died (3,466 women; 5,462 men), a crude mortality rate of 27.9 per 10,000 person-years. Baseline descriptive characteristics by vital status and by screen-time and discretionary activity tertiles are shown in Tables 1 and 2, respectively.

Associations with all-cause mortality

Partition models—As shown in Table 3, each 30 minute/day difference in screen-time was associated with a 1% higher hazard of all-cause mortality, independent of time spent in activity and all other confounding variables included in the model. Furthermore, each 30

minute/day difference in daily-life activities and in structured exercise was independently associated with a 4% and 12% lower hazard for all-cause mortality. When examining the two screen-time variables separately, associations for TV viewing time were the strongest, showing a 2% higher mortality hazard for each 30 minute/day difference, whereas associations for computer use were non-significant. A significant interaction between computer use and sex was identified (p=0.001). Examining the independent associations with all-cause mortality for computer use separately by sex, there was a positive association (1.015 (1.001-1.031)) in women, whereas the association was negative (0.986 (0.975-0.996)) in men. Therefore, iso-temporal substitution for computer use was modelled in men and women separately.

Iso-temporal substitution models—As shown in Figure 1, each 30 minute/day difference in screen-time was associated with a lower mortality hazard when modelling substitution of screen-time by an equal amount of daily-life activities as well as by an equal amount of structured exercise. Although modelling 30 minute/day replacements of screen-time by structured exercise resulted in the lowest mortality hazard (0.87 (0.84-0.90)), modelling substitution by daily-life activities also suggested a relevant protective effect (0.95 (0.94-0.97)). When looking at more specific subtypes of daily-life activities, the lowest mortality hazards were found when modelling 30 minute/day re-allocations from screen-time into walking for pleasure (0.95 (0.92-0.98)) and into heavy DIY (0.93 (0.90-0.96)); whereas potential mortality benefits were more limited when modelling re-allocation into light DIY (0.97 (0.94-1.00)). Confidence intervals did however overlap between estimates for these activity subtypes. As expected, the modelled effects of replacing 30 minutes of screen-time with an equivalent duration of strenuous sports (0.87 (0.79-0.95)) and other types of exercise (0.88 (0.84-0.91)) were stronger.

Results when modelling substitution of TV viewing time were similar to those when modelling substitution of screen-time (Figure 1). The modelled effects of substitution of computer time by different activity types were less consistent, with generally weaker effect estimates than for screen and TV viewing time. In both men and women a potential protective effect was found when modelling substitution of computer time by daily-life activities (men: 0.98 (0.96-1.00); women: 0.94 (0.91-0.97)) and structured exercise (men: 0.89 (0.85-0.93); women: 0.90 (0.84-0.96)). For daily-life activities in women, this was mainly driven by walking for pleasure (0.93 (0.89-0.98)) and heavy DIY (0.84 (0.76-0.94)). Modelling re-allocation of computer time into other exercises showed a potential protective effect in men (0.88 (0.84-0.93)) and women (0.90 (0.84-0.97)), whereas results for re-allocation into strenuous sports only reached significance in men (0.90 (0.81-0.99)).

Results were similar when those who died within the first 2 years of follow-up were excluded. [see Table, Supplemental Digital Content 1, Hazard ratios (95% confidence intervals) for all-cause mortality from partition models for screen time and different types of discretionary activity; see Table, Supplemental Digital Content 2, Hazard ratios (95% confidence intervals) for all-cause mortality when modelling 30 minute/day substitutions of screen time.]

Potential impact fractions—Figure 2 displays PIFs for time-re-allocation of overall screen and TV viewing time (i.e. the sedentary behaviours which consistently showed associations with mortality) into the different discretionary activity types. For example, if UK Biobank participants were to decrease their screen-time by an average of 30 minutes/day in exchange for a daily 30 minute walk, the incidence of all-cause mortality would decrease by 5.9%, assuming causality. The estimated PIFs were highest when replacing TV viewing time by either strenuous sports or other exercises (14.9% and 14.6%, respectively) and lowest when replacing screen-time with light DIY (4.3%). Sensitivity analysis using the weighted HSE 2012 distribution for TV viewing time (restricting the age range to that of UK Biobank participants, i.e. 40-69 years) gave similar PIF estimates to those obtained using the UK Biobank distribution (Figure 2).

Discussion

The findings of this study provide novel insights into the potential beneficial effects on mortality risk of substituting recreational screen-time by different types of discretionary active alternatives in a large population-based sample of UK middle-aged adults. They suggest that replacing small amounts of screen-time (i.e. 30 minutes/day) by everyday activities such as DIY and walking, which are generally more easily adopted (19), results in important mortality benefits. Replacement by sports and other exercise provides additional benefits. The substantial differences in effect estimates arising from different substitution scenarios highlight the importance of using iso-temporal substitution modelling to more fully inform public health guidance on effective behaviour change to increase longevity.

The direction and strength of the associations from partition models found for screen-time (32) and TV viewing time (14) confirm those found previously; as well as the stronger and more consistent associations for TV viewing compared to computer time (2, 4, 26). Previous meta-analytical work has also indicated protective mortality effects for exercise/sports as well as daily-life activities, with stronger effect estimates for the former (28). However, none of these studies examined the substitutional effects between screen-time and these different discretionary activity types. Indeed, the few studies that have employed an iso-temporal substitution approach in relation to mortality have focused on non-domain specific sedentary time and/or non-domain specific physical activity (11, 23, 33). We chose to specifically focus on leisure-screen-time, given its high prevalence across all age groups, stronger associations with health compared to other sedentary behaviours, and responsiveness to change through intervention (8, 20, 21, 27, 29, 30, 35, 38)). We specifically focused on discretionary activity types in the leisure and home domain, as these are likely more realistic and feasible alternatives for replacing leisure-screen-time in a middle-aged population compared to activities in the occupational and transportation domain.

Our findings suggested that both replacement by lower (i.e. walking for pleasure and light DIY) and higher intensity activities (i.e. heavy DIY, strenuous sports and other exercise) was found to be beneficial; however, the latter conferred the largest benefit. This is in line with findings for intermediate health risk factors. Some intermediate cardio-metabolic risk factors (such as adiposity) require substitution of sedentary time by higher intensity activities, whereas others (such as glucose and lipid metabolism markers) may respond beneficially

from substitution into both lower (i.e. as low as standing) and higher intensity activity (7, 17). For risk factors reliant on energy balance, this may be due to the higher energy cost associated with higher-intensity activities for the same duration. Other risk factors may be influenced via other protective pathways related to features such as more fragmented accumulation patterns or an upright posture, which may be applicable to both low and high intensity activities. Enzymes regulating glucose and lipid metabolism, for example, may be up-regulated with muscle activity related to standing and non-sedentary activities and with higher activity fragmentation (13, 15). In terms of mental health as an intermediate risk factor, replacements of sitting time into both lower and higher intensity activity have been shown to be beneficial, which is likely also due to differential pathways, such as increased socialisation and increased β-endorphines (6, 24).

We have estimated that 4.3% to 14.9% of premature deaths in the UK could be avoided through substitution of 30 minutes/day of total screen or TV viewing time by discretionary active alternatives, with the highest potential shift in mortality cases to be gained from substituting TV viewing by sports and exercise. Lee et al. estimated that physical inactivity (i.e. not achieving 150 minutes/week of MVPA) causes 9% of premature mortality globally (an effect on par with smoking and obesity (22)). The latter is an estimate of the excess proportion of deaths that could be avoided through the increase in MVPA to prescribed levels, keeping all other activities constant. A direct comparison of study results is challenging due to differences in populations and methodology. However, most of our PIF estimates for discretionary activities, which would be classified as moderate-to-vigorous in terms of intensity, exceeded 9% (e.g. 30 minute/day reallocation of TV viewing into heavy DIY (10%), strenuous sports (15%) or other exercises (15%)). Although caution is needed when comparing these study results, this may be partially due to our PIF estimates reflecting the combined effect of reducing screen-time and increasing activity levels. The latter provide more realistic estimates of the potential public health impact of behavioural change, as reducing one type of activity necessarily results in increased engagement in another type of activity (39). Future studies should, therefore, aim to also incorporate such estimates.

There are several strengths of this study. A wide range of potential confounding variables was controlled for. These included several dietary variables, confounding the associations for physical activity. These dietary covariates may, however, be on the causal pathway between screen-time, especially TV viewing time, and premature mortality (12, 16), potentially resulting in over-adjustment and, therefore, underestimation of the effect estimates for screen-time. Inclusion of a large population-based sample of UK adults enabled us to exclude all those with baseline chronic conditions, and in sensitivity analyses additionally those who died in the first 2 years of follow-up. This helped us to minimise the risk of reverse causality influencing our estimates, and potentially also the risk of severe recall bias by those with chronic disease influencing our findings. We minimised the potential risk of selection bias influencing the PIF estimates, by recalculating these estimates in a separate population-representative sample of English adults (30). Finally, we examined the substitution effects for both types of screen-time separately. However, there were also limitations to the study. Iso-temporal substitution modelling estimates are based on statistical modelling rather than actual behavioural change. It is also unlikely that the self-report instrument captured all screen-time and activity behaviours in the domestic and

leisure domain. Screen-time and physical activity were self-reported through questions which were categorical and have not been directly examined for criterion validity, and social desirability bias may have caused over-reporting of physical activity and underreporting of screen time. However, most self-report instruments have similar validity (18) and effect estimates were comparable to those found previously in comparable populations using similar adjustment strategies (14, 28, 32). We examined potential bias associated with differences in education level, by adjusting for education level instead of Townsend index, which resulted in very similar effect estimates (results not shown). The questionnaire did not distinguish between week- and weekend days, and the time frame of reference for screen-time ("typical day") was different to that for physical activity ("last 4 weeks"), although it is unlikely the latter would have substantially impacted on results (9). Objective activity measures are currently unable to classify activities by type and domain, which makes subjective measures particularly valuable for these types of research questions (23, 33). Finally, while we aimed to increase internal validity by excluding those with baseline conditions, this may have enhanced the healthy cohort effect on observed associations. Replication in populations with different health status, age, ethnicity, and lifestyle profiles is needed. Ideally these studies would also incorporate repeated objective measures for screen-time and physical activity, allowing consideration of the patterns of sitting and activity, and have longer follow up.

In conclusion, replacing small amounts of screen-time (i.e. 30 minutes/day) by everyday activities such as DIY or walking could result in considerable public health benefits. These may be important targets for adults for whom taking up more structured activities or higher intensity sports (which show stronger mortality benefits) to replace screen-time initially is less feasible or compromised through ill health. Given the ubiquitous nature of screen-time, the achievability of the examined behavioural change options and the substantial mortality benefits estimated, specific guidelines on reductions in screen-time, so far mainly implemented for pediatric populations (36), could be considered for adult age groups, to complement emerging guidelines on occupational sitting (5). These could not only recommend reductions in screen-time but also substitution by alternative healthy activities which can take place in the home and leisure domain.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgements

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Screen time

Activity type

Daily-life activities	0.95 (0.94, 0.97)
Structured exercise	0.87 (0.84, 0.90)

Activity subtype

Walking for pleasure	0.95 (0.92, 0.98)
Light DIY	0.97 (0.94, 1.00)
Heavy DIY	0.93 (0.90, 0.96)
Strenuous sports	0.87 (0.79, 0.95)
Other exercises	0.88 (0.84, 0.91)

TV viewing time

Activity type

Daily-life activities	0.94 (0.93, 0.96)
Structured exercise	0.87 (0.84, 0.90)

Activity subtype

Walking for pleasure	0.94 (0.92, 0.97)
Light DIY	0.96 (0.94, 0.99)
Heavy DIY	0.92 (0.89, 0.95)
Strenuous sports	0.86 (0.79, 0.95)
Other exercises	0.87 (0.83, 0.91)

Computer time, men

Activity type

Daily-life activities	0.98 (0.96, 1.00)
Structured exercise	0.89 (0.85, 0.93)

Activity subtype

Walking for pleasure	0.98 (0.95, 1.01)
Light DIY	0.99 (0.96, 1.02)
Heavy DIY	0.97 (0.93, 1.00)
Strenuous sports	0.90 (0.81, 0.99)
Other exercises	0.88 (0.84, 0.93)

Computer time, women

Activity type

Daily-life activities	0.94 (0.91, 0.97)
Structured exercise	0.90 (0.84, 0.96)

Activity subtype

Walking for pleasure	0.93 (0.89, 0.98)
Light DIY	0.99 (0.94, 1.04)
Heavy DIY	0.84 (0.76, 0.94)
Strenuous sports	0.88 (0.73, 1.06)
Other exercises	0.90 (0.84, 0.97)

Figure 1.

Hazard ratios (95% confidence intervals) of all-cause mortality when modelling 30 minute/day substitutions of screen time (total screen time, TV viewing time or computer time) by equivalent durations of different types of discretionary physical activity in 423,659 UK men and women, UK Biobank, 2006-2016. Models have omitted the sedentary behaviour component under study, and are adjusted for total discretionary time, sex, ethnicity, socio-economic status, employment status, smoking status, alcohol, fruit and vegetable, processed and red meat, salt and oily fish intake, sleep duration, blood pressure

lowering medication, dyslipidaemia medication, personal diabetes history and parental history of CVD or diabetes and cancer. Model for TV viewing substitution is adjusted for computer time and vice versa.
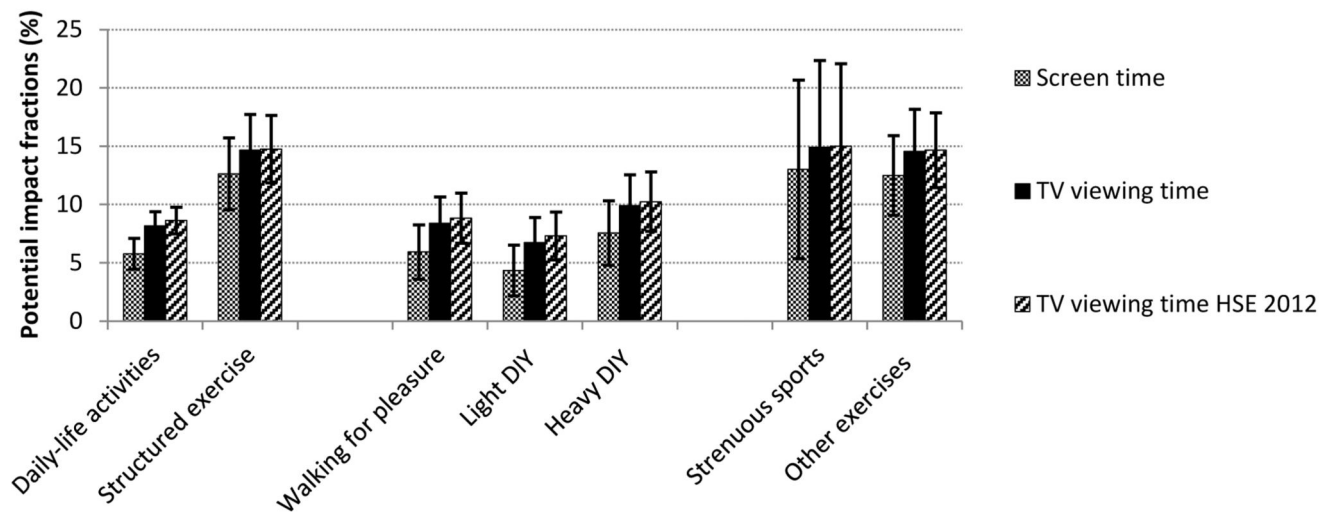
Figure 2.
Potential impact fractions (%; 95% confidence intervals) representing the proportionate decrease in incidence of all-cause mortality in the population if average screen time were to decrease by 30 minutes/day, while average time spent on the respective discretionary physical activity type increased by the same amount, assuming causality. Grey and black bars are based on distribution estimates from UK Biobank for screen time and TV viewing time respectively, whereas striped bars are based on the weighted TV viewing time distribution from the Health Survey for England 2012.

Table 1

Descriptive characteristics at baseline by vital status in 423,659 UK Biobank participants, 2006-2016

Characteristics	Alive (n=414,731)	Deceased (n=8,928)
Male sex, n (%)	187,264 (45.0)	4,786 (61.4)
Age (yrs)	56.0 (8.1)	61.0 (6.7)
Ethnicity, n (%)		
White	392,736 (94.7)	8,655 (96.9)
Mixed	2,390 (0.6)	39 (0.4)
Asian	7,953 (1.9)	102 (1.1)
Black	6,617 (1.6)	60 (0.7)
Chinese	1,340 (0.3)	15 (0.2)
Other	3,695 (0.9)	57 (0.6)
Townsend index	-1.39 (3.0)	-0.8 (3.4)
Unemployed, n (%)	162,616 (39.2)	5,694 (63.8)
Alcohol status, n (%)		
Never	17,471 (4.2)	378 (4.2)
Previous	13,499 (3.3)	551 (6.2)
Current (<3 times/week)	200,838 (48.4)	4,038 (45.2)
Current (3 times/week)	182,923 (44.1)	3,961 (44.4)
Smoking status, n (%)		
Never	233,713 (56.4)	3,472 (38.9)
Previous	139,544 (33.7)	3,585 (40.2)
Current	41,474 (10.0)	1,871 (21.0)
Fruit and vegetable intake, n (%)		
Low	80,658 (19.5)	2,061 (23.1)
Moderately low	124,324 (30.0)	2,774 (31.1)
Moderate	113,359 (27.3)	2,261 (25.3)
Moderately high	69,709 (16.8)	1,356 (15.2)
High	26,681 (6.4)	476 (5.3)
Processed and red meat intake (N days/week)	0.9 (0.6)	1.0 (0.6)
Salt adding, n (%)		
Never/rarely	231,473 (55.8)	4,514 (50.6)
Sometimes	116,434 (28.1)	2,517 (28.2)
Usually	47,690 (11.5)	1,251 (14.0)
Always	19,134 (4.6)	646 (7.2)
Oily fish intake, n (%)		
Never	45,474 (11.0)	1,083 (12.1)
<1 time/week	139,811 (33.7)	2,813 (31.5)
1 time/week	156,693 (37.8)	3,306 (37.0)
> 1 time/week	72,753 (17.5)	1,726 (19.3)
Sleep duration, n (%)		
<7 hrs/day	100,894 (24.3)	2,350 (26.3)

Characteristics	Alive (n=414,731)	Deceased (n=8,928)
7-8 hrs/day	284,281 (68.6)	5,572 (62.4)
>8 hrs/day	29,556 (7.1)	1,006 (11.3)
Antihypertensive drug intake, n (%)	75,938 (18.3)	2,854 (32.0)
Lipid lowering drug intake, n (%)	59,905 (14.4)	2,280 (25.5)
History of diabetes, n (%)	18,650 (4.5)	993 (11.1)
Parental CVD/diabetes history, n (%)	307,191 (74.1)	6,271 (70.2)
Parental cancer history, n (%)	126,502 (30.5)	2,788 (31.2)
Body mass index (kg/m^2)	27.3 (4.7)	28.0 (5.3)
Screen time (hrs/day)	3.8 (1.9)	4.2 (2.1)
TV time (hrs/day)	2.7 (1.5)	3.2 (1.8)
Computer use time (hrs/day, median (IQR))	1.0 (0.0-1.0)	0.5 (0.0-1.0)
Daily-life activities (min/day, median (IQR))	15.8 (4.0-37.5)	13.9 (2.3-39.9)
Walking for pleasure (min/day, median (IQR))	6.4 (0.0-16.1)	4.0 (0.0-16.1)
Light DIY (min/day, median (IQR))	0.0 (0.0-8.0)	0.0 (0.0-6.7)
Heavy DIY (min/day, median (IQR))	0.0 (0.0-4.0)	0.0 (0.0-3.2)
Structured exercise (min/day, median (IQR))	0.8 (0.0-16.1)	0.0 (0.0-6.7)
Strenuous sports (min/day, median (IQR))	0.0 (0.0-0.0)	0.0 (0.0-0.0)
Other exercises (min/day, median (IQR))	0.0 (0.0-13.4)	0.0 (0.0-6.4)

Results are means (SD) unless otherwise indicated. Parental CVD/diabetes history includes a maternal or paternal history of heart disease, stroke, hypertension or diabetes. Parental cancer history includes history of bowel, lung, maternal breast or paternal prostate cancer.

Table 2

Descriptive characteristics at baseline by tertiles of screen time and physical activity in 423,659 UK Biobank participants, 2006-2016

Characteristics	Screen time tertiles			Discretionary physical activity tertiles		
	Lowest n=125,679	Middle n=164,728	Highest n=133,252	Lowest n=141,584	Middle n=141,203	Highest n=140,872
Median ((IQR), hrs/day)	2.0 (1.5-2.0)	3.5 (3.0-4.0)	6.0 (5.0-7.0)	0.1 (0.0-0.2)	0.4 (0.3-0.5)	1.3 (0.9-1.8)
Male sex, n (%)	49,750 (39.6)	75,051 (45.6)	67,248 (50.5)	56,869 (40.2)	62,014 (43.9)	73,166 (51.9)
Age (yrs)	54.4 (8.0)	56.4 (8.0)	57.3 (8.0)	55.7 (8.1)	55.7 (8.1)	56.9 (8.1)
Ethnicity, n (%)						
White	118,985 (94.7)	157,067 (95.4)	125,339 (94.1)	129,560 (91.5)	135,242 (95.8)	136,589 (97.0)
Mixed	701 (0.6)	886 (0.5)	842 (0.6)	1,031 (0.7)	724 (0.5)	674 (0.5)
Asian	2,869 (2.3)	2,867 (1.7)	2,319 (1.7)	4,440 (3.1)	2,185 (1.6)	1,430 (1.0)
Black	1,572 (1.3)	2,156 (1.3)	2,949 (2.2)	3,857 (2.7)	1,661 (1.2)	1,159 (0.8)
Chinese	399 (0.3)	476 (0.3)	480 (0.4)	715 (0.5)	365 (0.3)	275 (0.2)
Other	1,153 (0.9)	1,276 (0.8)	1,323 (1.0)	1,981 (1.4)	1,026 (0.7)	745 (0.5)
Townsend index	-1.5 (3.0)	-1.5 (3.0)	-1.1 (3.2)	-0.8 (3.3)	-1.6 (2.9)	-1.8 (2.8)
Unemployed, n (%)	33,844 (26.9)	64,604 (39.2)	69,862 (52.4)	51,506 (36.4)	50,179 (35.5)	66,625 (47.3)
Alcohol status, n (%)						
Never	5,844 (4.7)	6,511 (4.0)	5,494 (4.1)	8,652 (6.1)	4,830 (3.4)	4,367 (3.1)
Previous	3,801 (3.0)	4,943 (3.0)	5,306 (4.0)	6,048 (4.3)	3,947 (2.8)	4,055 (2.9)
Current (<3 times/week)	57,817 (46.0)	80,030 (48.6)	67,029 (50.3)	75,220 (53.1)	67,615 (47.9)	62,041 (44.0)
Current (3 times/week)	58,217 (46.3)	73,244 (44.5)	55,423 (41.6)	51,664 (36.5)	64,811 (45.9)	70,409 (50.0)
Smoking status, n (%)						
Never	77,555 (61.7)	92,392 (56.1)	67,238 (50.5)	77,217 (54.5)	81,342 (57.6)	78,626 (55.8)
Previous	37,575 (29.9)	56,013 (34.0)	49,541 (37.2)	45,506 (32.1)	47,480 (33.6)	50,143 (35.6)
Current	10,549 (8.4)	16,323 (9.9)	16,473 (12.4)	18,861 (13.3)	12,381 (8.8)	12,103 (8.6)
Fruit and vegetable intake, n (%)						
Low	20,943 (16.7)	32,290 (19.6)	29,486 (22.1)	36,683 (25.9)	25,625 (18.2)	20,411 (14.5)
Moderately low	36,630 (29.2)	49,549 (30.1)	40,919 (30.7)	45,389 (32.1)	43,457 (30.8)	38,252 (27.2)
Moderate	35,532 (28.3)	44,903 (27.3)	35,185 (26.4)	35,064 (24.8)	39,684 (28.1)	40,872 (29.0)
Moderately high	23,115 (18.4)	27,656 (16.8)	20,294 (15.2)	18,448 (13.0)	23,746 (16.8)	28,871 (20.5)
High	9,459 (7.5)	10,330 (6.3)	7,368 (5.5)	6,000 (4.2)	8,691 (6.2)	12,466 (8.9)
Processed and red meat intake (N days/week)	0.8 (0.5)	0.9 (0.5)	1.0 (0.6)	0.9 (0.6)	0.9 (0.5)	0.9 (0.6)
Salt adding, No (%)						
Never/rarely	75,118 (59.8)	91,857 (55.8)	69,012 (51.8)	74,063 (52.3)	80,437 (57.0)	81,487 (57.8)
Sometimes	33,823 (26.9)	46,647 (28.3)	38,481 (28.9)	40,955 (28.9)	39,659 (28.1)	38,337 (27.2)
Usually	12,453 (9.9)	18,889 (11.5)	17,599 (13.2)	17,788 (12.6)	15,680 (11.1)	15,473 (11.0)
Always	4,285 (3.4)	7,335 (4.5)	8,160 (6.1)	8,778 (6.2)	5,427 (3.8)	5,575 (4.0)
Oily fish intake, n (%)						
Never	12,450 (9.9)	17,481 (10.6)	16,626 (12.5)	19,923 (14.1)	13,871 (9.8)	12,763 (9.1)
<1 time/week	41,268 (32.8)	54,828 (33.3)	46,528 (34.9)	52,663 (37.2)	48,011 (34.0)	41,950 (29.8)

Characteristics	Screen time tertiles			Discretionary physical activity tertiles		
	Lowest **n=125,679**	**Middle** **n=164,728**	**Highest** **n=133,252**	**Lowest** **n=141,584**	**Middle** **n=141,203**	**Highest** **n=140,872**
Median ((IQR), hrs/day)	**2.0 (1.5-2.0)**	**3.5 (3.0-4.0)**	**6.0 (5.0-7.0)**	**0.1 (0.0-0.2)**	**0.4 (0.3-0.5)**	**1.3 (0.9-1.8)**
1 time/week	48,921 (38.9)	63,050 (38.3)	48,028 (36.0)	49,073 (34.7)	55,175 (39.1)	55,751 (39.6)
> 1 time/week	23,040 (18.3)	29,369 (17.8)	22,070 (16.6)	19,925 (14.1)	24,146 (17.1)	30,408 (21.6)
Sleep duration, n (%)						
<7 hrs/day	28,332 (22.5)	39,497 (24.0)	35,415 (26.6)	39,795 (28.1)	32,364 (22.9)	31,085 (22.1)
7-8 hrs/day	90,375 (71.9)	114,072 (69.3)	85,406 (64.1)	90,278 (63.8)	99,697 (70.6)	99,878 (70.9)
>8 hrs/day	6,972 (5.6)	11,159 (6.8)	12,431 (9.3)	11,511 (8.1)	9,142 (6.5)	9,909 (7.0)
Antihypertensive drugs, n (%)	16,398 (13.1)	30,788 (18.7)	31,606 (23.7)	30,724 (21.7)	24,208 (17.1)	23,860 (16.9)
Lipid lowering drugs, n (%)	11,825 (9.4)	24,110 (14.6)	26,250 (19.7)	23,674 (16.7)	18,894 (13.4)	19,617 (13.9)
History of diabetes, n (%)	3,574 (2.8)	7,062 (4.3)	9,007 (6.8)	9,009 (6.4)	5,519 (3.9)	5,115 (3.6)
Parental CVD/diabetes history, n (%)	92,595 (73.7)	122,121 (74.1)	98,746 (74.1)	104,913 (74.1)	105,153 (74.5)	103,396 (73.4)
Parental cancer history, n (%)	37,482 (29.8)	50,487 (30.6)	41,321 (31.0)	42,265 (29.9)	43,184 (30.6)	43,841 (31.1)
Body mass index (kg/m^2)	26.0 (4.3)	27.4 (4.6)	28.5 (5.0)	28.3 (5.3)	27.1 (4.5)	26.6 (4.1)

Results are means (SD) unless indicated otherwise. Parental CVD/diabetes history includes a maternal or paternal history of heart disease, stroke, hypertension or diabetes. Parental cancer history includes history of bowel, lung, maternal breast or paternal prostate cancer.

Table 3

Hazard ratios (95% confidence intervals) for all-cause mortality from partition models for screen time and different types of discretionary physical activity (all expressed in 30 minute/day units) in 423,659 UK men and women, UK Biobank, 2006-2016

Model 1	Screen time		Daily-life activities	Structured exercise
	1.01 (1.01-1.02)[*]		0.96 (0.95-0.98)[*]	0.88 (0.85-0.91)[*]
Model 2	TV viewing time	Computer use	Daily-life activities	Structured exercise
	1.02 (1.01-1.03)[*]	1.00 (0.99-1.01)	0.96 (0.95-0.98)[*]	0.88 (0.85-0.92)[*]

Models are mutually adjusted for all screen time and physical activity variables mentioned, as well as for sex, ethnicity, socio-economic status, employment status, smoking status, alcohol, fruit and vegetable, processed and red meat, salt and oily fish intake, sleep duration, blood pressure lowering medication, dyslipidaemia medication, personal diabetes history and parental history of CVD/diabetes and cancer.

[*] p<0.001