Childhood and Adolescent Television Viewing and Metabolic Syndrome in Mid-Adulthood

Nathan MacDonell, BBiomedSc, Robert J. Hancox, MD

abstract

BACKGROUND: Excessive sedentary behaviors, such as television viewing or other screen time, may have adverse metabolic effects. We hypothesized that television viewing time in childhood would be associated with the risk of metabolic syndrome at 45 years of age.

METHODS: We studied a population-based birth cohort born in Dunedin, New Zealand in 1972 and 1973. Parent- and self-reported weekday television viewing times were recorded at ages 5, 7, 9, 11, 13, 15, and 32 years. The primary outcome was metabolic syndrome at age 45 years, defined as 3 or more of: high glycated hemoglobin; high waist circumference; high blood triglyceride; low high-density lipoprotein cholesterol; and high blood pressure. Reported television viewing time and metabolic syndrome data were available for 870 (87%) of 997 surviving participants.

RESULTS: Mean television viewing time between ages 5 and 15 years was associated with metabolic syndrome at 45 years of age. This association persisted after adjusting for sex, socioeconomic status, and BMI at age 5 (odds ratio: 1.30; 95% confidence interval: 1.08 to 1.58; P = .006) and after further adjustment for adult television viewing (odds ratio: 1.26; 95% confidence interval: 1.03 to 1.54; P = .026). Childhood television viewing was also associated with lower cardiorespiratory fitness and higher BMI at 45 years of age.

CONCLUSIONS: Time spent watching television during childhood and adolescence is associated with the risk of metabolic syndrome in mid-adulthood. Interventions to reduce screen time for children and young people may have long-lasting benefits for health.

Department of Preventive and Social Medicine, Dunedin School of Medicine, University of Otago, Dunedin, New Zealand

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Address correspondence to R.J. Hancox, MD, Department of Preventive and Social Medicine, Dunedin School of Medicine, University of Otago, PO Box 56, Dunedin 9054, New Zealand. E-mail: bob.hancox@otago.ac.nz

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WHAT'S KNOWN ON THIS SUBJECT: Sedentary behavior is associated with the risk of metabolic syndrome, obesity, and poor fitness. There is some evidence that this risk may extend from childhood into adulthood, but long-term follow-up studies are lacking.

WHAT THIS STUDY ADDS: Television viewing in childhood and adolescence is associated with a higher risk for metabolic syndrome, obesity, and poor fitness in mid-adulthood. This association is independent of adult viewing, indicating that childhood television viewing has long-term adverse effects on metabolic health.

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Sedentary behaviors, such as television viewing, increase the risk of morbidity and mortality.[1–3] Young people now spend much more time undertaking sedentary behaviors than previous generations, a trend that accelerated during the coronavirus disease 2019 pandemic.[4–7] The long-term consequences of this are not yet clear.

The Dunedin Multidisciplinary Health and Development Study (Dunedin study) previously reported that childhood and adolescent (ages 5–15 years) television viewing was predictive of several indicators of poor health, including higher BMI and lower cardiorespiratory fitness (oxygen consumption at maximal exertion [$V'O_2$ max]) at ages 26 and 32 years.[8,9] In addition, television viewing time from childhood and adolescence was a better predictor of both BMI and cardiorespiratory fitness at age 32 than concurrent viewing,[9] suggesting that childhood television viewing has lasting effects on adult health, regardless of changes in habits in adulthood.[1,2,9,10]

Metabolic syndrome is a cluster of cardiometabolic risk factors associated with the risk of type 2 diabetes mellitus, cardiovascular disease, and nearly 60% higher mortality.[11–13] Metabolic syndrome can be defined in several ways, but the core features include obesity, insulin resistance or hyperglycemia, hypertension, and dyslipidemia.[11,14] The worldwide prevalence of metabolic syndrome has increased along with aging populations and the prevalence of obesity. These secular trends also parallel increases in sedentary behavior (particularly screen time) and reductions in physical activity.[13] Few long-term studies have investigated whether television viewing in childhood increases the risk for metabolic syndrome: most research has either been cross-sectional or is limited by short follow-up times.[15–17] One study found that watching “several shows a day” compared with “one show/week or less” at age 16 was associated with metabolic syndrome at age 43 years. This association remained after adjustment for adult television and other potential confounders.[2] Increasing television viewing over 6 to 12 years follow-up of Danish adolescents was associated with metabolic syndrome scores and insulin levels independently of physical activity,[18] while digital media use by European children was associated with metabolic syndrome, independently of physical activity, over 6 years follow-up.[19] The Nurses’ Health Study II identified an association between television viewing at ages 3 to 5 years and 5 to 10 years and adult type 2 diabetes in women.[20] More than 4 hours per day of screen time at age 16 in the 1970 British Birth Cohort was associated with the risk of developing type 2 diabetes over the following 30 years.[21] Television viewing at age 23 was also associated with adverse cardiometabolic profiles at age 44 years in the 1958 British Birth Cohort, but this was not significant after adjusting for early adult BMI, suggesting that the critical risk period for developing metabolic syndrome due to sedentary behavior may be in childhood or adolescence.[22]

We tested the hypothesis that sedentary behavior, as indicated by television viewing time, in childhood and adolescence increases the risk for metabolic syndrome in mid-adult life using data from the Dunedin study. We further extended follow-up of the relationship between childhood and adolescent television viewing and adult obesity and cardiorespiratory fitness in this cohort[9] to age 45 years.

SUBJECTS AND METHODS

Participants

The Dunedin study is an investigation of health and behavior in a population-based cohort. Full details of the study are published elsewhere.[23] Participants were born in 1972 and 1973 in Dunedin, New Zealand. Those still living in the Otago region were invited to the first follow-up at 3 years, when 1037 children (91% of those eligible: 52% male) attended constituting the base sample of the study. Participants have been followed up at frequent intervals throughout childhood and adulthood and were most recently assessed at age 45, when 938 (94%) of 997 surviving cohort members participated. The sample includes the full range of socioeconomic status and is mostly of New Zealand-European ethnicity. Written informed consent was obtained for each assessment, which was approved by the relevant ethics committee at the time (currently the Health and Disability Ethics Committee [17/STH/25/AM05]).

Assessments

At ages 5 ($n = 991$), 7 ($n = 954$), 9 ($n = 955$), and 11 ($n = 925$) years, parents were asked how much time the participants spent watching weekday television. Participants themselves were asked about television viewing time at ages 13 ($n = 850$), 15 ($n = 976$), and 32 ($n = 969$) years of age. A composite variable of childhood and adolescent television viewing comprises the mean viewing hours per weekday between the ages of 5 and 15 years, as previously reported.[8] Weekday television viewing at age 32 was used as the adult variable.[9] Childhood socioeconomic status was based on the education level and income associated with the highest parental occupation (6 = unskilled laborer, 1 = professional).[24,25] These scores were averaged over the assessments between birth and age 15. Height and weight in light clothing without shoes were measured for 893 participants at age 5 and used to calculate BMI in kg/m^2. Missing BMI values at age 5 were imputed from the measurements taken at age 3 years for a further 120 participants.[8] Time spent doing physical activity was assessed using the modified Minnesota Leisure Time Physical Activity Questionnaire at age 15 years.[26]

At age 45, height (Seca 264 stadiometer, Hamburg, Germany) and weight (Tanita BC-418MA, Tokyo, Japan) were measured in light clothing without shoes to calculate BMI. Waist circumference was measured twice using a steel tape midway between the iliac crest and the lower ribs. Systolic and diastolic blood pressures (BPs) were measured while the participants were sitting and resting using an automated sphygmomanometer (BpTRU, Coquitlam, Canada). Pressures were measured 5 times, and the mean value was used. Cardiorespiratory fitness was measured using a cycle ergometer (Monark 839E, Varberg, Sweden) through a submaximal exercise test. After a warm-up, exercise intensity was modified to maintain a steady-state heart rate of 130 to 170 beats per minute during 6 minutes of exercise at constant power. Maximum aerobic power ($V'O_2$ max) was calculated from the final heart rate using the modified Åstrand-Rhyming method.[8,27] Non-fasting blood samples were collected ∼4 hours after lunch. High-density lipoprotein (HDL) levels and triglycerides were analyzed using a Cobas c702 analyzer (Roche Diagnostics, Mannheim, Germany). Glycated hemoglobin (HbA1c) was measured using a BioRad D-100 analyzer (BioRad Laboratories, Hercules, CA). Metabolic syndrome at age 45 was based on the modified harmonized definition with 2 modifications to allow for non-fasting blood samples: a higher cut-point for triglycerides was used and glycated hemoglobin was used instead of fasting blood glucose.[28] The presence of metabolic syndrome was defined as 3 or more of: glycated hemoglobin ≥5.7%; waist circumference ≥102cm (men) or ≥88cm (women); triglycerides ≥200mg/dL; HDL <40mg/dL (men) or <50mg/dL (women); and BP ≥130/85mmHg (or drug treatment of hypertension).

Statistical Analysis

Descriptive statistics for categorical variables are reported as frequency (%) and for continuous variables as means and standard deviations (SD). Childhood and adolescent television viewing was compared between those with and without complete metabolic syndrome data at age 45 using *t* tests. The prevalence of metabolic syndrome in women and men was compared using a χ^2 test.

Associations between childhood and adolescent television viewing and metabolic syndrome at age 45 were analyzed using logistic regression with metabolic syndrome as the dependent variable. All analyses were adjusted for sex. Additional adjustments were made for childhood socioeconomic status, age 5 BMI, and weekday television viewing at age 32. To investigate whether associations differed by sex, the analyses were repeated with a sex-by-television interaction term, and further analyses were split by sex.

We used linear regression to investigate the associations between childhood television viewing and the individual components of the metabolic syndrome, $V'O_2$ max, and BMI at age 45. These analyses adjusted for sex, and further analyses adjusted for childhood socioeconomic status, age 5 BMI, and television viewing at age 32. Models were checked by visual inspection of histograms of the residuals, scatterplots of residuals versus fitted values, residuals versus predictor (childhood television viewing), and leverage versus residual-square plots. Triglycerides, HDL cholesterol, glycated hemoglobin, and age 45 BMI values had skewed distributions. Log-transformation of these variables to approximate normal distributions improved the distributions of the residuals but made no material difference to the interpretation of the analyses. Hence, only the findings from the analyses using untransformed variables are shown.

To explore whether the association between television viewing and metabolic syndrome was due to displacement of physical activity, a post hoc analysis adjusted the association for physical activity at age 15 years.

Analyses used Stata 17 (StataCorp, College Station, TX).

RESULTS

Metabolic syndrome data were available for 879 participants at age 45 and childhood, and adolescent television viewing estimates were available for 870 of these (Table 1). Participants with missing metabolic syndrome data at age 45 (n = 148, 57% men) tended to have watched slightly less television during childhood and adolescence (mean 2.17 vs 2.36 hours, P = .013). $V'O_2$ max was measured in 849 participants at age 45, of whom 841 have estimates of childhood and adolescent television viewing (Table 1).

Metabolic syndrome was more common in men than women (34% vs 20% respectively). Television viewing between ages 5 and 15 years was associated with metabolic syndrome at age 45 in analyses adjusted for sex and with additional adjustments for childhood BMI, childhood socioeconomic status, and adult television viewing (Table 2, Fig 1). These associations were not statistically significantly different between men and women in any of the models (all sex-interaction P values ≥.19). However, when split by sex, the associations were only statistically significant among women (Table 2). Television viewing hours at age 32 were associated with a higher risk for metabolic syndrome at age 45 years (odds ratio [OR] = 1.15; 95% confidence interval [CI]: 1.02 to 1.30; P = .021, adjusted for sex) but not when adjusted for childhood television viewing (OR = 1.10; 95% CI: 0.96 to 1.25; P = .158).

Television viewing between ages 5 and 15 years was also associated with greater BMI values, lower cardiorespiratory fitness, greater waist circumference, and higher systolic and diastolic BP at age 45. No statistically significant associations were found between television viewing and HbA1c, HDL, or triglyceride concentrations (Table 3). There were no statistically significant sex interactions in these analyses (all P values >.05).

Television viewing time at age 15 years was weakly correlated with less physical activity time (sex-adjusted partial correlation r = -0.11, P = .012). Physical activity time at age 15 was not associated with metabolic syndrome at age 45 (P = .731) and the association between television viewing from

TABLE 1 Television Viewing Times, Metabolic and Cardiorespiratory Fitness Values in Male and Female Participants					
	n	Male	*n*	Female	*P*
Predictors[a,b]					
Childhood TV, mean (SD) hrs/d	435	2.42 (0.86)	428	2.30 (0.88)	.045
Adult TV, mean (SD) hrs/d	429	1.83 (1.26)	425	2.00 (1.24)	.039
Age 5 BMI[c], mean (SD) kg/m^2	425	16.0 (1.2)	424	15.8 (1.2)	.003
Metabolic syndrome and components[b]					
Metabolic syndrome, *n* (%)	435	148 (34%)	428	86 (20%)	<.001
HbA1c, mean (SD) mmol/mol	436	5.7 (0.6)	431	5.6 (0.5)	.002
Waist circumference, mean (SD) cm	449	96.8 (12.6)	447	87.4 (14.6)	<.001
Systolic BP, mean (SD) mmHg	450	126 (14)	447	117 (14)	<.001
Diastolic BP, mean (SD) mmHg	450	85 (10)	447	76 (9)	<.001
Triglycerides, mean (SD) mg/dL	438	236 (148)	432	140 (84)	<.001
HDL cholesterol, mean (SD) mg/dL	438	47.5 (12.4)	430	60.6 (17.0)	<.001
Other health outcomes[b]					
$V'O_2$ max, mean (SD)	426	31.6 (6.0)	415	22.1 (5.4)	<.001
Adult BMI, mean (SD) kg/m2	456	28.4 (4.7)	455	28.3 (6.7)	.759

[a] Only participants with measurement of metabolic syndrome at age 45 viewing are included.
[b] Only participants with estimates of childhood television viewing are included.
[c] Includes imputed measures from age 3.

ages 5 to 15 and metabolic syndrome at 45 persisted after adjustment for physical activity time (OR = 1.24; 95% CI: 1.02 to 1.52; $P = .032$). The association between television viewing at just age 15 and metabolic syndrome at 45 also persisted after adjusting for age 15 physical activity (OR = 1.15; 95% CI: 1.04 to 1.27; $P = .006$).

DISCUSSION

In this long-term follow-up of a general population sample, we found that the time spent watching television during childhood and adolescence was associated with a higher risk of metabolic syndrome in mid-adult life. Childhood and adolescent television viewing was also associated with higher values for BMI and lower cardiorespiratory fitness. These findings support our hypothesis that excessive television viewing in childhood increases the long-term risk of metabolic syndrome and is likely to have adverse consequences on adult health.

Our findings that the association between child and adolescent television viewing and adult metabolic syndrome persisted after adjustment for adult television viewing lends support to the idea of a sensitive period during childhood and adolescence, during which sedentary behaviors, such as television viewing, may have a greater influence on adult health than adult behaviors. This is consistent with an earlier analysis from the Dunedin study that found that childhood and adolescent television viewing was associated with obesity and poor fitness at age 32 years independently of concurrent adult viewing.[9] The findings are also consistent with those of Wennberg et al, who reported an association between television viewing at age 16 and metabolic syndrome during adulthood independently of television viewing at ages 21 and 30 years.[2]

The associations between childhood television viewing and adult metabolic syndrome tended to be stronger and were only statistically significant in women. However, none of the sex-interaction terms were statistically significant, indicating that these apparent differences between men and women could be due to chance. Wennberg et al also find no evidence of statistically significant sex interactions but did not present sex-specific findings.[2]

TABLE 2 Associations Between Childhood and Adolescent TV Viewing and Metabolic Syndrome at Age 45 y									
	All[a]			Male			Female		
	n	OR (95% CI)	*P*	*n*	OR (95% CI)	*P*	*n*	OR (95% CI)	*P*
Model 1	863	1.33 (1.11 to 1.58)	.002	435	1.21 (0.96 to 1.52)	.113	428	1.51 (1.15 to 1.98)	.003
Model 2[b]	845	1.30 (1.08 to 1.58)	.006	427	1.26 (0.97 to 1.62)	.078	421	1.39 (1.04 to 1.86)	.028
Model 3[c]	837	1.26 (1.03 to 1.54)	.026	422	1.23 (0.94 to 1.61)	.135	418	1.32 (0.97 to 1.81)	.078

Analyses by logistic regression. ORs associated with each additional hr of mean weekday television viewing between ages 5 and 15:
[a] Analyses of both sexes are adjusted for sex.
[b] Adjusted for childhood BMI and socioeconomic status.
[c] Adjusted for childhood BMI, socioeconomic status, and TV viewing in adulthood.

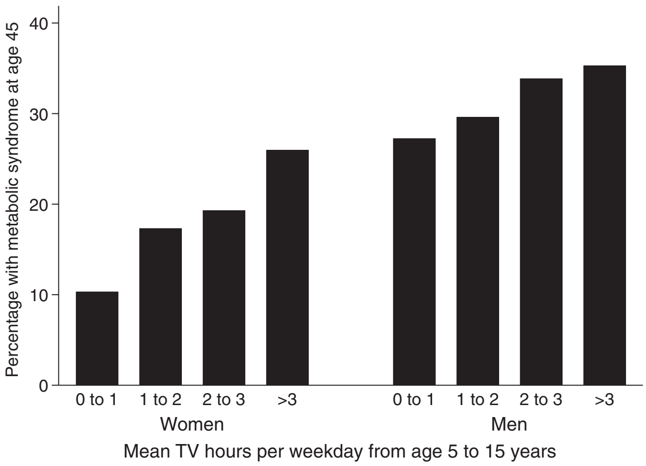

FIGURE 1
Percentage of women and men with metabolic syndrome at 45 years of age according to their reported television viewing time between ages 5 and 15 years.

We did not find statistically significant associations between childhood and adolescent television viewing and HbA1c or triglycerides. This indicates that associations with body weight, poor fitness, and BP may be the primary drivers of the association with metabolic syndrome. This lack of an association between television viewing and HbA1c appears to conflict with the observations that screen time at age 16 predicted adult type 2 diabetes risk in the British Birth Cohort[21] and that television viewing in earlier childhood predicted diabetes risk in the Nurses Health Study II.[20] However, in the British Birth Cohort the increased risk was only present among heavy viewers of 5 hours per day, and few participants in the Dunedin study watched this amount of television. Interestingly, an association between young people's television viewing and adult BP was not observed in an analysis of the Dunedin study at age 26, suggesting that this risk may develop over many years.[8] The clinical importance of this effect, which suggests an approximate mean of a 1.5 mmHg increase in systolic BP for each additional hour of mean screen time, is uncertain, but on a population level, even small changes in mean BP may have major public health implications.[29]

As with any observational study, we cannot prove that the association between childhood and adolescent television viewing and metabolic syndrome at age 45 years is causal. However, there are several biologically plausible mechanisms by which longer television viewing times could lead to poorer long-term health. Television viewing has low energy expenditure and could displace physical activity and reduce sleep quality.[30–32] Our only concurrent estimate of physical activity was at age 15 and a limitation of our analysis is that we cannot fully explore whether the association between television viewing and metabolic syndrome is mediated by the displacement of physical activity. However, although reported physical activity at age 15 was weakly inversely associated with television viewing, it was not associated with adult metabolic syndrome, and the association between television viewing and metabolic syndrome persisted after adjusting for physical activity. This is consistent with previous research suggesting that displacement is not the main mechanism of the longitudinal association between television viewing and BMI or fitness.[8,18,19,33] Screen time may also promote higher energy intake, with children consuming more sugar-sweetened beverages and high-fat dietary products with fewer fruit and vegetables.[32,34–38] These habits may persist into adulthood. However, there is also evidence that longitudinal associations between television viewing and BMI are not due to eating habits.[33]

This study has multiple strengths that support causal inference. It has a high follow-up rate of a general population

TABLE 3 Associations Between Childhood and Adolescent TV Viewing and Adult Health Outcomes

	Model 1[a]			Model 2[b]			Model 3[c]		
	n	Coefficient (95% CI)	*P*	*n*	Coefficient (95% CI)	*P*	*n*	Coefficient (95% CI)	*P*
Components of metabolic syndrome									
HbA1c (mmol/mol)	867	0.30 (−0.15 to 0.76)	.194	849	0.22 (−0.27 to 0.72)	.373	841	0.14 (−0.38 to 0.66)	.597
Waist circumference (cm)	896	2.20 (1.18 to 3.22)	<.001	877	1.58 (0.49 to 2.66)	.004	869	1.22 (0.08 to 2.36)	.036
Systolic BP (mmHg)	897	1.72 (0.65 to 2.78)	.002	878	1.48 (0.35 to 2.62)	.010	870	1.55 (0.35 to 2.74)	.011
Diastolic BP (mmHg)	897	0.94 (0.24 to 1.64)	.009	878	0.74 (−0.01 to 1.50)	.054	870	0.71 (−0.09 to 1.51)	.081
Triglycerides (mmol/L)	870	0.04 (−0.06 to 0.15)	.402	852	0.01 (−0.10 to 0.12)	.842	844	−0.03 (−0.14 to 0.09)	.647
HDL cholesterol (mmol/L)	868	−0.05 (−0.08 to −0.02)	.001	850	−0.04 (−0.07 to −0.01)	.019	376	−0.03 (−0.06 to 0.01)	.133
Other health outcomes									
$V'O_2$ max.	841	−1.01 (−1.45 to −0.56)	<.001	824	−0.82 (−1.29 to −0.34)	.001	819	−0.70 (−1.20 to −0.19)	.007
Adult BMI (kg/m^2)	911	0.98 (0.55 to 1.41)	<.001	892	0.68 (0.23 to 1.13)	.003	887	0.59 (0.11 to 1.06)	.016

Analyses by linear regression. Coefficients represent the unit difference in the outcome associated with each additional hr of mean weekday television viewing between ages 5 and 15:
[a] Adjusted for sex.
[b] Adjusted for sex, childhood BMI, and childhood socioeconomic status.
[c] Adjusted for sex, childhood BMI, childhood socioeconomic status, and adult television viewing.

sample. We were able to control for the potential confounding influence of childhood socioeconomic status. We also adjusted for childhood BMI at the start of documenting television viewing because of the potential for reverse causation: the possibility that some children chose to watch more television because they already have overweight/metabolic problems. We were further able to control for the potential mediating influence of adult television viewing at age 32. We do not, however, have contemporaneous measures of adult viewing at age 45. Other limitations of the study are that television viewing was reported either by the participant or their parent, and we have no way of assessing the accuracy of these reports. However, the use of multiple reports throughout childhood and adolescence is likely to provide a better representation of overall television viewing time than single estimates. Reporting errors in viewing times are unlikely to be biased by the outcome of metabolic syndrome >30 years later, and such errors are more likely to underestimate than overestimate the strength of the association between television viewing and metabolic syndrome. We did not ask about weekend television viewing between ages 5 to 11, but weekday viewing correlates with weekend viewing, and it is unlikely that using weekday averages has substantially affected the validity of our findings.[8] The blood tests were non-fasting but obtained ~4 hours after lunch. We modified the triglyceride cut point to allow for this. We also measured glycated hemoglobin rather than fasting blood glucose. These will have introduced some errors in the definition of metabolic syndrome, but it is unlikely that they will have biased the findings toward an association with television viewing. Participants with missing data for metabolic syndrome at age 45 tended to report watching less television during childhood and adolescence than those with complete data, but it also seems unlikely that these missing data would have substantially altered the observed association between television viewing and metabolic syndrome.

How much screen time should children have? Recent WHO guidelines recommend that children limit the amount of time being sedentary, particularly recreational screen time, but concluded that there was insufficient evidence for a dose-response association and did not specify a time limit.[39] Our data suggest that there is an approximately linear dose-response between young people's television viewing and their later risk of metabolic syndrome (Fig 1). However, our cohort had few screen time options when they were growing up, limiting their exposure. Children today have access to many more screen-based media, greatly increasing the potential for sedentary behavior,[5] and recent data indicate that children have higher screen times.[4,5,40] Although we cannot establish whether these other forms of screen-based activities are associated with long-term health outcomes, such as metabolic syndrome, it seems likely that the consequences would be similar. Our finding that the association between young people's television viewing and the later risk for metabolic syndrome was independent of adult viewing also indicates that there may be a sensitive period during childhood when excessive television viewing has a long-lasting influence on adult health. These findings lend support to the WHO recommendation that children and adolescents should limit their recreational screen time.[39]

This study provides evidence that there is a long-term association between television viewing during childhood and adolescence with metabolic syndrome in mid-adulthood. This adds further evidence of the adverse health effects of television viewing across the life course. Interventions to reduce the time that children and young people spend in screen-based activities may have substantial long-lasting benefits for health.

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ABBREVIATIONS

BP: blood pressure
CI: confidence interval
HbA1c: glycated hemoglobin
HDL: high-density lipoprotein
OR: odds ratio
SD: standard deviation
$V'O_{2max}$: oxygen consumption at maximal exertion

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