Screen-time is associated with adiposity and insulin resistance in children

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**Conflicts of interest declaration**

We declare that we have no conflicts of interest.

**Contributors**

All authors contributed substantially to the conception and design of this paper. PHW conceived, raised funding for and directed the CHASE Study with help from DGC. All authors contributed to the collection of data used in this paper. CMN and ARR carried out the statistical analyses. CMN drafted the paper, which was critically appraised by all authors for intellectual content. All authors approved the final version to be published and agree to be accountable for all aspects of the manuscript.

**Abstract**

**Background:** Higher Screen-time is associated with type 2 diabetes (T2D) risk in adults, but the association with T2D risk markers in children is unclear. We examined associations between self-reported screen-time and T2D risk markers in children.

**Methods**: Survey of 4495 children aged 9-10y who had fasting cardiometabolic risk marker assessments, anthropometry measurements and reported daily screen-time; objective physical activity was measured in a sub-set of 2031 children.

**Results:** Compared to an hour or less screen-time daily, those reporting screen-time over three hours had higher ponderal index (1.9%, 95%CI 0.5,3.4%), skinfold thickness (4.5%, 0.2,8.8%), fat mass index (3.3%, 0.0,6.7%), leptin (9.2%, 1.1,18.0%) and insulin resistance (10.5%, 4.9,16.4%); associations with glucose, HbA1c, physical activity and cardiovascular risk markers were weak or absent. Associations with insulin resistance remained after adjustment for adiposity, socioeconomic markers and physical activity.

**Conclusion:** Strong graded associations between screen-time, adiposity and insulin resistance suggest that reducing screen time could facilitate early T2D prevention. While these observations are of considerable public health interest, evidence from randomised controlled trials is needed to suggest causality.

## Introduction

The global prevalence of type 2 diabetes (T2D), overweight and obesity has been increasing, in adults as well as adolescents and children.(1;2) Awareness of the early determinants of adiposity and T2D risk in young people may be important for reducing risks of T2D and obesity across the life course. The health effects of activities that encourage sedentary behaviour, such as time spent watching television, using computers or games consoles (together referred to as ‘screen-time’) have been a particular focus. Increased screen-time has been prospectively associated with adiposity (3) and T2D risk in adults.(4) Studies have shown graded positive associations between prolonged screen-time and adiposity in childhood.(5;6) However, less is known about the effects of prolonged screen-time on T2D risk markers in childhood, particularly insulin resistance and glycaemia. Such associations could be of public health importance in providing evidence-based recommendations for healthy screen-time duration, especially as recent trends suggest that screen-time is increasing in childhood.(7) We therefore examined the association between self-reported daily screen-time and risk markers for T2D and cardiovascular disease, in a large-scale multi-ethnic population-based study of 9 to 10 year old children.

## Methods

The Child Heart and Health Study in England (CHASE) was a cross-sectional survey of cardiovascular health in 9-10 year old UK schoolchildren of White European, black African-Caribbean and South Asian origin carried out in a sample of 200 primary schools in London, Birmingham and Leicester; full details of the study have been reported elsewhere.(8-10) Ethical approval for the study was obtained from the relevant multicentre ethics committee. A single survey team carried out all measurements between October 2004 and February 2007. Children’s ethnic origin was based on the ethnicity of both parents or (where not available) the parentally-defined ethnicity of the child; in a small proportion of children where this was not available (1%) child information on the place of birth of parents and grandparents was used to define ethnicity. Ethnic group was classified as ‘white European’ which includes those of white European including white British ethnicity, ‘black African-Caribbean’ which includes black African, black Caribbean and black other, ‘South Asian’ which includes Indian, Pakistani, Bangladeshi and South Asian other; those of mixed or other ethnic origins were included in an ‘other ethnic groups’ category Socioeconomic status was based on self-reported parental occupation (highest of mother or father) and coded using the National Statistics Socio-economic Classification (NS-SEC).(11)

Height was measured to the last complete millimetre using a portable stadiometer (Chasmors Ltd, London, UK) and weight was measured using an electronic digital scale (Tanita Inc, Tokyo, Japan). Ponderal index was calculated as a weight divided by height cubed (kg/m3), providing a weight for height measure which was largely independent of height in the study population. Right-sided skinfolds were measured at four locations (biceps, triceps, subscapular, suprailiac) and summed. Hand-to-foot bioimpedance was measured using the Bodystat 1500 bioimpedance monitor (Bodystat Ltd, Isle of Man, UK); fat mass was derived using ethnic and sex specific validated equations (12) and presented as a fat mass index (fat mass/height5), which was independent of height. Blood samples were collected after an overnight fast. HbA1c was analysed in whole blood by ion exchange high performance liquid chromatography. Plasma glucose was measured using the hexokinase method; triglyceride, HDL-cholesterol and total-cholesterol were measured in serum using an Olympus autoanalyser. Insulin was measured in serum using an ELISA method(13), C-reactive protein using ultra-sensitive nephelometry and leptin using a radioimmunoassay. Homeostasis model assessment (HOMA) equations provided an estimate of insulin resistance (14). Seated blood pressure was measured twice in the right arm after 5 minutes rest using an Omron 907 blood pressure monitor and adjusted for appropriate cuff size; (15) average systolic and diastolic blood pressure were calculated from the two readings. In a sub-set of children in the last 80 schools studied, objective physical activity counts and time spent in moderate to vigorous physical activity (MVPA) were measured using a waist-worn accelerometer (ActiGraph GT1M, ActiGraph, LLC, Pensacola, FL).(9) Pubertal status was measured in girls only, using the Tanner breast development score.(16) Child questionnaires administered on the same day that physical measurements were taken asked ‘‘How many hours each day do you spend watching television or video and playing computer games?” and children were asked to tick one of the following options:- “none; an hour or less; one to two hours; two to three hours or more than three hours”.

Outcomes following approximately log-normal distributions were log transformed; geometric means and percentage differences are presented for log transformed variables. We compared differences in outcomes by self-reported screen-time category using those that reported “an hour or less of screen-time” as a reference group, and tested for a linear trend using multilevel linear regression models adjusted for sex, age (in quartiles) ethnicity and month as fixed effects. The intraclass correlation (ICC) for school level clustering was between 0.02 and 0.09 for all cardiometabolic risk markers and physical activity counts and was higher for time spent in MVPA (ICC=0.32); hence, it was important to adjust for school as a random effect to account for clustering of children within schools. The effect of adjustment for socioeconomic status (NS-SEC), pubertal status (girls only) and physical activity was assessed because these are potential confounders of the association between screen-time and diabetic risk markers. Further adjustment for adiposity was also made, acknowledging that this may be a potential mediator. We examined whether associations between screen-time and outcome variables were consistent in boys and girls and in different ethnic groups by testing for an interaction between screen-time and sex or ethnic group.

## Results

Of 8,641 children who were invited, 5887 (68%) took part in the study. Of these, 4884 (83%) provided a fasting blood sample. Analyses focused on 4495 children (2,337 girls and 2,158 boys), average age 9.9 years (95% reference range 9.2, 10.7 y), who answered the question on daily screen-time, had full anthropometric measurements and a fasting blood sample. Of these 2031 children also had measurements of physical activity using accelerometery. Participant characteristics are shown in Supplementary Table 1, including mean age of participants, gender and ethnic balance, head of household socioeconomic classification and month of measurement. Overall 4% of the study population reported no screen-time, 37% reported an hour or less, 28% reported one to two hours, 13% reported two to three hours and 18% reported more than three hours of screen-time. A larger proportion of boys (22%) than girls (14%) reported more than three hours of daily screen-time. A higher proportion of black African-Caribbeans (23%) reported more than three hours of daily screen-time compared to white Europeans (16%) and South Asians (16%). Adiposity and cardiometabolic risk markers are shown by sex and overall in Table 1. In general, girls had higher levels of adiposity markers, leptin, fasting insulin, insulin resistance, triglyceride, CRP, and lower levels of fasting glucose and HDL cholesterol than boys; girls had lower levels of physical activity counts and time spent in MVPA than boys. There were trends between screen-time and ponderal index, sum of skinfolds and fat mass index (Table 2). Levels of these adiposity variables were higher among children who reported more than three hours of screen-time compared to those who reported an hour or less of screen-time. There was a strong trend between screen-time, leptin, fasting insulin and HOMA-insulin resistance (Table 2). Children who reported more than three hours of screen-time had higher levels of leptin (9.2%, 95%CI 1.1, 18.0%), insulin (10.7%, 5.1, 16.7%) and HOMA-insulin resistance (10.5%, 4.9, 16.4%) compared to those who reported an hour or less. Adjustment for fat mass index reduced effect sizes for insulin and insulin resistance by approximately one quarter (7.9%, 95%CI 2.9, 13.1%; 7.7%, 2.8, 13.0% respectively). There was a borderline significant trend between screen-time and triglycerides and physical activity counts and time spent in MVPA. There was no formal evidence of a trend between screen-time and HbA1c, fasting glucose, and other cardiovascular risk factors, including lipids and blood pressure (even with further adjustment for height). Associations between screen-time and fasting insulin, insulin resistance, ponderal index, sum of skinfolds and fat mass index were not appreciably affected by adjustment for socioeconomic status or physical activity measures in a sub-set (i.e., the magnitude of associations were similar and statistically significant associations remained significant). Adjustment for pubertal status in girls slightly weakened associations for insulin resistance markers though associations for fasting insulin and HOMA-IR remained statistically significant; associations for adiposity markers were attenuated though the association with ponderal index remained statistically significant. There was no evidence that associations differed in boys and girls and between ethnic groups (all tests for interaction p≥0.05, data available from authors).

## Discussion

The present study showed an association between screen-time and measures of adiposity, which has previously been observed in prospective studies of children.(5) We extend these observations by demonstrating strong graded associations with T2D risk factors, particularly insulin resistance (although not glucose or HbA1c). The association for insulin resistance was independent of socioeconomic markers, pubertal status and objectively measured physical activity levels. The association with insulin resistance was substantially independent of adiposity (fat mass index).

Strengths of the present study include the large sample size, measurement of key type 2 diabetes risk markers including insulin resistance (17;18) and the assessment of potential confounders including socioeconomic markers, pubertal status and physical activity. The children in the study were asked about the amount of time spent watching television, video or playing computer games which was appropriate to capture ‘screen-time’ when the study was conducted in 2004-7. Studies in current settings would also need to take account of the use of more recently introduced electronic devices for example electronic tablets and smart phones, also potentially related to sedentary behaviour, which are now more widely used by children. Pubertal status was only assessed in girls in the present study, as evidence suggests that age of pubertal onset in boys is substantially higher than that in our study population.(19-21) The CHASE study was powered to detect small (~0.2 SD) ethnic differences in risk markers presented here, however, we have been able to estimate associations between screen-time and adiposity and cardiometabolic risk markers with narrow confidence intervals suggesting a high level of precision. Although the study response rate was modest, the characteristics of participants who provided a fasting blood sample were mostly similar to participants who did not (10). The participants in this study were recruited from three UK cities (London, Birmingham and Leicester) which together account for two thirds of South Asians and black African-Caribbeans in the UK. The study sample is therefore likely to be representative of these ethnic minority populations; it may be less representative of white Europeans, as these were recruited from the same schools as the ethnic minority participants. However, the representativeness is unlikely to have biased the association between screen-time and insulin resistance (22).

While the present findings are of considerable potential public health interest, evidence from randomised controlled trials is needed to establish causality. Intervention studies in children showing decreased body size associated with reduced screen-time are supportive of a causal effect,(23;24) although causal associations between screen viewing and early T2D risk factors remain to be established. Future studies could illuminate the causal pathways by which screen-time manifests itself such as diet and lack of breaks in sedentary behaviour as well as decreased physical activity. Current recommendations from the American Academy of Pediatrics suggest that children should limit daily screen-time to <2 hours,(25) although more recent advice proposes a more pragmatic interpretation, given the pervasive use of electronic devices,(7) advocating a more nuanced approach to limits on screen-time.(26) However, such limitations, which may be beneficial for other aspects of health, must not overlook the underlying sedentary nature of screen related activities and their potential impact on metabolic health. Our findings suggest that reducing screen-time may be beneficial in reducing T2D risk factors, in both boys and girls and in different ethnic groups from an early age. This is particularly relevant given rising levels of T2D, the early emergence of T2D risk (1) and recent trends suggesting that screen-time related activities are increasing in childhood,(7) and may pattern screen related behaviours in later life.(27)

**What is known:-**

- Increased screen-time is prospectively associated with adiposity and type 2 diabetes in adults.

- Evidence suggests graded associations between screen-time and adiposity in children.

**What this study adds:-**

- Demonstrated strong graded positive associations between screen-time, adiposity and risk markers for type 2 diabetes (particularly insulin resistance) in children.

- The associations between screen-time and insulin resistance markers were largely independent of socioeconomic status, pubertal status, objectively measured physical activity and adiposity.

Table 1: Adiposity and cardiometabolic risk markers: overall and by sex

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Geometric mean (95% CI)** | | | | | |
|  | **Boys (n = 2158)** | | **Girls (n = 2337)** | | **All participants (n = 4495)** | |
| Ponderal Index (kg/m3) | 13.0 | (13.0, 13.1) | 13.2 | (13.1, 13.3) | 13.1 | (13.1, 13.2) |
| Sum of skinfolds (mm) | 36.7 | (35.9, 37.6) | 45.7 | (44.7, 46.7) | 41.1 | (40.4, 41.9) |
| Fat mass index (kg/m5) | 1.91 | (1.87, 1.94) | 2.17 | (2.13, 2.21) | 2.04 | (2.01, 2.07) |
| HbA1c (%) | 5.24 | (5.22, 5.26) | 5.25 | (5.23, 5.26) | 5.24 | (5.23, 5.26) |
| Glucose (mmol/L) | 4.56 | (4.54, 4.58) | 4.47 | (4.45, 4.49) | 4.51 | (4.50, 4.53) |
| Insulin (mU/L) | 6.46 | (6.23, 6.69) | 8.14 | (7.86, 8.43) | 7.28 | (7.07, 7.51) |
| HOMA IR | 0.82 | (0.79, 0.85) | 1.02 | (0.99, 1.06) | 0.92 | (0.89, 0.95) |
| Leptin (ng/ml) | 7.15 | (6.83, 7.48) | 11.49 | (11.00, 12.00) | 9.15 | (8.83, 9.48) |
| C-reactive protein (mg/L) | 0.44 | (0.42, 0.47) | 0.57 | (0.54, 0.60) | 0.50 | (0.48, 0.53) |
| Triglycerides (mmol/L) | 0.76 | (0.74, 0.77) | 0.85 | (0.84, 0.87) | 0.81 | (0.79, 0.82) |
| HDL-cholesterol (mmol/L) | 1.53 | (1.51, 1.54) | 1.44 | (1.42, 1.45) | 1.48 | (1.47, 1.49) |
| LDL-cholesterol (mmol/L) | 2.60 | (2.57, 2.64) | 2.60 | (2.57, 2.63) | 2.60 | (2.58, 2.63) |
| Total cholesterol (mmol/L) | 4.53 | (4.49, 4.56) | 4.47 | (4.44, 4.50) | 4.50 | (4.47, 4.52) |
|  | **Mean (95% CI)** | | | | | |
| Systolic BP (mmHg) | 105.2 | (104.6, 105.7) | 104.2 | (103.7, 104.8) | 104.7 | (104.2, 105.2) |
| Diastolic BP (mmHg) | 62.8 | (62.3, 63.3) | 63.0 | (62.5, 63.5) | 62.9 | (62.4, 63.3) |
| Daily counts\* | 437,416 | (429,717, 445,114) | 362,857 | (355,382, 370,332) | 397,973 | (391,604, 404,342) |
| Daily time spent in MVPA (mins)\* | 78.4 | (75.9, 80.9) | 61.6 | (59.1, 64.1) | 69.5 | (67.1, 71.9) |

Means (geometric means) adjusted for sex (all participants), age (quartiles), ethnic group, month, and a random effect to allow for clustering within schools.

Geometric means are presented for log transformed variables.

\* Based on 2031 participants with data for daily counts and time spent in MVPA, the numbers for each screen-time group were as follows:- None = 80, An hour or less = 729, One to two hours = 593, Two to three hours = 270, More than three hours = 359

Table 2: Associations between self-reported screen-time (television, video and computer games) and adiposity and cardiometabolic risk markers

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **% difference compared to 'An hour or less self-reported screen time' as the reference group (95% CI), p(difference)** | | | | | | | | | **p(linear trend)** |
|  | **None (n = 180)** | | **An hour or less (n = 1664)** | **One to two hours (n = 1268)** | | **Two to three hours (n = 575)** | | **More than three hours (n = 808)** | |
| Ponderal Index (kg/m3) | -1.2 | (-3.7, 1.3) | 0 | 1.5 | (0.3, 2.8) | 1.0 | (-0.6, 2.6) | 1.9 | (0.5, 3.4) | 0.003 |
| Sum of skinfolds (mm) | -5.7 | (-12.4, 1.6) | 0 | 4.6 | (1.0, 8.4) | 2.3 | (-2.3, 7.1) | 4.5 | (0.2, 8.8) | 0.01 |
| Fat mass index (kg/m5) | -5.9 | (-11.2, -0.2) | 0 | 2.8 | (0.0, 5.7) | 1.6 | (-2.0, 5.3) | 3.3 | (0.0, 6.7) | 0.01 |
| HbA1c (%) | 0.4 | (-0.6, 1.3) | 0 | 0.3 | (-0.2, 0.7) | 0.6 | (0.0, 1.1) | 0.0 | (-0.5, 0.5) | 0.68 |
| Glucose (mmol/L) | -0.4 | (-1.6, 0.8) | 0 | 0.5 | (-0.1, 1.0) | 0.1 | (-0.6, 0.9) | 0.2 | (-0.5, 0.8) | 0.40 |
| Insulin (mU/L) | 3.1 | (-6.2, 13.3) | 0 | 9.0 | (4.2, 14.0) | 4.9 | (-1.0, 11.2) | 10.7 | (5.1, 16.7) | <0.001 |
| HOMA IR | 3.2 | (-6.1, 13.3) | 0 | 8.9 | (4.2, 13.9) | 5.3 | (-0.6, 11.6) | 10.5 | (4.9, 16.4) | <0.001 |
| Leptin (ng/ml) | -9.0 | (-20.9, 4.6) | 0 | 10.9 | (3.8, 18.5) | 9.3 | (0.3, 19.1) | 9.2 | (1.1, 18.0) | 0.002 |
| C-reactive protein (mg/L) | -23.5 | (-37.4, -6.6) | 0 | 1.8 | (-7.4, 12.0) | 0.8 | (-10.9, 14.1) | 0.9 | (-9.7, 12.8) | 0.26 |
| Triglycerides (mmol/L) | 0.7 | (-5.0, 6.7) | 0 | 3.2 | (0.4, 6.1) | 2.2 | (-1.4, 5.9) | 3.3 | (0.0, 6.7) | 0.05 |
| HDL-cholesterol (mmol/L) | -0.7 | (-3.7, 2.4) | 0 | -1.1 | (-2.5, 0.4) | 0.1 | (-1.8, 2.0) | -1.6 | (-3.3, 0.1) | 0.17 |
| LDL-cholesterol (mmol/L) | -2.2 | (-5.8, 1.6) | 0 | -1.1 | (-2.9, 0.7) | -2.5 | (-4.7, -0.1) | -2.0 | (-4.1, 0.1) | 0.06 |
| Total cholesterol (mmol/L) | -1.3 | (-3.8, 1.3) | 0 | -0.6 | (-1.8, 0.6) | -1.1 | (-2.6, 0.5) | -1.4 | (-2.8, 0.1) | 0.10 |
|  | **Difference compared to 'An hour or less self-reported screen time' as the reference group (95% CI), p(difference)** | | | | | | | | |  |
| Systolic BP (mmHg) | 0.3 | (-1.3, 1.9) | 0 | 0.2 | (-0.6, 0.9) | -0.2 | (-1.2, 0.7) | -0.5 | (-1.4, 0.4) | 0.24 |
| Diastolic BP (mmHg) | 0.0 | (-1.4, 1.4) | 0 | 0.0 | (-0.7, 0.7) | -0.2 | (-1.0, 0.7) | 0.0 | (-0.8, 0.8) | 0.85 |
| Daily counts\* | 11,286 | (-10,753, 33,325) | 0 | -4,720 | (-15,012, 5,572) | -13,490 | (-26,724, -256) | -6,637 | (-18,815, 5,541) | 0.05 |
| Daily time spent in MVPA (mins)\* | 2.0 | (-2.3, 6.3) | 0 | -0.3 | (-2.3, 1.7) | -2.6 | (-5.2, -0.1) | -1.2 | (-3.6, 1.2) | 0.06 |

Differences (% differences) adjusted for sex, age (quartiles), ethnic group, month, and a random effect to allow for clustering within schools.

Percentage differences are presented for log transformed variables.

\* Based on 2031 participants with data for daily counts and daily time spent in MVPA, the numbers for each screen-time group were as follows:- None = 80, An hour or less = 729, One to two hours = 593, Two to three hours = 270, More than three hours = 359

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