Increased television viewing is associated with elevated body fatness but not with lower total energy expenditure in children\textsuperscript{1-3}

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ABSTRACT

Background: Television (TV) viewing in children is associated with a higher body mass index, but it is unknown whether this reflects body fatness, and, if it does, why.

Objective: The objective was to investigate whether TV viewing is associated with body fatness, physical activity, and total energy expenditure in preschool children.

Design: Eighty-nine children were recruited into a cross-sectional study. Total daily energy expenditure (TEE) was measured by doubly labeled water, body composition by dual-energy X-ray absorptiometry, and physical activity by accelerometry.

Results: There was a significant positive association between fat mass (corrected for fat-free body mass) and TV viewing ($F = 9.05, P = 0.004$). Each extra hour of watching TV was associated with an extra 1 kg of body fat. Children who watched more TV were also significantly less physically active ($F = 5.16, P = 0.026$). Independent of body composition and sex, children with greater physical activity levels had higher levels of TEE ($F = 5.15, P = 0.029$); however, physical activity did not mediate the relation between TV viewing and adiposity ($P > 0.05$).

Conclusions: Preschool children who watch more TV are fatter and are less active, and activity influences TEE. However, despite TV viewing being linked to lower physical activity, the relation between TV viewing and fatness is not mediated by physical activity. The results suggest that a relation between TV viewing and fatness is more likely to be due to an effect on food intake. \textit{Am J Clin Nutr} 2009;89:1–6.

INTRODUCTION

Obesity is a predisposing factor for many chronic diseases, such as cardiovascular disease, cancer, and type 2 diabetes mellitus (1, 2). Rates of adult obesity have increased throughout the world such that a global pandemic was described by the World Health Organization as one of the most important health issues facing humankind (3). The recent Foresight document published by the UK government highlighted the enormous effect that rising obesity levels are having on the UK population (4). Childhood obesity rates have risen steadily over the past 2 decades (5). Because obese children tend to become obese adults, it is important that effective interventions are designed to tackle obesity in children. Recent Cochrane reports reviewing childhood obesity interventions have reported a lack of successful strategies aimed at treating and preventing this condition in this age group. Among the stated recommendations were that more research was needed to investigate potential intervention targets in different age groups (6, 7). Given the increasing number of studies showing the importance of the preschool age range for the development of energy balance–related behaviors, eg, physical activity and dietary behaviors (8–11), it is important that we study children at a young age to investigate the mechanisms involved to develop strategies for the prevention of obesity and chronic disease.

One such potential intervention target is television (TV) viewing (12, 13). Increased TV viewing has been consistently shown to be linked to increased body mass index (BMI) in both children and adults (14, 15). The relation appears stronger in young children (16). However, there is a paucity of studies that have investigated TV viewing and fatness (measured directly rather than as BMI) in younger children (16), and the mechanism behind the association, if it is real, remains unknown.

A number of hypotheses have been proposed to explain the link between TV viewing and BMI. Increases in body fat occur when there is an imbalance between energy intake and energy expenditure. Changes in both food intake and physical activity have been implicated in the relation between TV viewing and body fatness.

Several studies have shown that a considerable proportion of a child’s daily energy intake is consumed while watching TV, especially on weekends (17), and children who watch more TV eat less fruit and vegetables and consume more energy-dense snacks (18). Furthermore, a recent study showed that TV watching increases motivated responses to food and energy intake in children (19). Alternatively, TV viewing is a sedentary activity that allows less time for children to be physically active and therefore potentially reduces total energy expenditure (TEE) (20). Energy expenditure during TV viewing has been shown

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to be only 18% higher than the resting metabolic rate (RMR), equivalent to other sedentary activities in adults (21), and has been shown to be low in adolescents (22). Many studies have shown a weak but negative association between physical activity and TV viewing, but most of these studies were conducted in older children (7–18 y) and used subjective measures of physical activity rather than direct measures of TEE or used direct measures of physical activity using activity monitors.

In this study, 2 hypotheses were tested in preschool children: 1) TV viewing is associated with increased body fatness measured by using a more objective direct method than BMI (dual energy X-ray absorptiometry; DXA) and 2) that TV viewing is associated with lower physical activity levels (measured directly by using physical activity monitors) and hence with lower daily energy expenditure measured directly by using the doubly labeled water (DLW) method (23).

SUBJECTS AND METHODS

Participants

Eighty-nine healthy white children aged 2–6 y (42 boys and 47 girls) were recruited into the Rowett Assessment of Childhood Appetite and Metabolism (RASCAL) study from the Aberdeen area of northeast Scotland (United Kingdom) between 2002 and 2004 through advertisements in local nurseries and health centers. Verbal consent was obtained from the children before any measurements were taken, and approval for the study was obtained from the Grampian Research Ethics Committee. Because of the age of the subjects, usable data were not always obtained; therefore, the samples sizes for each measurement are provided in the tables and figure legends.

Body composition

Body composition was determined by DXA (Norland XR-26, Mark II high-speed pencil beam scanner; Norland Corporation, Fort Atkinson, WI) after the children fasted overnight. Subjects were scanned from head to foot for ∼15 min while laying flat and wearing light clothing. The DXA instrument was calibrated each day, and all calibrations and scan measurements were carried out by a trained investigator using the procedures provided by the manufacturer. The CV for repeated measurements with this machine in a total-body scan were reported previously (24). Weekly quality-control checks were performed on the DXA instrument with a phantom over 7 mo, which indicated CVs of 0.94% and 1.52% for bone mineral density and bone mineral content, respectively. The CV for the assessment of fat mass (FM) was 2.6% (25). The subjects were weighed to the nearest 0.1 kg while in the fasting state by using a high-precision digital scale (model CD11; OHAUS Corporation, Pine Brook, NJ). Height was measured to the nearest 0.1 cm with a standard stadiometer (Holtain Ltd, Crymych, United Kingdom). BMI was calculated by dividing weight (in kg) by the square of height (in m). Data on weight, height and BMI were converted to an SD score (SDS) normalized for age and sex according to UK reference data (26).

Energy expenditure

TEE was measured by using the DLW method, which was described in detail elsewhere (23, 27). A baseline urine sample was collected from each child to evaluate background isotope enrichments before they were given an oral dose of 2H2O and H218O, which was individually based on the weight of the child: 0.15 g/kg 2H2O (99% enriched) and 1.5 g/kg H2O18 (10% enriched: normalized). The first 3 urine samples were collected ∼2, 4, and 6 h after dosing; additional urine samples were collected at daily intervals for a total of 14 d. Isotope enrichments were measured in duplicate by using isotope ratio mass spectrometry at the stable isotope facility of the Rowett Research Institute, Aberdeen, United Kingdom. The rate of carbon dioxide production was obtained from the differential disappearance of the 2 isotopes by using a computer-based program (28). The multipoint method was used to evaluate the elimination constants of deuterium and oxygen-18, and carbon dioxide production was calculated by using equation A6 from the publication of Schoeller et al (27). The Weir equation was used to calculate TEE (29).

Physical activity monitoring

Actiwatch-L (Cambridge Neurotechnology Ltd, Cambridge, United Kingdom) was used to estimate the free-living physical activity of the children for 7 consecutive days. This small, uniaxial device is specifically designed to measure acceleration over 0.05 g, converting these accelerations to activity counts while suppressing high accelerations to eliminate readings outside the 3–11 Hz range. Actiwatch was programmed to register activity counts of 1-min epochs before data collection began. This wrist-worn accelerometer correlates well with direct observation scales and has been validated for use in preschool children (30). Children were instructed to wear the Actiwatch on the nondominant wrist for 7 consecutive days, except during bathing, showering, and water-based activities. Actiwatch data were downloaded by using a reader unit and were analyzed by using the Actiwatch analysis software (Cambridge Neurotechnology Ltd).

Lifestyle questionnaire

Parents or guardians of children were asked to complete a Lifestyle questionnaire containing questions on Socioeconomic and lifestyle characteristics of their children and family. The questionnaire was structured to provide information such as the amount of time spent watching TV per day, the number of siblings, birth weight and type of housing.

Statistical analyses

All data were analyzed by using version 14 of MINITAB statistical software package (Minitab Inc, State College, PA) and SPSS 17 for the mediation analysis with a macro developed by Preacher and Hayes (31). Means and SDs were calculated for the descriptive statistics, and frequency distributions were computed for categorical data. A general linear model (GLM) was used to explore the associations between continuous [fat-free mass (FFM), age, and time spent TV viewing] and categorical (sex) variables on body fatness (FM), physical activity levels, and TEE. Mediating variable analysis was performed per the method proposed by Baron and Kenny (32) by using the Sobel test (bootstrap procedure) with 1000 samples as detailed by Preacher and Hayes (31). Statistical significance was set at P < 0.05 for all analyses.
RESULTS

Descriptive statistics of the children

Subject characteristics are shown in Table 1: 18.8% of children were overweight (>85th and <95th percentile) and 11.8% were obese (>95th percentile) when compared with UK reference data in 1990 (26). The sample recruited were exclusively white and mainly affluent (mean deprivation category: 2.4 ± 1.43) (33). There were no sex differences in age, weight, height, BMI SDS, FFM, and FM; however, TEE was significantly higher in boys (Table 1).

Hypothesis 1: association between TV viewing and body fatness

Body fatness (kg fat measured by DXA) was entered as a dependent variable in a GLM analysis with FFM from DXA, age, sex, TV viewing time, and the 2-factor interactions of these traits as predictor variables. None of the interactions were significant and were removed from the model. Of the remaining variables, there was a highly significant relation between FFM and body fatness ($F = 13.53$, $P = 0.001$), but no associations with either sex ($P = 0.064$) or age ($P = 0.598$). There was a highly significant positive relation between time spent TV viewing and body fatness ($F = 9.05$, $P = 0.004$) (Figure 1). The model explained 46.9% of the variation in body fat. Children who watched more TV each day were fatter. The least-squares fitted coefficient of the relation of fatness to TV viewing was 1.095 kg/kj, which indicated that each extra hour a child spent watching TV each day was associated with an increase of ≈1 kg in body fatness.

Hypothesis 2: associations between TV viewing, physical activity, and total daily energy expenditure

Average physical activity was entered as a dependent variable in a GLM analysis with FFM, FM, age, sex, and TV viewing time as predictor variables. FFM ($P = 0.284$), FM ($P = 0.617$), age ($P = 0.785$), and sex ($P = 0.500$) were all not significant. However, there was a significant negative association between the time spent viewing TV and physical activity. The least-squares fit regression explained 6% of the variance in average physical activity level ($F = 5.16$, $P = 0.026$). Children who watched more TV were on average less physically active.

In a GLM analysis, TEE measured by the DLW method was significantly positively related to FFM ($F = 13.88$, $P = 0.001$), FM ($F = 24.85$, $P < 0.001$), sex ($F = 4.80$, $P = 0.035$) and physical activity levels ($F = 5.15$, $P = 0.029$), but was not related to age ($P = 0.876$) or time spent watching TV ($P = 0.685$). Combined, the significant predictors explained 80.3% of the variation in TEE. We removed the influence of FFM on FM and then reanalyzed the association between TV viewing and this trait, including physical activity and TEE as predictors, to assess whether the effect of TV viewing on fatness was mediated only by the association between TV viewing and physical activity and hence TEE. There was a significant positive link between body fatness and TEE ($F = 5.70$, $P = 0.022$), there was no association between physical activity and body fatness ($P = 0.355$), and the significant relation with TV viewing remained (Figure 2A; $F = 6.68$, $P = 0.014$). This analysis indicated that, despite TV viewing being linked to lower physical activity and lower physical activity being associated with lower TEE, these relations did not mediate the effect of TV viewing on body fatness. Greater body fatness was associated with higher levels of TEE because of a significant direct effect of body fatness on TEE. To test this further, a separate formal test of mediation was

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**TABLE 1**

Characteristics of the preschool children enrolled in the study

<table>
<thead>
<tr>
<th></th>
<th>Boys</th>
<th>Girls</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>4.02 ± 1.48 (42)</td>
<td>4.1 ± 1.20 (47)</td>
<td>4.06 ± 1.33 (89)</td>
</tr>
<tr>
<td>Weight (kg)</td>
<td>18.0 ± 5.14 (42)</td>
<td>17.66 ± 5.01 (46)</td>
<td>17.82 ± 5.04 (88)</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>1.05 ± 0.11 (40)</td>
<td>1.04 ± 0.10 (45)</td>
<td>1.04 ± 0.11 (85)</td>
</tr>
<tr>
<td>BMI SD score (%)</td>
<td>0.15 ± 1.36 (40)</td>
<td>0.14 ± 1.25 (45)</td>
<td>0.15 ± 1.30 (85)</td>
</tr>
<tr>
<td>Fat mass (kg)</td>
<td>6.72 ± 3.00 (25)</td>
<td>7.47 ± 3.13 (32)</td>
<td>7.14 ± 3.10 (57)</td>
</tr>
<tr>
<td>Fat-free mass (kg)</td>
<td>11.84 ± 2.72 (25)</td>
<td>10.68 ± 2.80 (32)</td>
<td>11.19 ± 2.80 (57)</td>
</tr>
<tr>
<td>Total energy expenditure (kJ)</td>
<td>6756 ± 1371 (32)</td>
<td>5850 ± 1523 (34)</td>
<td>6239 ± 1511 (66)</td>
</tr>
<tr>
<td>7-d Activity (counts/min)</td>
<td>458.1 ± 97.8 (40)</td>
<td>428.5 ± 105.9 (45)</td>
<td>442.4 ± 102.6 (85)</td>
</tr>
<tr>
<td>Television viewing (h/d)</td>
<td>1.75 ± 1.0 (41)</td>
<td>1.97 ± 0.98 (46)</td>
<td>1.87 ± 0.99 (87)</td>
</tr>
</tbody>
</table>

1 All values are means ± SDs; n in parentheses.
2 Normalized for age and sex according to UK reference data (26).
3 Corrected for age.
4 $P < 0.05$, two-sample $t$ test for comparison between boys and girls.
TABLE 1. A summary of relations between television (TV) viewing, energy expenditure, body fat, and physical activity levels determined by using general linear models. Values represent regression coefficients using standard errors for direct effects (i) and mediated by physical activity (ii). The effect of TV viewing on adiposity was not significantly reduced with the addition of physical activity to the model (Sobel z = −0.155; P > 0.05; bootstrap 95% CI: −0.221, 0.176). +ve, positive; −ve, negative.

FIGURE 2. A: Summary of relations between television (TV) viewing, energy expenditure, body fat, and physical activity levels determined by using general linear models. B: Mediation model for the relation between TV viewing and body fat content. Values represent regression coefficients ± SE for direct effects (i) and mediated by physical activity (ii). The effect of TV viewing on adiposity was not significantly reduced with the addition of physical activity to the model (Figure 2B; Sobel z = −0.155, P > 0.05; bootstrap 95% CI: −0.221, 0.176), +ve, positive; −ve, negative.

PERFORMED (31) TO TEST WHETHER PHYSICAL ACTIVITY MEDIATES THE RELATION BETWEEN TV VIEWING AND ADIPOSITY (FIGURE 2B). THE EFFECT OF TV VIEWING ON ADIPOSITY IS NOT SIGNIFICANTLY REDUCED WITH THE ADDITION OF PHYSICAL ACTIVITY TO THE MODEL (FIGURE 2B; SOBEL z = −0.155, P > 0.05, bootstrap 95% CI: −0.221, 0.176), WHICH SUGGESTS THAT PHYSICAL ACTIVITY DOES NOT MEDIATE THE RELATION BETWEEN TV VIEWING AND ADIPOSITY.

DISCUSSION

Increased TV viewing is associated with increased BMI in children and adults, which suggests that TV viewing has contributed to the global epidemic of obesity. However, the association with BMI is not strong evidence linking TV viewing to obesity, because of the problems equating BMI with body fatness—particularly in children (34). The present study overcame these shortcomings by directly measuring body fatness by DXA. These more objective data unequivocally show that increased TV viewing is associated with greater levels of body fat in preschoolers.

The mechanism underpinning this association could lie on either (or both) side of the energy balance equation, because both displacement of physical activity and promotion of food intake have been previously implicated (16). On the basis of results from a meta-analysis of media use, body fatness, and physical activity in youth, displacement of vigorous physical activity is suggested to be a possible mechanism for the relation, but the available literature is fraught with technical measurement and statistical power problems (16). To overcome some of these issues, the present study used more direct methods to measure the children's total physical activity (with activity monitors) and total daily energy demands using DLW. Children who watched more TV were significantly less physically active as indicated by lower counts determined by accelerometry. This correlation may have resulted for 2 reasons. First, increased TV viewing might take up time that would otherwise be spent being active. However, an equally tenable explanation is that the children watching TV more became fatter for reasons linked to food intake (see below) and were less physically active because of their obesity. In this case, low physical activity would be a consequence rather than a cause of obesity. Other studies have also shown that more obese individuals (adults) are less physically active (35). Once adjusted for body composition, total daily energy expenditure was lower in children who were less physically active. Despite these significant associations, the link between TV viewing and body fatness did not appear to be mediated by lowered physical activity, because fatness (adjusted for FFM) was not significantly associated with physical activity levels, and fatter children had greater levels of TEE. This result suggests that the direct positive effects of fatness on TEE outweighed any indirect negative effects arising because of associations between fatness and lower physical activity.

Only one previous study has addressed the link between TV viewing and energy expenditure (in an older sample of children) using the less reliable method of heart rate monitoring to estimate TEE over a single day (36) compared with the use of the gold standard DLW method over 14 d as used in the present study. They compared children with high and low levels of TV viewing behaviors and suggested that TEE was not significantly different between groups. These findings are consistent with our data, but are difficult to interpret because of no corresponding data on physical activity levels. Moreover, the absence of an association might equally reflect the short measurement duration and the inherent errors in the heart rate monitoring method used to estimate TEE.

The sustained influence of TV viewing on body fatness, even when physical activity and TEE were included into the predictive model, and the results of the mediation analysis suggest that it is more likely that the association between TV viewing and body fatness is due to increased energy intake. Direct evidence tends to support this hypothesis. Several studies have shown that a considerable amount of a child’s daily energy intake is consumed while watching TV (17), and children who watch more TV eat less fruit and vegetables and consume more energy-dense snacks (18). In a recent large cross-sectional study in 5–6-y-old children, increased TV viewing was shown to be associated with an increased index of energy intake and increased consumption of sweet snacks and high-energy drinks (37). Furthermore, a recent randomized controlled trial aimed at reducing TV viewing to improve BMI has shown that reducing TV viewing reduces energy intake but not physical activity level, which agrees with the results of this study (38). Studies of children’s ingestive behavior in direct response to TV viewing suggest that TV watching can disrupt the development of habituation to food and therefore increase energy intake while children are watching TV.
There has been an increase in exposure to food advertising on TV among children, and evidence indicates that increases in TV viewing are associated with increased energy intake coupled with an increased intake of energy-dense foods that are frequently advertised on TV (41, 42). However, it is worth noting that a few studies have found no relation between diet and TV viewing (36, 39).

Strengths and limitations

Our sample of children came from mainly upper- to middle-class white families; therefore, we were unable to compare social class or race in our sample. Low social class has been suggested to be a possible factor in increased TV viewing (36), but we were unable to investigate this further. We did not measure TV viewing directly, but used a parental report of the children’s TV viewing, as with most previous studies. It is difficult to measure TV viewing directly. To our knowledge, only one study has measured TV viewing directly in relation to physical activity (39). In a recent review of screen-based media use in youth, this was an area that was highlighted for further research (16). The main strength of this study was its use of gold standard techniques to measure body composition, physical activity, and energy expenditure. Our study was the first to investigate the relation between TV viewing and body fat using gold standard techniques to measure body composition (DXA), physical activity (7-d objective accelerometry), and energy expenditure (DLW) in a sample of young children.

Conclusions

This study investigated the relation between TV viewing, adiposity, and objectively measured physical activity levels and total daily energy expenditure in a sample of preschool children (mean age: 4.1 y). There was a strong positive relation between TV viewing time and body fatness, which supports the findings of previous studies that estimated body fatness from measures of BMI. We also found that children who watched more TV were less physically active, and this lowered physical activity was associated with lower daily energy expenditure. Yet, the effect of TV viewing on fatness was not mediated by physical activity in the statistical analysis, which suggests that a relation between TV viewing and body fatness is more likely due to an association with food intake. Given that programming aimed at preschool children on terrestrial TV has doubled in the United Kingdom between 1996 and 2001 and programming on dedicated children’s channels has quadrupled, our work emphasizes the need to investigate further the relation between diet and TV viewing in children to inform future public health programs (43).

We thank all the families who took part in the study.

The authors’ responsibilities were as follows—DMJ: was the principal investigator; DMJ, KD, and JRS: devised the study concept; DMJ, KD, and JS: collected the data; and DMJ, KD, and JRS: interpreted and drafted the paper. All authors were involved in the data analysis. None of the authors reported a conflict of interest.

REFERENCES


