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ORIGINAL ARTICLE

Mediating effects of dietary intake on associations of TV viewing, body mass index and metabolic syndrome in adolescents

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Summary

Objective

Evidence suggests that TV viewing is associated with body mass index (BMI) and metabolic syndrome (MetS) in adolescents. However, it is unclear whether dietary intake mediates these relationships.

Methods

A cross-sectional analysis was conducted in adolescents (12–19 years) participating in the 2003–2006 United States National Health and Nutrition Examination Survey. BMI *z* scores (zBMI) ($n = 3{,}161$) and MetS ($n = 1{,}379$) were calculated using age- and sex-specific criteria for adolescents. TV viewing (h/day) was measured via a self-reported questionnaire, and dietary intake was assessed using two 24-h recalls. Using the MacKinnon method, a series of mediation analyses were conducted examining five dietary mediators (total energy intake, fruit and vegetable intake, discretionary snacks, sugar-sweetened beverages and diet quality) of the relationships between TV viewing and zBMI and MetS.

Results

Small positive relationships were observed between TV viewing and zBMI ($\beta = 0.99$, $p < 0.001$) and TV viewing and MetS (OR = 1.18, $p = 0.046$). No dietary element appeared to mediate the relationship between TV viewing and zBMI. However, sugar-sweetened beverage consumption and fruit and vegetable intake partially mediated the relationship between TV viewing and MetS, explaining 8.7% and 4.1% of the relationship, respectively.

Conclusions

These findings highlight the complexity of the relationships between TV viewing, dietary intake and cardiometabolic health outcomes, and that TV viewing should remain a target for interventions.

Keywords: BMI, dietary intake, metabolic syndrome, television.

Introduction

Currently, 17% of adolescents from the United States (US) are obese, and 5.8% have extreme obesity (1). Concerningly, among obese adolescents, 30% have the metabolic syndrome (MetS) (2), a condition characterized by a collection of risk factors that increase a person's chances of developing type 2 diabetes and cardiovascular disease (3). Because obesity has been shown to track from adolescence to adulthood (4) and obesity-related behaviours are often established at a young age (5,6), it is imperative to understand the key drivers of adolescent obesity and MetS to help inform effective interventions.

Time spent watching TV has consistently been shown to have adverse links with adolescent obesity (7) and MetS (8). However, the exact mechanism underlying these associations remains unclear. It has been suggested that TV viewing may displace time spent in physical activity. However, a meta-analysis of 163 studies in children and adolescents found that the association between TV viewing and physical activity was very small ($r = -0.108$), implying that children and adolescents may have both high amounts of TV viewing and physical activity (9). Alternatively, TV viewing has been consistently linked to elements of an unhealthy diet such as a higher energy intake, a greater intake of sugar-sweetened beverages (SSB) and snacks, lower intakes of fruit and vegetables, and a poorer overall diet (10–13). These unhealthy dietary elements are also important risk factors for obesity (14) and MetS (15).

Therefore, this poses the question as to whether the associations found between TV viewing, body mass index (BMI) and MetS could be partially explained by elements of a less healthy diet. If dietary intake is found to partially mediate these relationships, these findings will help to inform future interventions that targeting both TV viewing and dietary intake may have a greater impact on reducing obesity or MetS prevalence rather than targeting these behaviours individually. To date, only one study has specifically explored the mediating role of diet in an adolescent population and found TV snacking and junk food consumption did not mediate the relationship between TV viewing and BMI (16). However, this study was limited by only examining two dietary mediators, and only explored the relationship between TV viewing and BMI.

Therefore, the present study aims to identify whether five different elements of dietary intake (e.g. total energy intake, fruit and vegetable intake, discretionary snacking, SSB consumption and dietary quality) may partially mediate the relationships between TV viewing, BMI and MetS in a large sample of US adolescents. It is hypothesized that a lower intake of fruit and vegetables and dietary quality score, and a higher intake of total energy, discretionary snacks and SSB will mediate the relationships between TV viewing with BMI, and TV viewing with MetS.

Methods

The National Health and Nutrition Examination Survey conducted in 2003–2004 and 2005–2006 had a multistage, stratified sampling design used to recruit a representative cross-sectional sample of the US population. The 2003–2004 and 2005–2006 years were selected because of having the same dietary variables in both datasets and availability of the accelerometer data. Ethics was approved by the National Center for Health Statistics Institutional Review Board and Research Ethics Review Board (Protocol #98-12). Full details of the data-collection procedures are available elsewhere (17). In total, 5,138 adolescents aged 12–19 years were initially contacted and invited to participate in the study. Of those approached, 4,591 adolescents provided consent and completed a questionnaire on their demographics and activity/sedentary behaviour levels. Afterwards, 4,455 adolescents attended a health examination visit to collect physiological measurements and to complete one of two 24-h dietary recall. The same participants were then followed up 4 to 11 days later to complete the second 24-h dietary recall.

Cardiometabolic measurements

Height, weight, waist circumference, blood pressure, fasting blood glucose and insulin, and serum lipids were measured from the participants who attended the health examination visit. The full protocol and assessment of anthropometric measures and blood analyses can be found elsewhere (18,19). Briefly, height and weight were measured in a light gown without shoes by a research nurse, and waist circumference was measured using a flexible steel measuring tape underneath clothing at the uppermost lateral border of the ilium crest. Height and weight were used to calculate each participant's BMI z scores (zBMI) using age- and sex-specific BMI percentiles (STATA, SJ13-2 dm0004_1) based on the 2000 Centers for Disease Control and Prevention US growth charts (20). Waist circumference, systolic and diastolic blood pressure, blood glucose and insulin, and serum lipids were used to calculate the presence of MetS following the age- and sex-specific criteria specifically designed for adolescents set by the International Diabetes Federation. According to these criteria an adolescent (aged 12–19 years) has MetS if he or she has an elevated waist circumference and two or more of the following four criteria: elevated systolic or diastolic blood pressure, low HDL-cholesterol, elevated triglycerides and elevated plasma glucose (3).

Television viewing

The amount of time spent watching TV was self-reported via the question 'Over the past 30 days, on average about how many hours did you sit and watch TV or videos?'. The response options were: none, less than 1 h, 1 h, 2 h, 3 h, 4 h and 5 h or more. Similar questions have been shown to be reliable in youth (21). For all analyses, TV viewing was treated as a continuous variable.

Dietary intake mediators

Dietary intake was assessed via two interviewer-administered 24-h dietary recalls, delivered via a computer-assisted system (the Automated Multiple-Pass Method) (22). Participants aged 12 years and older reported their first dietary recall at the health examination visit, and the second dietary recall was conducted 4 to 11 days later by telephone. All dietary data were coded using the USDA National Nutrient Database for Standard Reference (23).

Based on previous associations with TV viewing time (11,12,24,25), the dietary intake elements examined as mediators included: (i) total energy intake; (ii) fruit and vegetable consumption; (iii) discretionary snack consumption; (iv) SSB consumption and (v) diet quality. All dietary intake elements were calculated based on the average of two days of dietary recall data. Total energy intake (calories) was calculated for each participant based on the quantity of food and beverages reported. Daily servings of fruit and vegetables were calculated using the Food Patterns Equivalents Database (26). Fruit was defined as any whole fruit (not including fruit juice) and vegetables included potatoes, beans and legumes. A serving of fruit or vegetables was equivalent to one cup of raw, canned or frozen fruit or vegetables, or two cups of leafy green vegetables (26).

Discretionary snacks were defined as grain-based and dairy-based desserts, cereal-, protein-, granola- and other-bars, sweet snacks and candies, sugar-syrups and preserves, salty snacks from grain or starchy vegetables and dips/spreads. Artificially sweetened snacks were excluded (27). SSB were defined as any non-alcoholic beverage with added sugar including soda, fruit-flavoured drinks (not 100% juice), sweetened tea, coffee and milk drinks, sport drinks and energy drinks (28). Any 'diet' drinks, 100% fruit juice, or unsweetened tea or coffee were not included as a SSB. A serving of discretionary snacks and a serving of SSB was equivalent to 143 calories (600 kilojoules) (29).

Diet quality was measured using the Healthy Eating Index 2010 (HEI-2010) (30). The HEI-2010 is a scoring system developed by the US Department of Agriculture that measures the degree of compliance to the 2010 Dietary Guidelines for Americans (31). Briefly, the HEI-2010 is made up of 12 food-based components: (i) total fruit; (ii) whole fruit; (iii) total vegetables; (iv) greens and beans; (v) whole grains; (vi) dairy; (vii) total protein foods; (viii) seafood and plant proteins; (ix) fatty acids; (x) refined grains; (xi) sodium and (xii) empty calories (defined as calories from solid fat, alcohol and added sugars). The first nine components represent adequacy components and the last three represents moderation components. The compliance to each of the 12 components is scored separately, and then summed together (scores ranging from 0 to 100) with higher scores indicating greater compliance with dietary recommendations.

Covariates

The covariates considered in the analyses were based on previous literature examining mediation analyses between screen time and zBMI in adolescents (16). The covariates included age (in years), sex, ethnicity, socioeconomic position (SEP), self-reported physical activity intensity and dietary intake under-reporting. SEP represents the family poverty-income-ratio and was calculated by dividing family income (reported by a parent) by the poverty guidelines (scores range 0–5), and self-reported physical activity intensity was calculated by averaging the metabolic equivalence score of all activities performed over the past 30 days (scores range 2.5–10). An objective accelerometer-derived measure of moderate-to-vigorous physical activity was initially considered as a covariate in the analyses; however, it reduced the sample by almost 50%. Dietary intake under-reporting was assessed on the basis of the ratio of total energy intake with estimated energy expenditure. Those with an energy intake to energy expenditure ratio of at least 2 standard deviations below the mean were classified as under-reporters (32).

Statistical analysis

To be included in the analyses (Figure 1), participants must be aged 12–19 years and not pregnant, have two days of complete dietary data obtained from the 24-h food recalls, have complete data on self-reported TV viewing, physical activity intensity, ethnicity and SEP, and have complete height and weight measures in order to calculate zBMI ($n = 3{,}161$). To examine the presence of MetS, separate analyses were also undertaken from a subsample of participants who had the previous inclusion criteria as well as a fasting blood sample at the health examination visit ($n = 1{,}379$).

Analyses were conducted using STATA/SE 14.0 software (StataCorp LP, College Station, Texas, 2015). To account for the complex survey sampling design, sample weights were applied to the descriptive statistics and to all mediation analyses. The 2-year weights were calculated to a combined 4-year weight by multiplying half of the assigned 2003–2004 and 2005–2006 2-year weight (e.g. 1/2*WTDRD1). The 4-year dietary weight was then used for all analyses involving zBMI and the 4-year fasting blood sample weight was used in the analyses involving MetS. The significance level was set at $P < 0.05$ for all statistical tests.

Prior to the analyses, all variables were checked for normal distribution. Total energy intake, servings of fruit and vegetables, servings of discretionary snacks and servings of SSB were not normally distributed and were log transformed. Using the product of coefficients method by MacKinnon *et al.* (33), individual linear regression models were used to test whether each of the five dietary variables mediated the association between TV

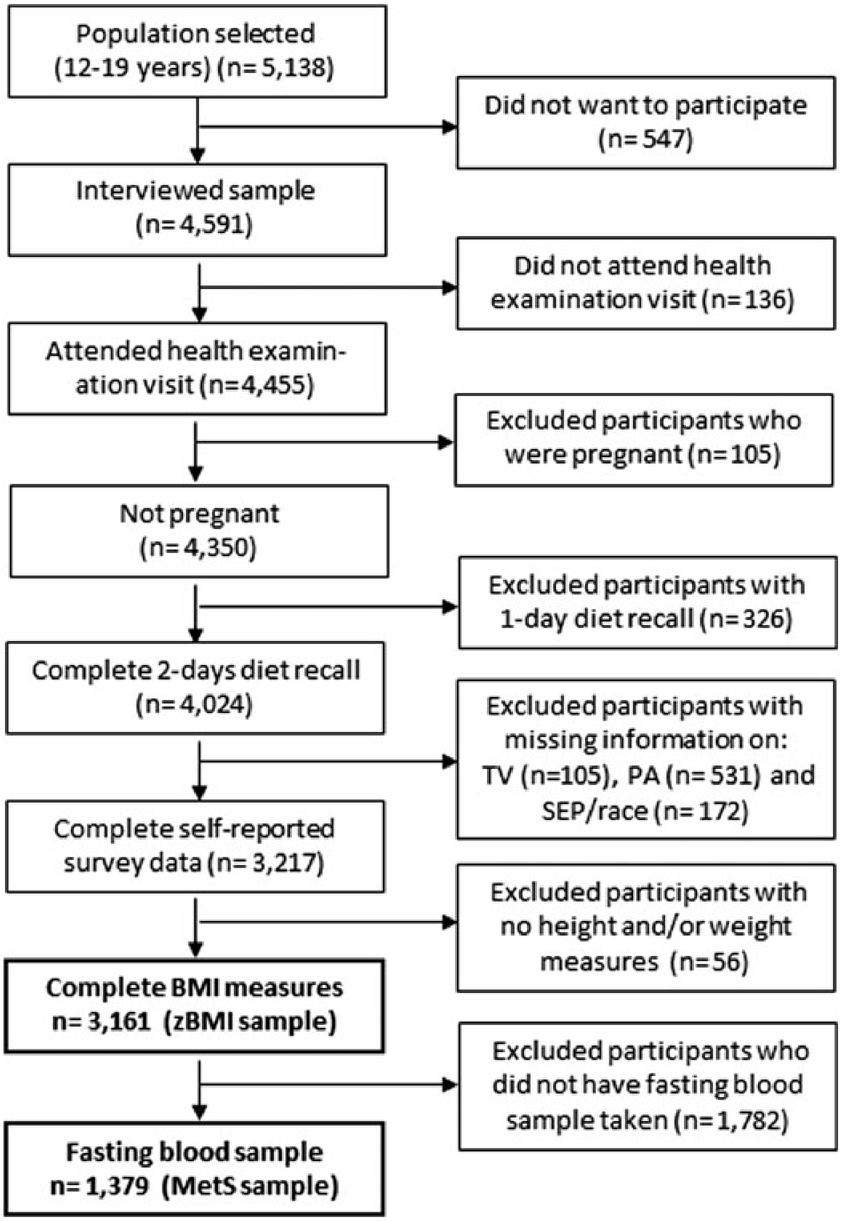

Figure 1 Study inclusion flow diagram of National Health and Nutrition Examination Survey 2003–2006 cohort and analytic sample.

viewing and zBMI or MetS (Figure 1). All dietary mediators were entered into separate regression models to minimize collinearity between variables (e.g. fruit and vegetables with dietary quality). All models controlled for age, sex, ethnicity, SEP, dietary intake under-reporting and self-reported physical activity.

As shown in Figure 2, for each mediation model, the following associations were tested: (i) associations between TV viewing time and the five dietary mediators (a-coefficient); (ii) associations between the five dietary mediators with zBMI or MetS, adjusting for TV viewing time (b-coefficient); (iii) the total effect of TV viewing time and zBMI or MetS (c-coefficient) and (iv) the direct effect of TV viewing time with BMI or MetS, accounting for the dietary mediators (c′-coefficient). The mediating effect, also known as the indirect effect, of the dietary variables was calculated by multiplying the *a* and *b* coefficients ($a \times b$) and presented as a percentage of the mediated effect ($ab / (c' + ab)$). For the MetS outcome, the coefficients were used to calculate the mediating pathways; however, the odds ratios are presented in the tables for descriptive purposes.

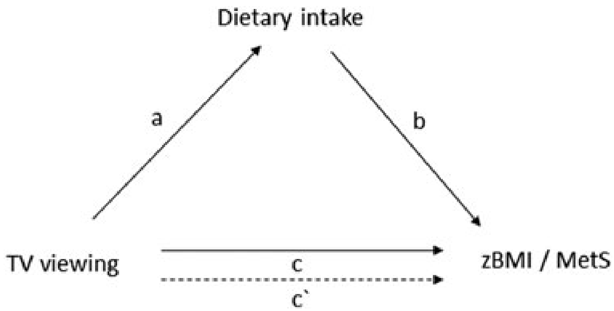

Figure 2 Theoretical diagram of the mediation pathways between TV viewing, dietary intake and zBMI/MetS. a-coefficient: association between TV viewing time with the dietary mediators; b-coefficient: association between the dietary mediators with zBMI/MetS; c-coefficient: total effect of TV viewing time with zBMI/MetS; c′-coefficient: the direct effect of TV viewing time with zBMI/MetS, accounting for the dietary mediators; zBMI: BMI *z* score, MetS: metabolic syndrome.

Results

Participant characteristics

Participant characteristics are shown in Table 1. Overall, 3,161 participants had complete zBMI profiles and 1,379 participants had complete data for identifying MetS. Approximately 53.1% of participants were male, and the mean age was 15.4 years. In the group with complete data for identifying MetS, 9.1% were classified as having MetS.

Relationship between TV viewing and diet (a-coefficient)

In the zBMI sample, TV viewing had a significant inverse association with diet quality, implying that for every hour of TV watched, diet quality decreased by 6.86 units (95%CI −1.45, −2.28) (Table 2). In the MetS sample, TV viewing was also inversely associated with dietary quality (β = −7.59; 95%CI −13.65, −1.53) and had a significant positive association with SSB consumption (β = 0.39; 95%CI 0.03, 0.76) (Table 3).

Relationship between diet and body mass index/metabolic syndrome (b-coefficient)

In the zBMI sample, total energy intake (β = −0.09; 95%CI −0.17, −0.00) and discretionary snacks (β = −2.02; 95% CI −3.16, −0.87) both showed a small inverse association with zBMI, after accounting for the covariates and TV viewing (Table 2). In the MetS sample, no significant associations were observed between any of the five dietary variables and MetS ($p > 0.05$) (Table 3).

Table 1 Demographic characteristics, blood profiles, TV viewing and dietary intake in US adolescents aged 12–19 years by health outcome (zBMI and MetS)

Characteristics	zBMI ($n = 3{,}161$)	MetS ($n = 1{,}379$)
Age, years	15.4 (2.2)	15.4 (2.3)
Sex [%], mean (95%CI)		
Boys	53.1 (50.8, 55.5)	53.1 (48.8, 57.5)
Girls	46.9 (44.5, 49.2)	46.9 (42.5, 51.2)
Ethnicity [%], mean (95%CI)		
Non-Hispanic white	65.9 (59.6, 71.7)	65.7 (59.4, 71.4)
Non-Hispanic black	13.7 (10.3, 18.1)	13.5 (10.3, 17.5)
Hispanic	10.6 (0.8, 14.5)	10.2 (7.3, 14.1)
Hispanic, other	3.4 (2.5, 4.8)	4.6 (3.2, 6.6)
Other race	6.3 (4.3, 9.1)	6.0 (3.8, 9.3)
SEP	2.7 (1.6)	2.7 (1.6)
Physical activity*	6.4 (1.4)	6.3 (1.4)
BMI		
kg/m^2	23.5 (5.6)	23.3 (5.7)
*z*BMI	0.6 (1.1)	0.5 (1.1)
Cardiometabolic		
Waist circumference, cm	n/a	81.1 (14.8)
Systolic BP, mm Hg	n/a	109.4 (10.3)
Diastolic BP, mm Hg	n/a	60.3 (11.5)
Plasma glucose, mmol/L	n/a	5.2 (1.0)
HDL-cholesterol, mg/dL	n/a	1.4 (0.3)
Triglycerides, mg/dL	n/a	1.0 (0.6)
MetS [%], mean (95% CI)	n/a	9.1 (8.7, 9.4)
TV viewing, h	2.2 (1.4)	2.1 (1.4)
Diet		
Total energy intake, kcal	2,248.0 (906.4)	2,219.1 (899.0)
Fruit/vegetables, servings	1.7 (1.1)	1.8 (1.3)
Discretionary snacks, servings	2.5 (2.1)	2.5 (2.2)
SSB, servings	2.1 (1.7)	2.1 (1.6)
Diet quality score, HEI-2010	40.8 (11.7)	40.8 (11.5)

Values weighted to account for survey design; mean and standard deviation in parentheses unless otherwise stated. SEP: socioeconomic position (range from 1 to 5); BMI, body mass index; zBMI: body mass index *z* score; BP: blood pressure; HDL: high-density lipoprotein; MetS: metabolic syndrome; SSB: sugar-sweetened beverages; n/a: sample does not have complete data.
*Physical activity intensity score (range from 2.5 to 10).

Relationship between TV viewing and body mass index/metabolic syndrome (c- and c′-coefficients)

Total

In the zBMI sample, TV viewing had a small but significant positive association with zBMI (β = 0.99; 95%CI 0.52, 1.46 $p < 0.001$), implying for every hour spent watching TV, zBMI increased by 0.99 units (equivalent to a 0.8 kg/m(2) increase in BMI) (Table 2). Similarly, in the MetS sample, TV viewing was also significantly related to having MetS, with for every hour spent watching

Table 2 Associations between TV viewing (h/day) with zBMI accounting for mediation by dietary variables ($n = 3{,}161$)

	a-coefficient	b-coefficient	c′-coefficient	ab	ab/c
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)	%
Total energy intake (kcal)	1.85 (−1.70, 5.41)	−0.09 (−0.17, −0.00)*	1.00 (0.53, 1.48)*	−0.16 (−0.50, 0.17)	−1.6
Fruit/vegetables (servings)	−0.14 (−0.34, 0.05)	−0.15 (−1.65, 1.35)	0.99 (0.51, 1.46)*	0.02 (−0.19, 0.23)	0.2
Discretionary snacks (servings)	0.16 (−0.17, 0.50)	−2.02 (−3.16, −0.87)*	1.02 (0.56, 1.48)*	−0.33 (−1.00, 0.34)	−3.3
SSB (servings)	0.15 (−0.18, 0.48)	0.74 (−0.58, 2.05)	0.98 (0.52, 1.44)*	0.11 (−0.19, 0.41)	1.1
Diet quality score (HEI-2010)	−6.86 (−11.45, −2.28)*	−0.01 (−0.07, 0.06)	0.98 (0.52, 1.45)*	0.05 (−0.36, 0.47)	0.5

Total effects (c-pathway) of TV viewing and zBMI: β = 0.99 (95%CI 0.52, 1.46) $p < 0.001$. Because of the small effect sizes, all results (except for the ab/c% column) have been multiplied by 10. Analyses adjusted for age, sex, ethnicity, socioeconomic position, self-reported physical activity intensity and dietary intake under-reporters. The unadjusted estimates are reported in Supplement file (Table S2). zBMI: body mass index *z* score; SSB: sugar-sweetened beverages.
*$P < 0.05$.

TV, the odds of having MetS increased by 18% (95% CI 1.00, 1.38; $p = 0.046$) (Table 3).

Direct

In the zBMI sample, similar to the total effect, but after accounting for each of the dietary mediators, the direct association between TV viewing and zBMI remained significant, and in some cases was stronger in magnitude ($p < 0.05$) (Table 2). For example, even after accounting for discretionary snacks, zBMI increased by 1.02 units (95%CI 0.56, 1.48) for every hour spent watching TV. However, in the MetS sample, the direct effect between TV and MetS was no longer significant after separately accounting for fruit and vegetable intake, SSB consumption and diet quality (Table 3).

Indirect/mediating

In the zBMI sample, when examining the indirect effect, or mediating effect, none of the five dietary variables showed a significant mediating effect on the relationship between TV viewing and zBMI (Table 2). However, when examining the indirect effect in the MetS sample, SSB consumption and fruit and vegetable intake were both found to be significant positive mediators of the relationship between TV viewing and MetS, explaining 8.7% and 4.1% of the relationship respectively (Table 3). When examining the mediating effects of fruit and vegetable intake separately, only fruit intake remained a significant positive mediator explaining 5.2% of the relationship (results reported in Supplement file; Table S1).

Discussion

This study examined the relationships between TV viewing with BMI and MetS in a large representative sample of US adolescents, and whether the relationships were partially mediated by five elements of dietary intake. The findings suggest that TV viewing is positively associated with both BMI and MetS. After examining the mediating effects, no dietary mediators were observed in the TV viewing and zBMI relationship; however, SSB consumption and fruit and vegetable intake showed partial mediation effects in the TV and MetS relationship.

Table 3 Associations between TV viewing (h/day) with MetS accounting for mediation by dietary variables ($n = 1{,}379$)

	a-coefficient	b-coefficient	c`-coefficient	ab	ab/c
	β (95% CI)	OR (95% CI)	OR (95% CI)	β (95% CI)	%
Total energy intake (kcal)	−0.11 (−4.32, 4.09)	0.98 (0.94, 1.01)	1.17 (1.00, 1.38)*	0.03 (−6.58, 6.63)	0.2
Fruit/vegetables (servings)	−0.15 (−0.35, 0.06)	0.63 (0.30, 1.37)	1.17 (0.99, 1.37)	0.67 (0.29, 1.05)*	4.1*
Discretionary snacks (servings)	0.13 (−0.22, 0.47)	0.96 (0.69, 1.38)	1.18 (1.00, 1.33)*	−0.05 (−0.62, 0.52)	−0.3
SSB (servings)	0.39 (0.03, 0.76)*	1.44 (0.93, 2.22)	1.16 (0.98, 1.37)	1.43 (0.61, 2.25)*	8.7*
Diet quality score (HEI-2010)	−7.59 (−13.65, −1.53)*	0.99 (0.97, 1.00)	1.17 (0.99, 1.38)	0.87 (−0.37, 2.11)	5.3

Total effects (c-pathway) of TV viewing and MetS: OR 1.18 (95% CI 1.00, 1.38) $p = 0.046$. Because of the small effect sizes, the beta coefficient columns have been multiplied by 10. Analyses adjusted for age, sex, ethnicity, socioeconomic position, self-reported physical activity intensity and dietary intake under-reporters. The unadjusted estimates are reported in Supplement file (Table S3). MetS: metabolic syndrome, SSB: sugar-sweetened beverages.
*$P < 0.05$.

The finding that TV viewing was significantly associated with BMI is consistent with evidence from cross-sectional (7) and longitudinal studies (34), and reviews (8,35). Although, the literature on the TV viewing and MetS relationship in adolescents is limited, the findings from the present study are consistent with the few studies that have examined relationships between either TV viewing or screen time with markers of MetS or the presence of MetS (34,36,37). However, it is important to note, in both the current study and previous studies examining TV and MetS, the proportion of adolescents who were classified as having MetS was quite low (e.g. $<$10%) and results should be viewed with caution.

In addition, the finding that TV viewing was adversely associated with diet quality and positively associated SSB consumption is consistent with the literature. In an earlier National Health and Nutrition Examination Survey cohort examining TV viewing and dietary quality in 3,343 US adolescents, less time spent watching TV was associated with higher diet quality (13). Similarly, in a large cross-national study involving 162,305 adolescents from various countries, those who watched high amounts of TV were more likely to consume soft drink on a daily basis and less likely to consume fruit and vegetables (38).

However, the latter is in contrast to the current study where no significant associations were found between TV viewing with fruit and vegetable intake. In addition, other cross-sectional and longitudinal studies have reported positive associations between TV viewing and discretionary snacking (11,39), whereas the current study found no significant findings. These differences could be because of different definitions used to describe 'discretionary snacking' or different methods used to collect the dietary information (e.g. food frequency questionnaires vs. 24-h food recalls).

In the current study, many of the dietary elements were significantly related to BMI but not to MetS. Interestingly, two of the dietary elements, total energy intake and discretionary snacking, had count-intuitive associations with BMI. For example, a lower energy intake and a lower intake of discretionary snacks were associated with a higher zBMI. These counter-intuitive associations were also observed in a previous mediation study (16) and could potentially be explained by social desirability bias where overweight or obese participants may under-report their dietary intake (40). The null findings between diet and MetS are in contrast to an earlier National Health and Nutrition Examination Survey study (1999–2002) examining MetS in adolescents. They found a higher intake of fruit and a higher diet quality score (measured via the HEI-2005) was associated with a decrease in MetS prevalence (15). The differences between studies could be because of the low prevalence of MetS in both samples or to the different dietary quality scores that were used (e.g. HEI-2005 vs. HEI-2010).

Only one other cross-sectional study from Canada has examined the mediating effects of dietary intake on the relationship between TV and BMI in a large group of adolescents. Their results were similar to the current study, where no dietary variables were found to mediate the TV and BMI relationship (16). However, in a study involving younger children (aged 10 years), a combined unhealthy dietary variable consisting of high fat food, fruit juice and soda consumption was found to be a significant mediator in the TV viewing and BMI relationship (41). The differences in findings between studies may be because of different population groups being studied (children vs. adolescents). However, given the lack of studies that have performed mediation analyses, further studies examining both child and adolescent populations are needed to clarify whether any differences exist between these age groups.

To our knowledge, this is the first study to examine the mediating effects of dietary intake between TV and MetS. SSB consumption and fruit and vegetable intake were both found to partially mediate the TV and MetS relationship. SSB consumption is not a surprising mediator given the consistent associations it has with both TV viewing (42) and cardiometabolic health (14). However, the counter-intuitive findings that a higher intake of fruit and vegetables may mediate the TV and MetS relationship are difficult to explain. Similar to the counter-intuitive associations found between diet and BMI, social desirability bias may have occurred where participants with the MetS may have over-reported their intake of healthier food items such as fruit and vegetables (43,44). Alternatively, given this is a cross-sectional study, it is possible that some participants with MetS may have already been instructed to change their eating behaviours, and thus consume more fruit and vegetables.

The main strengths of this study include having a large representative-based sample and using objective measures of BMI status and MetS. Other strengths include the use of two 24-h recalls using the Automated Multiple-Pass Method to collect dietary intake data and adjusting for a variety of well-known confounders in the analyses. Limitations include the self-reported measures of TV viewing time, physical activity intensity and dietary intake as it is possible that under- or over-reporting may have occurred. Further, time spent in 'TV viewing' a decade ago may not be reflective of time spent in 'TV viewing' today. Advancing technology over the last decade has introduced watching TV on many portable devices (e.g. tablets, phones and computers); thus, 'total screen time' may be the contemporary equivalent term to use in future studies assessing TV viewing. Additionally, using an objectively measured physical activity measure may have altered the results; however, by doing so it reduced the sample by almost 50%. Although a variety of covariates were adjusted for, other unmeasured covariates such as pubertal status may have influenced the observed associations. Further, given the number of mediation variables tested, multiple analyses were conducted for both the zBMI sample and MetS sample, which can lead to some findings being significant because of chance. Last, data on TV viewing and dietary intake were not collected for the same days and the cross-sectional design of the study limits the ability to determine the cause and effect relationship.

Conclusion

Contrary to our hypothesis, this study found that five aspects of dietary intake were not significant mediators in the TV viewing and BMI relationship. However, the consumption of SSB and fruit and vegetable intake were found to be significant mediators in the TV viewing and MetS relationship. This suggests that it is important to target TV viewing in interventions; however, the mechanisms explaining the health associations are still unclear. Further research examining other sedentary behaviours (e.g. computer use, video gaming), and total sedentary time is needed to determine if these behaviours have similar findings. Longitudinal and experimental studies should be conducted to better understand the role of dietary intake and how much, if any, it contributes to the TV viewing and cardiometabolic health relationship.

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Conflict of Interest Statement

The authors have no conflicts of interest.

Author contributions

The authors' responsibilities were as follows: EAF had full access to the data in the study and had primary responsibility for the integrity of the data, the accuracy of the data analysis, and the final content. EAF, SAM, KEL, DWD, JS: conceived and designed the study; EAF performed the statistical analysis with guidance from SAM, VC and JS. All authors were involved in writing the paper and had final approval of the submitted and published versions.

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Supporting Information

Additional supporting information may be found in the online version of this article at the publisher's web site.

Table S1: Associations between TV viewing (h/day) with MetS accounting for mediation effects of fruit and vegetable intake.
Table S2: Unadjusted associations between TV viewing (h/day) with zBMI accounting for mediation by dietary variables ($n = 3,161$).
Table S3: Unadjusted associations between TV viewing (h/day) with MetS accounting for mediation by dietary variables ($n = 1,379$).