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Time with friends and physical activity as mechanisms linking obesity and television viewing among youth

Elizabeth A Vandewater^{1*}, Seoung Eun Park¹, Emily T Hébert¹, Hope M Cummings²

Abstract

Background: Though bivariate relationships between childhood obesity, physical activity, friendships and television viewing are well documented, empirical assessment of the extent to which links between obesity and television may be mediated by these factors is scarce. This study examines the possibility that time with friends and physical activity are potential mechanisms linking overweight/obesity to television viewing in youth.

Methods: Data were drawn from children ages 10-18 years old ($M = 13.81$, $SD = 2.55$) participating in the 2002 wave of Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID) ($n = 1,545$). Data were collected both directly and via self-report from children and their parents. Path analysis was employed to examine a model whereby the relationships between youth overweight/obesity and television viewing were mediated by time spent with friends and moderate-to-vigorous physical activity (MVPA).

Results: Overweight/obesity was directly related to less time spent with friends, but not to MVPA. Time spent with friends was directly and positively related to MVPA, and directly and negatively related to time spent watching television without friends. In turn, MVPA was directly and negatively related to watching television without friends. There were significant indirect effects of both overweight/obesity and time with friends on television viewing through MVPA, and of overweight/obesity on MVPA through time with friends. Net of any indirect effects, the direct effect of overweight/obesity on television viewing remained. The final model fit the data extremely well ($\chi^2 = 5.77$, $df = 5$, $p < 0.0001$, $RMSEA = 0.01$, $CFI = 0.99$, $TLI = 0.99$).

Conclusions: We found good evidence that the positive relationships between time with friends and physical activity are important mediators of links between overweight/obesity and television viewing in youth. These findings highlight the importance of moving from examinations of bivariate relationships between weight status and television viewing to more nuanced explanatory models which attempt to identify and unpack the possible mechanisms linking them.

Background

Despite recent reports suggesting that childhood obesity rates in the U.S. may be leveling off or starting to decline [1], obesity among children and youth continues to be one of the most persistent public health problems in the United States. Approximately 22.8% of 2- to 5-year-olds, 34.2% of 6- 11-year-olds, and 34.5% of 12-19 year-olds are overweight or obese [1]. Obesity in childhood is of

particular concern because it is linked to both immediate and long-term health problems and tends to persist into adulthood [2,3]. Unless reversed, the current rates of obesity among U.S. children and youth will dramatically affect public health well into the middle of the 21st century.

Over the past 35 years or so, an enormous amount of intellectual and financial capital has been spent on identifying and understanding the factors contributing to the obesity epidemic. Early on, television viewing was identified as a possible major contributor to childhood obesity. In 1985, Dietz and Gortmaker reported that the prevalence of obesity among adolescents aged 12-17 (drawn

* Correspondence: Elizabeth.Vandewater@uth.tmc.edu

¹Michael & Susan Dell Center for Healthy Living, The University of Texas School of Public Health Austin Regional Campus, 1616 Guadalupe St., Austin, TX 78701, USA

Full list of author information is available at the end of the article

from the cross-sectional National Health and Nutrition Examination Surveys or NHANES) increased 2% with each hour of television viewed [4]. They proposed that television viewing plays a causal role in childhood obesity—a view that was largely accepted then and now. Thirty years later, this study is still widely cited as definitive evidence that television causes obesity in youth, and a voluminous body of research aimed at replicating this result has been produced.

Yet, empirical evidence for the link between television and obesity has been surprisingly inconsistent. Despite high levels of media use and a high incidence of obesity among youth, evidence that these concurrent trends are strongly related is mixed at best [5]. Some studies find weak but positive associations between television viewing and obesity among youth [6-9], some find no relationship [10-12], and others find that the relationship is no longer statistically significant once important confounders are controlled for [13-15]. In a meta-analysis, Marshall, Biddle, Gorely, Cameron & Murdey found that the associations between media use and obesity among youth, though consistently positive, tend to be extremely weak, and concluded that they are of little clinical relevance [16]. Though this debate is by no means settled, the notion that media use must somehow be responsible for the increased prevalence of obesity in American children is deeply held by policy makers, the general public, and scholars alike.

The most commonly assumed mechanism linking media use to obesity is reflected in the “couch-potato hypothesis,” whereby media use is related to obesity because it encourages inactivity, increases food consumption, or both. Despite widespread belief in the veracity of these mechanisms, few scholars have undertaken direct empirical assessment of such mediators, a weakness that has been noted by others [17,18]. Moreover, scholars have struggled to find strong and consistent links between television viewing and either physical activity or caloric intake [9,19-25]

Other factors related to obesity and physical activity: the importance of friends

Within the voluminous literature aimed at identifying influences on youth obesity, friends have emerged as an important factor related to both obesity and physical activity [26]. There is a strong evidence that the social worlds of overweight and obese youth tend to be hostile, rejecting and negative [27-30]. Compared to normal-weight youth, children perceive overweight youth more negatively and are less likely to seek their company [31-33]. At the individual level, there is consistent evidence that overweight youth have fewer friends, are less likely to have mutual or reciprocated friendships, and

are alone more frequently than normal-weight youth [30,34-36].

The relatively friendless state of overweight youth is unfortunate, because research also consistently show that time spent with friends is positively related to physical activity. A number of studies have found that children and adolescents are more physically active in the presence of friends than when alone, and that youth who report a greater presence of friends also report engaging in more physical activity [37,38]. Children who report being friendless and rejected by peers also report the least amount of physical activity [39,40]. Moreover, there is some evidence that overweight and non-overweight children may be equally physically active when in the presence of friends [36].

Connecting youth obesity, television viewing, friends, and physical activity

To summarize, associations between television viewing and obesity among youth have proven to be unreliable, yet continue to appear sporadically in empirical studies. Overweight and obese children have fewer friends and spend less time with friends, and time spent with friends is positively related to physical activity. Though there is little evidence that television viewing decreases physical activity, there is evidence that time spent watching TV with friends is positively related to engaging in other activities with friends (i.e., youth with friends spend time with them, watching TV or otherwise [41].

Thus, despite the widespread belief that television viewing increases weight status, an equally plausible hypothesis is that overweight or obese youth spend less time with friends, which in turn is related to less time spent in physical activities, which they then fill with television viewing. Evidence indicates that a large proportion of television viewing occurs as a default when other options are not available [22,42]. This hypothesis suggests that television viewing may simply be a marker of the relatively meager social lives of overweight and obese youth.

The purpose of this paper is to examine the possibility that time with friends and physical activity are important mediators of the relationship between obesity and television viewing among older children and adolescents. Specifically, we posit that overweight/obese weight status will be negatively related to both time spent with friends and time spent in moderate-to-vigorous physical activity (MVPA). In turn, we expect time with friends to be positively related to time spent in MVPA, and that both time with friends and MVPA will be negatively related to time spent viewing television without friends. We hypothesize that overweight/obesity will be related to time spent viewing television without friends only indirectly via time spent with friends and time spent in MVPA.

Methods

Sample and procedures

We utilized data collected as part of the 2002 wave of the Child Development Supplement (CDS) to the Panel Study of Income Dynamics (PSID). The PSID has been an ongoing panel study since 1968, focusing primarily on the transfer of social and economic capital within families. In 2002, the CDS supplemented the core PSID with data focusing on family and child development collected via interview, parent-report, and child-report drawn from families who remained active in the PSID as of 2001. The CDS successfully reinterviewed 2017 families (91%) who provided data on health, cognitive, academic, and behavioral development, as well as time use from 2908 children and adolescents ages 5 to 18 [43].

Because the major variables of interest (overweight/obesity, physical activity, friendships and television viewing) and the relationships among them are known to vary between very young children and older children, we limited our sample to children and adolescents ages 10 to 18 years ($n = 1,545$, $M \text{ Age} = 13.81$, $SD = 2.55$); 49% were boys; 45.8% were White, 42.8% were Black, 6.9% were Hispanic or Latino, and the remainder were Asian, Pacific Islander, Native American or Other race. Family median income was \$48,800, with 15.1% of the families falling below poverty level. Parents had 12.90 ($SD = 2.62$) years of education on average.

Measures

Child weight status

Weight and height information were collected via strain gauge lithium bath scales (Measurement Specialties, Inc. "Thinner MS-7" model; <http://www.msusa.com/default/index.asp>) and measurement tape, respectively, during the home interview. Children were measured in stocking feet, in light clothing, with pockets emptied. BMI was calculated using the formula from the National Center for Chronic Disease Prevention and Health Promotion ($\text{weight [lbs]} \div \text{stature [in]} \div \text{stature [in]} \times 703$), and converted to a BMI z-score using the Centers for Disease Control's BMI growth reference to determine an age- and sex-specific BMI z-score for ages 2 to 20 years [44].

Child weight status is defined based on the 2000 Centers for Disease Control and Prevention growth reference for the United States [45]. Children are categorized as obese (BMI for age at or above the 95th percentile), overweight (BMI for age at or above the 85th percentile but less than the 95th percentile of BMI for age), or normal weight (BMI for age is less than the 85th percentile). In order to assess the association between overweight/obese status and other variables in the model, children with overweight or obese status were combined (coded 1) and compared to children of normal weight (coded 0).

Time spent in activities: television viewing, time with friends & physical activity

Unique to the CDS are 24h time diaries logging the flow of children's activities for 24 hours on one randomly chosen weekday and weekend day beginning at midnight. The diaries record the time every activity began and ended (duration of primary activities); where the child was; who was participating with the child; who was there but not participating; and what else the child was doing (secondary activities). Though always interviewer administered, diary activity reporters necessarily differ by child age. While younger children are incapable of self-report, not only are older children increasingly able to self-report, but they also need privacy to accurately do so. In 2002, The 36% of children who reported their activities without help from a primary caregiver averaged 14.48 years old; the 20% of children who reported their activities with caregiver help averaged 9.82 years old, and the 43% of children whose primary caregivers reported their activities averaged 7.68 years old. No diaries were administered solely to children under the age of 9. During consent/assent, all participants are informed that their answers are kept completely confidential and cannot be shared with any other participant. If completed, all diaries include a full accounting of activities over the 24 hour period. Participants in this study completed at least one time diary (98.3% completed both diaries, 0.5% completed a single weekend diary, and 1.3% completed a single weekday diary) [43]. There were no significant differences between participants who completed both time diaries versus those who completed either single day diaries (weekday or weekend).

Validity of time diary methods

An extensive body of research has demonstrated the validity and reliability of such diaries as representations of the way children and adults spend their time [46-48]. A large body of evidence demonstrates the validity and reliability of 24h time diaries as representations of the way children and adults spend their time [46,47,49,50]. Diary activities are generally highly correlated (on the order of .70 to .84) with direct observations [50] and substantially more accurate than self-report estimates of average daily or weekly time spent in activities [47,50,51]. In addition, there is evidence that parental report of their children's TV viewing is more accurate in diaries than via parent or child self-report of average weekly estimates, and highly correlated with direct observational measures [52,53].

Representativeness of activities

Because 24h diaries are typically collected for 2 days, they are quite good at capturing daily activities, but less so for infrequent activities (e.g., volunteering). Unfortunately, asking respondents to keep 24h diaries for longer than 2 days results in precipitous drops in response rates (from

around 80% to 40% or less for 3 or more days [48]), while adding considerable cost and respondent burden [54]. This may be less of a concern for viewing as most youth watch TV daily (even with the availability of newer media) [55,56]. CDS diary estimates of TV viewing are consistent with studies using weekly media diaries [57-59] and those based on representative samples in similar age ranges [60], fostering confidence in the accuracy of the diary estimates of TV viewing.

Time spent viewing television

Television viewing is represented as the number of hours per day children view television. In order to represent viewing in this way, the number of hours of viewing reported in the weekday diaries were multiplied by five, and the number of hours of viewing reported in the weekend diaries were multiplied by two. These products were then summed and divided by seven to arrive at a daily estimate of viewing per week using the following formula: $[(\text{sum of weekday hours} \times 5) + (\text{sum of weekend hours} \times 2)]/7$.

Time spent with friends

Time spent with friends is represented as the number of hours per day children spend in all activities with their friends. Because the CDS time diaries capture the social context of all activities (e.g., who, if anyone, was participating in activities with the child), we are able to capture the total amount of time children spend in all activities with their friends. Daily hours spent in activities where friends were present was calculated using the same formula presented for daily television viewing, above.

Moderate-to-vigorous physical activity (MVPA)

All activities in the time diaries were assigned metabolic equivalent (MET) scores utilizing the procedure advocated by Ainsworth et al. [61] to create measures of physical activity (PA). MET values are used to classify the relative energy cost of physical activities and describe activity patterns with one MET defined as the energy expended while sleeping [62,63]. MET values for activities published in the Compendium of Energy Expenditures for Youth [64] were assigned to activities by trained coders. Consensus was reached on all METs values before assignment. This procedure has been used to assess physical activity level (PAL) in the time diaries provided by the American Time Use Survey (ATUS) [65] and has been shown to provide a valid method for estimating energy expenditure in METS values, and time spent in adolescent MVPA [66-68]. Time spent in sedentary, light, moderate and vigorous activities were calculated based on duration and MET values for each activity. As with time spent viewing television and time spent with their friends, youth moderate-to-vigorous physical activity (MVPA) is represented as the numbers of hours per day spent in MVPA.

Covariates

Model covariates included factors known to influence obesity, television viewing, physical activity, and/or time

with friends. These included: (a) child age, (b) child gender, (c) child race/ethnicity, (d) family income-to-needs ratio (computed by dividing family income by the 2002 poverty threshold provided by the U.S. Census Bureau appropriate for family size), and (e) child maturational status

Because maturation-related misclassification may result in overestimations of overweight prevalence rates among early maturing adolescents and underestimations among later maturing adolescents [69,70], we utilized the Khamis-Roche (KR) method for predicting percent of adult stature [71]. Percent of adult stature has been shown to be significantly correlated with maturational status (range $r = 0.50$ to 0.70) and thus is a good proxy for maturational status when other measures (such as observational report of stages of pubertal development) are not available [72-74]. It is calculated from current stature (in), current weight (lb), and mid-parent stature (average height of both parents) (in). The regression equation for predicting adult stature takes the form: predicted adult stature = $\beta_0 + \beta_1$ stature + β_2 weight + β_3 mid-parent stature, where β_1 , β_2 , and β_3 are the coefficients by which stature, weight, and mid-parent stature, respectively, are multiplied. Predicted adult stature / current stature then provides a measure of percent of adult stature at a given age.

Statistical analysis

As the variables examined are observed in nature, we utilized path analysis to assess the fit of the model to the data. Path analysis has two advantages over linear regression for our purposes. First, because our proposed model is not fully-saturated, path analysis allows assessment of model-fit (in contrast to regression models which are fully-saturated by default). Second, path coefficients are estimated via simultaneous equation estimation, thus adjusting standard errors for the number of equations computed [75]. We utilized full-information-maximum-likelihood estimation with robust standard errors, a procedure that provides robust estimates utilizing all available data and accounts for non-independence within families [76]. Model fit was assessed using the combination of fit indices recommended by Bollen (1989), including (a) the Chi-square statistic, (b) the Comparative Fit Index (CFI), (c) the Tucker-Lewis index (TLI), and (d), the Root Mean Square Error of Approximation (RMSEA). Because Chi-square is highly sensitive in large samples, minimally acceptable fit includes the combination of CFI and TLI estimates greater than .95 and RMSEA estimates of .05 or below. Very good fit is indicated by the combination of a non-significant Chi-square test ($p < .05$), CFI and TLI estimates of .98 or above, and RMSEA estimates of .03 or below.

Mediation was assessed by computing estimates of direct, indirect, and total effects of the associations specified in the

model using full information maximum likelihood with robust standard errors. Direct effects represent associations between variables unmediated by any other variable in the model. Indirect effects represent mediated effects (or combined mediated effects for paths through multiple mediators). Total effects are the sum of the direct and indirect effects. In order to examine specific mediated effects when indirect effects represent combined mediated effects (for example the mediated effect of overweight/obese on time spent television via time spent with friends only), we conducted product-of-coefficient tests [77]. This consists of (1) estimating the effect of overweight/obesity on potential mediators (α coefficient), (2) estimating the independent effect of the potential mediators on television viewing (β coefficient), and (3) computing the mediated effect (the product of the $\alpha\beta$ coefficients). This mediated effect represents the effect of obesity on television viewing via the proposed mediators in units of television viewing (the outcome). Because significant mediation can exist even in the presence of non-significant direct effects, both single and multiple mediator models were assessed [78]. Bootstrapping resampling techniques were used to estimate standard errors and confidence intervals of mediated effects [77,79].

Analyses were conducted in Stata 13.1. Covariates (Child Age, Child Gender, Child Race, Child Maturation Status, and Family Income-to-Needs Ratio), were included in path models as correlated exogenous variables predicting all other variables in the model as suggested by Bollen [75], and in mediator analyses [77,78].

Results

Preliminary results

Descriptive statistics are presented in Table 1. Twenty-one percent of youth were classified as obese, 16% as overweight, and 62% as normal weight, a finding generally in-line with current estimates [1,80]. Overall, youth watched an average of 2.62 hours of television per week. This estimate is consistent with existing studies using weekly media diaries [57-59]. It is interesting to note that much more of this viewing occurred without friends ($M=2.32$) than with friends ($M=.28$, or about 17 minutes per week). It also worth noting that youth spent almost 2 hours per week with their friends, but only 45 minutes per week, on average, in moderate-to-vigorous physical activity. Zero-order correlations among all variables utilized in the path analyses are presented in Table 2.

Path analyses results

Standardized path coefficient estimates for our hypothesized model whereby overweight/obesity is only indirectly related to time spent television viewing via time spent with friends and time spent in MVPA are presented in figure 1. Our hypothesized model (Model 1)

Table 1. Sample Characteristics (N=1,545)

Variables	Mean (SD) or %
Child Age, years	13.81 (2.55)
Boys	49 %
Child Race	
Non-Hispanic White	46 %
Non-Hispanic Black	43 %
Hispanic or Latino	7 %
Other (Asian, Pacific islander, Native American, Other Race)	4 %
Family Income	\$ 68,149 (93,867)
Income-to-Needs Ratio	3.80 (5.34)
Parental Education, years	12.90 (2.62)
Child Weight Status	
Child Normal Weight	62 %
Child Overweight	16.1 %
Child Obese	21.9 %
Time Spent with Friends, hours per week	1.88 (2.19)
Moderate-to-Vigorous Activity, hours per week	.75 (1.05)
Total TV Viewing, hours per week	2.62 (1.83)
Television Viewing with Friends, hours per week	.28 (.69)
Television Viewing without Friends, hours per week	2.32 (1.77)

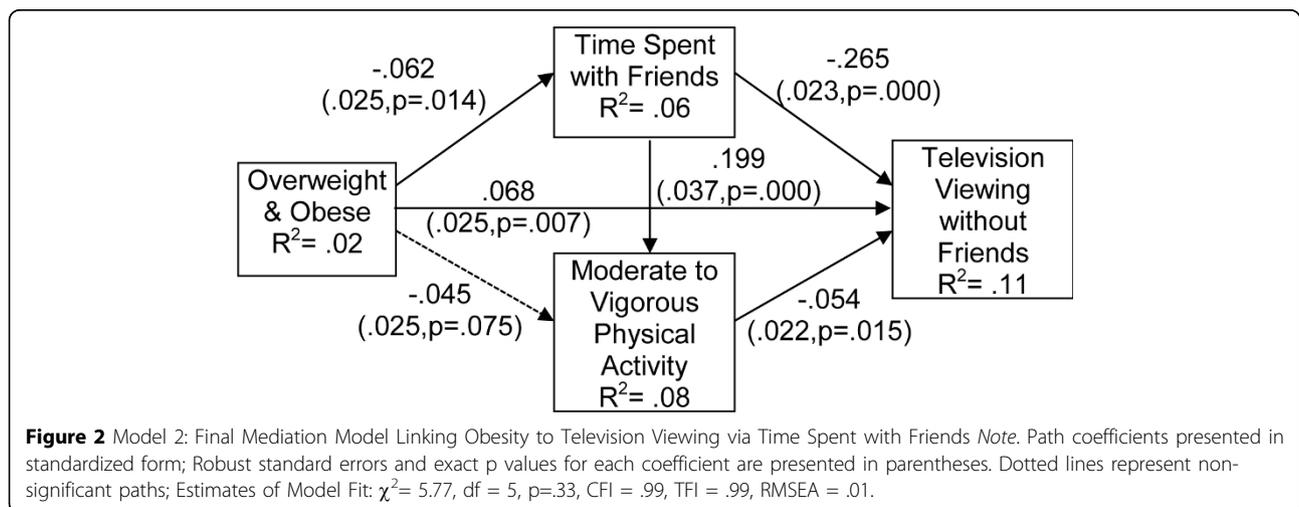
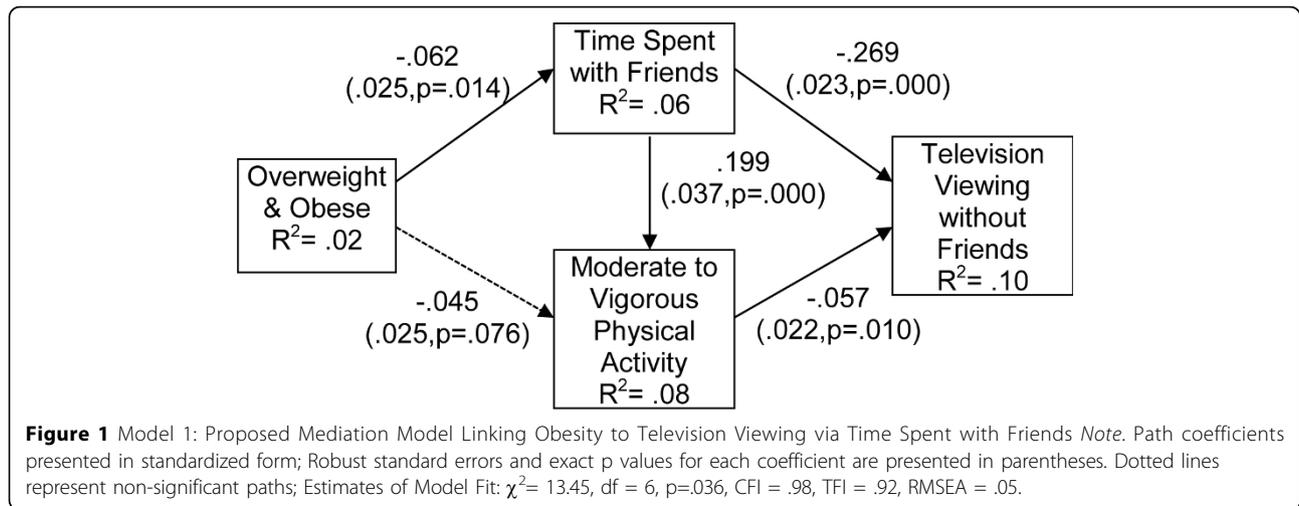
had only minimally acceptable fit with the data ($\chi^2=13.45$, $df=6$, $p=.036$, $CFI=.98$, $TFI=.92$, $RMSEA=.05$), indicating that important relationships were omitted. Therefore, we estimated a second model (Model 2) which included a direct relationship between obesity and television viewing, while identical to Model 1 in all other aspects. The standardized path estimates for Model 2 are presented in Figure 2. Model 2 fit the data extremely well ($\chi^2=5.77$, $df=5$, $p=.33$, $CFI=.99$, $TFI=.99$, $RMSEA=.01$), and significantly better than Model 1, our proposed model ($\Delta\chi^2=7.68$, $df=1$, $p=.01$) [75].

All of the path coefficients were in the expected direction in both models. However, regardless of significance, the path coefficients tended to be somewhat small. It should also be noted that despite its excellent fit statistics, Model 2 explained 10% of the variance in time spent television viewing ($R^2=.102$). When the variance explained by covariates is removed, Model 2 explained 8% of the variance in television viewing ($R^2=.079$). The magnitude of the effects found in this study echo those of existing studies examining obesity and television viewing in youth, in which small to extremely small effect sizes are the norm rather than the exception [6-9,16].

However, there are two notable exceptions in Model 2 (Figure 2). Time spent with friends was negatively related to time spent viewing television without friends ($\beta=-.26$), and positively related to time spent in MVPA

Table 2. Correlation matrix for all variables in the model

	1	2	3	4	5	6	7	8
1. Child Age								
2. Child Gender ^a	-0.06							
3. Child Ethnicity ^b	-0.06	-0.03						
4. Income-to-Needs Ratio	0.03	-0.04	0.22					
5. Child Maturation Status	0.80	-0.18	-0.09	0.02				
6. Overweight & Obese ^c	-0.04	0.02	-0.16	-0.05	-0.02			
7. Time Spent with Friends ^d	0.26	-0.06	0.06	0.04	0.23	-0.11		
8. Moderate-to-vigorous Activity ^d	-0.04	0.21	0.07	-0.01	-0.05	-0.05	0.13	
9. Television Viewing without Friends ^d	-0.05	0.05	-0.11	-0.08	-0.04	0.12	-0.29	-0.09



($\beta = .20$). The relationship between time spent with friends and physical activity is well-established [37-40], and thus unsurprising. However, friendship measures of any kind are scarce to non-existent in the voluminous literature examining associations between obesity and screen media among youth [26]. Our findings suggest

that the omission of friendship indicators may be hindering more nuanced understandings of the relationship between television viewing and youth obesity.

Assessment of mediation

Estimates of the direct, indirect and total effects from model 2 are presented in Table 3. Blank cells in Table 3

Table 3. Direct, indirect, and total effect estimates of overweight/obese status, time spent with friends, and time spent in MVPA on time spent television viewing

	Model Outcomes									
	Time with Friends			Time in MVPA			Time Viewing TV without Friends			
	Coefficient (SE)	p value	95% CI	Coefficient (SE)	p value	95% CI	Coefficient (SE)	p value	95% CI	
Direct Effects:										
Overweight/Obese	-0.279 (0.114)	0.015	(-0.50, -0.06)	-0.096 (0.054)	0.074	(-0.20, 0.01)	0.246 (0.093)	0.008	(0.06, 0.42)	
Time in MVPA	-	-	-	-	-	-	-0.091 (0.038)	0.017	(-0.17, -0.02)	
Time with Friends	-	-	-	0.095 (0.019)	0.000	(0.05, 0.13)	-0.214 (0.020)	0.000	(-0.25, -0.18)	
Indirect Effects:										
Overweight/Obese	0	0	0	-0.027 (0.011)	0.015	(-0.05, -0.01)	0.071 (0.026)	0.006	(0.02, 0.12)	
Time in MVPA	-	-	-	-	-	-	0	0	0	
Time with Friends	-	-	-	0	0	0	-0.009 (0.002)	0.000	(-0.012, -0.005)	
Total Effects:										
Overweight/Obese	-0.279 (0.114)	0.015	(-0.50, -0.06)	-0.123 (0.055)	0.026	(-0.23, -0.01)	0.317 (0.097)	0.001	(0.13, 0.51)	
Time in MVPA	-	-	-	-	-	-	-0.091 (0.038)	0.017	(-0.17, -0.02)	
Time with Friends	-	-	-	0.095 (0.019)	0.000	(0.06, 0.13)	-0.222 (0.019)	0.000	(-0.26, -0.18)	

Note. Effect coefficients are presented in unstandardized form.

represent associations which were not specified in model 2. As noted, direct effects represent unmediated associations between variables, while indirect effects represent combined mediated effects (e.g., the indirect relationship between variables via all specified mediators combined). All direct associations examined in the model were significant except one – overweight/obese status was not directly related to time spent in MVPA, a finding already reflected in Figure 2. The indirect relationship between overweight/obesity and time spent in MVPA via time spent with friends was significant, as was the indirect relationship between overweight/obesity and time spent watching television. The proportion of the relationship between overweight/obesity and MVPA mediated by time spent with friends was .21, while the proportion of the relationship between overweight/obesity and television viewing mediated by time spent with friends and MVPA combined was .22. This suggests that mediated associations between overweight/obesity and television viewing were driven almost entirely by time spent with friends. This conclusion is further supported by product-of-coefficient tests estimating mediation between overweight/obesity and television viewing via time spent with friends and time spent in MVPA separately. These analyses indicated that the mediated relationship of overweight/obesity and television via time with friends was .057 (SE = .011, p=.014, 95% CI .03-.08) while the mediated relationship of overweight/obesity and television via time spent in MVPA was .013 (SE = .014, p=.231, 95% CI -.13-.04).

Discussion

In this study we examined an alternative to the often proposed notion that television viewing increases childhood obesity via increased caloric intake, decreased physical activity, or both. Existing evidence of associations among

friendship, physical activity and youth obesity [9,19-25], as well as evidence linking these factors to television viewing served as the bases for our proposal that obese youth, who have fewer friends and are thus less active, tend to watch more television as a default activity (Model 1).

Overall, we found reasonable evidence to suggest that elevated weight status may well be related to television viewing through social factors such as friendships. Overweight/obese status was negatively related to time spent with friends, which in turn was positively related to time spent in MVPA and negatively related to television viewing without friends. Time spent in MVPA was negatively related to television viewing without friends. Time spent with friends significantly mediated the relationship between overweight/obesity and television viewing. On the other hand, Overweight/obesity was not related to time spent in MVPA, nor was there a mediated effect of MVPA on the relationship between overweight/obesity and time spent viewing television.

However, we also found that overweight/obesity remained directly related to television viewing without friends, over and above any indirect effects via either time with friends or time spent in MVPA. This suggests that some important but as yet unidentified mechanism linking obesity to television viewing may be operating. Given that our measure of television viewing reflected viewing without friends present, it seems likely that the direct relationship between obesity and viewing without friends may reflect an aspect of friendship not captured in these data.

Limitations

There are several limitations worth noting. First, as the data were all drawn from the same time period, temporal or causal associations cannot be assessed. We view

these findings as a first step to assessing more fully how the associations among obesity, friendships, physical activity and television viewing unfold overtime. Second, in this paper we focus specifically on time spent television viewing for two reasons, (1) the vast majority of existing research in this area focuses specifically on associations between youth obesity and television viewing [81,82], and (2) despite media reports and popular opinion, television viewing still occupies the largest amount of time youth spend with screen media [83,84]. However, it is clear that youth are also engaged in other forms of screen media, including those on mobile platforms [83]. Preliminary analyses examining the proposed model with either time spent playing videos games or computer use indicated large variation between models including each type of screen media, differences found by others as well [85-87]. Thus, while we believe that examining models including various types of media use is important and needed, these multiple examinations are beyond the scope of this paper, and will be reserved for future work. Moreover, the year these data were collected (2002) does not allow us to examine newer forms of media popular with youth, such as mobile devices and social media. This will be an important area for future inquiry. In addition, we examined only one aspect of friendships-hours per week that youth spend time with friends. There is evidence to suggest that other aspects of friendships, such as the quality of youth friendships and perceptions of social support by friends, are related to both childhood overweight and obesity [26,35,88,89]. This is also true of peer group factors, such as experiences in school [90-92]. Thus, it will be important to assess exactly how these different aspects of social relationships may influence associations between obesity and media use, and the ways in which these influences unfold over time as children develop. Finally, because gender, age, ethnicity and SES were treated as covariates in these analyses, it will be important to assess the extent to which associations might vary by these factors (by gender or developmental stage for example) in future research.

Conclusions

Despite a great deal of empirical work, evidence for the hypothesis that television must cause elevated weight status via physical activity or caloric intake has proven remarkably elusive [9,19-25]. For example, there is little evidence supporting the notion that physical activity is importantly related to television viewing [23], a finding replicated in this study. Additionally, empirical assessment of the mediating effects of physical activity or caloric intake on associations between media use and youth obesity are surprisingly scarce [93]. We would like to call attention again to the fact that the magnitude

of associations between overweight/obesity and television viewing, as well as the proportion of variance explained in this study were fairly small. Though rarely discussed, small (though significant) associations between weight status and television viewing in youth is quite common in this literature, as evidenced by several meta-analyses [81,82].

Taken together, our results indicate that including friendship measures is important for future attempts to “unpack” relationships between obesity and television viewing. Our findings do not negate the possibility that television viewing is linked to obesity via other mechanisms such as increased caloric intake. Rather, they underscore the importance of moving from examinations of simple or bivariate relationships between television viewing and weight status, to models aimed at identifying key mechanisms mediating their relationship. They also underscore the importance of considering other pathways, such as friendships, through which screen media might be related to obesity. Finally, our results suggest the possibility that interventions focused on youth obesity might benefit from re-thinking the pervasive commitment to decreasing screen-time via careful attention to peer and friendship dynamics.

List of abbreviations used

CDS: Child Development Supplement; PSID: Panel Study of Income Dynamics; BMI: body mass index; NHANES: National Health and Nutrition Examination Surveys; MET: metabolic equivalent of task; PA: physical activity; PAL: physical activity level; MVPA: moderate-to-vigorous physical activity; ATUS: American Time Use Survey; CRPBI: Child Report of Parent Behavior Inventory

Competing interests

The authors declare that they do not have competing interests.

Authors' contributions

EV and SEP conducted the statistical analysis and interpretation of results, and contributed to the writing and editing of the manuscript. EH and HC contributed to the writing and editing of the manuscript. All authors have read and approved the final manuscript.

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Declarations

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Authors' details

¹Michael & Susan Dell Center for Healthy Living, The University of Texas School of Public Health Austin Regional Campus, 1616 Guadalupe St., Austin, TX 78701, USA. ²Harvard University, 677 Huntington Avenue, Kresge Building, 7th Floor, Boston, MA 02115, USA.

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