Title

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Body mass index, new modes of TV viewing, and active video games

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Abstract

Background—Recent technologies have changed screen time. TV can be viewed anywhere, anytime. Content can be collected via digital recorders and online streaming and viewed on smartphones. Video games are no longer strictly sedentary.

Objective—We sought to assess the unknown relations between new modes of TV viewing—recorded, online, downloaded, and on hand-held devices—and active video games with BMI.

Methods—Cross-sectional analysis of the 2011 wave of the Growing Up Today Study 2 cohort. We used gender-specific generalized estimating equations to examine screen time and BMI among 3,071 females and 2,050 males aged 16–24 years.

Results—Among females, each hour/day of online TV (0.47; CI: 0.12, 0.82) and total non-broadcast TV (0.37; CI: 0.14, 0.61) was associated with higher BMI, as was watching ≥½ h/week of TV on hand-held devices (1.04; CI: 0.32–1.77). Active video games were associated with BMI among females, but not after restricting to those not trying to lose/maintain weight. Broadcast TV was associated with higher BMI (kg/m^2) among females and males ($P<0.05$).

Conclusions—Among females, online TV, TV viewed on hand-held devices, and the sum of non-broadcast TV time were associated with higher BMI. Broadcast TV was also associated with BMI in females and males.

Keywords

Adolescent; young adult; television; video games; obesity; body mass index

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Conflicts of Interest Statement

Drs. Falbe, Willett, Rosner, and Field have nothing to disclose.

Introduction

In 2011, Americans spent more time watching TV than with any other leisure activity—a pattern that has remained unchanged since 2003.[1] What has changed is the way individuals are accessing and consuming media. Among young adults, time spent viewing digital video content increased 53% from 2013 to 2014.[2] Among adolescents, despite declines in broadcast TV viewing, total TV time increased from 2004–2009 due to higher viewing of recorded and on demand TV, videos on digital versatile discs (DVDs) and online, and downloaded or streaming content on hand-held devices.[3]

Observational studies and interventions provide strong evidence that watching TV increases adiposity among adults[4] and youth,[5,6] in part by promoting poor diets and excess energy intake through advertising for unhealthy foods/beverages.[7–9] In contrast, non-broadcast TV exposes viewers to fewer traditional commercials. For example, TV shows on DVD are typically commercial free except for commercials at the beginning; many digital video recorders (DVRs) allow fast-forwarding through commercials; and websites like Hulu (www.Hulu.com) stream TV shows with fewer commercial minutes than broadcast shows.[10] In response to such technologies, food companies are spending increasing amounts of money on product placements.[11] Because of these differences in marketing and lack of studies collecting data on exposure to new TV-viewing technologies, it is unclear how new modes of TV viewing would be related to BMI.

Also, other technological advances, such as active video games, have the potential to reduce unhealthy weight gain if they displace TV time or sedentary games. However, active games may have the opposite impact if they displace vigorous physical activity.

To our knowledge, no large observational studies have examined relations of these new forms of screen time with BMI among young people. We sought to assess associations of time spent watching TV through different modes (broadcast, recorded, online, downloaded and on hand-held devices) and active and sedentary video game time with body mass index (BMI). We assessed these aims in participants of the Growing Up Today Study (GUTS) 2 aged 16–24 years.

Methods

Participants were members of GUTS2, an ongoing cohort of adolescents. To recruit participants, investigators sent letters explaining the study to 20,700 mothers from the Nurses' Health Study 2 (NHS2) who had children aged 9–15 years. Invitation letters and questionnaires were mailed to 8,826 females and 8,454 males whose mothers had granted written consent. Of those invited, 6,002 females and 4,917 males returned completed questionnaires, assenting to participate. Follow-up questionnaires were sent in 2006, 2008, and 2011. A total of 3,899 females and 2,760 males returned questionnaires in 2011. The primary analysis was limited to those with complete data on screen time and BMI from the 2011 questionnaire. Females reporting a pregnancy in the survey year or year prior were excluded. Additional exclusions are described below. The study was approved by the Human Subjects Committee at Brigham and Women's Hospital, and the analyses presented in this

article were approved by the institutional review boards at Brigham and Women's Hospital and Boston Children's Hospital.

Outcomes

The primary outcome was BMI (kg/m^2) calculated from self-reported height and weight, which has been validated.[12] Since 85% of the sample was ≥18 years of age, it was more appropriate to use BMI (which serves as the basis for adult obesity cut-offs) than BMI z-score as the outcome. We excluded those with BMI<12 kg/m^2, the biological lower limit based on clinical opinion, and those with outlying BMI identified using the generalized extreme Studentized deviate many-outlier procedure.

Exposures

Exposures were hours/day of different TV viewing modes and hours/day of sedentary and active video games. Time spent watching TV through the following ways was assessed: broadcast TV (watching TV shows/movies when they are broadcast), recorded TV (shows/movies that have been recorded [e.g, by DVR]), online TV (shows/movies on websites like Hulu), downloaded TV (shows/movies that have been downloaded or available on demand or on DVD), and TV on hand-held devices (shows/movies on smartphones or tablets). We also assessed time playing sedentary video games (computer/console/online) and time playing active video games (e.g., W2 Fit, DDR, Rock Band). For each media, participants could select from options ranging from 0–61+ hours/week, which were divided by 7 to obtain hours/day. We also examined the sum of non-broadcast TV in relation to BMI. Non-broadcast TV was calculated by summing hours/day across all modes of viewing except broadcast. A similar instrument assessing traditional screen time was moderately correlated with a 24-hour activity recall (r=0.54).[13] We excluded observations with implausibly high total TV time (>10 hours/day).

Covariates

Hours/week of moderate-to-vigorous recreational physical activity (≥3 metabolic equivalents) was assessed by asking participants to recall the amount of time/week within each season over the past year they engaged in 18 activities. A compendium was used to classify activities as moderate-to-vigorous.[14] Implausible estimates (i.e., >40 hours/week) were reassigned to 40 hours/week; (n=10 females and 21 males).

Race/ethnicity was self-reported and categorized as non-Hispanic white (yes or no) or missing due to small sample size in non-white groups. Quintile of parental census tract median income was determined by the home address of the participant's mother in 2009 and was used as an indicator of SES. Surveys also assessed participant's current living arrangement: with parents, in an apartment or house with others (not family) or a partner, in a dorm, in a sorority or fraternity, alone, or other. Frequency of dieting was assessed by asking, 'In the past year, how often did you go on a diet to lose weight or keep from gaining weight?' Responses were categorized as never, a couple to several times, or often/always. In secondary analyses, to address whether associations with active video games could be explained by youth using active video games in order to control weight, we restricted the sample to those not trying to lose or maintain weight, which was assessed by asking, 'In the

past year, did you try to lose weight or keep from gaining weight?' Missing indicators were used for missing race/ethnicity, living arrangement, and dieting data. We also examined frequency of smoking as a covariate, but results from models including smoking suggested that it did not confound the relationships examined. Therefore, frequency of smoking was not retained in final models.

Sample

A total of 3,126 females and 2,060 males had complete data on screen time and BMI. We excluded 33 females reporting a pregnancy in the survey year or year prior. Additionally, we excluded 19 females and 8 males with outlying or implausible BMIs and 3 females and 2 males reporting implausible TV time. After exclusions, the analytic sample for assessing screen time and BMI included 3,071 females and 2,050 males

Statistical Analysis

Gender-specific multivariate linear regression models were used to examine relations of screen time with BMI. To account for correlations between siblings, we used generalized estimating equations specifying a compound symmetry covariance structure. Regression models assessing associations between different modes of TV viewing and BMI adjusted for age, age^2, race/ethnicity, hours/week of moderate-to-vigorous physical activity, hours/day of sedentary video games, hours/day of active video games, frequency of dieting, quintile of parental census tract median income, and living arrangement. All models, except those examining total and non-broadcast TV, simultaneously included continuous terms for broadcast, recorded, online, and downloaded TV (hours/day) and a dichotomous term for TV on hand-held devices. Because so few participants reported viewing on phones or tablets, we modeled TV viewing on hand-held devices as a dichotomous predictor (≥½ vs. <½ hour/week).

Models examining associations of video games with BMI adjusted for age, age^2, race/ethnicity, physical activity, dieting, quintile of parental census tract median income, living arrangement, and total hours/day of TV. These models included terms for both sedentary and active games. Since those trying to lose weight may take up active video gaming as a means to lose weight, biasing estimates upward, we also examined associations among only those not trying to lose/maintain weight and compared estimates to the main analysis. In these models, we did not adjust for frequency of dieting, as there were no dieters in this subgroup. All analyses were conducted with SAS (version 9.2; SAS Institute, Cary, NC, USA).

Results

Table 1 summarizes subject characteristics in 2011. Participants were aged 16.1–24.7 years and 92.8% non-Hispanic white, reflecting the racial/ethnic distribution of their mothers in NHS2. Males reported more time physically active, playing sedentary video games, and watching TV on hand-held devices than did females. A larger proportion of females than males reported trying to lose or maintain weight (73.4% vs. 36.7%). Females were also more likely than males to report dieting over the past year. In this population, participants watched more non-broadcast (67%) than broadcast TV (33%), and more time was spent watching

online TV (25% of total TV time) than any other forms of non-broadcast TV (Supplemental Figure 1).

Among females but not males, there was a very weak inverse correlation between total TV time and physical activity (Spearman r=−0.07). Among females and males, time spent with sedentary video games was very weakly and inversely associated with time spent physically active (Spearman r=−0.10). Among males only, active video games was very weakly associated with physical activity (Spearman r=0.05).

Among females, greater time spent watching broadcast, online, and total non-broadcast TV was associated with higher BMI (Table 2, Supplemental Figure 2): each hour/day of broadcast TV was associated with a 0.26 kg/m^2 (95% confidence interval [CI]: 0.00, 0.51) higher BMI; each hour/day of online TV was associated with a 0.47 (CI: 0.12, 0.82) higher BMI; and each hour/day of the sum of non-broadcast TV was associated with a 0.37 (CI: 0.14, 0.61) higher BMI. Among males, only broadcast TV was significantly associated with higher BMI (0.52; CI: 0.17, 0.87). The magnitude of the coefficient for online TV (0.45; CI: −0.09, 0.99) among males was not significant but was similar to that in females. Recorded and downloaded TV was not associated with BMI in either gender. Among females only, watching >½ hour/week of TV on hand-held devices was associated with higher BMI (1.04; 95% CI: 0.32, 1.77).

Relationships of sedentary and active video games with BMI are presented in Table 3. Among females, active but not sedentary video game time was positively associated with BMI. However, when analyses were restricted to those not trying to lose/maintain weight, active video game playing was no longer associated with BMI (0.80, 95% CI: −2.52, 4.13).

Discussion

More time spent watching TV—particularly broadcast TV—was significantly associated with higher BMI among 5,121 adolescents and young adults from across the US. A novel finding of this study is that online TV time, TV viewed on hand-held devices, and the sum of non-broadcast TV time were also significantly associated with higher BMI among females only. For males, while associations between these forms of TV time and BMI were positive, they were not significant. Among females, active video game playing was associated with higher BMI, but this significant association disappeared in analyses restricted to females not trying to lose/maintain weight.

Traditionally, screen time research has focused on broadcast TV, in large part because the introduction of alternative modes of viewing occurred only recently in time. Broadcast TV has also been targeted because it exposes viewers to more traditional commercials than, say, watching videos on DVD, and the largest proportion of food marketing expenditures for unhealthy foods is still dedicated to TV commercials.[15] We found that in addition to time with broadcast TV, time with non-broadcast TV, particularly online TV and TV viewed on hand-held devices, was also associated with higher BMI among females. Because these relationships were observed after adjustment for physical activity, they may be the consequence of excess energy intake, consistent with experimental evidence on the influence

of food marketing on diet.[7,8] Dietary intake may have been influenced by exposure to food/beverage product placements within shows and movies. For instance, food and beverage companies have poured millions of dollars into product placements on "American Idol," "The Big Bang Theory," and other popular TV shows that can be downloaded, digitally recorded, or viewed online or on DVD.[16] This ensures that no matter when or how a show is watched, viewers are exposed to brand advertising.

In addition to product placements, commercials may also explain observed associations between online TV viewing and BMI. Websites that stream TV content contain commercials, including interactive ads with links to company websites.[10] The interactive nature of these commercials may increase their influence on behavior. Another potential mechanism explaining observed associations is that TV provides a distraction that can result in higher intake in current[17] and subsequent[18] eating occasions and may affect memory of consumption[18] and appetite.[19] However, stronger associations with BMI for modes of viewing (broadcast and online) likely containing the most marketing suggest a potential additional impact of advertising in this study.

Our finding that among females, the association between active video games and BMI disappeared in analyses restricted to those not trying to lose/maintain weight, suggests the possibility that, as opposed to active video games inducing weight gain, those trying to lose/maintain weight may have taken up active gaming to control their weight. This direction of association is plausible, given evidence from two trials[20,21] that active video games can contribute to healthier BMI or body fat trajectories among youth. However, another trial detected no benefits on BMI of active video games,[22] and in a recent exergaming trial for adolescent girls, only adherers significantly decreased adiposity.[23] This trial was novel because girls could self-select their intensity level of exergaming, but it was limited by a small sample size (n=41).[23] Thus, based on available evidence, the effectiveness of active gaming for weight control remains uncertain. Additionally, neither of two interventions[24,25] detected effects of active gaming on total physical activity. So, while active video games can result in moderate energy expenditure in youth[26] and adults[27] this activity may be partially compensated for by reduced activity at other times. There is also conflicting evidence on whether obese youth may have less of an energy expenditure benefit from active gaming than their leaner peers.[28,29] Another area of uncertainty is the impact of exergaming on weight in adults, since research in this area has focused on children and adolescents. More longitudinal and experimental studies are needed to investigate relations of active video games with adiposity, sedentary time, total physical activity, and energy intake, and how these may differ by population characteristics like age and weight status.

Our study was limited by the cross-sectional design, obscuring the direction of association. However, cross-sectional relationships between new forms of screen-based media and adiposity in this study were in the same direction as associations between traditional forms of screen time (e.g., TV, total screen time, and video games) and adiposity observed prospectively in other studies.[5,6] The generalizability of our results may be limited because GUTS2 includes few children of color and low socioeconomic status. Screen time and BMI reported in this population is lower than national averages; however, it is unlikely that the biological relationships between screen time and BMI would differ in direction by

socioeconomic status, but magnitude may vary by food and physical activity environments, food access, and financial resources. Another limitation is that data were self-reported and likely to result in random error in screen time, attenuating associations. We also anticipate that self-reported weight was underestimated, particularly among obese individuals.[30] Nevertheless, self-reported weight has been highly correlated with measured weight.[12] There may also have been unmeasured confounding (e.g., by health consciousness or other traits that affect BMI) that are related to screen time and/or screen modality of choice. Additionally, we did not have measures of media content or type of active games played; thus we do not know the advertisements or product placements to which the participants were exposed or energy expenditure for games played. Lastly, other increasingly popular screen-based diversions, like social media usage, were not measured in the study. This study also has several strengths, including a large sample size of adolescents and young adults living across the US and novel data on time spent using a range of methods for watching TV and playing video games.

To our knowledge, this is the first large cohort study to assess relations of new ways of watching TV and active video games with BMI. While future studies are necessary to examine these associations longitudinally, our results suggest the possibility that exposure to non-broadcast TV content, such as TV shows accessed through online streaming, may be linked to adiposity.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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JF designed, conceptualized, and carried out the analysis, interpreted the data, drafted the manuscript, and revised the manuscript. WCW and BR contributed to the analysis and interpretation. AEF contributed to the concept, design, analysis, and interpretation and supervised the analysis. All authors were involved in the editing and revising of the article and approve of the submitted and published versions.

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Abbreviations

TV	television
DVD	digital versatile disc
DVR	digital video recorder
BMI	body mass index
GUTS	Growing Up Today Study

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What is already known on this subject

- Among young people, associations between both broadcast TV viewing and sedentary video game playing with BMI have been detected across multiple studies.
- However, associations with BMI of new modes of TV viewing and of active video games are unknown.

What this study adds

- Among females, TV viewed online and on hand-held devices and total non-broadcast TV time were associated with higher BMI.
- We did not find a meaningful association between active video gaming and BMI.

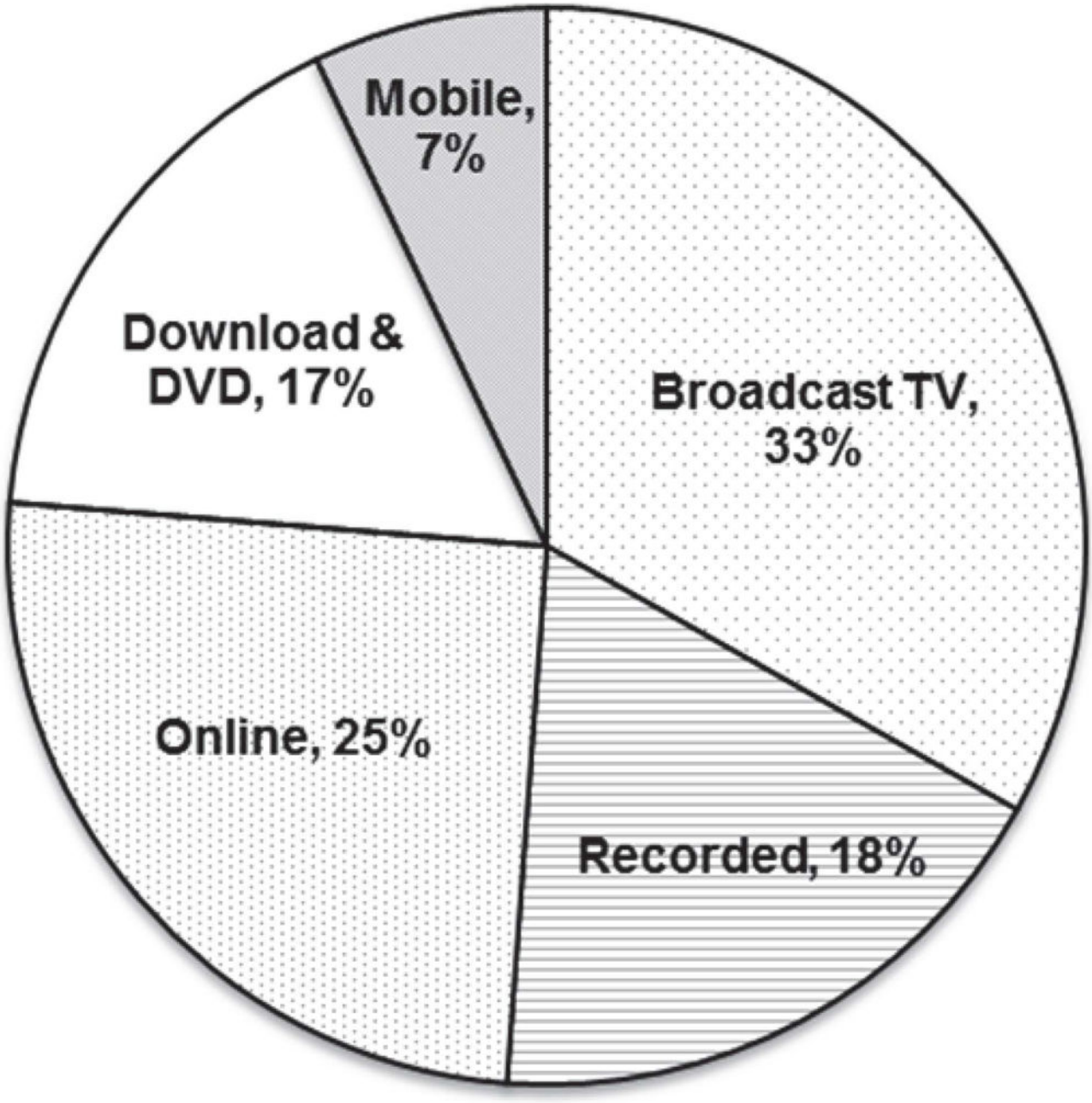

Figure 1.
Mean proportion of TV content consumed via different platforms and devices (n=5,121)

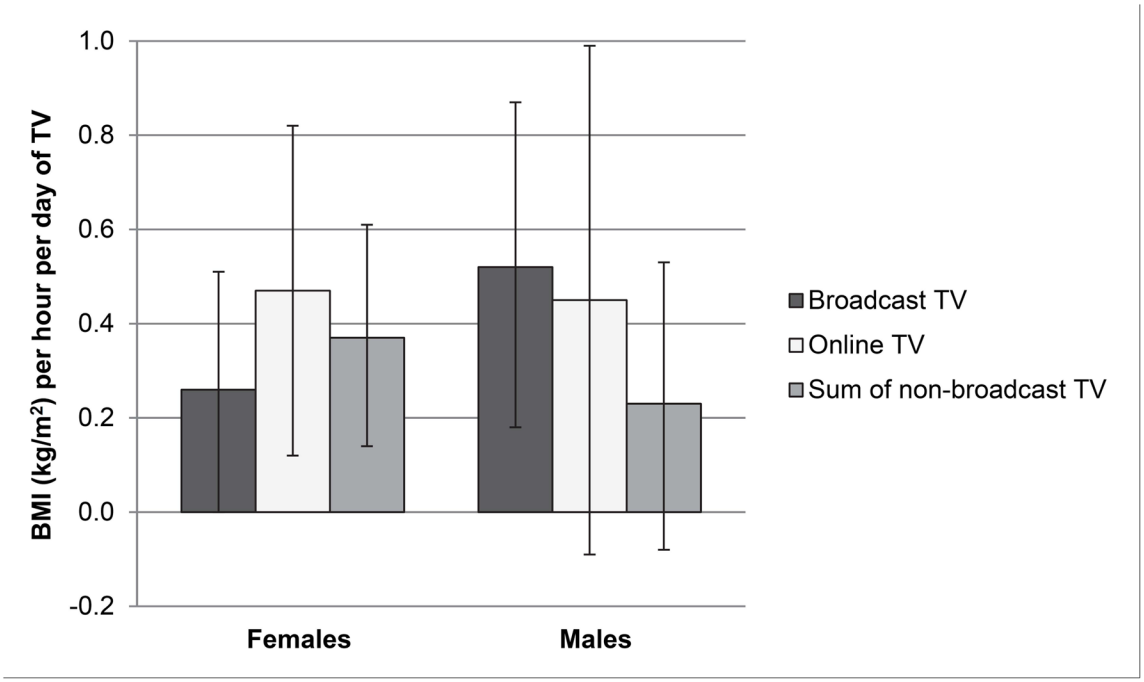

Figure 2.

Error bars represent 95% confidence intervals. Estimated from multivariate linear regression models using generalized estimating equations for estimation, adjusted for age, age^2, non-Hispanic white race/ethnicity, recreational moderate-vigorous physical activity (h/week), watching ≥1/2 h/week of TV on a hand-held device, sedentary video game time (h/d), active video game time (h/d), frequency of dieting, quintile of parental census tract median income, and living arrangement. Models examining broadcast, recorded, online, and downloaded TV simultaneously included all modes of TV viewing. Models assessing the sum of non-broadcast TV adjusted for broadcast TV.

Table 1

Characteristics of Growing Up Today Study 2 participants in 2011

	Females (n=3,071)		Males (n=2,050)	
	Mean±SD or %	50th (10th, 90th) percentile	Mean±SD or %	50th (10th, 90th) percentile
Characteristics				
Age, years	20.3±1.8	20.4 (17.7, 22.7)	20.1±1.9	20.1 (17.5, 22.6)
Non-Hispanic white[a]	93.2		92.2	
BMI, kg/m^2	23.2±4.2	22.5 (18.8, 28.5)	24.5±5.0	24.1 (18.6, 30.8)
Obese[c]	6.6		11.6	
Overweight or obese[c]	24.9		40.5	
Physical activity,[d] **h/wk**	7.8±6.6	6.1 (1.1, 16.3)	10.1±8.1	8.3 (1.3, 21.1)
Trying to lose/maintain weight[a]	73.4		36.7	
Dieting in the past year[a]				
Often or always	12.3		5.1	
Couple to several times	39.7		19.4	
Never	48.0		75.6	
Smokes at least weekly	4.3		6.5	
Parental census tract median income,[e] **$1,000**	71±26	67 (43, 103)	73±27	67 (44, 105)
Living arrangement				
Parents	38.7		48.4	
In apartment or house with others (not family) or partner	30.9		24.9	
Dorm	25.1		21.6	
Sorority or fraternity	1.9		2.4	
Alone	2.9		1.9	
Other	0.5		0.8	
Types of TV viewing				
TV broadcast, h/day	0.39±0.67	0.11 (0.04, 1.14)	0.44±0.70	0.11 (0.04, 1.14)
TV recorded, h/day	0.20±0.44	0.04 (0.04, 0.50)	0.20±0.41	0.04 (0.04, 0.50)
TV online, h/day	0.27±0.47	0.11 (0.04, 0.50)	0.26±0.49	0.11 (0.04, 0.50)
TV download, h/day	0.17±0.30	0.04 (0.04, 0.50)	0.21±0.40	0.04 (0.04, 0.50)
TV hand-held (≥½ h/week)	5.8		13.2	
Sum of types of TV, h/day	1.08±0.98	0.71 (0.25, 2.21)	1.18±1.1	0.79 (0.25, 2.39)
Video games				
Sedentary games, h/day	0.11±0.37	0.04 (0.04, 0.11)	0.66±1.18	0.11 (0.04, 2.21)
Active games, h/day	0.06±0.11	0.04 (0.04, 0.11)	0.10±0.27	0.04 (0.04, 0.11)

[a] Calculation of percentage does not include individuals with missing values in the denominator.

[c] Based on age- and sex-specific cutoffs defined by the International Obesity Task Force for youth <18 years of age and World Health Organization standards for adults (≥25 kg/m^2 for overweight and ≥30 kg/m^2 for obese).

[d] Moderate-to-vigorous recreational physical activity (≥3 Metabolic equivalents).

[e] Determined from mother's home address in 2009.

Table 2

Associations[a] between different modes of TV viewing and BMI

	BMI (kg/m^2)			
	Females (n=3,071)		Males (n=2,050)	
	β[b]	(95% CI)	β[b]	(95% CI)
Broadcast TV, h/d	0.26*	(0.00, 0.51)	0.52**	(0.17, 0.87)
Recorded TV, h/d	0.28	(−0.06, 0.62)	−0.08	(−0.61, 0.46)
Online TV, h/d	0.47**	(0.12, 0.82)	0.45	(−0.09, 0.99)
Downloaded TV, h/d	0.08	(−0.45, 0.62)	0.08	(−0.49, 0.65)
Sum of non-broadcast TV, h/d[c]	0.37**	(0.14, 0.61)	0.23	(−0.08, 0.53)

*P<0.05,

**P<0.01.

[a]From multivariate linear regression models using generalized estimating equations for estimation, adjusted for age, age^2, non-Hispanic white race/ethnicity, recreational moderate-vigorous physical activity (h/week), watching ≥1/2 h/week of TV on a hand-held device, sedentary video game time (h/d), active video game time (h/d), frequency of dieting, quintile of parental census tract median income, and living arrangement. Models examining broadcast, recorded, online, and downloaded TV simultaneously included all modes of TV viewing. Models assessing the sum of non-broadcast TV adjusted for broadcast TV.

[b]Units of BMI (kg/m^2) per hour/day of TV.

[c]Sum of recorded, online, and downloaded TV and TV viewed on hand-held devices.

Table 3

Associations[a] between time playing sedentary and active video games and BMI

	BMI (kg/m^2)							
	Females				Males			
	All (n=3,071)		Not trying to lose weight (n=862)		All (n=2,050)		Not trying to lose weight (n=1,319)	
	β[b]	(95% CI)	β[b]	(95% CI)	β[b]	(95% CI)	β[b]	(95% CI)
Sedentary games, h/d	0.28	(−0.29, 0.86)	0.21	(−0.28, 0.70)	0.10	(−0.11, 0.31)	0.08	(−0.19, 0.36)
Active games, h/d	2.69**	(0.90, 4.48)	0.80	(−2.52, 4.13)	0.44	(−0.26, 1.13)	0.62	(−0.19, 1.44)

** P<0.01

[a] From multivariate linear regression models using generalized estimating equations for estimation, adjusted for age, age^2, non-Hispanic white race/ethnicity, recreational moderate-vigorous physical activity (h/week), frequency of dieting, quintile of parental census tract median income, living arrangement, and total TV time (h/d). Models restricted to those not trying to lose or maintain weight did not adjust for frequency of dieting, since there were no dieters in this subgroup.

[b] Units of BMI (kg/m^2) per hour per day of video games.