Winter 2-2005

Longitudinal Invariance of the Center for Epidemiologic Studies-Depression Scale among Girls and Boys in Middle School

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Journal of Adolescence 29 (2006) 19–32
Journal of Adolescence
www.elsevier.com/locate/jado

Naturally occurring changes in time spent watching television are inversely related to frequency of physical activity during early adolescence

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Abstract

In this longitudinal study, we examined the relationship between changes in time spent watching television and playing video games with frequency of leisure-time physical activity across a 2-year period among adolescent boys and girls ($N = 4594$). Latent growth modelling indicated that a decrease in time spent watching television was associated with an increase in frequency of leisure-time physical activity. That relationship was strong in magnitude and independent of sex, socioeconomic status, smoking, and the value participants placed on health, appearance, and achievement. Our results encourage the design of interventions that reduce television watching as a possible means of increasing adolescent physical activity.
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Introduction

The prevalence of physical inactivity among adolescents in the US (Centers for Disease Control and Prevention, 2002) has been recognized as a public health burden (Sallis & Patrick, 1994), with

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0140-1971/$30.00 © 2005 Published by Elsevier Ltd. on behalf of The Association for Professionals in Services for Adolescents.
doi:10.1016/j.adolescence.2005.01.005

an emphasis on the increased rate of obesity (Wang & Dietz, 2002). There has been a longstanding concern that physical inactivity among adolescents is related to time spent watching television and playing video games (DiNubile, 1993; Kuntzleman, 1993). Adolescents spend approximately three hours per day in those activities (Woodard, 2000). Hence, reducing the amount of time that adolescents spend in sedentary behaviours represents a possible method for increasing physical activity levels (Epstein, 1998; Robinson, 1999; Steinbeck, 2001).

Evidence from cross-sectional studies supports an inverse association between time spent watching television and playing video games with physical activity (e.g. Pate, Heath, Dowda, & Trost, 1996; Trost et al., 1996; Bungum & Vincent, 1997; Strauss, Rodzilsky, Burack, & Colin, 2001; Lowry, Wechsler, Galuska, Fulton, & Kann, 2002). Evidence from two longitudinal studies, however, does not support an association between time spent watching television and physical activity (Robinson et al., 1993; Neumark-Sztainer, Story, Hannan, Tharp, & Rex, 2003). For example, baseline hours of after-school television viewing were not associated with a change in levels of physical activity across a 2-year period in a sample of 279 adolescent girls (Robinson et al., 1993). Likewise, change in television watching was not associated with change in levels of physical activity across an 8-month period in a sample of 201 adolescent girls (Neumark-Sztainer et al., 2003). Limitations of those studies included relatively small samples of only adolescent girls and a focus on solely the relationship between television watching and physical activity. More research is needed that includes a large sample of boys and girls and that examines sedentary leisure habits conceived more broadly as including both television watching and video game playing as independent correlates of longitudinal changes in adolescent physical activity. This is necessary before interventions are developed that target the transformation of time spent in sedentary activities into an increase in physical activity levels (Baranowski, Anderson, & Carmack, 1998; Sallis, Prochaska, & Taylor, 2000).

There are several factors that might confound an examination of the relationships among television watching, video game playing, and physical activity. Such factors include sex, socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement. For example, boys are more physically active and spend more time watching television and playing video games than girls, whereas parental income exhibits a positive association with physical activity and a negative association with time spent watching television and playing video games (Sallis et al., 2000; Woodard, 2000). Smoking has a negative association with physical activity (Pate et al., 1996) and a positive association with television watching (Gidwani, Sobol, DeJong, Perrin, & Gortmaker, 2002). The value participants placed on their health, appearance, and achievement has been positively and negatively associated with physical activity and sedentary leisure habits (television watching and video game playing), respectively, particularly among adolescent girls (Schmitz et al., 2002).

Herein, we examined the relationships between naturally occurring changes in time spent watching television and playing video games and the frequency of leisure-time physical activity across a 2-year period among a large cohort of adolescent boys and girls. We initially established the patterns of longitudinal change in leisure-time physical activity, television watching, and video game playing. We then examined the relationships changes among leisure-time physical activity, television watching, and video game playing accounting for the influence of sex. Finally, we examined the aforementioned relationships controlling for the possible confounding factors of socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement.

Method

Data

Analyses were conducted using data from the Teens Eating for Energy and Nutrition at School (TEENS) study (Lytle & Perry, 2001). The TEENS study was a school-based, group-randomized trial designed to alter cancer-related dietary risk behaviours in young adolescents in the Twin Cities, Minnesota. The TEENS study involved the evaluation of school-based environmental, classroom, and family interventions to increase fruit and vegetable intake and reduce fat intake in 7th and 8th grade students; the interventions did not target physical activity or sedentary leisure habits. Though the primary purpose of the TEENS study involved school-based environmental, classroom, and family interventions, the secondary goal involved an examination of correlates of change in physical activity and other behaviours (Schmitz et al., 2002).

School districts located within a 30-mile radius of the St. Paul, Minneapolis, MN, metropolitan area and with a minimum of 20% of students approved for the free/reduced lunch programme were eligible to participate in the TEENS study. Schools were required to have both 7th and 8th grades in one building and enroll at least 30 students in each of those grades. Fourteen districts (33 schools) were eligible and nine districts (20 schools) agreed to participate. One of the 20 schools was chosen for pilot evaluation, and three were judged ineligible because of scheduling conflicts. The remaining 16 schools formed the school sample for the study. The schools were randomized within pairs to intervention and comparison (delayed intervention) conditions. The pairs were matched on participation in free and reduced-price lunch programmes and proportion of 7th graders expected to be exposed to all intervention components.

Data were collected on three occasions over a 2-year period. The three occasions were Fall of 1998 (beginning of 7th grade; baseline data), Spring of 1999 (end of 7th grade; interim data), and Spring of 2000 (end of 8th grade; follow-up data). The sample consisted of 4594 adolescents who provided data on one or more of the three occasions. There were 3878 adolescents who completed the survey in 1998; 3798 students in 1999; and 3588 students in 2000. The students were balanced between females (49%) and males (51%) and primarily were White (62.6%), with additional racial categories of African-American (13.8%), Hispanic (3.8%), Asian (7.2%), Native American (1.7%), Multiethnic (6.5%), and other (4.4%).

Measures

Physical activity was measured by a single-item that has been sensitive to detecting intervention effects (Kelder, Perry, & Klepp, 1993) and effective in the tracking of physical activity among youth (Kelder, Perry, Klepp, & Lytle, 1994). The item, "Do you get some regular physical activity outside of school? By regular we mean at least three times a week for at least 20 min at a time.," was rated using a five-point scale with anchors of *Most of the time* (1), *Usually* (2), *Once in a while*

(3), *Hardly ever* (4) and *Never* (5). The item was reverse scored such that higher scores reflected more frequent physical activity outside of school. The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.69. This supports that the relative rank ordering of the participants' frequency of physical activity was moderately stable across time.

Time spent watching television was measured by two items, "How many hours per day do you usually watch television during the *weekdays*?" and "How many hours per day do you usually watch television during the *weekends*?." The items were rated using a five-point scale with anchors of *I don't watch TV during the weekdays/weekend* (1), *Less than one hour per day* (2), *One to two hours per day* (3), *Three to four hours per day* (4), and *More than four hours per day* (5). Scores from the two items were summed to form an overall measure of time spent watching television. The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.82, supporting that the relative rank ordering of participants' time spent watching television was moderately stable across time.

Time spent playing video games was measured by two items, "How many hours per day do you usually play video games (including hand-held video games and computer games) during the *weekdays*?" and "How many hours per day do you usually play video games (including hand-held video games and computer games) during the *weekends*?." The items were rated using the same aforementioned five-point scale. Scores from the two items were summed to form an overall measure of time spent playing video games. The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.78. Once again, the relative rank ordering of the participants' time spent playing video games was moderately stable across time.

Smoking behaviour was measured by a single item, "How frequently have you smoked cigarettes during the *past 30 days*?" This item was rated using a seven-point scale with anchors of *Not at all* (1), *Less than one cigarette per day* (2), *One to five cigarettes per day* (3), *About one-half pack per day* (4), *About one pack per day* (5), *About one and one-half packs per day* (6), and *Two packs or more per day* (7). The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.54, and this supported that the moderate stability of the relative rank ordering of the participants' smoking behaviour across time.

Socioeconomic status was measured as a trichotomous index (Birnbaum et al., 2002). The index was based on combining four variables: participation in free or reduced-price lunch meal programme at school, the highest level of education for mother and father, the number of parents the student reported living with, and number of parents who worked full-time (Birnbaum et al., 2002). The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.81. Thus, the relative rank ordering of the participants' socioeconomic status was moderately stable across time.

The value participants placed on their health, appearance, and achievement was measured using a seven-item scale (Birnbaum et al., 2002). An example item is "How well I do in school is very important to me." The seven items were rated on a five-point scale with anchors of *Strongly disagree* (1) and *Strongly agree* (5). Scores from the items were summed to form a single composite score. The test–retest reliability, based on an intraclass correlation, of the single-item measure across time was 0.66. This too supports that the relative rank ordering of the participants' values was moderately stable across time.

Latent growth modelling

We used latent growth curve modelling (LGM; Meredith & Tisak, 1990; Willett & Sayer, 1994; Lance, Vandenberg, & Self, 2000) to examine (a) the patterns of change in physical activity, watching television, and playing video games separately across time; (b) the consequence of a change in watching television and playing video games on a change in physical activity; and (c) possible confounding influences on the relationship between changes in physical activity, watching television, and playing video games. The LGM analyses were performed using LISREL 8.50 with full-information maximum likelihood estimation (Jöreskog & Sörbom, 1996) which is an appropriate and optimal method for the treatment of missing data in covariance modelling (Arbuckle, 1996; Enders & Bandalos, 2001; Enders, 2002), particularly in applications of longitudinal modelling with missing data (Wothke, 2000).

LGM is a two-stage process that invokes a confirmatory factor analytic framework on variables measured longitudinally. The first stage of LGM involves examining the pattern of change on a variable of interest, for example physical activity, across time. This first stage can be used to test for heteroscedastic (i.e., $\varepsilon_{11} \neq \varepsilon_{22} \neq \varepsilon_{33}$) and homoscedastic (i.e., $\varepsilon_{11} = \varepsilon_{22} = \varepsilon_{33}$) residuals, and linear (i.e., 0.0, 1.0, 2.0), quadratic (i.e., 0.0, 1.0, 4.0), or optimal (i.e., 0.0, 1.0, freely estimated) change functions.

The second stage of LGM involves examining the relationship between measures of television watching and physical activity, as an example. This model includes the first stage of LGM, plus the addition of paths (β-coefficients) between the initial status latent variables and between the change latent variables. All of the β-coefficients in this paper are presented as completely standardized parameter estimates, and thus can be more easily interpreted based on standardized units rather than the original metric of the variables.

Model fit

The fit of the models was evaluated with multiple indices. The chi-square (χ^2) statistic assessed absolute fit of the model to the data, but it is sensitive to sample size (Bollen, 1989; Browne & Cudeck, 1993). The root mean square error of approximation (RMSEA) represents closeness of fit (Browne & Cudeck, 1993). The RMSEA value should approximate or be less that 0.05 to demonstrate close fit of the model (Browne & Cudeck, 1993). The 90% confidence interval (CI) around the RMSEA should contain 0.05 to indicate the possibility of close model-data fit (Browne & Cudeck, 1993). The non-normed fit index (NNFI) and comparative fit index (CFI) are incremental fit indices, and test the proportionate improvement in fit by comparing the target model to a baseline model with no correlations among observed variables (Bentler & Bonett, 1980; Bentler, 1990). NNFI and CFI values approximating 0.95 were indicative of good model-data fit (Hu & Bentler, 1999).

Results

Descriptive statistics

The mean scores and standard deviations for the measures of physical activity, television watching, and video game playing across the three time points are provided for the overall sample and males and females separately in Table 1. The correlation coefficients among the measures of physical activity, television watching, and video game playing across the three time points for the overall sample are provided in Table 2.

Physical activity first-stage LGM

The growth in physical activity was best described by an optimal growth function with a homoscedastic residual structure. This model provided an excellent fit for the physical activity data (df = 2, $\chi^2 = 4.77$, $p = 0.09$, RMSEA [90% CI] = 0.017 [0.000–0.038], NNFI = 0.998, CFI = 0.998). The mean scores provided in Table 1 illustrate the curvilinear change in physical activity across time. There was a slight initial increase in physical activity at the interim measurement, followed by a lack of change in physical activity at the follow-up measurement.

Watching television first-stage LGM

The growth in watching television was best described by an optimal growth function with a heteroscedastic residual structure. This model, which was just identified (Bollen, 1989), provided an excellent fit for the data ($\chi^2 = 0.00$, df = 0, RMSEA = 0.000). The mean scores provided in Table 1 illustrate the curvilinear change in watching television across time. There was a large initial decrease in television watching at the interim measurement, followed by a smaller decrease in television watching at the follow-up measurement.

Table 1
Descriptive statistics for the measures of physical activity, television watching, and video game playing across time for the overall sample and males and females separately

Measure and time point	Overall		Boys		Girls	
	M	S.D.	*M*	S.D.	*M*	S.D.
Physical activity						
Baseline	4.22	1.12	4.36	1.07	4.08	1.15
Interim	4.33	1.06	4.43	1.04	4.23	1.07
Follow-up	4.30	1.05	4.45	1.01	4.15	1.07
Television watching						
Baseline	6.96	1.93	7.14	1.91	6.77	1.93
Interim	6.78	1.92	7.00	1.93	6.56	1.88
Follow-up	6.70	1.95	6.95	1.97	6.44	1.89
Video game playing						
Baseline	4.48	2.12	5.43	2.10	3.48	1.61
Interim	4.44	2.13	5.39	2.10	3.47	1.68
Follow-up	4.36	2.20	5.41	2.16	3.30	1.66

Note. The means are expressed as arbitrary units and do not reflect hours of participation.

Table 2
Correlation coefficients among the measures of physical activity, television watching, and video game playing across the three time points for the overall sample

	1	2	3	4	5	6	7	8	9
1. Activity baseline	1.00								
2. Activity interim	0.48	1.00							
3. Activity follow-up	0.46	0.47	1.00						
4. Television baseline	−0.12	−0.10	−0.10	1.00					
5. Television interim	−0.11	−0.13	−0.13	0.63	1.00				
6. Television follow-up	−0.15	−0.16	−0.21	0.53	0.62	1.00			
7. Video baseline	0.01	0.03	0.04	0.33	0.26	0.20	1.00		
8. Video interim	−0.04	−0.06	0.00	0.29	0.37	0.30	0.58	1.00	
9. Video follow-up	−0.01	−0.05	−0.02	0.23	0.27	0.36	0.52	0.57	1.00

Note. Correlations were computed using the saturated model and full-information maximum likelihood estimation in LISREL 8.50. Activity = physical activity; Television = time spent watching television; Video = time spent playing video games.

Video game playing first-stage LGM

The growth in video game playing was best described by an optimal change function and a homoscedastic residual structure. This model provided an excellent fit for the data ($\chi^2 = 0.93$, df = 2, $p = 0.63$, RMSEA [90% CI] = 0.000 [0.000–0.023], NNFI = 1.001, CFI = 1.000). The mean scores provided in Table 1 illustrate the curvilinear change in video game playing across time. There was an initial decrease in playing video games at the interim measurement, which was followed by a larger decrease in playing video games at the follow-up measurement.

Television watching, video game playing, and physical activity second-stage LGM

Next, we tested a model specifying direct effects of initial status and change factors for television watching and video game playing on initial status and change factors for physical activity, controlling for sex because it likely explains variance in television watching, video game playing, and physical activity and was a potential confounder of the relationships of interest. Based on our first-stage LGM analyses, physical activity and video game playing were both modelled as optimal change functions (i.e. 0.0, 1.0, freely estimated) with homoscedastic residuals (i.e., $\varepsilon_{11} = \varepsilon_{22} = \varepsilon_{33}$); television watching was modelled as an optimal change function with heteroscedastic residuals (i.e., $\varepsilon_{11} \neq \varepsilon_{22} \neq \varepsilon_{33}$). There were auto-correlations between uniquenesses for indicators of television watching and video game playing as both were measures of sedentary leisure time behaviours. Sex (coded as 0 = female and 1 = male) was modelled as an influence of the initial status and change factors for television watching, video game playing, and physical activity.

The model provided an excellent fit to the data (df = 25, $\chi^2 = 122.58$, $p < 0.001$, RMSEA [90% CI] = 0.029 [0.024–0.034], NNFI = 0.984, CFI = 0.991) and the completely standardized path coefficients between television watching, video game playing, and physical activity, but not sex, are provided in Fig. 1. With the physical activity initial status factor, there were statistically significant and negative direct effects from the television watching ($\beta_{5,1} = -0.23$) and video game playing ($\beta_{5,3} = -0.07$) initial status factors, and a positive direct effect from sex ($\beta_{5,7} = 0.24$). Thus, initially higher levels of television watching and video game playing were associated with initially lower levels of physical activity. With the physical activity change factor, there were statistically significant and negative direct effects from the television watching ($\beta_{6,2} = -0.55$) and video game playing ($\beta_{6,4} = -0.39$) change factors; the direct effect from sex was weak and not statistically significant ($\beta_{6,7} = 0.06$). Thus, change in television watching and video game playing across time were inversely associated with a change in levels of physical activity across time. There were statistically significant and positive direct effects between sex and watching television initial status ($\beta_{1,7} = 0.11$) and change ($\beta_{2,7} = 0.09$) factors as well as video game playing initial status ($\beta_{3,7} = 0.59$) and change factors ($\beta_{4,7} = 0.12$). Thus, the males reported higher initial levels of television watching and video game playing and larger changes in television watching and video game playing across time than did the females.

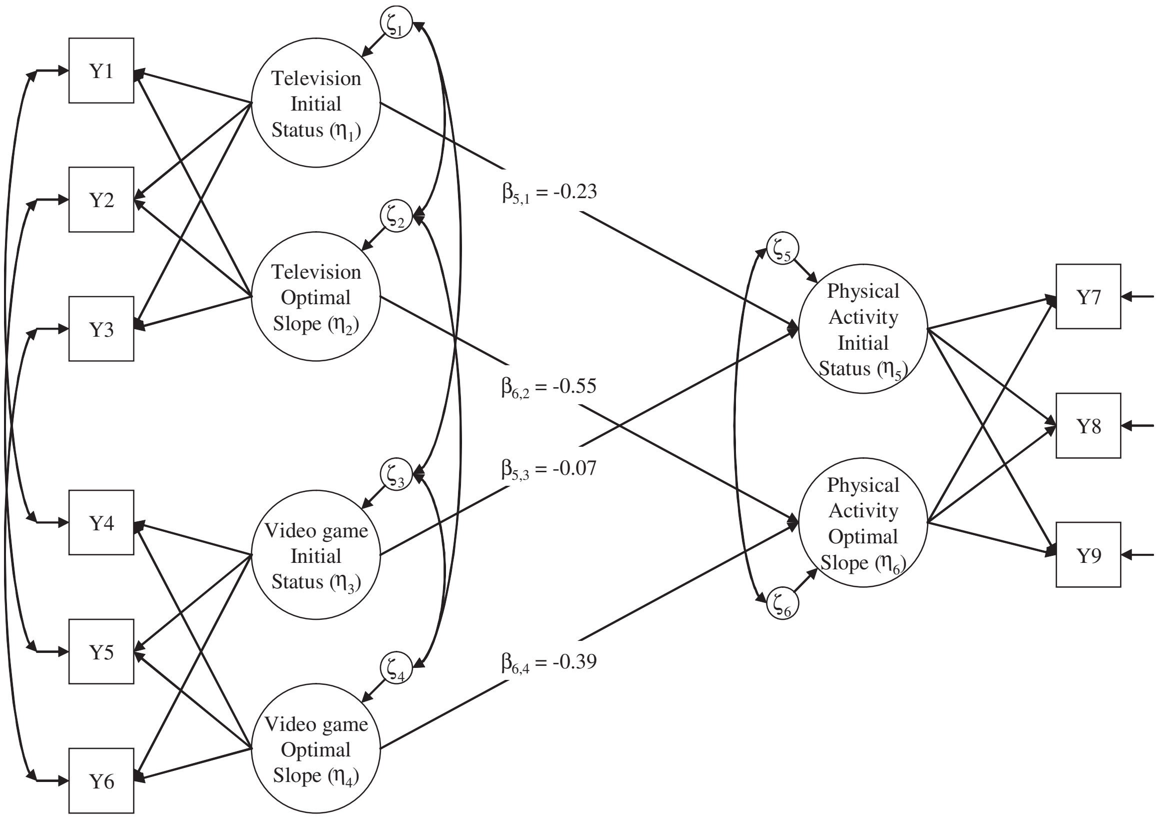

Fig. 1. Model tested with second-stage latent growth modelling that included direct effects of initial status and change for television watching and video game playing on initial status and changes for physical activity. Sex was included in the model, but the effect of sex and the associated path coefficients are not provided in the figure for clarity. The path coefficients are presented in completely standardized units. Y1–Y3 represent indicators of television watching measured at baseline, interim, and follow-up. Y4–Y6 represent indicators of playing video games measured at baseline, interim, and follow-up. Y7–Y9 represent indicators of physical activity measured at baseline, interim, and follow-up.

Covariate influences. We tested another model that examined the relationships among television watching, video game playing, physical activity, and sex and controlled for initial status and change in socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement. Based on first-stage LGM analyses, socioeconomic status was modelled with a linear change function and homoscedastic residuals; value placed on health, appearance, and achievement was modelled with a linear change function and heteroscedastic residuals; and smoking was modelled with a quadratic change function and heteroscedastic residuals.

The model that included the covariates provided an excellent fit to the data (df = 117, $\chi 2 = 359.97$, $p<0.001$, RMSEA [90% CI] = 0.021 [0.019–0.024], NNFI = 0.980, CFI = 0.986). With the physical activity initial status factor, there was a statistically significant and negative direct effect from initial status for television watching ($\beta_{5,1} = -0.18$) as well as a positive direct effect from sex ($\beta_{5,7} = 0.20$), but the effect of initial status for video game playing was zero-order and non-significant ($\beta_{5,3} = -.001$). There were additional direct effects on the physical activity initial status factor from initial status for SES ($\beta_{5,8} = 0.19$) and the value participants placed on their health, appearance, and achievement ($\beta_{5,10} = 0.37$), but not for smoking ($\beta_{5,12} = 0.02$). Thus, initially higher levels of television watching were associated with initially lower levels of physical activity, and this effect was independent of sex and initial status for socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement.

With the physical activity change factor, there was a statistically significant and negative direct effect from change in television watching ($\beta_{6,2} = -0.59$) as well as a positive direct effect from sex ($\beta_{6,7} = 0.16$), but the effect of change in video game playing was attenuated and not statistically significant ($\beta_{6,4} = -0.24$). There were additional direct effects on the physical activity change factor from change in smoking ($\beta_{6,13} = -0.16$) and the value participants placed on their health, appearance, and achievement ($\beta_{6,11} = 0.37$), but not for SES ($\beta_{6,9} = -0.02$). Thus, change in television watching across time was inversely associated with a change in levels of physical activity across time, and this effect was not attenuated by sex and change in socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement. We tested one final model that included the covariates and treatment group (i.e., school-based environmental, classroom, and family interventions versus control condition coded as 1 and 0, respectively), and, although the model provided an excellent fit (df = 125, $\chi^2 = 363.13$, $p<0.001$, RMSEA [90% CI] = 0.020 [0.018–0.023], NNFI = 0.977, CFI = 0.986), treatment group did not influence the magnitude of the relationships between time spent watching television and physical activity.

Results summary

Recognizing the complexity of the data analysis and results, we provide a brief summary that highlights the important results of this study. The first-stage LGM analyses demonstrated that there was (1) a slight initial increase in physical activity at the interim measurement, followed by a lack of change in physical activity at the follow-up measurement; (2) a large initial reduction in television watching from baseline to interim, which was followed by a smaller reduction in television watching from interim to follow-up; and (3) a large initial reduction in playing video games from baseline to interim, which was followed by an even larger reduction in playing video games from interim to follow-up. The second-stage LGM analyses demonstrated that initial status and change in television watching, but not video game playing, were independently associated with initial status and change in physical activity. The associations were independent of sex and socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement.

Discussion

To our knowledge, this is the first study to demonstrate that a change in television watching is inversely and independently related to a change in physical activity across a two-year period among adolescent boys and girls. The primary novel finding was that a decrease in the amount of time spent watching television was associated with an increase in the frequency of leisure-time physical activity. This effect of television watching on physical activity was large in magnitude and not modified by sex nor confounded by socioeconomic status, smoking, or the value participants placed on their health, appearance, and achievement. Such findings encourage the development of interventions that attempt to reduce time spent watching television as a method of increasing physical activity levels among adolescents (Epstein, 1998; Robinson, 1999; Steinbeck, 2001).

There was mixed support for playing video games as a correlate of changes in physical activity. Initially, the change in video game playing was inversely associated with the change in levels of physical activity, but this association was attenuated and not statistically significant in the subsequent analysis that included change in socioeconomic status, smoking, and the value participants placed on their health, appearance, and achievement. The lack of an association in the subsequent analysis is likely explained by (a) the presence of statistically significant correlations between change in playing video games with changes in smoking ($\psi_{4,13} = 0.17$) and value participants placed on their health, appearance, and achievement ($\psi_{4,11} = -0.18$) in combination with (b) the effects of changes in smoking and value participants placed on their health, appearance, and achievement on change in physical activity. Thus, controlling for changes in smoking and value participants placed on their health, appearance, and achievement accounted for the relationship between changes in video game playing and physical activity; a similar effect was likely not observed with television viewing because there were weak and non-significant correlations among change in television watching with changes in smoking ($\psi_{2,13} = 0.07$) and value participants placed on their health, appearance, and achievement ($\psi_{2,11} = -0.11$), respectively.

Previous research using cross-sectional data has provided support for a negative association between television viewing and physical activity (e.g. Pate et al., 1996; Trost et al., 1996; Bungum & Vincent, 1997; Strauss et al., 2001; Lowry et al., 2002). For example, based on the 1999 national Youth Risk Behavior Survey and a representative sample of high school students ($N = 15,349$), individuals who reported watching 5 or more hours of television per day reported higher rates of inactivity relative to those who reported watching 2 or less hours of television per day (Lowry et al., 2002). In another study, television watching was inversely and independently related to both vigorous and moderate-to-vigorous physical activity among a sample of male and female 5th grade students (Trost et al., 1996). Herein, we provide evidence that the cross-sectional association between television viewing and physical activity was weaker ($\beta_{5,1} = -0.18$) than the longitudinal association ($\beta_{6,2} = -0.59$). The stronger longitudinal association between changes in television watching and physical activity likely has greater public health importance than the weaker cross-sectional association. The longitudinal association demonstrates that naturally occurring changes in time spent watching television have a negative relationship with naturally occurring changes in the frequency of leisure-time physical activity. Thus, a reduction in time spent watching television would seemingly yield a concomitant increase in the frequency of physical activity among adolescents.

Watching television exhibited a strong and independent direct effect on physical activity, while playing video game exhibited a weak effect. One possible explanation for this differential effect is that adolescents have greater access to televisions than video games and spend more time watching television than playing video games. Recent estimates indicate that 98% percent of all US households have at least one television, whereas only 68% of households have ownership of video game equipment (Woodard, 2000). Moreover, 60% of adolescents have a television in their bedrooms (Woodard, 2000). Consequently, adolescents spend nearly four-times as much time watching television (147 average daily minutes) than playing video games (33 average daily minutes). The differences in television access and time spent watching television likely contribute to the larger effect of television watching than playing video games on physical activity.

As an additional step toward understanding sedentary behaviours as a risk factor for physical inactivity among adolescents, the present study examined the relationship between naturally occurring changes in television watching, video game playing, and physical activity among a large sample of adolescent boys and girls. We do not have any information about the cause of the change in time spent watching television. The change in watching television might have been caused by other confounding factors including social, familial, or affective processes during this transitional life stage. Importantly, we only demonstrated a correlation between change in television watching and change in physical activity, and recognize that a change in physical activity might cause a change in television watching. Hence, the observed relationship between change factors does not establish sequentiality in the inverse association between television and physical activity. Conditional upon the premise that a change in television watching yielded a change in physical activity, future research should identify the factors that influence natural history changes in television watching, which will provide a stronger foundation for interventions aimed at increasing physical activity levels by reducing time spent watching television among adolescents.

Additionally, subsequent inquiry would do well to examine these relationships within existing theoretical models of behaviour change. Social cognitive theory (Bandura, 1986), for example, provides a straight-forward conceptual model for possibly explaining the association between television watching and physical activity. Social cognitive theory describes the reciprocal determinism among the environment, personal factors, and behaviour. Environmental factors, particularly parental behaviours, have been considered to be important influences on adolescent television and physical activity habits through familial aggregation. Adolescents of heavy television viewing parents themselves report spending significantly more time watching television (Woodard, 2000), and there has been a consistent association between parent and offspring levels of activity and inactivity (e.g. Pérusse, Leblanc, & Bouchard, 1988; Simonen et al., 2002). Those associations are likely the result of parental behaviours that serve as a model for adolescent television and physical activity habits. Hence, researchers could adopt a social cognitive perspective and focus on altering parental behaviours in an attempt to reduce time spent watching television and increase physical activity among adolescents.

Behavioural choice theory provides another conceptual framework for understanding the relationship between television watching and physical activity levels (Epstein, 1998). Sedentary activities, such as television watching, can be more highly preferred and reinforcing than physical activity among adolescence (Epstein, 1998), and thus might take precedence over physical activity during an adolescent's leisure time. Two primary avenues for reducing sedentary behaviours and increasing physical activity, based on behavioural choice theory, are manipulations of access and contingency. Manipulations of access might involve setting limits on the amount of time that an adolescent spends watching television and removing television sets from the adolescent's bedroom (American Academy of Pediatrics, 2001). Another possibility involves arranging television viewing access to be contingent upon spending an adequate portion of an adolescent's daily leisure time being physical active (Epstein, 1998).

In summary, naturally occurring changes in time spent watching television had a large, inverse effect on changes in frequency of leisure-time physical activity across a 2-year period among adolescent boys and girls. That effect of time spent watching television on physical activity was not modified by sex nor confounded by socioeconomic status, the value participants placed on their health, or smoking behaviour. Because of the prevalence and public health burden of inactivity during adolescence (Sallis & Patrick, 1994; Centers for Disease Control and Prevention, 2002; Wang & Dietz, 2002), future research should investigate the efficacy of low-risk interventions for reducing the amount of time spent watching television and increasing physical activity levels. Such interventions could be based on environmental manipulations that focus on parental modelling, restrictions on television access, and physical activity–television contingencies. Early adolescence may be an especially critical time for such environmental manipulations because of corresponding increases in the presence and use of television sets in the bedroom, the overall amount of television watched, and the rate of inactivity.

Acknowledgements

This research was supported by a Grant from the National Cancer Institute, 5R01 CA71943-03.

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