The television-to-exercise ratio is a predictor of overweight in adolescents: Results from a prospective cohort study with a two year follow up

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ABSTRACT

Objective. To determine whether the ratio of television-to-exercise predicted overweight in adolescents.

Method. Prospective cohort study with two years of follow-up of 1276 thirteen and sixteen year olds in Flanders, Belgium. Self reported weight, height, and the television-to-exercise ratio were registered in 2003. The main outcome measure was being overweight in 2005.

Results. In the lowest quartile of the television-to-exercise ratio each 7 h of television were accompanied by at least 2.5 h of exercise per week. In the second quartile the Relative Risk (RR) of being overweight after two years, adjusted for age, sex and BMI at baseline, was 2.7 (95%CI: 0.9 to 7.6). In the third quartile the adjusted RR was 5.4 (95%CI: 2.0 to 14.4). In the highest quartile the adjusted RR was 8.9 (95%CI: 3.4 to 23.3). The adjusted RR was 5.2 (95%CI: 1.8 to 15.3) for the 9.3% subjects who reported no exercise.

Seventy-two percent of the incidence of overweight in the sample could be attributed to a television-to-exercise ratio in excess of 2.3.

Conclusions. One extra hour of exercise per week could reduce the two year cumulative incidence of overweight in adolescents by 14%. Two and a half hours of exercise are needed to compensate for 7 h of television per week to protect against overweight.

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Introduction

It is widely accepted, in both expert and lay opinion, that television (TV) viewing is at least partly to blame for the increased incidence of overweight and obesity in adolescents in recent times. Marshall et al. (2004) point out that both groups commonly assume that the causal mechanism explaining this relationship is that TV viewing has gradually displaced physical activity. There are two problems with this approach. First, the evidence of a strong relationship between TV viewing and body mass is limited (Marshall et al., 2004; Gorely et al., 2004). Even though the relationship has been called “clinically relevant” (Hancox et al., 2004), a meta-analysis showed that the effect is generally small (Marshall et al., 2004). Second, there is little or no evidence to support the displacement hypothesis. Whereas some have suggested that those who engage less in physical activity are more likely to watch a lot of TV (Eisenmann et al., 2002) most studies have suggested no relationship between TV viewing and physical activity (see Marshall et al., 2004; Gorely et al., 2004; Biddle et al., 2004; Vandewater et al., 2004). Neither volume of TV viewing nor volume of exercise activity appear to be big predictors of adolescents’ weight. In spite of these findings one intervention study suggested

that either reducing sedentary behavior or increasing exercise activity leads to a reduction of the number of overweight subjects (Epstein et al., 2000). Another study suggested that increasing physical activity led to decreased BMI after one year, whereas increased inactivity leads to increased BMI (Berkey et al., 2003). This suggests that neither TV viewing nor exercise activity alone explain changes in the incidence of overweight. One recent study of Australian adults showed that whereas physical activity was not directly associated with being overweight there was an interaction between physical activity and TV viewing (Salmon et al., 2000). The current study therefore examined whether the ratio of TV viewing to exercise predicts overweight.

Methods

Participants

We used data from the Leuven study on media and adolescent health (SOMAH). Baseline data were collected in February 2003 with a follow up in February 2004 and February 2005. Participants were 1st and 4th year students in 15 secondary schools in the Flemish Community of Belgium. Schools were randomly selected from the government’s list of secondary schools. When a school agreed to take part all students in the first and fourth year were considered as potential participants. At baseline 2306 students took part in the

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study. 54.2% were boys. In the younger cohort, the average age was 13.2 years (SD 0.4), in the older cohort the average age was 16.4 years (SD 0.7).

At the first follow-up one year later 79% of the subjects were left in the study. Another 18% of the baseline sample was lost after two years. 5.8% of the baseline sample had missing data on the variables used in this study and had to be dropped from the analysis.

The Institutional Review Board of the Katholieke Universiteit Leuven approved the study and informed consent was obtained from the legal guardians of the children. We certify that all applicable institutional and governmental regulations concerning the ethical use of human volunteers were followed during this research.

Determinants

Television viewing volume (TV) was measured (in 2003) using a timeline for each day of the week. The timelines began at 7.00 A.M. and ended at 01.00 A.M. They consisted of 38 checkboxes, each representing a half hour of possible television viewing time. For each day of the week, participants were asked to mark the period(s) of time on which they watched TV on that particular day in a normal week. Total television viewing time (in hours) per week was obtained by counting the marked checkboxes for each participant and dividing the result by two.

Exercise volume was measured by asking participants how often they exercised in a normal week (see: Van den Bulck, 2000). Exercise was defined using a Dutch verb referring to structured physical activity. Answer categories were 1) never; 2) once or twice a month; 3) once a week; 4) twice a week; 5) three times a week; 6) four times a week; and 7) more than 4 times a week. Participants had to indicate the duration of an average session of doing exercise in hours and/or minutes. They were instructed not to include physical education classes at school. Without this instruction some participants might have added physical education whereas others might have thought that exercise only referred to what they did in their spare time. Both variables were combined to obtain an estimate of hours of exercise per week.

TV-to-exerciseratio was obtained by dividing hours of TV per week by hours of exercise per week.

Body mass index (BMI) was obtained by dividing self reported weight in kilograms by the square of length in meters.

Overweight was defined using the method described by Cole et al. (2000) and Skidmore and Yarnell (2004). This method defines overweight as a BMI larger than 25 at the age of 18 or older, but adjusts for age and gender. In girls aged 12 the cut-off point equivalent to a BMI of 25 or more at age 18, for instance, is 21.68. In boys of the same age this cut-off point is 21.22. An alternative measure that takes changes during adolescence into account is the Ponderal Index (PI, which divides the cube root of mass (in kilograms) by the height in centimeters). When multiplied by 1000 normal values of this index are between 20 and 25.

Statistical analyses

All statistical analyses were conducted using SPSS 16™ for windows.

Results

Loss to follow up

There was no statistically significant difference between loss to follow up in the younger and the older cohort, but there were more boys (50.7%) in the group lost to follow up than in the group that remained in the study (47.4%; RR=1.35; 95%CI: 1.1 to 1.6). The proportion of subjects with overweight was higher in the loss to

follow up group (12.6%) than in the group that stayed in the study (8.7%; RR=1.57; 95%CI: 1.19 to 2.1). The mean TV-to-exercise ratio in the final sample (15.7; SD=30.1, 95%CI: 14.0 to 17.4) was slightly lower than that of those lost to follow up (17.8; SD=46, 95%CI: 14.5 to 21.2), but the difference was not statistically significant ($F=1.5$; $df=1.1925$; $p=0.227$).

TV viewing and exercise

On average (SD) participants watched 3:04 (1:36) hours of TV per day. Average number of hours of exercise per week was 4:30 (4:08) hours. When hours of TV per week were divided by hours of exercise per week the average ratio was 15.7 (30.1).

The relationship between TV viewing and exercise

Television viewing volume at baseline did not predict hours of exercise per week at baseline (regression coefficient for “hours of TV per day” = 0.056; 95%CI -0.07 to 0.18; $F=0.783$; $p=0.376$) or at follow up (regression coefficient for “hours of TV per day” = -1.393; 95%CI -12.13 to 9.34; $F=0.065$; $p=0.799$) nor any decrease or increase in hours of exercise (regression coefficient = -2.769; 95%CI: -14.33 to 8.79; $F=0.221$; $p=0.638$). Even after adjusting for age and gender the relationships were statistically not significant.

Body mass index at follow up

Average BMI was 19.2 (3.0) at baseline and 20.3 (2.9) at follow up. Average change in BMI was 1.1 (2.2). There was no significant difference between the BMI of boys and girls in either the younger or the older cohort either at baseline or at follow up, but there were differences between the younger and the older cohort. BMI was 17.9 (2.6) at baseline in the younger cohort and 20.3 (2.8) in the older cohort ($t=16.1$, $p<0.0001$). At follow up BMI was 19.6 (2.9) in the younger and 21.0 (2.7) in the older cohort ($t=9.4$, $p<0.0001$). This means that the change in BMI between baseline and follow up was larger in the younger (Δ BMI: 1.3, SD: 2.1) than in the older (Δ BMI 0.7, SD: 2.2) cohort ($t=7.1$, $p<0.0001$).

The TV-to-exercise ratio was seriously skewed and was therefore log-transformed by taking its natural logarithm before entering it into a regression analysis. The log-transformed ratio was significantly and positively associated with an increase in BMI at follow up (Beta = 0.14, 95% CI = 0.01 to 0.26; $F=4.22$, $p=0.04$). The relationship did not disappear when the regression coefficients were adjusted for BMI at baseline and for age and gender (Beta = 0.10; 95% CI = 0.01 to 0.19; $F=274.3$, $p<0.0001$).

Overweight at follow up

8.7% of the participants were overweight at follow up. There were no significant differences between girls (two year cumulative incidence (2YCI): 8.6%) and boys (2YCI: 8.5%) or between the older (2YCI: 8.8%) and the younger (2YCI: 8.2%) cohort.

Hours of TV per day and hours of exercise per week were significant predictors of overweight after two years. The risk of being overweight increased by 22% for each hour of TV viewed per day (RR 1.22; 95% CI: 1.05 to 1.43) and decreased by 19% for each hour of exercise per week (RR 0.81; 95% CI: 0.73 to 0.89). The analysis adjusted for gender, age and BMI at baseline.

The TV-to-exercise ratio was divided into equal quartiles. Because there was no group with virtually no TV viewing the lowest quartile, in which the ratio was lowest, was used as the reference category. Those who did not do any exercise outside of school were added as a fifth group. The latter group constituted 9.3% of the sample.

In the second quartile the adjusted Relative Risk (RR) of being overweight after two years was 2.7 (95%CI: 0.9 to 7.6). In the third

Table 1

Estimated relative risk of overweight after 2 years for different levels of the TV-to-exercise Ratio, Flanders, Belgium, 2005

TV-to-exercise ratio ^a		N	Cases	2 year cumulative incidence	Attributable risk (in %)	Unadjusted relative risk (95% CI)	Adjusted relative risk ^b (95% CI)
Lower bound	Upper bound						
0.1	2.8	292	7	2.4	Reference	1.0 (reference)	1.0 (reference)
2.8	5.6	309	15	4.9	59%	2.0 (0.8–4.9)	2.7 (0.9–7.6)
5.7	14.0	291	33	11.3	79%	4.8 (2.1–11.1)	5.4 (2.0–14.4)
14.3	max	272	38	14.0	83%	6.5 (2.8–14.7)	8.9 (3.4–23.3)
No exercise		122	19	15.6	85%	7.2 (2.9–17.7)	5.2 (1.8–15.3)
		1276	112	8.7 ^c	72% ^d		

Table shows adjusted and unadjusted Relative Risk for variables measured at baseline. RR was estimated by logistic regression analysis. TV-to-exercise ratio was divided into quartiles and the group with no exercise was added.

^a TV-to-exercise ratio: hours of TV per week divided by hours of exercise per week.

^b Adjusted for age, gender and BMI at baseline.

^c Unstratified two year cumulative incidence.

^d Population attributable risk.

quartile the adjusted RR of being overweight was 5.4 (95%CI: 2.0 to 14.4) compared to the low exposure group. In the highest quartile the adjusted RR was 8.9 (95%CI: 3.4 to 23.3). For subjects who reported no exercise outside of school the adjusted RR of being overweight 2 years after the baseline measurement was 5.2 (95%CI: 1.8 to 15.3).

When not adjusted for age, gender and BMI at baseline the RR remained of a similar magnitude, although they decreased a little (with the exception of the group with no sports, in which the unadjusted RR was larger). RR of a similar size were obtained by using the Ponderal Index (PI) instead of the BMI.

Etiological fraction, population attributable risk and potential impact fraction

Table 1 estimated the attributable risk and the population attributable risk. Attributable risk or the etiological fraction (defined by Rothman and Greenland, 1998, as “excess caseload due to exposure”) is the proportion of the number of cases of overweight attributable to a high TV-to-exercise ratio in those with a high ratio. Compared to the low exposure group 59% of the cases of overweight at follow up appeared to be attributable to a high TV-to-exercise ratio in the next quartile. At higher levels, the attributable risk rose sharply. It was 79% in the third quartile and 83% in the highest quartile. In the group that reported no exercise out of school the attributable risk was 85%.

The Population attributable risk estimates the proportion of the total number of cases of overweight attributable to a high TV-to-exercise ratio. In our study 72% of the cases of overweight could be attributed to a low number of hours of exercise in relation to a high number of hours of TV.

Table 2 shows the potential impact of one extra hour of exercise per week. The TV-to-exercise ratio was recomputed assuming that each subject had one extra hour of exercise. By multiplying the number of subjects in each category by the observed 2 year cumulative incidence for each category the theoretical number of cases for each category was obtained. The table suggests that one hour of exercise per week

extra would have changed the TV-to-exercise ratio to such an extent that the unstratified two year cumulative incidence would have decreased from 8.7 to 7.5%, a reduction by 14%.

Discussion

We found no evidence of a television displacement effect: television viewing did not predict time spent exercising either cross-sectionally or longitudinally nor did it predict changes in exercise activities. The ratio of TV viewing volume to exercise activities, however, did predict increases in body mass index after two years. We found a clear dose–response relationship. The relative risk of being overweight two years after the baseline measurement was considerably higher in those respondents who did not balance each 7 h of TV viewed per week by at least two and a half hours of exercise per week.

Before we accept these findings a number of limitations should be discussed. First, this study relied on self-reported measures. BMI estimated using self reports has been shown to be highly reliable but underestimates the prevalence of overweight (Brenner et al., 2003; Elgar et al., 2005). One study suggested that 96% of a large, representative sample was correctly classified as obese on the basis of self-reported measures and concluded that young people report measures of height and weight accurately (Tsigilis, 2006). Misclassification is probably larger in the overweight group. Such non-differential misclassification is likely to lead to an underestimation of the true effect size. Regarding TV viewing measures it has been argued that people no longer feel inhibitions about admitting they are heavy viewers (Webster and Wakshlag, 1985). Nevertheless, TV viewing has been defined as “a residual category of leisure activity” (McQuail et al., 1972): people may not be aware of how much they view. Underestimation is probably most likely to occur when participants are asked to estimate how many hours they watch. The method used here mimics the diary method by asking subjects to check each half hour of TV viewing. There is no mental arithmetic involved. Because television programs have a standard length measurable in half hours (Chaffee and Mutz, 1988) under- or overestimation should be limited and random.

Second, while time-order is a necessary condition to establish causality it is not a sufficient condition. The TV-to-exercise ratio could be a marker for some other, as yet unidentified, process. If that is the case then attempts to change the ratio (by increasing exercise activities or reducing TV viewing) may not have any impact on BMI or overweight. Nevertheless the dose–response relationship appears to be strong and there is evidence that reducing TV viewing or increasing time spent doing exercise may positively affect the weight status of adolescents (Epstein et al., 2000).

Third, it has to be noted that the standard deviation of the exercise volume variable was substantial. Combined with the absence of a

Table 2

Potential Impact of 1 extra hour of exercise per week per subject, Flanders, Belgium, 2005

TV-to-exercise ratio ^a		Predicted N	Predicted cases
Lower bound	Upper bound		
0.1	2.8	373	9
2.8	5.6	325	16
5.7	14.0	364	41
14.3	max	198	28
No exercise		–	–
Total		1260	94

^a TV-to-exercise ratio: hours of TV per week divided by hours of exercise per week.

relationship with TV viewing this led to a large variation in the TV to exercise ratio (the SD of which was even more considerable). This suggests that the actual cut-off points used in the logistic regression to define subgroups may be volatile. Even small changes due to sampling error could have led to different cut-off points. At the same time the large standard deviation made it possible to compare groups in which the ratio differed substantially and thus study the dose–response relationship shown in Table 1.

Finally, this study looked at TV use and not at other forms of media use that may also be described as “passive”, such as computer game use. There are two reasons why TV was singled out. First, some authors believe that watching TV induces a particular kind of passive physical state. One laboratory experiment showed, for instance, that rest metabolic rate is lower in children who watch TV than in children who just rest (Klesges et al., 1993). Video game use has been linked to increased metabolic rate because of the excitement it induces (Segal and Dietz, 1991). If TV viewing reduces metabolic rate this means that viewing TV has a larger effect on body mass than many other non-active behaviors. Second, TV viewing was still the major form of media pastime for the children in the age groups in this study. A recent study showed that Flemish youngsters watch about three hours of TV per day, that they were on the internet less than one hour per day and that boys played less than one hour of computer games per day and girls less than two hours per week (Van den Bulck, 2004).

Our findings show no television displacement effect. It was suggested about 20 years ago that people tend to use television to fill unstructured time (Kubey, 1986). Kubey remarked that structured and unstructured time filling activities do not necessarily compete. People with a lot of unstructured time to fill may still have a lot of structured activities. This would explain why watching a lot of TV is not related to exercising less. Applied to the current study this means that the question is not whether young people watch too much TV nor whether they exercise too little. The question appears to be whether or not a large volume of passive behavior is compensated by a large enough volume of exercise. It may therefore be more appropriate to speak of a television compensation effect. Hancox et al. (2004) suggested that 17% of overweight could be attributed to watching TV for more than two hours a day. We found that 72% of overweight could be attributed to a high TV-to-exercise ratio. Watching a lot TV does not have to lead to an increase in body mass if that same person also does a lot of exercise. Reversely not engaging in a lot of exercise may not be such a big problem as long as that person does not engage in too many passive behaviors.

The compensation hypothesis offers interesting pathways for prevention and intervention. Table 2 suggests that increasing exercise activity by just one hour per week could have a substantial effect on the incidence of overweight. Such an approach would be in line with Wareham et al. (2005) who suggested that extra physical education classes at school might be one of the most effective ways to prevent weight gain in children. This, however, is a linear measure. For practitioners it might be a better idea to use the ratio as a basis for advice. The reference group compensated each 7 h of TV per week (the equivalent of 1 h per day) with at least two and a half hours of exercise. A child watching 3 h a day (21 hours per week) – which is the average in this study – should therefore attempt to compensate with at least 7.5 h of exercise. Conversely, an adolescent who only achieves

2.5 h of exercise per week ideally should not watch more than 1 h of TV per day. The ratio can be improved by either reducing TV exposure, increasing exercise activities or both.

In summary, we found a strong relationship between the TV-to-exercise ratio and an increase in body mass. This offers an explanation for the lack of a strong relationship suggested in previous studies.

Conflict of interest

Neither author reports any conflict of interest.

References

- Berkey, C.S., Rockett, H.R., Gillman, M.W., Colditz, G.A., 2003. One-year changes in activity and in inactivity among 10- to 15-year old boys and girls: relationship to change in body mass index. *Pediatrics* 111, 836–843.
- Biddle, S.J., Gorely, T., Marshall, S.J., Murdey, I., Cameron, N., 2004. Physical activity and sedentary behaviours in youth: issues and controversies. *J. R. Soc. Health* 124, 29–33.
- Brener, N.D., Mcmanus, T., Galuska, D.A., Lowry, R., Wechsler, H., 2003. Reliability and validity of self-reported height and weight among high school students. *J. Adolesc. Health* 32, 281–287.
- Chaffee, S.H., Mutz, D.C., 1988. Comparing mediated and interpersonal communication data. In: Hawkins, R.P., Wiemann, J.M., Pingree, S. (Eds.), *Advancing Communication Science: Merging Mass and Interpersonal Processes*. Sage, Newbury Park, pp. 19–43.
- Cole, T.J., Bellizzi, M.C., Flegal, K.M., Dietz, W.H., 2000. Establishing a standard definition for child overweight and obesity worldwide: international survey. *BMJ* 320 (7244), 1240–1243.
- Eisenmann, J.C., Barte, R.T., Wang, M.Q., 2002. Physical activity, TV viewing, and weight in U.S. youth: 1999 Youth Risk Behavior Study. *Obes. Res.* 10, 379–385.
- Elgar, F.J., Roberts, C., Tudor-Smith, C., Moore, L., 2005. Validity of self-reported height and weight and predictors of bias in adolescents. *J. Adolesc. Health* 37, 371–375.
- Epstein, L.H., Paluch, R.A., Gordy, C.C., Dorn, J., 2000. Decreasing sedentary behaviors in treating pediatric obesity. *Arch. Pediatr. Adolesc. Med.* 154, 220–226.
- Gorely, T., Marshall, S.J., Biddle, S.J., 2004. Couch kids: correlates of television viewing among youth. *Int. J. Behav. Med.* 11, 152–163.
- Hancox, R.J., Milne, B.J., Poulton, R., 2004. Association between child and adolescent television viewing and adult health: a longitudinal birth cohort study. *Lancet* 364 (9430), 257–262.
- Klesges, R.C., Shelton, M.L., Klesges, L.M., 1993. Effects of television on metabolic-rate – potential implications for childhood obesity. *Pediatrics* 91 (2), 281–286.
- Kubey, R.W., 1986. Television use in everyday life – coping with unstructured time. *J. Commun.* 36, 108–123.
- Marshall, S.J., Biddle, S.J., Gorely, T., Cameron, N., Murdey, I., 2004. Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *Int. J. Obes. Relat. Metab. Disord.* 28, 1238–1246.
- McQuail, D., Blumler, J., Brown, J., 1972. The television audience: a revised perspective. In: McQuail, D. (Ed.), *Sociology of Mass Communications*. Penguin, Harmondsworth, pp. 135–165.
- Rothman, K.J., Greenland, S., 1998. *Modern Epidemiology*. Lippincott Williams and Wilkins, Philadelphia PA.
- Salmon, J., Bauman, A., Crawford, D., Timmerio, A., Owen, N., 2000. The association between television viewing and overweight among Australian adults participating in varying levels of leisure-time physical activity. *Int. J. Obes.* 24, 600–606.
- Segal, K.R., Dietz, W.H., 1991. Physiological responses to playing a video game. *Am. J. Dis. Child.* 145 (9), 1034–1036.
- Skidmore, P.M., Yarnell, J.W., 2004. The obesity epidemic: prospects for prevention. *QJM* 97, 817–825.
- Tsigilis, N., 2006. Can secondary school students' self-reported measures of height and weight be trusted? An effect size approach. *Eur. J. Public Health* 16, 532–535.
- Van den Bulck, J., 2000. Is television bad for your health? Behavior and body image of the adolescent “couch potato”. *J. Youth Adolesc.* 29 (3), 273–288.
- Van den Bulck, J., 2004. Television viewing, computer game playing, and internet use and self reported time to bed and time out of bed in secondary-school children. *Sleep* 27 (1), 101–104.
- Vandewater, E.A., Shim, M.S., Caplovitz, A.G., 2004. Linking obesity and activity level with children's television and video game use. *J. Adolesc.* 27, 71–85.
- Wareham, N.J., van Sluijs, E.M., Ekelund, U., 2005. Physical activity and obesity prevention: a review of the current evidence. *Proc. Nutr. Soc.* 64, 229–247.
- Webster, J., Wakshlag, J.J., 1985. Measuring exposure to television. In: Zillmann, D., Bryant, J. (Eds.), *Selective Exposure to Television*. Lawrence Erlbaum, Hillsdale NJ, pp. 35–62.