Eur J Pediatr (2015) 174:631–639
DOI 10.1007/s00431-014-2443-y

ORIGINAL ARTICLE

Television, sleep, outdoor play and BMI in young children: the GECKO Drenthe cohort

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Received: 14 July 2014 / Revised: 13 October 2014 / Accepted: 20 October 2014 / Published online: 1 November 2014
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Abstract In this study, we investigated the interplay between screen time, sleep duration, outdoor play, having a television in the bedroom and the number of televisions at home and their association with body mass index (BMI) in preschool children. All participants, 3–4 years of age (n=759), were part of the Groningen expert center for kids with obesity (GECKO) Drenthe birth cohort. Weight and height were measured. Total screen time, number of televisions at home, a television in the bedroom, sleep duration and time of outdoor play were self-reported by parents in a questionnaire. Ordinary least square (OLS) regression-based path analysis was used to estimate direct and indirect effects on BMI in mediation models. A television in the bedroom or more televisions at home gave a higher screen time, which were associated with decreased sleep duration and resulted in higher BMI (indirect effect=0.0115, 95 % bootstrap interval=0.0016; 0.0368 and indirect effect=0.0026, 95 % bootstrap interval=0.0004; 0.0078, respectively). In contrast to the direct effect of screen time, sleep duration and a television in the bedroom on BMI, no direct effect was found for outdoor play and number or televisions at home on BMI.

Conclusions: Short sleep duration, long screen time and a television in the bedroom were associated with the presence of overweight in preschool children.

Keywords Obesity · Preschool · Sedentary lifestyle · Computer use · Home environment · Obesogenic environment

Abbreviations

BMI	Body mass index
GECKO	Groningen expert center for kids with obesity
TV	Television

Introduction

A high prevalence of overweight and obesity is seen not only in adults but also in young children [13, 31, 38, 40]. Moreover, recent evidence shows that changes in body mass index (BMI) between the young age of 2 and 6 years correlate strongest with adult overweight [12], and that prevention strategies in the first years of life deserve more attention to prevent general health risks later in life [2, 4, 9]. Therefore, to prevent overweight in adolescence and adulthood, detection and treatment of overweight and obesity already in the first years of life is necessary. In adults, the intake of energy dense food, often cheap and available everywhere, other unhealthy eating habits, a low amount of physical activity, sedentary behaviour and sleep deprivation are associated with the development of obesity [37, 46]. In children, especially young children, the home environment is important for providing a healthy lifestyle. Parents give their children the opportunity to play outside, decide how much time children spent on watching television and can affect their children's sleeping patterns.

Communicated By: Peter de Winter

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Several previous studies discuss behaviours that correlate with overweight in preschool as well as in school-aged children [22, 27, 28, 32]. These behaviours include a lack of outdoor play, short sleep duration and sedentary behaviour, like watching television. Studies in children younger than 5 years, evaluating the association of sleep duration, television time, number of televisions, a television in the bedroom and outdoor play with overweight, focused mainly on one or two aspects at the time. The interrelationships of these factors were less evaluated, although these factors may have complex interactions. Sleep duration may be a mediator in the relation between watching television, outdoor play and BMI. More outdoor play and less television time may be associated with a better and longer sleeping pattern. Better quality and quantity of sleep may in turn help to prevent adverse eating behaviours.

Therefore, the aim of this study is to investigate the interplay between screen time, sleep duration, outdoor play, having a television in the bedroom and the number of televisions at home and their association with BMI in 3- to 4-year-old children.

Table 1 Participant characteristics (n=759)

	N (%)
Boys	401 (53)
Overweight (excl. obese)[a]	66 (9)
Obese	12 (2)
TV in bedroom	25 (3)
≤1 TVs at home	213 (28)
2 TVs at home	419 (55)
>2 TVs at home	127 (17)
	Mean±SD (min–max)
Age (years)	3.9±0.1 (3.4–4.4)
Weight (kg)	17.5±2.2 (11.3–29.8)
Height (m)	1.05±0.04 (0.91–1.19)
BMI (kg/m^2)	15.7±1.3 (12.6–21.8)
BMI for age Z-score[b]	0.03±0.92 (−2.75–3.52)
Screen time (min/day)	61±40 (0–225)
TV time (min/day)	58±38 (0–180)
Computer time (min/day)	3±9 (0–90)
Sleep duration (min/day)	701±30 (591–810)
Outdoor play (min/day)	94±52 (0–180)

[a] Overweight and obesity classification according to Cole et al. [8]

[b] Z-score according to the Dutch population in 1997

Material and methods

Subjects

All children, 3 to 4 years of age, were participating in the Groningen expert center for kids with obesity (GECKO) Drenthe birth cohort. The GECKO Drenthe study is a population-based birth cohort studying early risk factors for overweight and obesity in children living in Drenthe, a northern province of The Netherlands. Details of the study design, recruitment and study procedures were described in detail elsewhere [23]. At baseline, parents of 2997 children intended to participate in the study, of whom 2874 ever actively participated. At the child's age of 3 to 4 years, complete data on weight, height and questionnaires on lifestyle factors was available from 759 children. Data was collected from 2009 to 2011. Missing data could mainly be attributed to logistic and organizational problems (e.g., lack of time during regular well-baby clinic visits, new nurses did not know about the research, questionnaires were out of stock at a clinic). For all children, written informed consent was obtained from parents, and the study was approved by the medical ethics committee of the University Medical Center Groningen.

Anthropometric measures

At the age of 3 or 4 years, children were measured by trained nurses at the well-baby clinics. Weight was measured in light clothing using an electronic scale with digital reading, and recorded to the nearest 0.01 kg. Height was assessed using a stadiometer and recorded to the nearest 0.1 cm. BMI was calculated as weight/height^2.

Lifestyle-related behaviours

In the same time period as the anthropometric measures, parents were asked to fill in a questionnaire about lifestyle-related behaviours of the child, which was provided by the well-baby clinic nurse. For this paper, we used the following questions: 'Does your child have a television in his/her bedroom?' (yes/no); 'How many televisions are present at home' (0, 1, 2 or >2); 'How many days per week and how many hours per day does your child watch television on weekdays/weekend days' (never, 0–½, ½–1, 1–2, >2 h); 'How many days per week and how many hours per day does your child plays computer games on weekdays/weekend days' (never, 0–½, ½–1, 1–2, >2 h); 'How many days per week and how many hours per day does your child plays outdoor on weekdays/weekend days' (never, 0–½, ½–1, 1–2, >2 h). The categories were translated to time in minutes: never=0 min, 0–½h=15 min, ½–1 h=45 min, 1–2 h=90 min and >2 h=180 min. Mean times per day watching television, playing computer games or playing outdoor was calculated as total minutes in 1 week divided by 7. Because the time spent on computer games was minimal, total screen time per day was calculated as the sum of the time watching television per day and the time playing computer games per day.

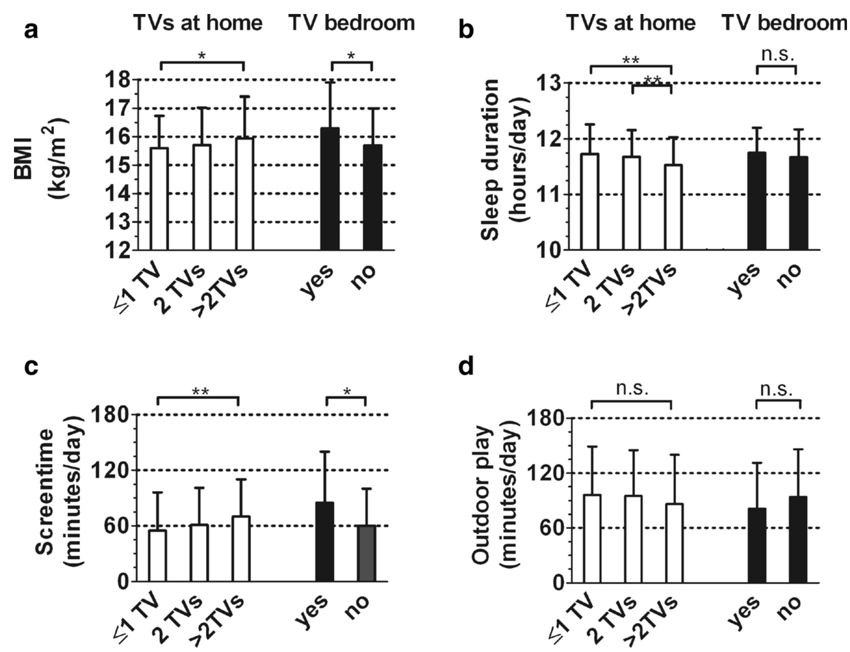


Fig. 1 Number of televisions at home and a television in the child's bedroom versus BMI (**a**), sleep duration (**b**), screen time (**c**) and outdoor play (**d**). Number of televisions at home: ≤1 TV, n=213 (28 %); 2 TVs, n=419 (55 %); >2 TVs, n=127 (17 %). Television in bedroom: yes, n=25 (3 %); no, n=734 (97 %). *p<0.05; **p<0.01

Finally, bedtimes and wake times were reported, separate for weekdays and weekend days. Mean sleep time per night in minutes was calculated.

Statistics

All children participating in the GECKO Drenthe birth cohort with sufficient data available were included. Data are presented as mean±SD, and range (min–max). BMI for age Z-scores were calculated according to the Dutch population 1997 with Growth Analyser (version 3.5 © 2001-2007, Dutch Growth Foundation, www.growthanalyser.org) Groups were compared by Student's t test or one-way ANOVA and associations by Pearson correlations. In the post hoc test, a Bonferroni correction was made. Ordinary least square (OLS) regression-based path analysis was used to estimate direct and indirect effects (path coefficients (unstandardized B)) on BMI in mediation models with the PROCESS macro for SPSS. (Hayes 2012, http://www.afhayes.com/). Model 1 is a mediation model with screen time as independent variable, sleep duration as mediator, BMI as outcome variable and gender as covariate. In model 2a, the independent variable, television in the bedroom (0: no, 1: yes), is added. In model 2b, the independent variable, number of televisions at home (1: ≤1 TVs, 2: 2 TVs, 3: >2 TVs), is added. In both models 2a and 2b, screen time and sleep duration were mediators, BMI was the outcome variable, and gender was the covariate. For the indirect effects, 10,000 bootstrap samples were used for bias-corrected bootstrap confidence intervals. Finally, we performed the path analyses models 2a and 2b separate for weekdays and weekend days. Screen time and outdoor play tended to deviate from normal distribution, but when included in the regression-based path analysis, the residuals were normally distributed, so the model assumptions were not violated by this. Statistical analyses were performed using PASW 18.0.3 for Windows (SPSS, Chicago Illinois, USA). The significance level was set to p<0.05 (two-tailed).

Results

Two thousand and seventy-four children participated actively at least once. Of those children, BMI could be calculated from height and weight measures in 1670 children. Of those 1670 children with available BMI, 759 parents filled in a

Table 2 Pearson correlation coefficients between BMI, screen time, sleep duration and outdoor play

	BMI		Outdoor play		Sleep duration	
	r	p	r	p	r	p
Screen time (min/day)	0.101	0.006	−0.101	0.006	−0.156	<0.001
Sleep duration (min/day)	−0.108	0.003	0.060	0.101	–	–
Outdoor play (min/day)	−0.010	0.794	–	–	–	–

Table 3 Path coefficients of lifestyle factors associated with BMI

Path	Path coefficients [95 % CI] model 1	Path coefficients [95 % CI] model 2a[a]	Path coefficients [95 % CI] model 2b[b]
TV→BMI	n.a.	0.5547 [0.0784; 1.1120]*	0.1320 [−0.0105; 0.2745]
TV→screen	n.a.	24.6976 [8.5287; 40.6666]*	7.2010 [2.8045; 11.5974]*
TV→sleep	n.a.	7.5731 [−4.2991; 19.4454]	−4.8996 [−8.1377; −1.6614]*
Screen→sleep	−0.1153 [-0.1679; -0.0627]*	−0.1190 [-0.1719; -0.0661]*	−0.1060 [-0.1586; -0.0533]*
Screen→BMI	0.0027 [0.0004; 0.0050]*	0.0024 [0.0001; 0.0047]*	0.0025 [0.0001; 0.0048]*
Sleep→BMI	−0.0038 [−0.0069; −0.0006]*	−0.0039 [−0.0071; −0.0008]*	−0.0035 [−0.0066; −0.0003]*
TV→screen→BMI	n.a.	0.0587 [0.0016; 0.1877[c]]*	0.0177 [0.0014; 0.0475[c]]*
TV→screen→sleep→BMI	n.a.	0.0115 [0.0016; 0.0368[c]]*	0.0026 [0.0004; 0.0078[c]]*
TV→sleep→BMI	n.a.	−0.0298 [−0.1044; 0.0045[c]]	0.0170 [0.0013; 0.0467[c]]*
Screen→sleep→BMI	0.0004 [0.0001; 0.0010[c]]*	n.a.	n.a.

OLS regression-based path analysis was used to estimate direct and indirect effects (unstandardized B); all models were adjusted for gender

Model 1: screen time, sleep duration, BMI; model 2a: model 1+TV in bedroom; model 2b: model 1+number of TVs at home

CI confidence interval, *Screen* screen time (minutes/day), *sleep* sleep duration (minutes/day), *n.a.* not applicable, *TV* television

*$p<0.05$

[a] TV=TV in bedroom (0: no, 1: yes)

[b] TV=number of TVs at home (1: ≤2 TVs, 2: 2 TVs, 3: >2 TVs)

[c] Bias corrected bootstrap 95 % CI

questionnaire. Mean BMI±SD was significantly different between children with (n=759) or without a questionnaire (n=911) (15.7±1.3 and 15.9±1.4, respectively, p=0.02), but the ranges were approximately equal and no significant difference in the percentage of children with overweight or obesity was found, making systematic bias due to missing vales from questionnaire data unlikely. From all children with questionnaire data, screen time was missing in eight (1 %) children and sleep duration in four (<1 %) children.

In Table 1, characteristics of the children are shown. Fifty-three percent were boys. Nine percent were overweight and 2 % were obese. At this young age, 15 children (2 %) played computer games for more than 30 min, of whom only 4 played more than 1 h, and 557 children (73 %) never played computer games. Therefore, computer time was analysed together with TV time as total screen time. Only four (<1 %) children had no television present in their home. Therefore, children with no or one television at home were combined in one group (≤1 television).

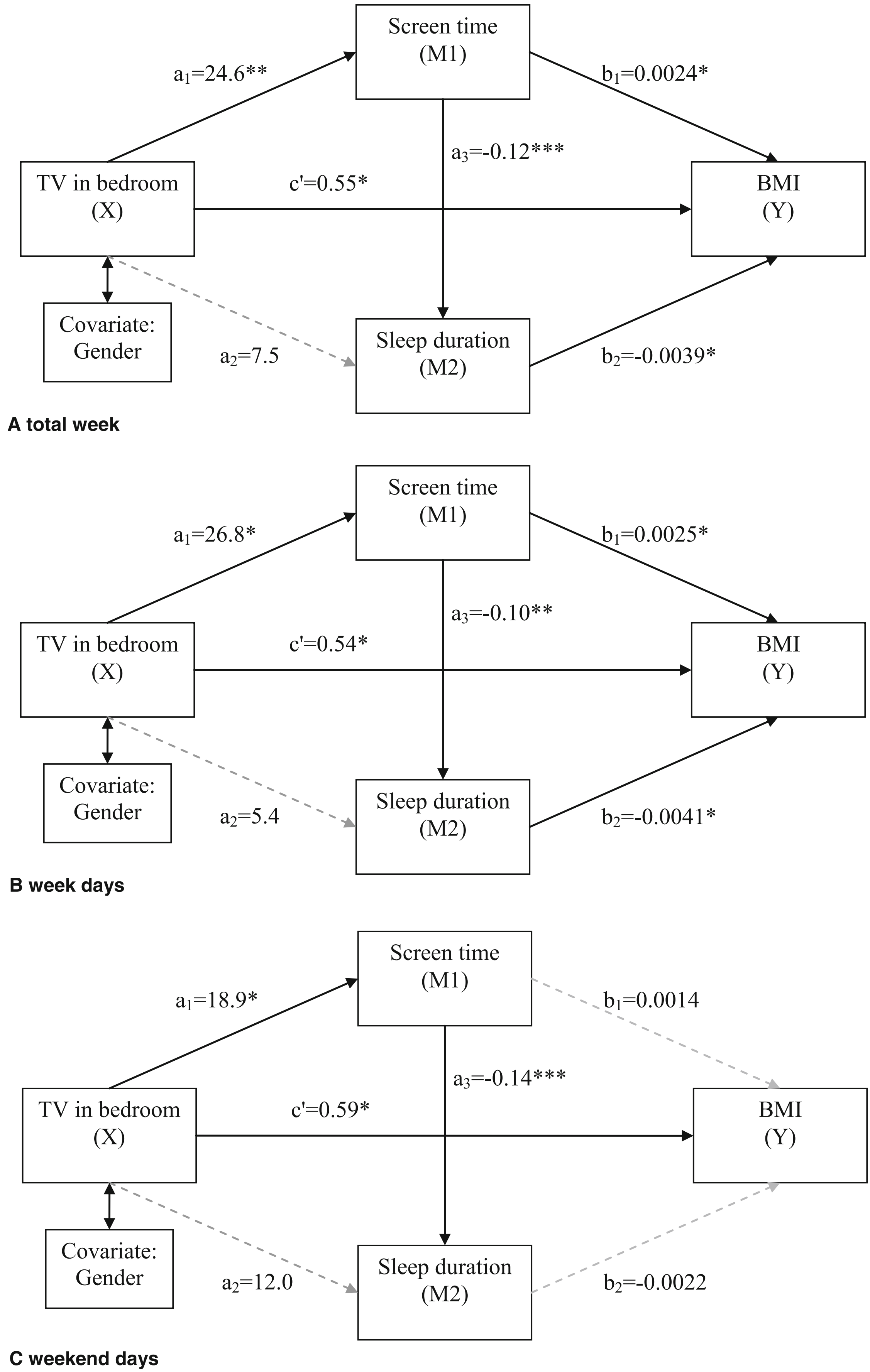
Screen time, outdoor play and sleep duration were reported by the parents separately for week and weekend days. Sleep did not differ between week and weekend days. Outdoor play and screen time did differ between week and weekend days, for outdoor play 88.8±53.3 and 105.5±61.3 min, respectively (p<0.001) and for screen time 58.3±41.6 and 67.1±46.9, respectively (p<0.001). In the analysis, we were interested in the total screen time, outdoor play and sleep duration per week, so we analysed the mean time per day over the week without distinguishing between week and weekend days.

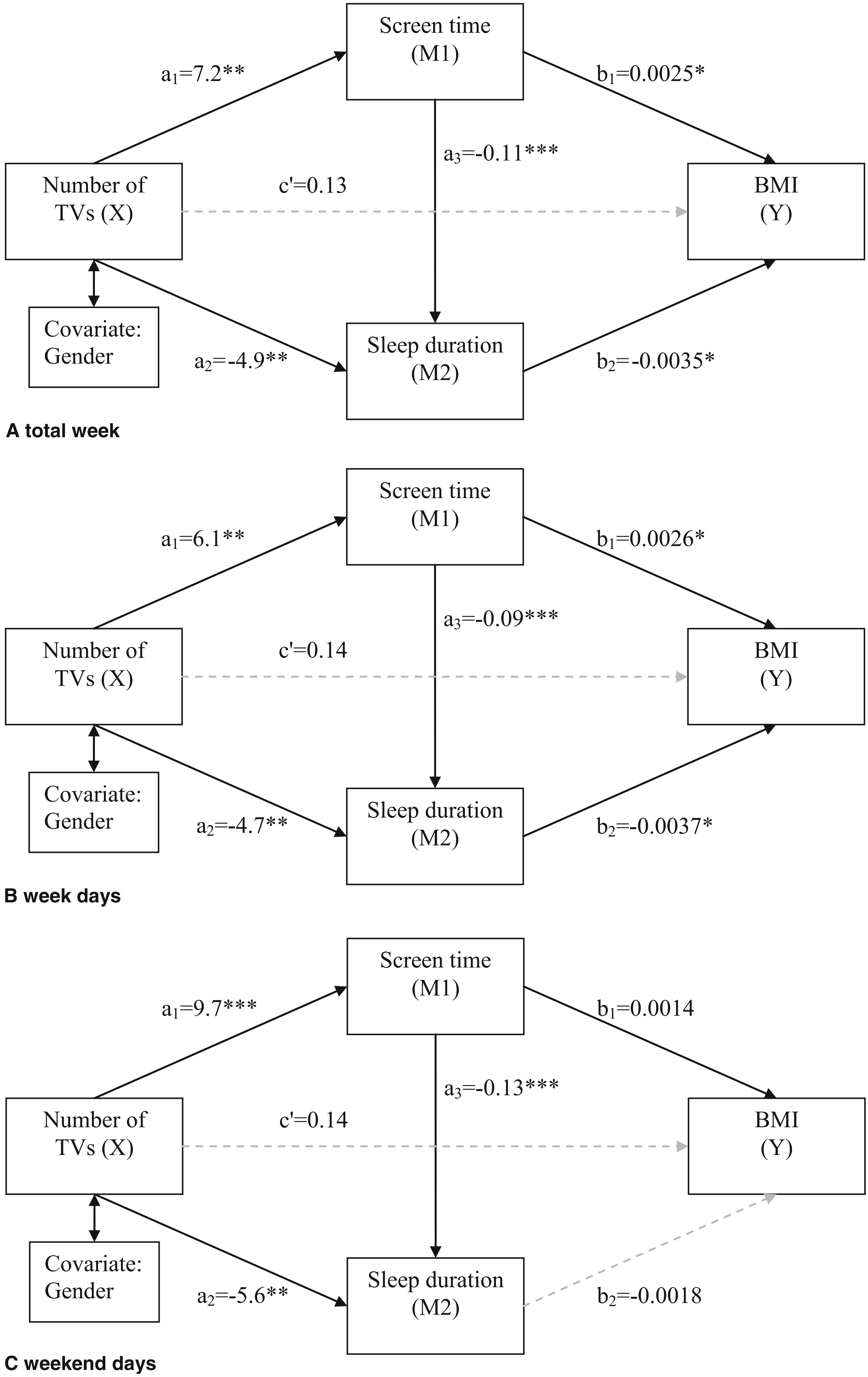
In Fig. 1, differences in BMI (A), sleep duration (B), screen time (C) and outdoor play (D) between the children with ≤1 television, 2 televisions and >2 televisions at home are shown. For children with ≤1 television, 2 televisions and >2 televisions, BMI was 15.6±1.1, 15.7±1.3 and 16.0±1.5 kg/m^2, respectively (≤1 TV vs. >2 TVs, p=0.046). Screen time was 55±41, 61±40 and 70±40 min/day, respectively (≤1 TV vs. >2 TVs, p=0.004). Sleep duration was 704±32, 701±29 and 692±30 min/day, respectively (≤1 TV vs. >2 TVs, p=0.001; 2 TVs vs. >2 TVs, p=0.006). Outdoor play time was 96±53, 95 ±50 and 86±54 min/day, respectively (n.s.).

In Fig. 1, also the differences in BMI, sleep duration, screen time and outdoor play between the children with a television in the bedroom and no television in the bedroom are shown. For a television in the bedroom versus no television in the bedroom, BMI was 16.3±1.6 and 15.7±1.3 kg/m^2, respectively (p=0.021). Screen time was 85±55 and 60±40 min/day, respectively (p=0.035). Sleep duration was 705±27 and 700±30 min/day, respectively (n.s.). Outdoor play time was 81±50 and 94±52 min/day, respectively (n.s.).

In Table 2, the correlations between BMI, screen time, sleep duration and outdoor play are shown. Longer screen

Fig. 2 Model 2a: a serial multiple mediator model with television (*TV*) in the child's bedroom (no=0, yes=1), screen time (minutes/day), sleep duration (minutes/day) and BMI. Path coefficients (unstandardized B) of the components of the indirect effects (a_1, a_2, a_3, b_1, b_2) and the direct, independent effect (*c*'). Analyses done for total week (*A*), weekdays (*B*) and weekend days (*C*). *p<0.05; **p<0.01; ***p<0.001


Screen time (M1)
a1=24.6**
b1=0.0024*
a3=-0.12***
TV in bedroom (X)
c'=0.55*
BMI (Y)
Covariate: Gender
a2=7.5
Sleep duration (M2)
b2=-0.0039*
A total week
Screen time (M1)
a1=26.8*
b1=0.0025*
a3=-0.10**
TV in bedroom (X)
c'=0.54*
BMI (Y)
Covariate: Gender
a2=5.4
Sleep duration (M2)
b2=-0.0041*
B week days
Screen time (M1)
a1=18.9*
b1=0.0014
a3=-0.14***
TV in bedroom (X)
c'=0.59*
BMI (Y)
Covariate: Gender
a2=12.0
Sleep duration (M2)
b2=-0.0022
C weekend days


Screen time (M1)
a1=7.2**
b1=0.0025*
a3=-0.11***
Number of TVs (X)
c'=0.13
BMI (Y)
Covariate: Gender
a2=-4.9**
Sleep duration (M2)
b2=-0.0035*
A total week
Screen time (M1)
a1=6.1**
b1=0.0026*
a3=-0.09***
Number of TVs (X)
c'=0.14
BMI (Y)
Covariate: Gender
a2=-4.7**
Sleep duration (M2)
b2=-0.0037*
B week days
Screen time (M1)
a1=9.7***
b1=0.0014
a3=-0.13***
Number of TVs (X)
c'=0.14
BMI (Y)
Covariate: Gender
a2=-5.6**
Sleep duration (M2)
b2=-0.0018
C weekend days

◀ **Fig. 3** Model 2b: a serial multiple mediator model with number of televisions (*TVs*), screen time (minutes/day), sleep duration (minutes/day) and BMI. Path coefficients (unstandardized B) of the components of the indirect effects (a_1, a_2, a_3, b_1, b_2) and the direct, independent effect (*c*'). Analyses done for total week (***A***), weekdays (***B***) and weekend days (***C***). * $p<0.05$; ** $p<0.01$, *** $p<0.001$

time ($p=0.006$) and shorter sleep duration ($p=0.003$) were associated with a higher BMI. Longer screen time was also associated with less outdoor play ($p=0.006$) and a shorter sleep duration ($p<0.001$).

To further investigate the interrelationships, the independent associations of the direct and indirect relationships were analysed in three-path coefficients models (Table 3). The given path coefficients are shown as unstandardized B. In model 1, as explained in the statistics, both the direct effect of screen time on BMI (c'=0.0027, $p=0.024$) and the indirect effect via sleep duration ($a_1b_1=0.0004$, 95 % bootstrap interval=0.0001; 0.0010) were significant (Table 3). Thus, firstly, 1 h (60 min) of more screen time is directly associated with a higher BMI of 0.0027*60=0.16 kg/m^2. And additionally, 1 h (60 min) of more screen time is associated with less sleep duration of 60*0.1153=7 min. And these 7 min of lower sleep duration are associated with 7*0.0038=0.03 higher BMI. Total effect: 1 h extra screen time gives a higher BMI of 0.03+0.16=0.19 kg/m^2. Figures 2a and 3a show the more complex serial multiple mediator models 2a and 2b. In models 2a and 2b, all separate pathways were significant, except for a television in the bedroom with sleep duration in model 2a (Fig. 2a) and the direct effect of number of televisions on BMI in model 2b (Fig. 3a). In model 2a, we found that children with a television in their bedroom have a higher BMI than children with no television in their bedroom (direct effect=0.5547, 95 % CI=0.0748; 1.1120), and two of the three indirect effects were significant (Table 3). A television in the bedroom was associated with a higher screen time, which in turn was associated with decreased sleep duration and resulted in higher BMI (indirect effect=0.0115, 95 % bootstrap interval=0.0016; 0.0368). In model 3, we found no direct effect of the number of televisions on BMI, but all three indirect effects were significant (Table 3). More televisions was associated with increased screen time, that in turn was associated with decreased sleep duration and resulted in a higher BMI (indirect effect=0.0026, 95 % bootstrap interval=0.0004; 0.0078). The models that included outdoor play were not shown. Outdoor play was not associated with BMI in both direct and indirect pathways.

The above-described path analysis where based on a total week. We also performed the path coefficients models 2a and 2b separated for week and weekend days (Figs. 2b, c and 3b, c, respectively). We found that the relation between screen time and sleep duration did not differ between week and weekend days: more screen time was associated with less sleep. But, we did found that sleep duration and screen time were significantly related to BMI for weekdays, but not for weekend days.

Discussion

Sleep duration, screen time and a television in the bedroom as well as the number of televisions at home are related to each other and are independently related to BMI, except for the number of televisions at home. Outdoor play is inversely associated with screen time, but not with BMI or sleep duration. Thus, we agreed with the assumption that more hours of watching television is related to a higher BMI and to less outdoor play, but our findings do not support that less outdoor play is related to a higher BMI in preschool children. The effect of watching television on BMI is rather acting trough less sleep, than through less outdoor play.

Previous literature, regarding the relation between watching television, or a television in the bedroom, and BMI in children younger than 5 years, confirms our results. Watching television in children this young was associated with overweight [14, 24, 29, 33]. It was also found that a television in the bedroom was associated with a higher BMI [14] and with more time watching television [14, 15, 34]. Above that, parents underestimated the amount of time watching television when the children had a television in their bedroom [34]. Therefore, when parental reports of television time are used, it is necessary to take into account whether or not the child has a television in the bedroom. We found that children who had a television in the bedroom had a higher BMI independent of the amount of time they watched television according to their parents. So possibly, these parents indeed underreported screen time and/or overestimated sleep duration.

Most studies confirmed our results that excess time in watching television may limit the time a child sleeps [7, 20, 29, 30, 42], and sleep duration is inversely associated with overweight [1, 17, 35] in young children. One study also suggested that television viewing partly mediated the association between limited sleep duration and future higher BMI [26]. In adults, sleep deprivation can cause a change in appetite regulating hormone levels, resulting in increased hunger and appetite [39]. In children, little is known about the underlying mechanism, but it was found that shorter sleep duration was associated with higher consumption of energy-rich foods [47]. Secondly, in adults, shorter sleep duration is also associated with fatigue and reduced physical activity, resulting in less total energy expenditure in adults [3, 36]. In children aged 3–5 years, a positive relation was found between physical activity and sleep duration [18]. Finally, shorter sleep duration gives more opportunity to eat, especially in the evening after dinner [37]. A study in 5–6-year-old children found that eating snacks while watching television was associated with a lower sleep duration, which gives a higher chance of being overweight [45]. In our study, we investigated the relation between sleep and BMI cross-sectional. We expect that in our study, decreased sleep duration increased the risk for a higher BMI and not the other way around. It is known that obesity can cause sleep problems, like obstructive sleep apnoea [5]. Since sleep problems were related to more severe forms of overweight like obesity [25] rather than to overweight and only 2 % of the children in this study were obese, we do not expect that the association between sleep and BMI are explained by sleep problems from obstructive sleep apnoea caused by obesity.

The association we found between watching more television and less outdoor play has not been confirmed [6, 19, 41, 43]. Playing outside could be protective for the development of overweight due to increased energy expenditure. In preschool children, one study found that less playing outdoor games was associated with overweight [21]. In contrast, in two other studies, outdoor play was not associated to overweight in preschool children [6, 44]. In our study, we neither found an association between outdoor play and BMI. A possible explanation is that in young children, a lot of activities outdoor are not specifically different from activities indoor.

In follow up of our analysis based on the mean of a whole week, we performed the analysis separate for weekdays and weekend days. More screen time was associated with less sleep, both on weekdays and on weekend days. For the association of screen time and sleep duration with BMI, we did find a difference. On weekend days, more screen time and less sleep duration were not significantly associated with a higher BMI anymore. An explanation could be that the weekend has only 2 days and the rest of the week has 5 days. This might indicate that a healthy week pattern is important, and might allow some space for alternating weekend rhythms.

A strength of this study is the path analysis that provides insight in the interrelationship between sleep duration, screen time, a television in the bedroom, the number of televisions at home and outdoor play time in association with overweight in children younger than 5 years of age.

An assumption not investigated in our study is the association of eating habits with sleep duration and watching television. Eating habits might mediate the relation of sleep duration and watching television with BMI. In two previous studies from a Dutch cohort, the number of sugared drinks and snacks did not affect the positive association between television viewing and BMI [11] or the negative association between sleep duration and BMI in 4–8-year-old children [10]. The supposed effects of sleep on hunger and satiety may translate in increased energy intake in several ways, either through food preferences, portion sizes or desire for snacking more. To adequately assess this in children of 3–4 years of age is a challenge for future research. A previous study of Fuller-Tyszkiewicz et al. [16] already suggested that dietary intake mediated the positive relation between watching television and BMI in children aged >4 years.

To conclude, short sleep duration, long screen time and a television in the bedroom may contribute directly and indirectly to the development of overweight in children aged 3–4 years. The assumption that watching television is related to less outdoor play is correct, but our findings do not support that this is related to a higher BMI in preschool children. These results can be implemented in prevention programs for overweight in young children.

Acknowledgments The study was sponsored with an unrestricted grant by Hutchison Whampoa Limited, 22/F Hutchison House, 10 Harcourt Road, Hong Kong. The study sponsor had no role in (1) the design and conduct of the study; (2) the collection, management, analysis and interpretation of the data; (3) the preparation, review or approval of the manuscript; and (4) the decision to submit the manuscript for publication.

Ethical standards For all children, written informed consent was obtained from parents, and the study was approved by the medical ethics committee of the University Medical Center Groningen. It has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Conflicts of interest The authors declare that they have conflict of interest.

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