

## PAPER

# Reduced risk for overweight and obesity in 5- and 6-y-old children by duration of sleep— a cross-sectional study

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**OBJECTIVE:** To assess the relationship between sleep duration and adiposity in 5- and 6-y-old Bavarian children.

**DESIGN:** Cross-sectional study.

**SUBJECTS:** A total of 6862 German children aged 5–6 y participating in the obligatory health examination in Bavaria, southern Germany.

**MEASUREMENTS:** Routine data were collected on the height and weight of children at the time of school entry in six public health offices in 1999 and in another two in 2000. Body fat mass was estimated by BIA performed in three of those offices. An extensive questionnaire was given to all children's parents in order to assess risk factors for overweight and obesity. The main outcome measures were overweight, defined by a body mass index (BMI) above the 90th centile and obesity, defined by a BMI above the 97th centile for the German children in Bavaria. Excessive body fat was defined as fat mass above the 90th centile for all German children seen in this survey. The main exposure was usual sleeping hours on week days.

**RESULTS:** The prevalence of obesity decreased by duration of sleep:  $\leq 10$  h, 5.4% (95% CI 4.1–7.0), 10.5–11.0 h, 2.8% (95% CI 2.3–3.3), and  $\geq 11.5$  h, 2.1% (95% CI 1.5–2.9). Similar relations were found with the prevalence of overweight and excessive body fat. These effects could not be explained by confounding due to a wide range of constitutional, socio-demographic and lifestyle factors. The adjusted odds ratio for obesity were: for sleeping 10.5–11.0 h, 0.52 (95% CI 0.34–0.78) and 0.46 (95% CI 0.28–0.75) for sleeping 11.5 h.

**CONCLUSION:** The effect of sleep duration on obesity in children reflects a higher body fat composition and appears to be independent of other risk factors for childhood obesity.

*International Journal of Obesity* (2002) 26, 710–716. DOI: 10.1038/sj/ijo/0801980

**Keywords:** primary prevention; body mass index; Bavaria; Germany; epidemiology; logistic models

### Introduction

Obesity is associated with sleep disorders and with changes in the sleep structure.<sup>1</sup> Recent studies reported an association between a short duration of sleep and overweight and obesity in 3-<sup>2</sup> and 5-y-old children.<sup>3</sup>

The aim of our study was to answer the following questions:

- Is the link between longer total sleeping hours and overweight/obesity in children independent of other known risk factors for childhood obesity?
- Can this association for body mass index (BMI) be confirmed for high body fat estimated from bioelectrical impedance analysis (BIA) measurement, a better indicator of true adiposity?

We analysed the association between sleep duration and overweight/obesity defined by BMI in a cross-sectional study enrolling 6862 children aged 5–6 y. A wide range of potentially confounding constitutional and constitutional, socio-demographic and lifestyle risk factors for childhood obesity were considered to estimate the independent impact of sleep duration. BIA measurements were performed in a subset ( $n = 1706$ ) of the population.

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Received 17 March 2001

## Methods

### Study population and data sources

Public health offices in eight out of 76 communities in Bavaria, who were willing to collaborate and were not involved in other studies, were invited to a questionnaire study on possible causes of childhood obesity during the 1999 ( $n=6$ ) and the 2000 ( $n=2$ ) school entrance health examinations. Two communities were excluded because of return rates of 25.5 and 49.1%. In six communities the return rates of the questionnaires were above 60%, allowing the data to be considered for further analyses. In these six communities the distributions of BMI, gender and number of siblings in the 1997 compulsory school entry health examination were similar to those in all regions of Bavaria, suggesting that the study region is representative for Bavarian children. The study region consists of one densely populated area (847 inhabitants/km<sup>2</sup>), the city of Ingolstadt, a population on the outskirts of the city of Augsburg (214 inhabitants/km<sup>2</sup>), and four rural areas (Miesbach, Günzburg, Kitzingen, and areas surrounding Regensburg) all with less than 200 inhabitants/km<sup>2</sup>. In these communities the overall return rate of the questionnaires was 75.9%.

The total number of completed questionnaires was 7754. The analysis was confined to the 5-y-old (5.00–5.99 y;  $n=2109$ ) and 6-y-old (6.00–6.99 y;  $n=4753$ ) German children with information on height and weight, which were measured as part of the routine health examination, leaving 6862 questionnaires for the analyses. Overweight was defined as BMI > 90th percentile and obesity as BMI > 97th percentile. The reference values for BMI were based on the age- and sex-specific distribution in 115 530 German children aged 5.00–6.99 y investigated during the 1997 school health examination in Bavaria.<sup>4</sup> The BMI cut-off values for the 90th and 97th percentile in the widely used reference values from France<sup>5</sup> were below the respective actual BMI cut-off values in Bavaria, which are likely to reflect a BMI increase in German children.<sup>6</sup> We attempted to analyse the relationship of sleeping hours to the extremes of the present distribution of BMI-values (> 90th/> 97th percentile) in Bavarian children. Fat mass was estimated by BIA (Tanita, TBF-300) in three of eight public health offices according to Deurenberg *et al.*<sup>7</sup> High body fat was defined as fat mass above the 90th age- and gender-specific percentile in the population studied here ( $n = 1706$ ).

### Questionnaire

The questions on sleep were: 'When does your child usually go to bed during the week? with the options (a) before 8 pm, (b) between 8 and 9 pm, (c) between 9 and 10 pm, (d) between 10 pm and 11 pm and (e) later than 11 pm; and 'When does your child usually get up in the morning during the week?' with the options (a) before 6 am, (b) between 6 and 7 am, (c) between 7 and 8 am and (d) after 8 am. If the bedtime or time for getting up had been given as the

interval, for example, 'between 7 and 8 am', the time was set as the lower figure plus 30 min. If the time had been given as before or after an hour the time was set as this specific hour (eg before 6 am was set as 6 am). The sleeping time was calculated by the difference between bedtime and time for getting up.

We considered the following potential confounders of the association between duration of sleep and childhood overweight/obesity:

- parental education—highest level attained by either parent, ordinal in degrees (self-reported by parents; dichotomized to less than 10 y vs 10 or more);<sup>8</sup>
- parental obesity, metric self-reporting, height in cm and weight in kg (BMI  $\geq 30$  in either parent);<sup>3,9</sup>
- single parenthood, dichotomous (yes/no; self-reported by parents);<sup>10</sup>
- maternal smoking during pregnancy, classified in categories: 0 cigarettes per day, 1–10, 11–20 and > 20 cigarettes per day;<sup>4</sup>
- population density—from statistical yearbook according to region of the respective public health office, living in a region with > 800 inhabitants/km<sup>2</sup> vs living in a region with < 250 inhabitants/km<sup>2</sup>;<sup>8</sup>
- age at introduction of complementary foods—continuous in months when introduced (self-reported by parents), dichotomized to before/after the 4th month of life;<sup>11</sup>
- caloric bottle to sleep in the first year of life—dichotomous (yes/no) (derived from five questions—tea without sugar, tea with sugar, juice, milk, other drinks; self-reported by parents);
- high birth weight<sup>8</sup>—continuous in kilograms from well-baby-check-up book measurements; dichotomized using cut-off-points from German percentiles (90th) taking sex and duration of pregnancy into account;<sup>12</sup>
- high weight gain during the first year of life—(1) *a*, weight at birth, and *b*, at 1 y from the well-baby-check-up book measurements; (2) difference of *b* – *a* divided by month of observation, multiplied with 12 to account for 1 y (12 months), measurements reported before or after the age of exactly 1 y; (3) dichotomized by cut-off-points at the third quartile (weight gain  $\geq 2.34$  times the child's birth weight);<sup>13</sup>
- watching TV or playing videogames—both were asked for by hours per day (self-reported by parents). Cumulated by addition, cut-off-point at 1 h daily chosen to allow for sufficient numbers in the respective categories;<sup>14</sup>
- regular sport-activities in a club—dichotomous (yes/no; self-reported by parents);<sup>15</sup>
- eating snacks while watching TV—ordinal; frequency per five week/day-categories (self-reported by parents), dichotomized to never vs ever;<sup>16</sup>
- having main meals alone—ordinal; frequency per five week/day-categories (self-reported by parents), dichotomized to ever vs never;

- present total caloric intake—food frequency-questionnaire with 64 sorts of food and options for usual portions per week, day, respectively (self-reported by parents); the total daily caloric intake was estimated from the 'Bundeslebensmittelschlüssel', a data-source of the average calorie-content of different food items in Germany published by the Statistical Office Germany; dichotomized to above vs below the 90th percentile (1921 kcal);<sup>17</sup>
- breastfed—dichotomized to ever vs never from continuous reporting in months (0–x; self-reported by parents).<sup>4</sup>

### Statistical analyses

The prevalence of overweight (BMI >90th percentile) and obesity (BMI >97th percentile) was calculated by the sleep categories  $\leq 10$ , 10.5–11 h and  $\geq 11.5$  h. Crude and adjusted odds ratios for 10.5–11 h and  $\geq 11.5$  h of sleep as compared to  $\leq 10$  h of sleep were calculated using Mantel–Haenszel statistics and logistic regression analysis, respectively. Potential confounding was considered for covariates significantly ( $P < 0.05$ ) associated with both the duration of sleep and overweight. Confounding was assumed for those covariates, which accounted for an at least 10% change of the odds ratio when introduced into the logistic regression model duration of sleep and overweight. Covariates significantly associated with overweight only in the bivariate analysis were taken into the final model by a forward selection procedure. All calculations were carried out in the software package SAS version 6.12.

### Results

There were 6645/6862 children with information on duration of sleep and BMI. In these 6645 children the usual duration of sleep over the week was  $\leq 10$  h in 961, 10.5–11 h in 3910, and  $\geq 11.5$  h in 1774. For 1676 of the 1706 children with additional information on BIA there was also data on the duration of sleep.

The proportions of overweight/obese children and children with a high amount of body fat mass are shown in Table 1. There was a dose dependent decrease in the proportion of

**Table 1** Impact of duration of sleep on overweight (BMI >90th percentile), obesity (BMI >97th percentile) and high body fat (BIA >90th percentile) in 5- and 6-y-old children

Duration of sleep	Overweight		Obesity		High body fat	
	%	95% CI	%	95% CI	%	95% CI
$\leq 10$ h (n = 961)	14.5	12.6–17.2	5.4	4.1–7.0	15.6 <sup>a</sup>	11.1–21.0
10.5–11 h (n = 3910)	10.0	9.1–11.0	2.8	2.3–3.3	9.8 <sup>b</sup>	8.0–11.9
$\geq 11.5$ h (n = 1774)	7.4	6.2–8.7	2.1	1.5–2.9	7.0 <sup>c</sup>	4.9–9.7

<sup>a</sup>n = 225; <sup>b</sup>n = 968; <sup>c</sup>n = 483.

overweight and obese children (defined on the basis of BMI) by duration of sleep and in the proportion of children with a high amount of body fat mass, which decreased from 15.6% (95% CI 11.1–21.0%) in children sleeping for 10 h or less to 7.0% (95% CI 4.9–9.7%) in children sleeping for 11.5 h or longer. The respective crude odds ratios for 10.5–11 and  $\geq 11.5$  h of sleep compared to sleeping for 10 h or less were 0.64 (95% CI 0.52–0.79) and 0.46 (95% CI 0.36–0.59) regarding overweight, 0.50 (95% CI 0.36–0.69) and 0.37 (95% CI 0.25–0.56) regarding obesity and 0.59 (95% CI 0.39–0.89) and 0.41 (95% CI 0.25–0.67) regarding high amount of body fat mass.

The association of the duration of sleep and overweight/obesity to all potential risk factors listed in the methods section was tested. Potential risk factors significantly associated with overweight, duration of sleep or both in the bivariate analyses are shown in Table 2. In the bivariate analyses the strongest risk factors for overweight/obesity by the order of magnitude were high BMI of either parent, high birth weight, maternal smoking in pregnancy, high weight gain in the first year of life, watching TV or playing videogames for more than 1 h, eating snacks while watching TV, early introduction of complementary foods and having been given a bottle containing milk or carbohydrates to sleep. The strongest protective factors in the bivariate analyses were sleeping for 11.5 h or longer, high level of parental education, breastfeeding and regular sports activities in a club.

Watching TV or playing videogames for more than 1 h daily, regular sports activities in a club, complementary foods introduced before month 4, having a bottle containing milk or tea with carbohydrates to sleep and eating snacks while watching TV were also associated ( $P < 0.05$ ) with the duration of sleep. None of these risk factors, however, accounted for a change of the odds ratio for duration of sleep and overweight by 10% or more when introduced into a logistic regression model.

The final logistic regression model is shown in Table 3. The effects of sleeping for  $\geq 11.5$  h on overweight, obesity and high body fat and those of sleeping 10.5–11 h on overweight and obesity remained significant following in the final logistic regression model. Sleeping for 11.5 h or more reduced the risk of obesity and high body fat content to less than a half. The strength of the effect was similar to that for a high level of parental education.

### Discussion

These population-based data show a dose-dependent decrease in the prevalence of overweight and obesity by duration of sleep in 5- and 6-y-old children. Sleeping for 11.5 h daily or more reduced the risk of obesity and excessive body fat mass to less than a half. The data confirm the results of two previous studies in children aged 3 and 5 y.<sup>2,3</sup> The additional and important new insight from this study is that the beneficial effects of sleep duration could not be

**Table 2** Potential confounders of the association between the duration of sleep and overweight/obesity in 5- and 6-y-old children: factors significantly associated with overweight

	Prevalence (%) of sleeping Exposed (unexposed)			Odds ratio Being overweight (95% CI)	
	≤ 10 h	10.5–11 h	≥ 11.5 h		
Watching TV or playing videogames (gameboy) more than 1 h daily <sup>a</sup>	18.4 (11.5)	57.6 (59.8)	24.0 (28.7)	1.78	(1.51–2.08)
Regular sport activities in a club <sup>b</sup>	12.6 (16.5)	59.1 (58.5)	28.3 (25.1)	0.79	(0.67–0.93)
Complementary foods introduced before month 4 <sup>a</sup>	17.4 (13.9)	57.4 (59.1)	25.2 (27.0)	1.30	(1.06–1.59)
Given a bottle containing milk or tea with carbohydrates to sleep <sup>a</sup>	16.1 (13.6)	57.9 (59.4)	26.0 (27.0)	1.26	(1.07–1.49)
Eating snacks while watching TV—never/ever <sup>a</sup>	15.7 (12.0)	60.0 (60.3)	26.3 (27.8)	1.69	(1.41–2.02)
High level of parental education (y) <sup>b</sup>	13.9 (15.6)	60.2 (55.6)	25.9 (28.8)	0.53	(0.45–0.63)
BMI of either parent ≥ 30 <sup>b</sup>	15.3 (14.4)	58.7 (58.7)	26.1 (26.9)	3.16	(2.62–3.80)
Birth weight > 90th percentile <sup>b</sup>	18.0 (14.1)	66.0 (59.0)	26.0 (26.8)	2.07	(1.62–2.66)
Weight gain > 2.34×birth weight (upper quartile) <sup>b</sup>	12.3 (14.3)	60.6 (58.7)	27.1 (27.0)	1.82	(1.52–2.17)
Any breastfeeding <sup>b</sup>	14.0 (15.5)	59.6 (56.9)	26.4 (27.5)	0.64	(0.54–0.76)
Maternal smoking in pregnancy <sup>b</sup>	17.1 (13.7)	57.0 (59.6)	25.9 (26.7)	1.88	(1.49–2.37)
Single parenthood <sup>c</sup>	20.6 (13.7)	57.0 (59.0)	22.3 (27.3)	1.24	(0.97–1.58)
Living in region with > 800 inhabitants/km <sup>2c</sup>	18.1 (14.0)	59.1 (58.2)	22.9 (27.2)	1.21	(0.96–1.52)

<sup>a</sup>Significantly associated with duration of sleep ( $P < 0.05$ ; Mantel–Haenszel  $\chi^2$ ) and overweight.

<sup>b</sup>Significantly associated with overweight only ( $P < 0.05$ ; Mantel–Haenszel  $\chi^2$ ).

<sup>c</sup>Significantly associated with duration of sleep only ( $P < 0.05$ ; Mantel–Haenszel  $\chi^2$ ).

**Table 3** Adjusted odds ratios for overweight or obesity and for high body fat content in 5- and 6-y-old children: duration of sleep 10.5–11 h and ≥ 11.5 h as compared to a baseline of ≤ 10 h sleep per night during the week and other independent risk factors in the final logistic regression model

Risk factors	Odds ratio (95% CI) for:					
	Being overweight		Being obese		High body fat	
Sleeping 10.5–11 h/night	0.77	(0.59–0.99)	0.53	(0.35–0.80)	0.61	(0.37–0.99)
Sleeping for ≥ 11.5 h/night	0.54	(0.40–0.73)	0.45	(0.28–0.75)	0.42	(0.24–0.76)
High level of parental education (≥ 10 y)	0.68	(0.56–0.83)	0.66	(0.46–0.94)	0.55	(0.37–0.81)
BMI of either parent ≥ 30	3.00	(2.41–3.76)	3.71	(2.59–5.33)	2.23	(1.41–3.54)
Birth weight > 90th quartile	2.43	(1.78–3.30)	2.66	(1.63–4.34)	2.61	(1.45–4.68)
Weight gain during first year > 2.34×birth weight (upper quartile)	1.95	(1.59–2.39)	1.59	(1.10–2.31)	1.63	(1.08–2.46)
Watching TV or playing videogames (gameboy) more than 1 h daily	1.32	(1.08–1.61)	1.67	(1.16–2.41)	1.24	(0.84–1.84)
Eating snacks while watching TV—never/ever	1.34	(1.08–1.67)	1.13	(1.76–1.69)	1.14	(0.74–1.76)

explained by confounding due to a considerable number of constitutional or lifestyle factors and that the effect can be attributed to increases in body fat indeed as shown by BIA measurements.

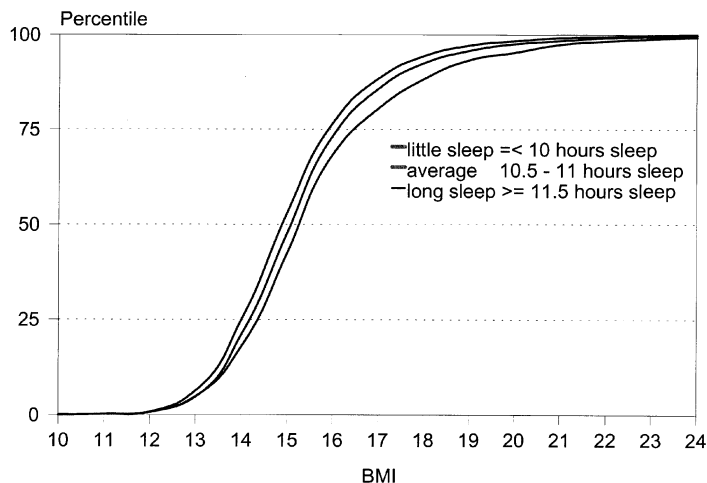
There are several issues regarding the validity of the data, that need to be discussed. These data were obtained from a questionnaire study in six Bavarian communities, which were representative for all children in Bavaria regarding the distributions of BMI, gender and number of siblings (data not shown). The return rate of the questionnaires was 75.9%, which is well above the 66% in other nationwide surveys,<sup>18</sup> suggesting that valid analyses are possible. The intraclass correlations (ICC) by communities showed poor associations: for BMI  $ICC_{BMI} = 0.02$  and for fat proportion  $ICC_{fat-proportion} = 0.02$ . Taking the intraclass correlations into account we therefore did not inflate the variances beyond the pooled estimates.

The exposure has not been optimally measured. What we report is time in bed rather than sleeping time. To measure

the sleeping time would have been optimal but is difficult in a population-based study because of logistics and the technical equipment required. Even time in bed could only be roughly estimated in broad categories from the usual time the child goes to sleep and gets up during the week. This imprecision is likely to account for random misclassification and bias towards unity.

Random misclassification of the outcome is likely as well since the scales and statimeters used in the different centres were not standardized, accounting for another source of bias towards unity.

The effects of sleep duration are therefore likely to be underestimated because of misclassification. The possibility of reverse causation, however, needs to be considered. Obesity appears to be an important risk factor for obstructive apnoea and sleep complaints in adults,<sup>1</sup> children and adolescents.<sup>19</sup> In children these sleep disturbances were mainly found in those with rather extreme obesity.<sup>19,20</sup> While there are some data to suggest that poor sleep



**Figure 1** BMI distribution in German 5- and 6-year-old children by duration of sleep.

quality in obese persons results in more sleeping hours,<sup>21–24</sup> others suggest that poor sleep quality reduces the net sleeping hours.<sup>25</sup> Our data additionally show that the different strata for duration of sleep account for a shift in the overall BMI distribution in children (Figure 1). Thus, the observed effect is not due to the extremes of the upper tail of the BMI distribution. Reverse causation therefore appears unlikely.

The core temperature during sleep is related to percentage body fat.<sup>26</sup> A reduction of the core temperature seems to be one of the triggers for sleeping.<sup>27,28</sup> Reduced sleep might at least possibly be rather a consequence of overweight and obesity than its cause.

The sleeping time of young children is likely to be a reflection of the families' lifestyle. Significant associations were found with TV watching or playing video games, sports activities, time of introduction of complementary food, eating snacks while watching TV, single parenthood, having a bottle with milk or carbohydrates to sleep and living in a densely populated area. None of these, however, were confounders accounting for a change of the odds ratio for duration of sleep and overweight/obesity by 10% or more, suggesting that the effect of the duration of sleep on overweight cannot be explained by the wide range of genetic, sociodemographic, constitutional and lifestyle risk factors for childhood obesity.

Television viewing habits with TV viewing at bedtime, particularly if the children have their own TV in their bedroom appear, to interfere with duration of sleep.<sup>29</sup> We have no data on TV viewing at bedtime, which appears to be correlated to the average weekday hours of television viewed.<sup>29</sup> Adjustment for excessive television viewing or use of video games did not explain the effect of sleep in our data, however.

Our data show that the duration of sleep has a clear effect on the children's body composition increasing total body fat.

Obesity is characterized by an excess of fat mass rather than body weight. Although correlation coefficients in the range of 0.6–0.8 between BMI and fat mass have been reported in large and heterogeneous samples of adults,<sup>30</sup> ponderal indices are inaccurate for the prediction of fatness in children who have not yet attained their peak height.<sup>31</sup> For a better evaluation of body fat mass the determination of the body composition is preferable. In the present study we were able to demonstrate that the beneficial effects of sleeping for 11.5 h or more for the reduction of prevalence rates of excessive body fat mass as defined by BIA were similar to those observed for overweight and obesity defined by BMI.

There are several possible explanations for biological plausibility of an impact of short sleep duration on the risk for overweight. Exercise may account for better and longer sleep. We found a significant association between the duration of sleep and sports. Regular sports activities, although probably only a rough estimate for exercise, were not a confounder in our data. The effect of exercise and exercise related energy expenditure on obesity in children might be negligible, however, as shown in a recent prospective study based on direct energy expenditure measurement.<sup>32</sup>

More convincing appears to be the mechanism suggested by Locard and co-workers, who hypothesized that an increased secretion of growth hormone (GH), might be instrumental. GH is mainly secreted during non-REM sleep periods (slow wave sleep, sleep stages 3 and 4).<sup>33</sup> The peak of slow-wave sleep and GH secretion is in the beginning of the night. There is, however, GH hormone release during the following hours as well as possibly related to short periods of slow-wave sleep during the rest of the night.<sup>34</sup> A higher net excretion of GH may therefore result from a longer duration of sleep (increased area below the curve). A higher activity of the somatotrophic axis might increase GH-mediated lipolysis and thus reduce the risk of overweight and obesity. In patients with sleep disorders the GH secretion has been

shown to be diminished.<sup>35</sup> These studies support the concept of a higher excretion of GH with a longer duration of sleep.

In summary, we have shown that the size of the impact of sleep duration was considerable and similar to other known risk factors for overweight confirmed in our data, such as parental education, excessive TV watching or playing videogames, high birth weight, and high weight gain in the first year of life.<sup>8,13,14,36</sup> The effect relates to total body fat and could not be explained by confounding by the wide range of genetic, sociodemographic, constitutional and lifestyle risk factors for childhood obesity. There are several possible mechanisms for biological plausibility of a causal relationship, although causal inference from cross-sectional studies is limited, however, because of potential bias due to reverse causation and non randomized exposure. Since confounding by unknown risk factors or those for which no data were collected in this survey cannot definitely be excluded our data cannot prove causality. In fact the considerable preventive potential for public health recommendations of longer sleeping hours in young children necessitates further studies to understand the actual causal mechanism, as yet unknown, and to rule out reverse causation.

### Acknowledgement

This study was supported by the Bayerisches Staatsministerium für Arbeit und Sozialordnung, Familie, Frauen und Gesundheit, Stiftung Kindergesundheit and the Democh Mauermaier Stiftung.

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