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# Adjusted population attributable fractions and preventable potential of risk factors for childhood obesity

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## Abstract

*Objective:* A number of individual risk factors for childhood obesity have been identified, but only some of these are amenable to prevention. To assess the amount of cases in a general population attributable to these risk factors, adjusted population-attributable fractions were estimated.
*Design:* Cross-sectional study.
*Setting:* Obligatory school entry examination in 2001/2002 in six Bavarian communities (Germany).
*Subjects:* 5472 children at age 5–6 years.
*Measures:* Anthropometric measures were ascertained by public health nurses, and measures concerning sociodemographics, lifestyle and child behaviour such as child's daily meal frequency were obtained with self-administered parental questionnaires. Obesity was defined according to sex- and age-specific body mass index cut-off points proposed by the International Obesity Task Force. Adjusted population-attributable fractions were calculated based on logistic regression.
*Results:* A combination of the risk factors low meal frequency, decreased physical activity, watching television $>1\ \text{h day}^{-1}$, formula feeding and smoking in pregnancy accounted for 48.2% of obese children. This combination yielded a maximal achievable prevalence reduction of 1.5% for obesity (3.2% observed prevalence).
*Conclusions:* A modification of five known risk factors for childhood overweight and obesity could reasonably lower obesity prevalences at school entry. These risk factors should be particularly considered in decision making on preventive measures.

**Keywords**
Prevention and control
Body weights and measures
Growth and development
Nutritional and metabolic diseases
Energy metabolism
Feeding behaviour

Overweight and obesity are the most common nutritional disorders in industrialised countries, which continue to increase in prevalence[1–4]. Childhood obesity predicts obesity in adulthood[5–7] and later cardiovascular disease[8–10]. Effective prevention strategies against childhood obesity are needed because therapeutic interventions are expensive and tend to have poor long-term results[4,11].

Previous studies identified several individual risk factors for childhood overweight and obesity amenable to prevention, such as low meal frequency[12], watching television (TV)[13,14], decreased physical activity[15], formula feeding[16–20] and smoking in pregnancy[21–24].

Although identification of risk factors is useful to define preventive strategies, decision making also requires information on the potential impact of the risk factors in populations. This is usually described as the population-attributable risk fraction (PARF), which considers not only the strength of the association, but additionally the prevalence of exposure. For example, a strong risk factor with a high individual risk such as a genetic mutation can have a low exposure prevalence and result in a low PARF or preventable potential, respectively. In contrast, a risk factor of moderate risk but high exposure prevalence could have a high impact on population level. Unadjusted PARFs are easy to estimate, but might overestimate corresponding preventable potentials of risk factors. Moreover, PARFs should consider confounding variables and, thus, should be estimated out of multivariate models.

To assess adjusted PARFs and respective preventable potentials for childhood overweight and obesity, data on $n = 5472$ pre-school children were analysed with a focus on modifiable risk factors amenable to prevention.

## Methods

### Study population and data sources

During the year before school entry, all children in Bavaria have to attend the mandatory school entry health examination in local public health offices. The purpose of this compulsory examination is to assess deficits which

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might influence school performance (e.g. impaired visual faculty) but can easily be corrected (e.g. prescription of glasses). Most of the children are at age 5 and 6 years when examined. Parents of 8741 children were invited to participate in a voluntary self-completion questionnaire study as part of their child's obligatory school entry examination in six Bavarian communities (Germany) from September 2001 to August 2002. Questionnaires were mailed together with the invitations for the school entry health examination. In the communities participating in this study, the distributions of body mass index (BMI), gender and number of siblings were similar in the 1997 compulsory school entry health examination to those in all regions of Bavaria, suggesting that the study region is representative for Bavarian children[25]. The region consists of one densely populated area (847 inhabitants $km^{-2}$) – the city of Ingolstadt, a population on the outskirts of the city of Augsburg (214 inhabitants $km^{-2}$) and four rural areas (Miesbach, Günzburg, Kitzingen and Schwandorf) all with $<200$ inhabitants $km^{-2}$. About 80% ($n = 7026$) of completed questionnaires were returned. Data on a number of sociodemographic and potential risk factors for childhood obesity were linked with children's stature and weight measures. The study was approved by the Bavarian State Office for Data Protection and the local ethical committee of the University of Munich.

The analysis was confined to children with full information on anthropometric measures (7.9% missing). Further inclusion criteria were full information on meal frequency (3.4% missing data), breast-feeding (3.0% missing data), smoking during pregnancy (2.7% missing data), decreased physical activity (2.7% missing data), parental education (4.2% missing data), parental obesity (5.1% missing data) and watching TV (1.3% missing data; multiple missing data were possible). Complete data for 2619 girls and 2853 boys (total $n = 5472$) were available for analysis.

### *Measures*

Stature and weight were measured in light clothing and without shoes by trained nurses of the respective public health offices. Stadiometers and balances are periodically calibrated by the respective gauging offices. Overweight and obesity were defined according to sex- and age-specific BMI cut-off points proposed by the International Obesity Task Force[26] which are equivalent to the widely used cut-off points of 25 and 30 $kg\,m^{-2}$ for adult overweight and obesity.

A number of covariates with previously reported associations with childhood overweight and obesity were considered as potential risk factors. All variables were dichotomised to allow for calculation of PARFs (see Statistical analysis). A low educational level of the parents was assumed when neither the father nor the mother achieved the equivalent of O-levels[27]. Parents were classified as obese[28,29] when at least one parent had a BMI of $>30\,kg\,m^{-2}$. Low meal frequency was assumed for children consuming $<5$ meals a day[12]. Children watching TV for $>1$ h a day were classified as having high TV consumption[13,14]. Children's physical activity was categorised as decreased if parental report on the respective Child Behaviour Checklist (CBCL) question was at least sometimes 'underactive, slow moving, or lacks energy'[30]. Furthermore, the variables smoking in pregnancy and breast-feeding[16–18] were included in the analysis as binary variables.

### *Statistical analysis*

Prevalence of obesity and 95% exact confidence limits associated with exposure/non-exposure to one of the risk factors were calculated based on the binomial distribution[31]. Crude and adjusted odds ratios and their respective 95% confidence limits for risk factors and overweight/obesity were calculated using logistic regression analysis.

Adjusted PARFs were calculated using multivariate logistic regression models according to Benichou[32]. Therefore, a logistic regression with all observed risk factors was calculated with obesity (the same for overweight) as outcome. To assess PARFs, one removes the risk factor of interest from the model by simply setting this covariate at zero for all individuals. Summing up the predicted probabilities for each individual gives the expected number of obese children on removal of the exposure. Calculating the PARF is now a simple matter of applying the formula

$$\begin{aligned}\text{PARF} =&(\text{observed no. of obese}\\ &- \text{expected no. of obese after}\\ &\text{removal of the exposure})/\\ &\text{observed no. of obese.}\end{aligned}$$

Preventable risk factors were estimated given the unpreventable factors. Within this approach, PARFs are additive. Maximal achievable reduction of prevalence was calculated by multiplying adjusted population-attributable fractions by the prevalences of overweight or obesity, respectively.

All calculations were carried out with the software package SAS version 9.1 (SAS Institute Inc.) and R version 2.1.1 (http://www.r-project.org/).

## Results

The number of overweight and obese children was $n = 616$ (11.3%) and $n = 176$ (3.2%). Smoking in the offspring's first trimester was reported by $n = 1248$ mothers (22.8%). Most children were breast-fed for $>1$ month ($n = 3221$; 58.9%), while $n = 921$ (16.8%) children were breast-fed for $<1$ month and $n = 1330$ (24.3%) were not breast-fed at all.

The number of children consuming four meals per day was 2362 (43.2%), while 2002 children (36.6%) consumed five meals daily. The proportion of children consuming more than five meals daily was only 3.0%, while 16.5% of the children had a maximum of only three meals a day.

Obesity at school entry was most strongly associated with parental obesity, followed by decreased physical activity, watching TV and smoking in pregnancy (Table 1).

Breast-feeding was inversely related to obesity, followed by high parental education. Adjustment for each other could not explain the observed associations (Table 2).

The highest PARF for overweight and obesity was observed for parental obesity, with 15.1% and 30.7%, respectively, which corresponds to the high adjusted odds of this factor (Table 2).

Although low meal frequency had one of the lowest adjusted odds ratios, the corresponding PARF for overweight was the second highest due to its high exposure prevalence (60.4%; Table 3).

For the variables watching TV, formula feeding, decreased physical activity, low meal frequency and maternal smoking in pregnancy which are amenable to prevention, a combined PARF and the maximal achievable reduction of prevalence (MARP) was calculated: a PARF of 42.5% with a corresponding MARP of 4.8% for overweight and a PARF of 48.2% with a corresponding MARP of 1.5% for obesity was estimated. Watching TV, decreased physical activity and low meal frequency explained a larger proportion of the high combined PARF and MARP compared with formula feeding and maternal smoking in pregnancy.

## Discussion

A combination of high TV consumption, maternal smoking in pregnancy, decreased physical activity, low meal frequency and early postnatal formula feeding could explain a reasonable amount of overweight (42.5%) and obese (48.2%) children. These risk factors are usually amenable to prevention and, thus, their avoidance could theoretically decrease the prevalence of overweight children from 11.3 to 6.5% and of obese children from 3.2 to 1.7%.

Some methodological limitations have to be mentioned. In a cross-sectional study, reverse causality has to be addressed[33]. However, reverse causality for TV consumption and childhood obesity seems to be unlikely, since a randomised controlled trial could confirm that high TV consumption accounts for a higher risk for childhood obesity[14].

Mothers might not answer the question on smoking in pregnancy correctly, more precisely concealing that they have smoked in pregnancy. However, other studies suggest that self-reports of smoking are mostly accurate[34].

The confinement to complete cases might yield a selection bias. Crude odds ratios for the entire sample were compared with crude odds ratios from the sample confined to complete cases. The odds ratios were still statistically significant and did not differ except to the first decimal place assuming no sensible selection bias due to complete case analysis (data not shown).

Additionally, the return rate of the questionnaires was high at 80.4%. This is well above the 66% found in other nationwide surveys[35], suggesting that valid inference for Bavarian children is possible.

The observed risk factors were also reported by other studies on childhood overweight/obesity. As in other studies, low parental education[27], parental obesity[36–38], decreased physical activity[15] and watching TV[13,14] were associated with childhood obesity, whereas breast-feeding[16–20] was apparently protective. To our knowledge, only two studies on childhood obesity report attributable fractions and are limited to unadjusted estimates of only one single modifiable risk factor each[39,40]. Although the fractions are difficult to compare with others due to unadjusted estimates, different ages of subjects, other definitions of obesity, etc., the PARF estimates are in a similar range compared with our estimates, with 12% for low exercise level[40] and 17% for high TV consumption[39]. This underlines the importance of such modifiable risk factors in the aetiology and prevention of childhood obesity even in transitional societies[40].

The importance of population-attributable fractions becomes clear when comparing individual risks (here odds ratios), e.g. for meal frequency and smoking in pregnancy, with corresponding population-attributable fractions. While the individual risk of obesity with intrauterine tobacco exposure is higher than that due to low meal frequency, the population-attributable fraction is not, due to a lower prevalence of the present risk factor.

Smoking during pregnancy, watching too much TV, formula feeding and a low frequency of meals are risk

**Table 1** Prevalence of overweight/obesity for exposure/non-exposure concerning respective risk factors; 95% confidence intervals based on binomial distribution

| | Prevalence of overweight (%) | | Prevalence of obesity (%) | |
|---|---|---|---|---|
| Risk factor | Exposed | Non-exposed | Exposed | Non-exposed |
| At least one parent with obesity | 22.8 (19.9–26.0) | 9.3 (8.5–10.2) | 9.8 (7.8–12.1) | 2.1 (1.7–2.6) |
| Decreased physical activity | 19.2 (17.0–21.5) | 9.0 (8.2–9.9) | 7.6 (6.1–9.2) | 2.0 (1.6–2.5) |
| Watching television $>1$ h day$^{-1}$ | 15.5 (14.0–17.1) | 8.5 (7.6–9.5) | 5.4 (4.5–6.4) | 1.8 (1.4–2.3) |
| Smoking in pregnancy | 15.1 (13.2–17.3) | 10.1 (9.2–11.1) | 5.6 (4.4–7.0) | 2.5 (2.1–3.0) |
| Low educational level of parents | 14.8 (13.1–16.7) | 9.7 (8.8–10.7) | 4.9 (3.9–6.1) | 2.5 (2.0–3.0) |
| No breast-feeding | 14.6 (12.7–16.6) | 10.2 (9.3–11.2) | 5.3 (4.1–6.6) | 2.6 (2.1–3.1) |
| $<5$ meals a day | 13.1 (12.0–14.3) | 8.4 (7.3–9.6) | 4.0 (3.3–4.7) | 2.1 (1.5–2.8) |

**Table 2** Crude and adjusted odds ratios (ORs) for respective risk factors related to overweight/obesity; 95% confidence intervals based on logistic regression

| | Overweight | | Obesity | |
|---|---|---|---|---|
| Risk factor (exposure prevalence) | OR | Adjusted OR | OR | Adjusted OR |
| At least one parent with obesity (14.2%) | 2.88 (2.37–3.49) | 2.52 (2.06–3.09) | 4.97 (3.65–6.76) | 4.01 (2.90–5.54) |
| Decreased physical activity (22.0%) | 2.39 (2.00–2.85) | 2.23 (1.86–2.67) | 4.01 (2.97–5.43) | 3.60 (2.63–4.92) |
| Watching television >1 h day$^{-1}$ (39.3%) | 1.97 (1.66–2.33) | 1.53 (1.28–1.83) | 3.10 (2.26–4.26) | 2.01 (1.44–2.80) |
| Smoking in pregnancy (22.8%) | 1.59 (1.32–1.91) | 1.32 (1.10–1.61) | 2.31 (1.70–3.14) | 1.75 (1.25–2.43) |
| Low educational level of parents (29.8%) | 1.61 (1.36–1.92) | 1.23 (1.02–1.48) | 2.01 (1.49–2.72) | 1.25 (0.90–1.73) |
| No breast-feeding (24.3%) | 1.51 (1.25–1.81) | 1.20 (0.98–1.46) | 2.12 (1.55–2.88) | 1.50 (1.07–2.09) |
| <5 meals a day (60.4%) | 1.65 (1.38–1.98) | 1.52 (1.26–1.83) | 1.95 (1.38–2.75) | 1.65 (1.16–2.35) |

**Table 3** Adjusted population-attributable fractions (PARFs) for respective risk factors on overweight/obesity and corresponding maximal achievable reduction of prevalence (MARP)

| | Overweight | | Obesity | |
|---|---|---|---|---|
| Risk factor | PARF adjusted (%) | MARP (%) (observed prevalence 11.3%) | PARF adjusted (%) | MARP (%) (observed prevalence 3.2%) |
| Unpreventable risk factors combined* | 20.4 | | 36.2 | |
| +Watching television >1 h day$^{-1}$ | 13.0 | −1.5 | 19.4 | −0.6 |
| +Less than 5 meals a day | 14.8 | −1.7 | 12.5 | −0.4 |
| +Decreased physical activity | 10.2 | −1.2 | 11.4 | −0.4 |
| +Formula feeding | 1.9 | −0.2 | 2.3 | −0.1 |
| +Smoking during pregnancy | 2.6 | −0.3 | 2.6 | −0.1 |
| Preventable risk factors combined | 42.5 | −4.8 | 48.2 | −1.5 |
| Overall adjusted PARF | 62.8 | | 84.6 | |

The factors marked by a ‘+’ were calculated sequentially, which means their PARF was calculated given the risk factors above them in the table.
*The factors parental obesity and low educational level were combined, and regarded as unpreventable.

factors which are preventable. If there would be a common awareness that a significant proportion of cases of overweight and obesity can be ascribed to these factors, a serious reduction of prevalence would be likely. We focused our research on established risk factors which can easily be ascertained. We did not assess the predictive potential of other easily obtainable and preventable risk factors such as consumption of soft drinks[41] due to lack of information in our data. This should be addressed in future studies, preferably prospective studies or randomised controlled trials.

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*What is already known on this subject?:* The individual risk factors low meal frequency, decreased physical activity, high TV consumption, formula feeding and smoking in pregnancy in childhood obesity are well known. However, decision making on preventive measures also requires information on the potential impact of risk factors in populations, and is usually not estimated.

*What does this study add?:* A combination of these risk factors accounted for 48.2% of obese children with a maximal achievable prevalence reduction of 1.5% (3.2% observed prevalence). Avoidance of these modifiable risk factors could reasonably lower obesity prevalence at school entry and, thus, could be a target for preventive measures.

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