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Breastfeeding and Childhood Obesity: Shift of the Entire BMI Distribution or Only the Upper Parts?

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A protective effect of breastfeeding on overweight (binary) has been reported by meta-analyses using logistic regression, whereas studies using linear regression and BMI (continuous) detected no significant association. To assess the relationship of these differences with different outcome classification, we compared results for linear, logistic, and quantile regression models in a cross-sectional data set of considerable size. Height, weight, and questionnaire data on 9,368 preschool children were collected during school-entry examinations in 1999 and 2002 in Bavaria, Southern Germany. We calculated multivariable linear, logistic, and quantile regression models with outcomes BMI, overweight, obesity, and BMI quantiles (as appropriate). Models considered the covariates breastfeeding (breastfed vs. never breastfed), gender, age, smoking in pregnancy, TV watching, maternal BMI, parental education, and early infant weight gain. No significant association was found in the linear regression model. In the logistic model, a significant association was observed for obesity (odds ratio: 0.72 (95% confidence interval (CI) 0.55, 0.94)). In quantile regression no significant point estimates were observed for the percentiles of 0.4–0.8. However, breastfeeding reduced the BMI of children having values on the 90th and 97th percentiles by −0.23 (95% CI −0.39, −0.07) and −0.26 (95% CI −0.45, −0.07) kg/m^2, respectively, on average. In contrast, breastfeeding was significantly associated with a low shift toward higher BMI values for BMI quantiles of 0.03 and from 0.1 to 0.3. The detection of associations between breastfeeding and childhood body composition might be related to the coding of the response variable (continuous or binary) and the statistical method used (linear, logistic, or quantile regression). Quantile regression should additionally be applied in such studies.

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INTRODUCTION

Three meta-analyses reported significant protective effects of breastfeeding against overweight in later life (1–3), whereas another one addressed a small effect of breastfeeding on mean BMI to confounding factors and publication bias (4). Additionally, a recently published intervention study failed to confirm a protective breastfeeding effect on obesity (5). Obviously, the meta-analyses with positive findings were those with binary BMI values classifying children as obese or not obese (1–3), whereas the nonpositive results came from studies assessing BMI as a metric outcome (4,5).

A potential effect of breastfeeding on upper percentiles of the BMI distribution only might be an explanation of the inconsistent finding between linear and binary outcome studies. A recent descriptive study reported an effect of breastfeeding on the upper BMI percentiles only, but did not adjust for potential confounders (6). Quantile regression is a statistical tool allowing the assessment of effects on different subgroups. We applied this method on a data set from the school-entry health examination in Bavaria, Germany, in 1999 and 2002 to assess whether the effect of breastfeeding is different in subgroups defined by percentiles of the children's BMI distribution.

METHODS AND PROCEDURES

Data

Data were available on n = 14,412 children participating in the school-entry health examination in Bavaria, Southern Germany, in 1999 (n = 7,386) and 2002 (n = 7,026). In the years 2000 and 2001, no data were collected. Children's age ranged from 54 to 88 months. Parental questionnaires on sociodemographic, lifestyle, and other risk factors for obesity were distributed together with the invitation to the compulsory school-entry examination. Parents were asked whether their children were breastfed at any time. Unfortunately, information on the duration of breastfeeding was missing for most individuals. Children's weight and height were measured in light clothing and with calibrated balances and fixed stadiometers during

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the examination. Both studies have been described in detail elsewhere (7,8).

Apart from breastfeeding as binary variable (breastfed/never breastfed) and the confounders sex and age, the following explanatory variables with previously reported associations to childhood body composition were *a priori* included in the analyses: maternal smoking in pregnancy, amount of watching TV, highest graduation of either parent (elementary/secondary/certificate qualifying for university), maternal BMI, and child's weight gain from birth to 2 years of life (8–10). We confined our analysis to cases with complete information on these variables. A further prerequisite for inclusion in the analysis was German nationality, as the questionnaires were only available in German language. These restrictions left in total data of 9,368 children from both studies for the analyses, with 9,287 (99.1%) of those in the age range of 60–83 months.

Statistical methods

Quantile regression enables to model different sample percentiles ("quantiles") of an outcome variable with respect to covariates (11,12). The approach and interpretation of quantile regression are similar to those of linear regression. However, quantile regression leads to more comprehensive results because of its ability to assess any part of the outcome distribution, while linear regression can model only the mean of the outcome. In contrast to logistic regression, quantile regression requires no transformation of the outcome to a binary variable.

We calculated linear, logistic, and quantile regression models with BMI information as outcome, breastfeeding as main explanatory variable and all confounders. To define overweight and obesity for the logistic regression models, we used the binary variables BMI above vs. below the 0.9 and 0.97 percentile in the data set analyzed, respectively. Within the quantile regression, we assessed the 0.03, 0.1, 0.2,…, 0.8, 0.9, and 0.97 percentiles of the BMI.

All calculations were carried out with the open-source software R 2.6.2 (http://cran.r-project.org), using the *quantreg* package.

RESULTS

The overall mean BMI of the 9,368 children was 15.29 kg/m^2 with a median of 15.03 kg/m^2 and an s.d. of 1.81 (Table 1). A total of 2,358 children (25%) had never been breastfed.

The empirical density functions of the BMI for breastfed vs. nonbreastfed children did not indicate a shift of the mean BMI, but of the upper tail of its distribution (Figure 1). This was also observed in the Tukey mean difference plot of both groups (Figure 2). Both figures, however, do not consider potential confounders.

Linear regression with adjustment for confounders showed similar results for the effect of breastfeeding on the mean BMI (point estimate: −0.01 (95% confidence interval (CI) −0.09, 0.07); Table 2). Similarly, breastfeeding was not a significant predictor of overweight in the logistic regression model (odds ratio: 0.92 (95% CI 0.78, 1.08)), whereas a considerable and significant effect for breastfeeding was observed in the logistic model for obesity (odds ratio: 0.72 (95% CI 0.55, 0.94)).

Quantile regression revealed a protective effect of breastfeeding confined to the 0.9 and 0.97 quantiles of the BMI distribution (Table 2, Figure 3). Breastfeeding reduced the BMI of children with BMI values on the 90th and 97th percentiles on average being −0.23 (95% CI −0.39, −0.07) and −0.26 (95% CI −0.45, −0.07) kg/m^2 lower. No significant point estimates were found for the percentiles of 0.4–0.8, but breastfeeding was associated with a low but significant shift toward higher BMI values among BMI quantiles between 0.03 and 0.3 (Table 2). We also tested the 85th and 95th percentiles, which

Table 1 Study characteristics

Variable	Mean (s.d.)/*n* (%)
Children's BMI (kg/m^2)	15.29 (1.81)
Age (months)	73.54 (4.64)
Maternal BMI (kg/m^2)	23.26 (3.87)
Weight gain in first 2 years (kg)	9.38 (1.39)
Males	*N* = 4,828 (52%)
Breastfed	*N* = 7,010 (75%)
Watching TV >2 h per day	*N* = 572 (6%)
Mother smoking in pregnancy	*N* = 843 (9%)
Elementary or less parental school degree	*N* = 2,574 (27%)

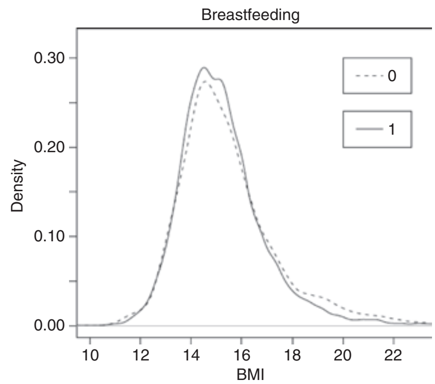

Figure 1 Univariate density distribution of children's BMI with regard to breastfeeding. The distribution of nonbreastfed children (0) seems to be slightly more right-skewed than that of breastfed children (1).

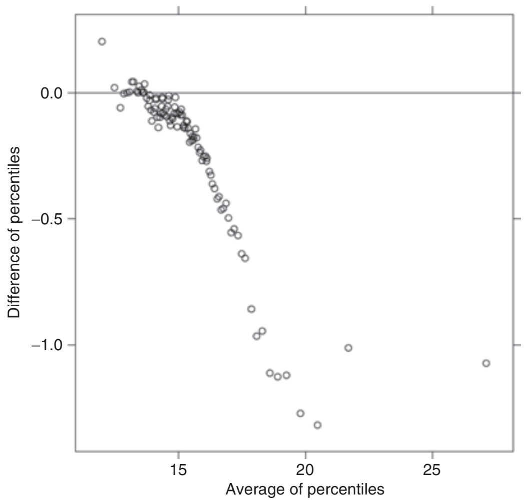

Figure 2 Tukey mean difference plot of BMI percentile differences between breastfed and nonbreastfed children. The BMI difference at identical percentiles of the BMI distribution in both groups (vertical axis) are plotted against the mean averages of the BMI estimates at identical percentiles in the two groups (horizontal axis). Each dot represents the difference in BMI at a defined percentile of breastfed vs. nonbreastfed children. The figure indicates that the locations of the percentiles of both groups are almost equal for lower BMI values, but increasingly different for values of BMI > 15.

Table 2 Regression coefficients of breastfeeding and their 95% confidence intervals (CIs) in the multivariable models of linear regression (LR), logistic regression for overweight (OV) and obesity (OB), and quantile regression for the 0.03, 0.1, 0.2,…,0.8, 0.9 and 0.97 percentiles (Q3, Q10,…)

	Regression coefficient	95% CI
LR	−0.01	−0.09, 0.07
OV	−0.09 (OR: 0.92)	−0.25, 0.07 (OR: 0.78, 1.08)
OB	−0.33 (OR: 0.72)	−0.61, −0.05 (OR: 0.55, 0.94)
Q3	0.17	0.03, 0.31
Q10	0.08	0.00, 0.16
Q20	0.10	0.02, 0.18
Q30	0.09	0.01, 0.17
Q40	0.06	−0.02, 0.14
Q50	0.04	−0.04, 0.12
Q60	−0.01	−0.09, 0.07
Q70	−0.04	−0.14, 0.06
Q80	−0.07	−0.21, 0.07
Q90	−0.23	−0.41, −0.05
Q97	−0.26	−0.48, −0.04

OR, odds ratio.

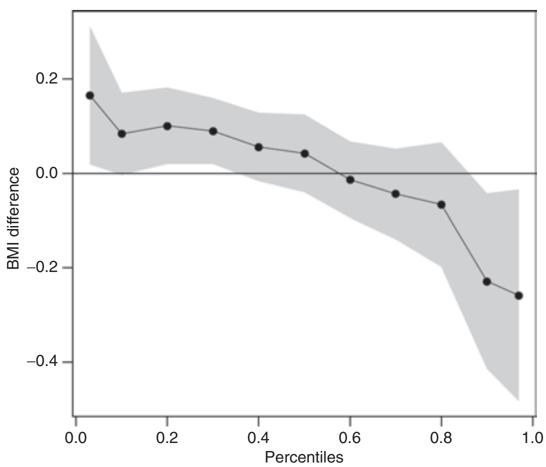

Figure 3 Point estimates and 95% confidence bounds for BMI differences between breastfed and formula-fed children for specific BMI percentiles (0.1–0.9 deciles and 0.03 and 0.97 percentile) in the multivariable quantile regression model including sex, age, maternal smoking in pregnancy, TV watching, parents' graduate, maternal BMI and child's weight gain in the first 2 years.

are recommended by CDC for the definition of overweight and obesity (13): Breastfeeding was not significant for the 85th percentile (point estimate (95% CI): −0.07 (−0.23, 0.11)), but for the 95th one (−0.27 (−0.53, −0.01)).

To examine the effects of confounding, we calculated all models excluding all confounders except sex and age. In contrast to the final adjusted linear model and similar to the results of Owen *et al.* (4), a protective effect of breastfeeding with a reduction in the mean BMI was observed in the analysis without the additional confounders (−0.23 (95% CI −0.31, −0.15)). In the quantile regression without adjustment, all quantiles above the median were shifted significantly to negative values (data not shown), suggesting protective effects not only for quantiles of ≥0.9.

DISCUSSION

At school entry, the BMI distribution in formerly breastfed and formula-fed children differed: while the middle part of the distribution was similar, the lower tail showed higher values in breastfed children, and the upper tail showed lower values. This finding suggests a lower proportion of overweight and obese children among breastfed children. Interestingly, as shown in a recent paper (14), the choice of the cutoff values seems to be of little importance for the identification of risk factors for childhood obesity.

The observed effects were similar for overweight and obese children and slightly bigger than for children at lower quantiles. As effects to the opposite direction were found for all quantiles lower than the 0.6 decile including even the median, effects might have edged out for the mean BMI.

Therefore, it is not surprising that meta-analyses applying binary outcomes (overweight or obesity) found protective effects of breastfeeding against childhood obesity, whereas those applying linear outcomes did not (1–3). The failure to observe a considerable effect of breastfeeding on BMI in children at school entry using BMI means or linear regression models (4), in contrast, may be due to contrary effects of breastfeeding on the upper and lower parts of the BMI distribution and to the unchanged middle part of the distribution.

Potential alternative explanations for our findings include residual confounding and selection bias (4). A number of established confounders were included in the analyses applied: gender, age, smoking in pregnancy, TV watching, maternal BMI, parental social status, and early weight gain. It is difficult to exclude residual confounding. We found it difficult, however, to imagine a risk factor associated with breastfeeding that selectively affects the upper and lower part of the BMI distribution in children. Selection bias might be a more serious issue: The participation rate in the studies was 76 and 80%, respectively (7,8), and the data set was further reduced by 35% due to the complete cases analysis and the restriction to German children. It is difficult as well to imagine why nonparticipation and failure to report all variables might account for different effects of breastfeeding on different parts of the BMI distribution. Furthermore, we detected no significant mean differences for any covariates between the full data set vs. data with full information about breastfeeding, indicating that missing information about breastfeeding is not related to confounding variables. This analysis was not confined to singletons, and no effort was undertaken to identify siblings in the 1999 and 2002 data sets. Potential intercorrelation in close family members seemed to be no significant issue in this paper with an emphasis on methodology.

Biological explanations for different effects of a potential risk or protective factor—such as breastfeeding—on different parts of the BMI distribution include interaction with other known or unknown determinants of the BMI in children such as genetics, environmental, and lifestyle factors. For example, a subgroup of children with a specific genetic makeup might be more susceptible to the effects of breastfeeding. For the effect of environmental tobacco smoke exposure on the development of asthma, e.g., such an interaction has been shown for GSTM1 and GSTT1 deficiency (15). Additionally, breastfeeding was somewhat arbitrarily dichotomized to "yes" or "no" in this analysis. There might, however, be considerable variability within breastfeeding duration and quality—some children breastfed longer or more exclusively—with effects on overweight and obesity confined to these children (16,17).

Our findings show that breastfeeding might prevent overweight and obesity (irrespective of the cutoff values applied) rather than account for a shift in the entire BMI distribution. Therefore, breastfeeding appears to be a useful public health strategy to prevent overweight and obesity without affecting underweight children in terms of weight reduction. This is reassuring: BMI at the lower percentiles is even higher in breastfed children.

It may appear surprising that breastfeeding shifts the upper and lower tail of the BMI distribution in different directions. Human milk, however, is unique in meeting the nutritional requirements of newborns and young infants and has proven its value since the beginning of mankind. All infant formulae attempt to be as close to human milk as possible, but so far have at best come close. If human milk is the optimal nutrient for children, it would not be surprising if breastfeeding shifts the weight of children toward the mean, as neither of the extreme values is likely to offer an advantage. The interesting finding in our data is that this possible shift toward the mean might also pertain to programming of the BMI in children at school entry.

The strength of quantile regression for the assessment of potential associations between breastfeeding and BMI in children is that it offers a more comprehensive approach than linear regression. While linear regression focuses on shifts of the mean that may be caused by a true shift of the mean with a shift of the entire distribution or a shift in the upper tail or lower tail only, quantile regression allows to differentiate shifts in different parts of the distribution. Particularly in the case of different directions of the effects of a single exposure on different parts of the distribution, effects on the upper tail, which is what we are looking for when we aim to study further the effects on overweight and obesity, may not be detected by linear regression. Furthermore, it makes use of the full information of the data—in contrast to logistic regression, which implies a loss of information due to the transformation of the outcome BMI to a binary variable.

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DISCLOSURE

The authors declared no conflict of interest.

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