PUBLISHED VERSION

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GMS Medizinische Informatik, Biometrie und Epidemiologie, 2006; 2(1):Doc03-1-Doc03-8

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Original Article

Body weight, body mass index, overweight and obesity in consecutive cohorts of children at school entry in a community in Lower Bavaria 1997-2002

Körpergewicht, Body-Maß-Index, Übergewicht und Fettleibigkeit bei Schulanfängern in konsekutiven Kohorten in Niederbayern zwischen 1997 und 2002

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Ziel: *Durchführung einer Analyse zeitlicher Trends von Gewicht, Body-Maß-Index (BMI), Übergewicht und Fettleibigkeit zwischen 1997 und 2002 bei 6 Einschulungsjahrgängen sowie die Analyse von Einflussfaktoren auf die Prävalenz und das Risiko dieser gewichtsbezogenen Parameter.*

Methodik: *Wir analysierten Größe, Gewicht und BMI bei 6.420 Schulanfängern zwischen 1997-2002. Übergewicht und Fettleibigkeit wurden nach internationalen alters- und geschlechtsspezifischen cut-off-Werten definiert. Neben der deskriptiven Statistik zur Beschreibung der zeitlichen Trends wurden eine Kovarianzanalyse zur Schätzung von Störvariablen bei Gewicht und BMI sowie eine logistische Regressionsanalyse zur Ermittlung von Störvariablen bei Übergewicht und Fettleibigkeit durchgeführt.*

Ergebnisse: *Obwohl wir eine allgemeine Senkung des mittleren Körpergewichts (minus 9%), des BMI (minus 9,5%), von Übergewicht (minus 7,4%) und Fettleibigkeit (minus 6,8%) zwischen 1997 und 2002 feststellen konnten, zeigten sich bedeutsame Unterschiede dieser Parameter mit Anstieg und Abfall zwischen den Jahrgängen. Die Kovarianzanalyse zeigte signifikante Effekte von Alter, Geschlecht und Jahr der Untersuchung auf Gewicht und BMI. Für Übergewicht wurden signifikante Unterschiede in den Altersgruppen gefunden, für Fettleibigkeit hingegen nicht. Multiple logistische*

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gby(M20051227.2)

Regressionsmodelle zeigten, dass Alter (OR, 2,8; 95% KI, 2,3-3,5) und weibliches Geschlecht (OR, 1,3; 95% KI, 1,2-1,5) signifikant mit Übergewicht, beziehungsweise signifikant (Alter: OR, 1,8; 95% KI, 1,2-2,9; weibliches Geschlecht: OR, 1,4; 95% KI, 1,0-1,99) mit Fettleibigkeit assoziiert waren. In diesen Modellen waren das Jahr der Untersuchung 1998 (OR, 1,9; 95% KI, 1,5-2,5) und 1999 (OR, 2,5; 95% KI, 1,97-3,3) signifikant mit Übergewicht und das Jahr 1999 (OR, 2,9; 95% KI, 1,6-5,2) signifikant mit Fettleibigkeit assoziiert.

Schlussfolgerungen: *Unsere Studie zeigte, dass Faktoren wie Alter und Geschlecht als potentielle Störvariablen aufgefasst werden sollten, wenn zeitliche Trends von Häufigkeit und Risikofaktoren für Übergewicht und Fettleibigkeit bei Kindern analysiert werden.*

Schlüsselwörter: Kinder, Body-Maß-Index, Übergewicht, Fettleibigkeit

Objective: *To study time trends of weight, body mass index, overweight and obesity of children at school entry and to analyze potential effects of changes in the structure of consecutive cohorts of children at school entry over time on these weight-related measures.*

Design: *We studied height, weight and body mass index (BMI) in 6 consecutive cohorts (1997-2002) of children at school entry (N=6,420). Overweight and obesity were defined by internationally valid sex and age specific cut-off points. In addition to descriptive statistics for time trends we applied an analysis of covariance to estimate the impact of covariates on weight and BMI and logistic regression models for the impact of covariates on overweight and obesity.*

Results: *Although we found an overall decrease of mean body weight (minus 9%), BMI (minus 9.5%), overweight (minus 7.4%) and obesity (minus 6.8%) between 1997 and 2002, there was a considerable variation in these measures between single years. The analysis of covariance showed significant impact of age, gender and year of examination on weight and BMI. Whereas there were significant differences in the proportion of overweight children between different age groups, the effect of age was not significant for the proportion of obesity. Multiple logistic regression models showed that age (OR, 2.8; 95% CI, 2.3-3.5) and female gender (OR, 1.3; 95% CI, 1.2-1.5) were significantly associated with overweight and significantly with obesity (age: OR, 1.8; 95% CI, 1.2-2.9; female gender: OR, 1.4; 95% CI, 1.0-1.99), respectively. In these models the years of examination of 1998 (OR, 1.9; 95 %CI, 1.5-2.5) and 1999 (OR, 2.5; 95% CI, 1.97-3.3) were significantly associated with overweight, and the year 1999 (OR, 2.9; 95% CI, 1.6-5.2) with obesity.*

Conclusions: *Our study showed that changes in age and gender distribution have to be taken into account when time trends of weight, BMI, overweight and obesity are derived from investigations of children at school entry.*

Keywords: children, BMI, body mass index, body weight, obesity

Introduction

Negative short-term and long-term health consequences of obesity on children, adolescents and adults are increasingly in the focus of public discussions and policies, and research [1], [2], [3]. Other comorbidities include asthma and orthopedic problems as well as a variety of more rare disorders [4], [5]. The psychological well-being and the quality of life can also be affected [2], [4], [6].

Routine diagnostic procedures, such as screening for overweight or obesity, and treatment recommendations

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for overweight/obese children are not well implemented in pediatric practice [7]. Lack of routine screening procedures might be related to difficulties with the definition of overweight and obesity in children since BMI cut-off points for adults are not necessarily valid in children. Since the body proportions and the relationship between body weight and height are changing during childhood and adolescence, substantial effort was placed into the definition of childhood overweight and obesity [8]. A promising approach to define overweight and obesity in children and adolescents was presented by Cole at el. as an international reference, referring the widely excepted adult (at age 18 years) cut-off points for BMI of 25 (overweight) and 30 (obesity) to age and sex specific cut-off-points in children and adolescents (2-18 years of age) [9]. Although this approach has attracted some criticism [10], it allows for national as well as international comparisons.

Previous approaches to define overweight and obesity in children were based on percentiles, e.g. 90^{th} and 97^{th} percentile estimates, and have been widely used in many studies on overweight and obesity in childhood [11], [12], [13], [14]. Changes in the prevalence of overweight and obesity over time in children and adolescents have been investigated in different countries using the percentile cut-off approach [15], [16]. Following this concept Kromeyer-Hauschild et al. reported changes in proportions of overweight and obese children over longer time periods between 1975-1995 with steps of 10 or more years indicating an increase of prevalence of overweight and obesity over time [17].

In Germany most of the studies reporting changes in overweight and obesity over time are based on routine data collected during compulsory examination of children at school entry and most of the results are usually reported as changes in unadjusted estimates despite many potential confounders. For example changes in age structure, sex or ethnic background may potentially affect the prevalence of overweight or obesity over time.

In this analysis we investigated time trends of weight-related measures in a community in Lower Bavaria during 1997-2002 and analyzed potential effects of changes in the structure of the cohorts of children at school entry over time on the measures of weight, body mass index, overweight and obesity.

Materials and methods

We performed an analysis of data collected routinely during compulsory medical examinations of 6,420 children at school entry in one administrative region of Lower Bavaria in the years 1997-2002. Each round of the examination started in autumn/winter and proceeded till spring of the following year. Date of the examination and birth date of the child was used to obtain exact age at the examination. Nationality of the children was used as an estimate of ethnic background. Children were measured in respect to the body weight and height and examined according to the Bavarian requirements for children at school entry by the same team of investigators consisting from a medical doctor and two assistants over the whole period. For body weight measurement a standard scale was used, which was controlled for accuracy according to requirements of the responsible institution after the examinations in 1998, 2000 and 2002.

We used the age and sex specific cut-off-points for overweight and obesity according to Cole et al. [9]. The body mass index (BMI) was calculated as body weight divided by squared body height in meters. The classification of overweight and obesity was based on the exact age of the children that was rounded to the nearest half year. Children with BMI at or above the cut-off value corresponding to a BMI of 25 kg/m^2 in late adolescence (e.g. BMI of 17.5/17.3 for 6 year old boys/girls) were classified as overweight (or obese when the respective age and sex specific cut-points were reached, e.g. BMI of 19.8/19.7 for 6 year old boys/girls). Age was used as a continuous variable for adjustment in multiple variable analyses and was classified into three groups (4.5-5.49 years; 5.5-6.49 years; 6.5-7.49 years) when proportions of obesity and overweight were compared for different years.

Statistical analysis

We used simple tabulation for the crude (unadjusted) analysis of mean values of body weight and BMI during the study period (Figure 1, Figure 2) and of the confounding factors (Table 1). Comparisons between groups were made with the Pearson's Chi-square test for categorical variables and either Student's t-Test (two categories) or 1-way analysis-of-variance (>2 categories) for continuous variables.

To estimate the impact of covariates on weight and BMI we used the analysis of covariance (GLM procedure in SPSS). In two separate models weight and BMI were the dependent variables and year of examination, age, gender, and nationality acted as independent continuous or categorical variables.

In a second step we analyzed impact of covariates on overweight and obesity applying models of multiple logistic regressions. The binary variables overweight and obesity were defined according to the age and sex specific cut-off-points by Cole et al. [9]. To estimate

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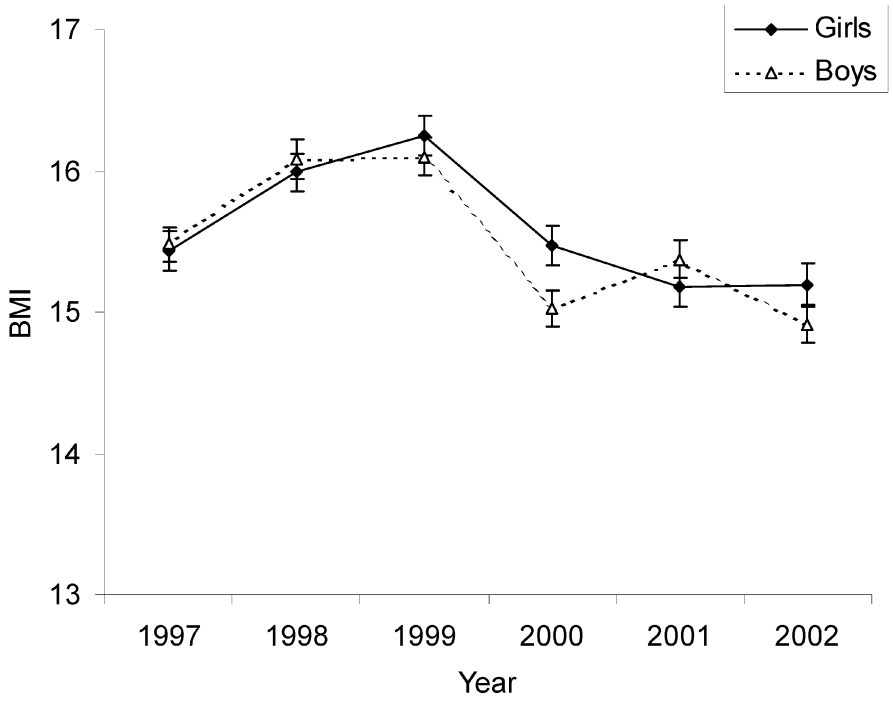
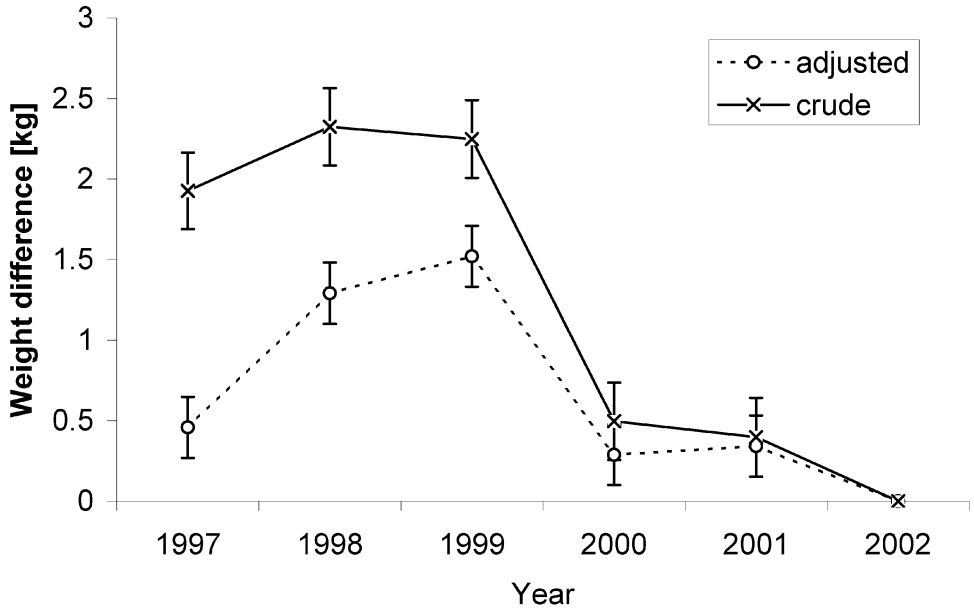


*adjusted for age = 6.05 years

Figure 1: Body mass index* of children at school entry in 1997-2002 (mean and 95%CI)



*adjusted for age, gender and height; baseline year 2002

Figure 2: Crude and adjusted* changes of body weight of children at school entry between 1997-2002

the effects of the year of examination we compared each single year with the reference year (2002), which had the lowest prevalence of overweight or obesity. Additional adjustment was performed for the following categorical or continuous covariates: age, gender, and nationality.

All statistics were performed with the statistic software SPSS Version 12.0 [18].

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Table 1: Characteristics of the sample

Year	N	Mean age [years]	Female [%]	Non-German nationality [%]	Mean body weight [kg]	Mean body height [cm]	BMI [kg/m^2]
1997	1147	6.15	46.5	5.6	21.79	118.05	15.6
1998	1108	6.16	51.1	6.2	22.20	116.91	16.2
1999	1060	6.08	49.4	5.7	22.14	116.66	16.2
2000	1095	6.00	49.5	6.8	20.37	115.66	15.2
2001	1006	5.94	47.6	7.2	20.31	115.72	15.1
2002	1004	5.89	45.3	5.9	19.86	115.65	14.8
Overall	**6420**	**6.04**	**48.3**	**6.2**	**21.14**	**116.47**	**15.5**

Results

• Study population

Overall, there were 6,420 children, about 1,000 for each year of investigation, with a mean age of 6.0 years (SD 0.36), (6.02 years for girls; 6.05 years for boys). The proportion of boys and girls was nearly equal (48.3% girls). Mean body weight was 21.1 kg (SD 2.9), mean height was 116.5 cm (SD 3.3) and the mean BMI was 15.5 (SD 1.8). On average boys had a higher body weight (21.3 kg vs. 20.9 kg; t-test: $p<0.01$), but lower BMI than girls, (BMI 15.6 vs. 15.4; t-test: $p<0.01$). A small proportion of the children (6.2%) had a non-German nationality.

The Bavarian general population of the investigated district Dingolfing-Landau is characterized by a stable socioeconomic status. The general population increased by 1.6% between 2000 and 2002 with a slight decrease (0.5%) of children below the age of 6 years and an increase of 1% among those aged 65 years and older. The employment rate increased between the years 2000 and 2002 from 44.6% to 47.5% and the total expenditure of the community was constant between the years 1996 and 2002 [19].

• Seasonal trends in BMI and body weight

There was a strong shift in timing of examinations during the study period with later rounds starting earlier (i.e. moving from January-April to November-February). Potentially, a seasonal variation in body weight could confound the changes between different years of examination. However, after adjusting for age and height at examination there was no variation in weight between different months in the studied interval.

• Time trends in BMI and body weight

Overall, there was a decrease of BMI of 0.8 kg/m² between 1997 and 2002 with a considerable variation in mean BMI between single years during the study period, with lowest BMI in 2002 (mean BMI 14.8; SD 1.6) and highest in 1998 and 1999 (mean BMI 16.2; SD 1.8) (Table 1, Figure 1). Crude difference in mean body weight between most extreme years was as large as 2 kg; however, after adjustment for age, gender and height the difference was strongly reduced for 1997 and remained large only for 1998 and 1999 (Figure 2).

As a next step we analyzed effects of the independent variables year of examination, age, gender and nationality on weight and BMI applying analysis of covariance. Table 2 shows statistically significant independent effects of age, gender, and year of examination on weight and BMI, but not for nationality.

• Trends in overweight and obesity 1997-2002

According to the international cut-off points defined by Cole et al. [9], we found an overall prevalence of 15.7% for overweight and 2.3% for obesity. The overall trend between 1997 and 2002 showed a decrease for overweight by 3.7% and for obesity by 0.8%. While the highest proportion of 24.4% for overweight was observed in 1999 and the lowest in 2002 (10.5%), we observed a maximum of 4.7% for obesity in 1999 and a minimum of 1.5% in 1998 and 2002.

Whereas female children (17.5%) were significantly more often overweight than male children (14.0%) (Chi^2-test: $p<0.001$), the difference in obesity by gender was not significant (boys 2.0%; girls 2.6%; Chi^2-test: $p=0.07$).

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Table 2: Analysis of covariance to estimate the impact of covariates on body weight and BMI of children at school entry

Variables	Weight			BMI		
	F-value	df	p	F-value	df	p
Age	2331.7	1	<0.001	724.5	1	<0.001
Gender	16.7	1	<0.001	14.8	1	<0.001
Year of examination	176.8	1	<0.001	131.9	1	<0.001
Nationality	1.3	1	0.26	0.4	1	0.5

The proportion of overweight and obesity showed also considerable variation by age of the children. While we observed a statistically significant increase in the proportion of overweight children between the three age groups (7.4% of the 4.5-5.49 years old; 15.1% of 5.5-6.49 years old; 24% of the 6.5-7.49 years old; Chi^2-test: $p<0.001$), no significant differences were found for obesity in the three age groups (3.1% of the 4.5-5.49 years old; 2.1% of 5.5-6.49 years old; 3.3% of the 6.5-7.49 years old; Chi^2-test: $p=0.25$).

Proportions of overweight and obesity did not vary between children of German and non-German nationality. This finding remained true in the analysis adjusted for time trends.

• Factors associated with overweight and obesity

Table 3 shows results from multiple logistic regression models to investigate effects of year of examination, age, gender and nationality on overweight and obesity. While female gender, age and year of examination (except for the year 2001) had a statistically significant effect on overweight, no significant effect of nationality was observed in this multivariate model. Obesity was statistically significant associated with female gender, age and year (the difference to 2002 was significant only for the year 1999), but not with nationality.

In order to analyze confounders of overweight and obesity in each single study year, we performed logistic regression analyses for each year of examination. These separate models showed increased odds ratios for the association of age and overweight in 1997 (OR 1.7; 95% CI, 1.0-1.8), 1998 (OR 2.3; 95% CI, 1.6-3.5), in 1999 (OR 3.5; 95% CI, 2.2-5.4), in 2000 (OR 7.1; 95% CI, 4.1-12.1), in 2001 (OR 2.7; 95% CI, 1.5-4.7) and in 2002 (OR, 3.2; 95% CI, 1.7-5.9). In addition, female gender was statistically significant associated with overweight in 2000 (OR, 2.6; 95% CI, 1.8-3.7) and in 2002 (OR, 1.8; 95% CI, 1.2-2.7).

The association of obesity and age was statistically significant for the year 2000 (OR, 4.5; 95% CI, 1.3-16.5) only. No other covariates were statistically significant associated with overweight or obesity.

Discussion

In this analysis of body weight, body mass index, overweight and obesity in 6 consecutive cohorts of children at school entry during 1997-2002, we found an overall decrease of mean body weight, BMI and proportions of overweight and obesity. These results are contrasting with several other studies among schoolchildren suggesting an increase of weight, BMI, overweight and obesity in Germany [17], [20], [21], [22], [23], [24]. The periods of investigation in most of these studies ended between 1995-1999, which might be an explanation of the different result in our study ending in 2002. When we looked at our results between 1997-1999, we also found an increase of BMI and body weight up to 1999 compared to 1997, which is similar to most previous studies in Germany [17], [22], [24]. The new aspect of our study is the decline of BMI and weight after 1999 which was happening along with a decline in height between the years 1997-2002. However, the decline of height is in line with a study among schoolchildren in Jena, Germany, carried out by Zellner et al. who reported a leveling off phenomenon of the secular increases of height after 1995 [20]. Apart from the question what is the general trend in Germany as a whole it could be that different trends occur regionally.

The rather large changes in weight measures between the years of investigation call for some attention. A single standard scale was used in the study for the assessment of weight which was controlled for accur-

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Table 3: Odds ratios derived from multiple logistic regression analyses for the effects of covariates on overweight and obesity of children at school entry

Variables	Overweight [1]		Obesity [1]	
	OR	95%CI	OR	95%CI
Age	3.0	[2.4-3.6]	2.0	[1.3-3.3]
Gender				
Female	1.3	[1.2-1.5]	1.4	[1.0-1.96] [reference]
Male	1	[reference]	1	
Year of examination				
1997	1.1	[1.0-1.5]	1.3	[0.7-2.5]
1998	1.7	[1.3-2.2]	0.8	[0.4-1.5]
1999	2.4	[1.8-3.1]	2.6	[1.4-4.5]
2000	1.2	[1.0-1.6]	1.0	[0.5-1.9]
2001	1.0	[0.8-1.4]	0.9	[0.4-1.8]
2002	1	[reference]	1	[reference]
Nationality				
Non-German	0.8	[0.6-1.1]	1.5	[0.8-2.7]
German	1	[reference]	1	[reference]

[1] Overweight and obesity defined according to the age and sex specific cut-off points by Cole et al. [9]

acy every second year. This was especially between the two years with the highest mean weight. Given the retrospective nature of this investigation we cannot rule out that systematic measurement error contributed to the observed changes. However, another explanation of the changes in weight measures could be that there is more variability between cohorts than the precision of formal significance testing would allow for.

Many studies evaluated differences in somatic development of children in relation to social background [25], [26], [27], [28]. These studies show that poverty can be associated with a decrease in height and obesity. Since we did not record variables to define social class properly, we cannot evaluate direct effects of social factors on height and weight related measures in our study. However, if we consider the stable socioeconomic status of the general population in the study district Dingolfing-Landau [19], we can assume that the decrease of height, weight and BMI during the study period is likely not to be affected by social factors in this study. Since this preliminary conclusion is based on ecological data, further studies considering social factors on the individual level of the study subjects are needed to investigate long-term trends.

We found that age and gender distribution had impact on body weight, BMI, overweight and obesity in cohorts of children at school entry. Previous studies on risk factors and prevalence of overweight and obesity looking at long-term changes over decades did not consider differing structures of the cohorts as potential confounders of their study results [17], [20], [21], [22], [24].

In conclusion, covariates such as age and gender should be considered in future studies on time trends of various weight-related measures. Furthermore, the analysis of the impact of covariates in our study gained even more importance when separate analyses for each year of examination were carried out. In these analyses overweight was affected by age in all years,

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whereas obesity was affected by age only in one year of examination. Future studies are needed to investigate whether decreased weight-related measures at the end of the last century are going to be continued in this century.

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Please cite as: Baune BT, Mikolajczyk RT, Stich HL, Krämer A. Body weight, body mass index, overweight and obesity in consecutive cohorts of children at school entry in a community in Lower Bavaria 1997-2002. GMS Med Inform Biom Epidemiol. 2006;2(1):Doc03.