Changing Characteristics of Obese Children and Adolescents Entering Pediatric Lifestyle Intervention Programs in Germany over the Last 11 Years: An Adiposity Patients Registry Multicenter Analysis of 65,453 Children and Adolescents

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Keywords
Children · Adolescents · Obesity · Lifestyle intervention · Comorbidities · Inpatient care · Outpatient care · Time trends

Abstract
Objective: To examine whether characteristics of children and adolescents who start lifestyle intervention (LI) for obesity in Germany changed over the last decade. Methods: 65,453 subjects (<21 years) from the APV database (Adiposity Patients Registry) with a BMI ≥ 90th percentile were included (years 2005–2015). Logistic regression models (confounders: age, sex, migration background) were created for overweight, obesity, extreme obesity, and obesity-related comorbidities.
related comorbidities. Comorbidities were further adjusted for weight category. Results were stratified by inpatient or outpatient care. **Results:** Extreme obesity was found to be more frequent at the onset of LI (2005: 11.6%; 2015: 12.7%) with a similar trend in subgroups (p < 0.001). Obesity increased (2005: 50.3%; 2015: 55.1%), and overweight decreased (2005: 34.1%; 2015: 29.0%) in the whole study population. Trends were similar for inpatient or outpatient care (all p < 0.001). Hypertension increased from 45.7% to 49.2% in the whole study population, and similar data were obtained in the subgroup of inpatients (both p < 0.0001). Dyslipidemia increased in all patients (2005: 21.9%; 2015: 28.0%) and in inpatients (2005: 20.2%; 2015: 25.7%; both p < 0.0001). Abnormal carbohydrate metabolism rose in all patients (from 5.2 to 6.4%; p = 0.0002) without significant trends in subgroups. **Conclusion:** During the last decade, children and adolescents presented with higher BMI SDS at the onset of LI and the proportion with obesity-related comorbidities increased. Particularly the presence of comorbidities differed between outpatients and inpatients.
implausible and inconsistent data are reported back to the centers for verification or correction. The APV initiative is authorized by the Ethics Committee of the University of Ulm, Germany.

Until April 2016, 100,746 patients from 202 centers were registered in the APV. Overweight patients (BMI ≥ 90th percentile) under the age of 21 years and documentation between the years 2005 and 2015 were included in this analysis. Due to country-specific health systems and a low number of patients from Austria or Switzerland, only patients from Germany were included, resulting in 65,453 subjects from 182 centers (fig. 1). 25,001 children were treated in outpatient centers (n = 155) and 40,452 children in inpatient rehabilitation units (n = 27). The number of included children and adolescents, stratified by treatment modality and calendar year, is illustrated in table 1.

**Anthropometric Measurements and Biochemical Parameters**

BMI was given as standard deviation score (SDS), using nationally representative reference values [16]. Overweight was defined as a BMI ≥ 90th to <97th percentile, obesity as a BMI ≥ 97th to <99.5th percentile, and extreme obesity as a BMI ≥ 99.5th percentile for age and sex [16]. To define hypertension, the 95th age- and sex-specific percentile of the KiGGS study was used [17]. Dyslipidemia was defined by at least one abnormal lipid value (total cholesterol (C) and LDL-C >95th percentile, or HDL-C <5th percentile [18]). Systolic and diastolic blood pressure as well as serum lipids were measured in local laboratories according to national guidelines [19]. An abnormal carbohydrate metabolism was defined as a fasting glucose level ≥ 100 mg/dl or 2-hour glucose level ≥ 140 mg/dl [20]. Additionally, the number of patients with at least one comorbidity was analyzed. For each patient, the records during the first month after their initial visit were analyzed.

**Statistical Analysis**

Descriptive statistics were implemented for the whole study population and separately for patients treated in rehabilitation or outpatient centers. Sociodemographic and clinical characteristics were presented as median (Q1; Q3) or as percentage. The percentage of patients with comorbidities refers to the number of
results

study population

The final study population comprised 65,453 children and adolescents \( (n_{\text{outpatient}} = 25,001; n_{\text{inpatient}} = 40,452) \). At the onset of LI, 34.2% were overweight, 52.3% obese, and 13.5% extremely obese (table 3). Unadjusted data indicated a higher proportion of extremely obese children and adolescents in outpatient centers compared to inpatient centers (14.6% vs. 12.8%; \( p < 0.0001 \)). In the whole study population, hypertension was most frequent (47.6%), followed by dyslipidemia (25.1%), and an abnormal carbohydrate metabolism (6.6%). Obesity-related comorbidities were more frequent in children treated in outpatient centers compared to those treated in rehabilitation centers \( (p < 0.05) \). More information on the study population and on differences between patients are summarized in table 3.

weight category – time trends

Logistic regression revealed an increase of patients classified as obese \( (>97\text{th to} <99.5\text{th percentile}) \) from 50.3% in 2005 to 55.1% in 2015 \( (p < 0.0001) \) in the whole study population.
Table 3. Sociodemographic and clinical characteristics of the whole study population and stratified by treatment modality

<table>
<thead>
<tr>
<th></th>
<th>n Whole study population</th>
<th>n (outpatient)</th>
<th>Patients treated in outpatient centers</th>
<th>n (inpatient)</th>
<th>Patients treated in rehab centers</th>
<th>p*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys, %</td>
<td>65,453</td>
<td>46.2</td>
<td>25,001</td>
<td>47.2</td>
<td>40,452</td>
<td>45.6</td>
</tr>
<tr>
<td>Age, years</td>
<td>65,453</td>
<td>12.8 (10.7; 14.5)</td>
<td>25,001</td>
<td>11.3 (9.2; 13.3)</td>
<td>40,452</td>
<td>13.5 (11.8; 15.0)</td>
</tr>
<tr>
<td>Migration background, %</td>
<td>65,453</td>
<td>13.5</td>
<td>25,001</td>
<td>17.5</td>
<td>40,452</td>
<td>11.0</td>
</tr>
<tr>
<td>BMI SDS</td>
<td>65,453</td>
<td>2.06 (1.77; 2.38)</td>
<td>25,001</td>
<td>2.07 (1.78; 2.39)</td>
<td>40,452</td>
<td>2.06 (1.76; 2.37)</td>
</tr>
<tr>
<td>Overweight, %</td>
<td>65,453</td>
<td>34.2</td>
<td>25,001</td>
<td>33.4</td>
<td>40,452</td>
<td>34.7</td>
</tr>
<tr>
<td>Obesity, %</td>
<td>65,453</td>
<td>52.3</td>
<td>25,001</td>
<td>52.0</td>
<td>40,452</td>
<td>52.5</td>
</tr>
<tr>
<td>Extreme obesity, %</td>
<td>65,453</td>
<td>13.5</td>
<td>25,001</td>
<td>14.6</td>
<td>40,452</td>
<td>12.8</td>
</tr>
<tr>
<td>Hypertension, %</td>
<td>53,111</td>
<td>47.6</td>
<td>19,261</td>
<td>48.5</td>
<td>33,850</td>
<td>47.1</td>
</tr>
<tr>
<td>Total cholesterol, mg/dl</td>
<td>41,541</td>
<td>161.3 (140.0; 184.5)</td>
<td>15,407</td>
<td>169.0 (150.0; 190.0)</td>
<td>26,134</td>
<td>156.0 (135.0; 180.0)</td>
</tr>
<tr>
<td>LDL-cholesterol, mg/dl</td>
<td>34,732</td>
<td>97.0 (78.0; 119.0)</td>
<td>14,687</td>
<td>102.0 (84.0; 121.0)</td>
<td>20,045</td>
<td>93.0 (74.0; 116.0)</td>
</tr>
<tr>
<td>HDL-cholesterol, mg/dl</td>
<td>35,737</td>
<td>46.0 (39.8; 54.0)</td>
<td>14,769</td>
<td>47.0 (41.0; 55.0)</td>
<td>20,968</td>
<td>45.2 (39.0; 53.0)</td>
</tr>
<tr>
<td>Non-HDL-cholesterol, mg/dl</td>
<td>35,458</td>
<td>113.0 (91.3; 136.9)</td>
<td>14,587</td>
<td>120.0 (100.5; 141.0)</td>
<td>20,886</td>
<td>107.0 (86.0; 132.3)</td>
</tr>
<tr>
<td>Dyslipidemia, %</td>
<td>41,840</td>
<td>25.1</td>
<td>15,596</td>
<td>28.2</td>
<td>26,244</td>
<td>23.3</td>
</tr>
<tr>
<td>Fasting glucose, mg/dl</td>
<td>36,731</td>
<td>83.0 (77.0; 89.0)</td>
<td>12,420</td>
<td>84.0 (78.0; 90.0)</td>
<td>24,311</td>
<td>82.0 (76.0; 88.2)</td>
</tr>
<tr>
<td>Two-hour glucose level, mg/dl</td>
<td>12,675</td>
<td>106.0 (94.0; 118.0)</td>
<td>3,910</td>
<td>107.0 (93.0; 122.0)</td>
<td>8,765</td>
<td>106.0 (95.0; 117.0)</td>
</tr>
<tr>
<td>Abnormal carbohydrate metabolism, %</td>
<td>36,788</td>
<td>6.6</td>
<td>12,451</td>
<td>8.9</td>
<td>24,337</td>
<td>5.4</td>
</tr>
</tbody>
</table>

aData are unadjusted medians (Q1; Q3) or percentages;
*p value for differences between outpatient- and inpatient (rehab) patients.
This trend was present in both subgroups (fig. 2b) ($p_{\text{outpatient}} = 0.0001$; $p_{\text{rehabilitation}} = 0.0008$). The prevalence of extreme obesity ($\geq 99.5\text{th percentile}$) at the beginning of a LI initially decreased in the whole study population from 11.6% in 2005 to 9.3% in 2008 and then increased again to 12.7% in 2015 ($p < 0.0001$). A similar trend was observed in both subgroups ($p_{\text{outpatient}} < 0.0001$; $p_{\text{rehabilitation}} = 0.0004$) (fig. 2c). Overweight prevalence (≥90th to <97th percentile) decreased in the whole study population from 34.1% in 2005 to 29.0% in 2015.
A decline was seen in patients from outpatient as well as from rehabilitation centers (both \( p < 0.001 \)) (fig. 2a).

**Trends for Obesity-Related Comorbidities**

Findings from logistic regression models for trends in the prevalence of obesity-related comorbidities at the beginning of LI, adjusted for demographics and weight category, are
shown in figure 3. The proportion of children and adolescents with hypertension increased from 45.7% in 2005 to 55.1% in 2013 and then decreased again to 49.2% in 2015 (p < 0.0001). In outpatient-treated subjects, prevalence decreased from 50.6% in 2005 to 44.3% in 2009 and then increased to almost 50% in 2015 (p = 0.0660). The number of inpatient-treated patients with hypertension increased from 44.0% in 2005 to 60.9% in 2013 and then declined to 49.6% in 2015 (p < 0.0001) (fig. 3a). Dyslipidemia increased in the whole study population from 21.9% to 28.0% and from 20.2% to 25.7% in rehabilitation-treated patients (both p < 0.0001). In outpatient-treated patients, no significant trend was present (p = 0.0660). Children and adolescents with an abnormal carbohydrate metabolism became more frequent during the last decade (from 5.2% to 6.4%; p = 0.0002). No significant trend was found in patients from inpatient or outpatient centers (p_{outpatient} = 0.2055; p_{rehabilitation} = 0.0723) (fig. 3c).

**Number and Trends of Patients with at Least One Comorbidity**

56.2% of the whole study population had at least one comorbidity. Stratified by weight category, the proportion was lowest in overweight patients (46.3%), followed by obese (59.9%) and extremely obese patients (66.0%). The number of overweight and obese subjects with at least one comorbidity was higher in outpatient compared to inpatient centers (49.2% vs. 44.7%; 62.2% vs. 58.6%). In extremely obese patients, a higher comorbidity prevalence was found in patients from rehabilitation units (68.8% vs. 61.8%).

The logistic regression model revealed an increase of patients with at least one comorbidity from 53.1% to 60.0% in the whole study population, and from 50.9% to 59.9% in inpatient centers (both p < 0.0001). The increase in outpatients was negligible (59.3% to 59.8%; p = 0.2883). Stratified by weight category (fig. 4a–c), a rise was observed in overweight (from 40.0% in 2005 to 50.9% in 2015) and in obese patients (from 57.8% to 62.4%; both p < 0.0001), but not in extremely obese subjects (69.6% vs. 71.0%; p = 0.0533). These trends were also valid when focusing on inpatient centers, but not when only outpatients were analyzed (fig. 4a–c).

**Trends for Weight Category and Comorbidities Stratified by Gender**

Regression analysis revealed an increase of obese subjects starting LI in boys (from 51.5% to 55.8%; p = 0.0002) as well as in girls (from 49.2% to 54.5%; p = 0.0022). The number of extremely obese patients initially decreased, and then increased until the year 2015. This trend was present in both sexes (boys: 12.2% (2005), 10.1% (2008), 13.8% (2015), p < 0.0001); girls: 11.2% (2005), 8.6% (2009), 11.2% (2015), p = 0.0004). The proportion of overweight children and adolescents decreased in boys from 32.7% to 27.1% and in girls from 35.4% to 30.6% (both p < 0.0001).

Similar to the results for the whole study population (fig. 3a), hypertension increased during the first years and then decreased again. This pattern was present in boys (46.9% (2005), 56.4% (2012), 51.3% (2015); p < 0.0001) and in girls (44.7% (2005), 54.3% (2013), 46.8% (2015); p < 0.0001). Dyslipidemia became more frequent in boys (23.3% vs. 32.1%), and in girls (20.6% vs. 24.9%; p < 0.0001). The proportion with an abnormal carbohydrate metabolism slightly increased in both sexes (boys: 4.9% vs. 6.6%; p = 0.0041 / girls: 5.4% vs. 6.2%; p = 0.0506). The number of patients with at least one comorbidity increased from 54.4% to 63.1% in boys, and from 52.0% to 56.6% in girls (both p < 0.0001).

**Trends for Weight Category and Comorbidities Stratified by Age Group**

In the younger children (<11 years of age), the number of obese children at the onset of LI increased non-significantly from 45.4% to 52.8% (p = 0.0774). In subjects ≥11 years of age, the proportion increased from 52.4% to 55.7% (p < 0.0001). Extreme obesity became more
frequent in both age groups (<11 years: 22.6% vs. 23.7%; ≥11 years: 10.0% vs. 12.8%; p < 0.0001). Overweight decreased in children <11 years of age from 30.8% to 23.2%, and in ≥11-year-olds from 37.3% to 31.7% (both p < 0.0001).

The prevalence of hypertension initially increased and then declined in both age groups (<11 years: 44.8% (2005), 48.9% (2012), 46.7% (2015); ≥11 years: 46.8% (2005), 57.7% (2012), 49.8% (2015); p < 0.0001). The proportion of <11-yea-ols with dyslipidemia
increased from 23.8% to 26.1% (p = 0.0053) and from 22.0% to 29.0% in ≥11-year-olds (p < 0.0001). A non-significant decline in the number of children with an abnormal carbohydrate metabolism was found in <11-year-olds (5.0% vs. 4.2%; p = 0.8513), whereas in subjects ≥11 years of age, this comorbidity became more frequent (5.4% vs. 7.1%; p < 0.0001). The percentage of children and adolescents with at least one comorbidity showed a higher increase over time in older children (≥11 years: 54.0% vs. 61.8%; p < 0.0001) than in younger ones (<11 years: 53.1% vs. 53.8%; p = 0.0016).

Discussion

The present analysis shows significant changes in patient’s characteristics at the onset of LI for obesity over the last 11 years. Furthermore, different trends were detected for patients treated as outpatients or inpatients, as well as for age groups or gender.

During the last decade, the proportion of overweight children and adolescents at the beginning of LI decreased, whereas the number of obese patients increased. The trend in patients with extreme obesity is less clear (fig. 2a–c). Previous studies indicated that a lower BMI at the beginning of a LI is one predictor of success as measured by BMI SDS [10, 11]. However, the indication to participate in an outpatient or inpatient LI depends on obesity degree and existing risk factors or comorbidities (table 4) [21, 22]. According to these criteria, a LI is only indicated in overweight children and adolescents with at least one additional comorbidity. This applies to 46.3% of our study population. Overall, the most common comorbidity was hypertension (2015: 49.2%), followed by dyslipidemia (2015: 28.0%), and an abnormal carbohydrate metabolism (2015: 6.4%). In our study population, the percentage of subjects with an abnormal carbohydrate metabolism is (of unknown reasons) lower compared to, e.g., that of the Swedish childhood obesity treatment registry BORIS showing a prevalence of 17.1% [5]. In contrast to other studies, the prevalence of hypertension in our study population is high [23, 24]. This can be explained by the high percentage of obese and extremely obese patients, and the use of KiGGS reference values for definition of hypertension [25].

The number of patients with at least one comorbidity increased by weight category (46.3% vs. 59.9% vs. 66.0%). The differences are in line with results of the Swedish BORIS or the American POWER (Pediatric Obesity Weight Evaluation Registry) registries indicating an association between the degree of obesity and a higher risk of cardiovascular risk [5, 26].

Table 4. German reimbursement criteria for outpatient LI in overweight/obese children [22]

<table>
<thead>
<tr>
<th>BMI</th>
<th>No risk factors</th>
<th>Risk factors*</th>
<th>Disease**</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;99.5 percentile</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>&gt;97. to &lt;99.5 percentile</td>
<td>no</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>&gt;90. to 97. percentile</td>
<td>no</td>
<td>no</td>
<td>yes</td>
</tr>
</tbody>
</table>

*Insulin resistance, dyslipidemia, familial predisposition (type 2 diabetes in parents, myocardial infarction or stroke before the age of 55, 1. and 2. degree of relationship).

**Arterial hypertension, type 2 diabetes, abnormal glucose metabolism, premature pubertal development, polycystic ovary syndrome, orthopedic illnesses.
parents and their children decide to participate in LI at a later stage. Moreover, the number of APV centers differs in the course of the observation period and more centers with higher-risk patients may participate in the APV initiative during recent years.

Stratified by outpatient or inpatient treatment, dyslipidemia and an abnormal carbohydrate metabolism were more frequently found in outpatient centers. This remains stable between the years 2005 and 2015 (fig. 3b–c). Considering patients with at least one comorbidity stratified by weight category, the proportion of overweight or obese patients with at least one comorbidity was higher in outpatient compared to inpatient centers (49.2% vs. 44.7% and 62.2% vs. 58.6%). In extremely obese patients, inverse results were found (61.8% vs. 68.8%). Regarding changes over time, the number of overweight or obese patients with at least one comorbidity increased in inpatient, but not in outpatient centers (fig. 4a–c).

In Germany, reimbursement for a LI in outpatient or inpatient centers is very different. Outpatient LI for obesity can be covered by statutory health insurance [27]. In the year 2004, a consensus paper was developed that should facilitate the assessment of treatment programs and provide orientation for reimbursement [28]. The decision depends on medical, mental, and social conditions, and training programs need to meet several evaluation criteria comprising concept quality as well as structure, process, and outcome quality [21, 22, 28]. The fulfillment of those criteria is a precondition for potential reimbursement by statutory health insurances. Moreover, the efficacy and efficiency of training programs have to be demonstrated. Several systematic reviews indicated a beneficial effect of training programs on BMI. However, due to unexplained heterogeneity of studies included and potential study bias, results have to be interpreted cautiously [29–31]. Despite the necessity to prove sustainable improvements, the willingness to finance such analysis appears to be limited. Therefore, studies examining the long-term effects of German training programs are still scarce, and thus financing of a LI remains difficult. A statement of the National Association of Statutory Health Insurance Funds for an updated version of the consensus paper was published in 2015 [32]. According to these recommendations, indication to participate in a LI for overweight or obese children and adolescents should only be given after an unsuccessful treatment by a pediatrician according to current guidelines [21, 32]. The financing of inpatient rehabilitation treatment is usually covered by pension funds [33]. Similar to the outpatient sector, the reimbursement depends on personal characteristics (e.g. sufficient physical and mental resilience), and on the quality of the rehabilitation units [34]. Apart from the financing system, differences in the completeness of information on comorbidities (table 2) could be attributed to the differences between outpatients and inpatients. Large differences and fluctuations during the last 11 years could be observed in both within a particular treatment modality as well as between treatment modalities. For example in 2009, information on blood pressure was available for 93.9% of inpatient-treated subjects but only for 75.2% of the outpatients. In contrast, in 2014, the completeness was lower in inpatients (60.0%) compared to outpatients (78.4%). Regarding the last 11 years, the number of documented inpatient-treated children and adolescents decreased, whereas the number of outpatient-treated patients increased in the APV database (table 1). Especially, trends in the number of patients with at least one comorbidity differed between outpatient and inpatient subjects. Whereas in inpatients, an increase was observed, no trend was indicated in outpatients (fig. 4a–b). Possibly, the number of inpatient-treated subjects became lower but those treatment-seeking patients have a worse cardiovascular risk profile.

We further identified differences in gender and age groups (<11 years vs. ≥11 years). Although the overall trends are comparable in gender or age groups, we found differences in the absolute frequencies. At the onset of a LI, boys were more frequently classified as obese or extremely obese compared to girls, and comorbidities were more prevalent. A review indicated that body satisfaction and well-being is more reduced in obese girls compared to boys.
and that obese females are more disliked and negatively rated by their peers compared to obese males [35]. Maybe, the higher social pressure could be one explanation for the earlier onset of LI in girls. Regarding age groups, a higher prevalence of extreme obesity at the beginning of a LI was present in the younger (<11 years of age) compared to the older children (≥11 years of age) (year 2015: 23.7% vs. 12.8%). In contrast, comorbidities were more frequently documented in patients ≥11 years of age. The higher prevalence of obesity-related comorbidities can be partly explained by a longer duration of overweight/obesity in older children which is associated with a higher risk for hypertension or dyslipidemia [36].

Strengths and Limitations

The study benefits from the large number of patients and the multicenter design. Another strength is the application of the same documentation software since 2005. Furthermore, detailed information on patients is documented in the APV to control for potential confounders. However, due to the multicenter nature of data collection, variability in the measurements of BMI as well as of biochemical parameters cannot be excluded despite standardized procedures. Another limiting factor could be that in 90% of the patients, blood pressure and laboratory data are measure only once. This might have resulted in e.g. somewhat higher values of blood pressure, also known as ‘white coat effect’. Moreover, it is unclear whether or not serum lipids were determined under fasting conditions. Furthermore, some clinical characteristics were not completely documented in all patients, and completeness also differs between treatment modalities. Another limitation is that the number of participating centers varies between the years. Therefore, a selection bias could be possible.

Conclusion

The number of obese children and adolescents starting a LI increased, and the proportion of patients with obesity-related comorbidities became higher. Therefore, more patients with unfavorable prospects of success started therapy during recent years, reflecting later instead of earlier structured LI. Boys were more obese and had a higher prevalence of comorbidities at the onset of a LI compared to girls. In younger children, extreme obesity was more frequent and comorbidities less frequent compared to older children. Especially trends regarding the presence of at least one comorbidity differed between outpatient and inpatient treatment centers. This can be partly explained by different financing systems or a switch in available treatment options.

Acknowledgements

We thank E. Bollow for statistical analysis. Furthermore, we thank all participating centers of the APV initiative, especially the collaborating centers.

Funding

The study was supported by the German Competence Network Obesity funded by the Federal Ministry of Education and Research (FKZ 01GI1130) (expired at the beginning of 2016). Further financial support was provided by the German Diabetes Association (DDG). Sponsors were not involved in data acquisition or analysis.

Disclosure Statement

The authors report no conflicts of interest.
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