Overweight and Obesity in Primary School Children –
Cognitive Correlates and Health-Related Outcomes

Dissertation

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<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>ANOVA</td>
<td>Analysis of variance</td>
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<tr>
<td>α</td>
<td>probability of making a type I error</td>
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<tr>
<td>BMI</td>
<td>Body mass index</td>
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<tr>
<td>DRKS</td>
<td>Deutsches Register Klinischer Studien (German Register of Clinical Trials)</td>
</tr>
<tr>
<td>EQSD-Y</td>
<td>EuroQol-Descriptive system of health-related quality of life states in Youth consisting of five dimensions</td>
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<tr>
<td>HRQoL</td>
<td>Health-related quality of life</td>
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<tr>
<td>ISAK</td>
<td>International Society for the Advancement of Kinanthropometry</td>
</tr>
<tr>
<td>KIGGS</td>
<td>Studie zur Gesundheit von Kindern und Jugendlichen in Deutschland (German Health Interview and Examination Study of Children and Adolescents)</td>
</tr>
<tr>
<td>KINDL\textsuperscript{R}</td>
<td>KINDer Lebensqualitätsfragebogen – Revidierte Form (Children’s quality of life questionnaire – revised version)</td>
</tr>
<tr>
<td>KITAP</td>
<td>Kinder Testbatterie zur Aufmerksamkeitsprüfung (Children’s test battery of attentional performance)</td>
</tr>
<tr>
<td>n</td>
<td>number of cases (sample size)</td>
</tr>
<tr>
<td>SPSS</td>
<td>Statistical Package for the Social Sciences</td>
</tr>
<tr>
<td>Tukey HSD</td>
<td>Tukey’s honestly significant difference</td>
</tr>
<tr>
<td>VAS</td>
<td>Visual Analogue Scale</td>
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<tr>
<td>WHtR</td>
<td>Waist-to-Height-Ratio</td>
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1 Introduction

The high prevalence of overweight and obesity and the associated health outcomes are one of the major concerns of economies and health-care systems in today’s industrialised countries (World Health Organization 2002). Excessive weight gain can often be traced back to childhood (Guo et al. 2002). In Germany, 14.8 % of children and adolescents are already overweight or obese (Kurth and Schaffrath Rosario 2010). Especially at the age of school entry, between 5 and 8 years, the greatest increase in the development of overweight takes place. Once overweight is established, it is quite problematic to reverse and is likely to follow through to adulthood (Latzer et al. 2008; Singh et al. 2008; Reilly et al. 2003; Ebbeling et al. 2002). Additionally, it is at this age when children start to become more and more autonomous and to develop health and risk behaviour, respectively. Decreased physical activity levels, a great amount of sedentary activities, an increased energy intake and breakfast habits are important determinants of overweight besides a genetic predisposition (Dupuy et al. 2011; Haug et al. 2009; Ebbeling et al. 2002). Early prevention and health promotion efforts addressing behavioural and lifestyle changes are therefore of particular importance.

Recently, the role of certain cognitive abilities in children’s overall development including social and emotional skills, behavioural disorders and academic performance as well as for later job success, social status and health has been acknowledged (Moffitt et al. 2011; Diamond et al. 2007). In the past 15 years there has been a growing research interest in executive functions, the higher-order control processes of our cognitive system that are related to self-regulation and goal-directed behaviour (Jurado and Rosselli 2007; Diamond et al. 2007). Certain abilities such as inhibitory control (the ability to withhold inappropriate actions) or cognitive flexibility (the ability to adjust to changed circumstances or demands) have been established as essential components of the executive system (Diamond et al. 2007). It is obvious that cognitive control abilities may also be associated with health behaviour and subsequently certain health outcomes (Riggs et al. 2010) but literature concerning childhood is still in its very early stages. To date, studies have mainly focused on inhibitory control but selectivity, small sample sizes and the use of self-reporting
measures still limit the validity of the results; findings beyond the inhibition scope are even more scarce and inconsistent (Reinert et al. 2013).

Paediatric obesity is associated with a high risk for chronic diseases such as hypertension or type 2 diabetes, an increased cardiovascular risk, pulmonary and musculoskeletal complications as well as with substantial psychosocial consequences such as poor self-esteem, depression or behavioural problems (Reilly et al. 2003; Ebbeling et al. 2002). There is some evidence that obesity is related to more school absenteeism and an increased health care use (Wijga et al. 2010; Hering et al. 2009). To gain information about children’s overall physical and psychosocial health and to evaluate prevention and intervention programmes the construct of health-related quality of life (HRQoL) is often used (Ravens-Sieberer et al. 2008). This term reflects the multidimensionality of health and considers not only the medical or mental condition of a person but also the subjective well-being as health is defined as “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity” (World Health Organization 1946).

1.1 Objective of the present research project

The health promotion programme „Komm mit in das gesunde Boot“ [Join the healthy boat] is a school-based project to promote physical activity and healthy diet in primary school children and to prevent overweight and obesity. The project has started in 2009 in the federal state of Baden-Württemberg, Germany, and was evaluated in the Baden-Württemberg Study, a randomized-controlled trial with over 1900 families participating in the baseline measurements in autumn 2010. In the context of this evaluation study risk factors and correlates of childhood overweight were to be determined (Figure 1). Considering the current research streams outlined in the introduction section, the following research questions have been developed:

1. Is there a relationship between inhibitory control and body weight in a large non-clinical sample of children starting school? Do children with overweight and obesity show lower inhibitory control than their normal weight counterparts? (Study 1)
2. Is there a relationship between different cognitive abilities and body weight in a large non-clinical sample of children starting school? Are cognitive abilities such as inhibitory control but also cognitive flexibility and further sustained attention directly associated with children’s body weight? (Study 2)

3. Is there a relationship between obesity and different health outcomes in a large non-clinical sample of children starting school? Do children with central obesity differ from non-obese children in terms of school absenteeism, visits to a physician and HRQoL? (Study 3)

*Figure 1.* Assumed correlates of children’s body weight. Illustration of relevant study parameters, objectives and research questions.
2 Material and methods

The research questions were embedded in the Baden-Württemberg Study, an evaluation study of the health promotion programme „Komm mit in das gesunde Boot“. The Baden-Württemberg Study was approved by the ethics committee of the University of Ulm and is registered at the German Clinical Trials Register (DRKS00000494). Primary school teachers in the federal state of Baden-Württemberg were recruited using a number of different public relations activities and volunteered to participate in the study. Written informed consent was obtained from the ministry of education, from headmasters and from parents.

The Baden-Württemberg Study is a longitudinal randomised controlled study (Dreyhaupt et al. 2012). For the present investigations baseline data of the control and intervention group were used. Baseline assessment took place in autumn 2010, at the beginning of the school year 2010/2011. The measuring period lasted 3 months from the end of summer vacation in September to the beginning of autumn vacation in November. Anthropometric, cognitive and sports-related parameters were measured. A scientific team visited the participating schools and performed the measurements on-site. Sociodemographic and behavioural data were collected via parental questionnaire which was issued directly after the measuring period in November 2010 and returned within six weeks.

2.1 Participants

The Baden-Württemberg Study focused on 1st and 2nd grades of regular primary schools in Baden-Württemberg. In total, 86 schools (157 teachers or school classes) volunteered to participate. Parents of 1964 children opted in, 1944 children took part in the baseline assessment. Anthropometric data were available from 1894 children. Due to the scope of measurements of the Baden-Württemberg Study, the long distances between schools and the required technical equipment, cognitive assessment was performed in a subsample in the region of Ulm / Stuttgart, the southern part of Baden-Württemberg. Cognitive data were available from 498 children. Sociodemographic and behavioural data (parental questionnaire) were available from 1714 children. Referring to the total sample (n = 1944)
mean age of the children was 7.08 ± 0.64 years, 52.7 % attended 1st grade (47.3 % 2nd grade), 51.2 % were boys.

2.2 Anthropometric measurement

Body height, weight and waist circumference were taken by trained staff according to the guidelines of the International Society for the Advancement of Kinanthropometry ISAK (Marfell-Jones et al. 2006). Height was measured without wearing shoes, using a portable stadiometer (Seca model 217, Seca, Germany), accurate to 0.1 cm. Weight was measured wearing underwear, using a calibrated electronic scale (Seca model 862, Seca, Germany), accurate to 0.05 kg. Waist circumference was measured using a flexible steel metal pocket tape measure (Lufkin model W606PM, Lufkin, USA), accurate to 0.1 cm. Body mass index (BMI) was calculated as weight divided by height squared (kg / m²) and converted to BMI percentiles according to national age- and sex-specific reference data (Kromeyer-Hauschild et al. 2001). Children were categorised as non-overweight (≤ 90th percentile), overweight (> 90th percentile and ≤ 97th percentile) and obese (> 97th percentile). International reference data (Cole et al. 2000) were used for comparison only. Waist-to-Height-Ratio (WHtR) was calculated as the ratio of waist circumference to height in cm. Children were further categorised as centrally obese (WHtR ≥ 0.5) and centrally non-obese (WHtR < 0.5).

2.3 Cognitive measurement in a subsample

Cognitive abilities were measured via the KITAP (Zimmermann et al. 2002), a computer-based test battery of attention for children. The test battery consists of several subtests in form of short computer games measuring different components of the cognitive system including more basal attention processes as well as higher-order executive functioning. Three tests of the KITAP were chosen: A Go/No-go task to measure inhibitory control, a cognitive flexibility task and a sustained attention task. The tests were administered in small groups by trained staff – one examiner had to supervise not more than 2 children. Laptops with a screen size of 15 inches were used. The children sat back to back and at
some distance to minimise distractions. The testing session lasted 30 minutes per group. The three tests were always administered in a fixed order and instructions were standardised. According to the test manual short preceding practice trials were performed each time to assure comprehension and willingness. The main tests started for the whole group when each child succeeded the practice trials and demonstrated comprehension. They were only administered once. Lack of comprehension, motivation or other irregular behaviour was documented and later considered in the data preparation process.

2.4 Parental questionnaire

Sociodemographic data, information about children’s health behaviour, health-related outcomes, early childhood development and parents’ health behaviour were assessed via parental questionnaire. To increase the response rate of the questionnaire only items were included that are supposed to be associated with childhood overweight. Parents were asked for birth date and sex of their children and data compared to the information gathered from the measurements on-site. Parents’ education level, migration background and further living conditions were assessed. Concerning children’s health behaviour, breakfast habits, beverage consumption, physical activity and screen media consumption were part of the query. Questions were based on the German KIGGS study (German Health Interview and Examination Study of Children and Adolescents; Kurth 2007). HRQoL was measured via the KINDL® proxy version (Erhart et al. 2009) and via the Visual Analogue Scale (VAS) of the EQ5D-Y proxy version (Ravens-Sieberer et al. 2010). Further, children’s days absent from school (sick days) and visits to a physician as well as parents’ days absent from work due to their child’s illness were requested. Finally, there were some questions about relevant pre-, peri- and postnatal parameters, medical history and diagnoses, parents’ weight and health parameters, parents’ health behaviour (e.g. smoking, TV consumption, physical activity) and parents’ attitude towards health. Data of the parental questionnaire were used in the analyses either as covariates or as main outcomes (e.g. HRQoL).
2.5 **Statistical analysis**

To analyse the association between inhibitory control and body weight in study 1 as well as the association between several cognitive abilities and body weight in study 2, hierarchical multiple linear regression analyses were performed. As predictive variables the respective total scores of each cognitive domain were used, as criterion BMI percentiles were used as an indicator of body weight. Important weight-influencing covariates such as parents’ weight, parents’ education, migration background and different lifestyle factors were controlled in both studies.

To determine group differences in inhibitory control (obese versus overweight versus non-overweight children), ANOVA and Tukey-HSD post-hoc analysis were performed in study 1. In study 3 weight group differences (centrally obese versus non-obese children) were analysed using Fisher’s exact test for categorical data and Mann-Whitney-U test for continuous data. Dependent variables were the mean values of the EQ5D-Y VAS, the KINDL® total score and the different KINDL® subscales as indicators of HRQoL. Further dependent variables were the number of children’s sick days, visits to a physician and parents’ days absent from work. Additionally, anthropometric measures, lifestyle factors, parents’ weight, health behaviour and health awareness, parents’ education, migration background, pre-, peri- and postnatal factors (e.g. mother’s smoking during pregnancy, breastfeeding) were included as dependent variables in the group analysis in study 3.

To investigate factors significantly associated with children’s sick days, logistic regression analysis was calculated in study 3. For the regression model, the dependent variable “sick days” was dichotomised. Subsequently, all other variables mentioned above (anthropometric measures, lifestyle characteristics, parents’ characteristics and pre-, peri- and postnatal factors) were included and stepwise backward elimination was applied. Adjusted odds ratios and 95% confidence intervals were computed.

Statistical analysis for all studies was carried out using the Software package IBM SPSS Release 19.0 for Windows. Significance level was set at $\alpha = 0.05$. 


3 Results

The following chapter contains an overview of the published results of the current research project. Table 1 summarizes the corresponding articles and provides information about the sample of interest, the relevant variables and the main findings.

Table 1

Overview of the published investigations and findings

<table>
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<th>Article</th>
<th>Sample</th>
<th>Variables</th>
<th>Results</th>
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<tr>
<td>1. Associations between inhibitory control and body weight in German primary school children</td>
<td>Evaluation study “Komm mit in das gesunde Boot”; baseline assessment 2010; subsample n = 498 (1st &amp; 2nd graders)</td>
<td>Inhibitory control, BMI percentiles, weight group; covariates: parental weight, parental education, migration background, TV consumption, breakfast habits</td>
<td>Significant association between inhibitory control and BMI percentiles; lower inhibitory control in obese children compared to non-overweight and overweight children</td>
</tr>
<tr>
<td>2. Early life cognitive abilities and body weight: Cross-sectional study of the association of inhibitory control, cognitive flexibility and sustained attention with BMI percentiles in primary school children</td>
<td>Evaluation study “Komm mit in das gesunde Boot”, baseline assessment 2010; subsample n = 498 (1st &amp; 2nd graders)</td>
<td>Inhibitory control, cognitive flexibility, sustained attention, BMI percentiles; covariates: parental weight, parental education, migration background, physical activity, TV consumption, consumption of sugar-sweetened beverages, breakfast habits</td>
<td>Significant association between inhibitory control and cognitive flexibility and BMI percentiles; no association between sustained attention and BMI percentiles</td>
</tr>
<tr>
<td>3. Is central obesity associated with poorer health and health-related quality of life in primary school children? Cross-sectional results from the Baden-Württemberg Study</td>
<td>Evaluation study “Komm mit in das gesunde Boot”, baseline assessment 2010; total sample providing parental questionnaire n = 1714 (1st &amp; 2nd graders)</td>
<td>WHtR, sick days, visits to a physician, HRQoL; covariates: parental weight and WHtR, parental health behaviour, parental health awareness, parental education, migration background, pre-, peri- and postnatal factors, physical activity, consumption of sugar-sweetened beverages, breakfast habits</td>
<td>Significant more sick days and visits to a physician and significant lower HRQoL in centrally obese children (WHtR ≥ 0.5)</td>
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3.1 Relationship between inhibitory control and body weight

The hierarchical regression analysis in study 1 revealed body weight of mothers and fathers to be significantly associated with children’s body weight (BMI percentiles). Additionally, inhibitory control contributed significantly to the prediction of children’s body weight. The additional amount of variance explained was 1.4%. Furthermore, the variance analysis displayed significant weight group differences in inhibitory control: Obese children showed lower inhibitory control than “pure” overweight and non-overweight children. The results were due to significantly more errors and shorter reaction times by tendency, indicating more impulsive reactions.

3.2 Relationship between different cognitive abilities and body weight

The hierarchical regression analysis in study 2 revealed body weight of mothers and fathers as well as migration background to be significant predictors of children’s body weight (BMI percentiles). Concerning the cognitive parameters inhibitory control and cognitive flexibility contributed significantly to the prediction. The additional amount of variance explained was 4.5%. There was no relationship between sustained attention and children’s body weight. Parental education and different lifestyle factors such as breakfast habits, beverage consumption, physical activity and screen media consumption assessed via parental questionnaire were not associated with body weight, either.

3.3 Relationship between obesity and different health outcomes

Fisher’s exact test and Mann-Whitney-U test, respectively, revealed significant weight group differences in school absenteeism, health care use and HRQoL: Centrally obese children had more sick days, more visits to a physician and lower parent-rated HRQoL (in EQ5D-Y VAS and in KINDL$^R$ subscales ‘school’ and ‘friends’). Parental work absenteeism as well as other KINDL$^R$ scores did not differ significantly. Further group differences were found in a range of variables: anthropometric measures, lifestyle factors (such as sporting
activity, beverage consumption, breakfast habits), parental weight, parental smoking, parental education, migration background, mother’s smoking during pregnancy and breastfeeding. Furthermore, the logistic regression analysis displayed central obesity and migration background as significantly associated with a high level of school absenteeism, whereas age, physical activity, parental education and maternal health awareness were significantly associated with a low level of school absenteeism.

### 3.4 Summary of the main findings

The significant and non-significant associations between parental, behavioural and cognitive factors and children’s body weight are illustrated in Figure 2. Figure 2 also shows the significant differences in school absenteeism, visits to a physician and HRQoL between children with and without central obesity.

**Figure 2.** Illustration of the main results corresponding to the research questions and integrated in the evaluation study frame (PA = physical activity; SSB = sugar-sweetened beverages; + = positive significant association; - = negative significant association).
4 Discussion

In modern industrialised countries one of the major public health concerns is childhood obesity. Objective of the present research project was to investigate cognitive correlates of body weight as they might play a role in the development of health behaviour as well as weight related health outcomes. Besides the field of childhood obesity the findings of the studies also contribute to the field of cognitive developmental psychology.

The research of executive functions in terms of academic performance, social and emotional development and psychopathologies (e.g. ADHD, depression, addictions) is already in full play. In recent years these research streams have spread out to the health and health behaviour domain as the importance of the cognitive system to regulate and control oneself has been acknowledged. Thus, it is obvious to assume associations with healthy choices and their outcomes as well. However, there is still a lack of literature concerning childhood, especially large non-clinical studies are missing. Investigating the role of cognitive factors in children’s health behaviour is particularly interesting because of the development of the cognitive system and differences in autonomy compared to adults.

In terms of childhood obesity there is a growing number of early prevention and intervention programmes. However, only a few of these programmes are adequately scientifically evaluated and intervention effects are still rather modest (Kropski et al. 2008; Stice et al. 2006; Summerbell et al. 2005). To improve obesity prevention factors that influence or correlate with body weight, weight gain or weight related health behaviour need to be identified and may be considered as additional components in future treatment.

The current findings of the first two studies indicate that executive functions are directly linked to body weight in the expected direction: The better the performance in inhibitory control and cognitive flexibility the lower the body weight of the children. And especially obese children, with extremely high body weight, had obviously lower inhibitory control abilities than other weight groups. These results conform to the existing literature in particular with regard to the inhibitory component (Reinert et al. 2013). However, standard deviations in the obese group were quite high. Hence, there may be different subgroups of obese children and at least some of them suffer executive function deficits. This is in line with findings from Riggs et al. (2012) who investigated the relationships between different
latent classes of obesity risk and executive functions. They found that some obesity risk profiles based on certain behaviour patterns (e.g. high sedentary behaviour, high consumption of snacks, not weight conscious) are more related to deficits in executive functions than others and suggested to develop specific programme contents tailored to different risk profiles.

Moreover, parental body weight was associated with children’s body weight what may be explained by genetic mechanisms as well as the shared environment (e.g. eating habits, physical activity patterns, recreational activities, living environment) and is a well-known finding in the literature (Kleiser et al. 2009). However, an association between behavioural factors such as physical activity, sedentary behaviour, eating and drinking habits and body weight could not be found (in study 1 or 2). One explanation might be that the corresponding data based on parental retrospective reports and single-item questions was subject to bias (recall bias, social desirability). Parents specific perception of their children’s behaviour might also be inaccurate or biased. Further, BMI percentiles might not be the ideal measure to represent body weight or body composition what will be discussed in more detail later on.

There is some indication that childhood overweight and obesity prevalence rates have reached a plateau and are not increasing anymore (Moss et al. 2012). Thus, political and health authorities may draw the conclusion that supporting early health promotion efforts is not necessary anymore. However, prevalences are still on an alarmingly high level. Additionally, even if obesity based on BMI is plateauing the number of children with central obesity (WHtR ≥ 0.5) is continuing to increase and even at a faster rate (Garnett et al. 2011).

The third study of the present dissertation project revealed that central obesity is related with the amount of days children were absent from school due to illness, the number of visits to a physician and their HRQoL perceived by their parents. Only a few studies have focused on associations with absenteeism or increased health care use with most of them reporting significant relationships between obesity and sick days or visits to a physician, especially for extreme but not always for moderate overweight children (Wijga et al. 2010; Rappaport et al. 2011).

The link between obesity and HRQoL is an ongoing topic. In their review Tsiros et al. (2009) reported a consistent inverse relationship between BMI and HRQoL. The association,
Discussion

however, depended on several factors such as assessment method (parental reports were mostly lower than children’s self-reports), life domain (impairments in obese children were mostly found in physical and social subscales) and severity of overweight (again extreme obese children showed lower HRQoL scores in more subscales than moderately obese children; Tsiros et al. 2009; Hughes et al. 2007; Pinhas-Hamiel et al. 2006). Nevertheless, all of the cited research articles referred to BMI to classify overweight and obesity. There has not yet been an investigation of central obesity based on WHtR and its impacts on the subjective well-being, school absenteeism or health care use.

There is a continuing debate about which anthropometric measure is the most suitable indicator for overweight and obesity and should be used as a worldwide screening tool to identify children, adolescents and adults at risk for severe health problems. Up to date, BMI is still the standard index for definition of overweight and most frequently used in clinical practice as well as in research (August et al. 2008; Barlow 2007). It is generally accepted, easy to determine, allows classification into weight groups based on international reference data (Cole et al. 2000), thus allows international comparisons, and is still officially recommended (August et al. 2008; Barlow 2007). However, more and more researcher recommend the use of other anthropometric parameters such as WHtR that consider body fat distribution, differences between fat and muscle mass and have found to be better and more sensitive indicators for obesity related health risks such as cardiovascular disease risk factors (Schneider et al. 2010; Rodriguez et al. 2004; Savva et al. 2000).

In the current studies both measures, BMI as well as WHtR, were used. Particularly, for reasons of comparability BMI was still considered in study 1 and 2 as relevant criterion. Results were similar using WHtR, especially in terms of inhibitory control. However, WHtR was considered in study 3 to contribute new findings to the research of health related outcomes of obesity. No associations with the main outcomes could be found using BMI in study 3 respectively.

4.1 Strengths and limitations

The design of the three studies has several strengths: First, they were part of a large epidemiologic study assessing children in the whole federal state of Baden-Württemberg,
south of Germany. Thus, the large and widespread sample increases the representativity of the findings and provides a descriptive picture of the situation of today’s primary school children. It allowed to detect even small effects and to consider a great amount of covariates even in the two subsample studies. Secondly, the considered age group is highly relevant as the increase of childhood overweight is particularly pronounced at early school age (Kurth and Schaffrath Rosario 2010), important cognitive developments take place and children start to get more autonomous. Prevention efforts at this point may therefore promote the development of a healthy lifestyle and avoid the emergence of unhealthy behaviour and its consequences. Thirdly, measurements in all studies are of high quality including standardised anthropometric and cognitive assessment what increases objectivity and validity of the results.

On the contrary, there are some limitations that need to be considered: All findings are based on a cross-sectional study design what precludes any causal interpretation. The analysis of longitudinal data is necessary to determine the directionality of the reported associations. Body weight, obesity, physical activity and diet, for example, may also influence cognitive performance and cognitive development or, more likely, there is a complex bidirectional association. Health problems, psychosocial impairments and a low perceived quality of life may also be a cause for excessive weight gain or both may underlie other common factors.

Furthermore, in all studies there are limitations concerning missing data and selection bias. First, teachers who participated with their classes opted in voluntarily. It may be that especially schools in disadvantaged areas decided not to take part in a health promotion project due to other difficulties or that the participating teachers are more motivated than the average teacher. The same applies to the individual child: Maybe less so-called multiproblem families agreed with the participation in the study and more families with social or language barriers opted out. Cognitive testing was performed in a subsample only in the southern region of Baden-Württemberg. There were a few drop-outs due to comprehension and motivation restraints, thus especially high-risk children (e.g. hyperactive children, children with large deficits in attention and executive functions, with lower intellectual abilities, with language problems) may have not been assessed. Concerning parental questionnaire there was a relatively high return rate (88%). Drop-outs, however, may also be due to language barriers, lack of compliance or time restraints.
Missing analyses were conducted in study 2 and 3 and revealed, in general, a more favourable profile of children who were included in the statistics than of those who dropped out.

Moreover, the parental questionnaire assessed subjective retrospective data which is subject to different response bias such as social desirability or recall bias. For example, parents with more than one child may have had difficulties to recall the right answers and self-reported parental weight may be less exact. Thus, there has only been an approximation and indirect measure of children’s lifestyle, parental health, sick days and visits to a physician, etc. HRQoL was also measured indirectly via parental report because of young children’s insufficient self-reflection skills, their lack of reading and writing skills and their lack of understanding of the concept “health”. Nevertheless, to assess HRQoL two different valid scales have been used (EQ5D-Y VAS, KINDL®) and one of them provided even subscales with more differentiated information. Further, an acceptable accordance between the parental and child version of the KINDL® has been reported (Erhart et al. 2009).

Finally, cognitive assessment was limited to three domains and each domain was operationalised by only one test. However, there is a wide variety of assessment tools especially in the field of executive functions, measuring different aspects (e.g. “hot” (= affective, motivational) versus “cool” (= emotionally neutral) executive functions) and there is up to date no consensus neither about the number and definition of executive functions per se nor about the appropriate assessment. Moreover, it would have been interesting to test more cognitive domains (e.g. memory, perception) also on a more basal level and to make comparisons. Hence, the interpretation is limited to the three measured and rather “cool” functions without any connection to eating stimuli or any emotional meaning. On the other hand, it is difficult to separate single cognitive abilities as tests usually require multiple cognitive skills. Inhibitory control, for example, may have also played a role in the cognitive flexibility and sustained attention task at least for a certain degree and perception, recall of rules, motoric skills etc., can be considered as influencing factors in all of the tests.
4.2 Conclusions and prospect

Cross-sectional results indicate an association between cognitive abilities such as inhibitory control and cognitive flexibility, also known as executive functions, and body weight in primary school children. The findings further suggest that obesity is linked to poorer inhibitory skills, thus, deficits in inhibitory control may constitute a risk factor especially for extreme weight gain. Future longitudinal and intervention studies are necessary to gain more insight in the directionality of the association. Furthermore, central obesity was linked to higher rates of school absenteeism, more visits to a physician and lower HRQoL. This emphasises the negative consequences of central obesity already in early school age: academic disadvantages, an impaired subjective well-being, higher health care costs. Early intervention measures such as the programme “Komm mit in das gesunde Boot” are necessary to establish a healthy lifestyle and self-controlled behaviour from the beginning and to avoid negative health outcomes. These measures might benefit from integrating cognitive training at least in children with deficits in certain cognitive self-control competences. Early identification of these children in combination with excessive weight gain may improve existing intervention efforts.
5 Summary

Background: One of the major public health concerns in modern industrialised countries is childhood obesity and its far-reaching consequences at the individual but also socio-economic level. Objective of the present research project was to investigate cognitive correlates of body weight and weight classification assuming certain cognitive abilities to play an important role in adopting and maintaining health behaviour. To justify and emphasise the need of early prevention programmes, associations of childhood obesity and health-related subjective and economic outcomes were to be determined.

Methods: In the context of a school-based health promotion project (cross-sectional analysis of baseline data of the evaluation study) 1944 primary school children (1st and 2nd grade) participated in anthropometric measurements. BMI percentiles were calculated according to national reference data, children were assigned to weight groups based on BMI percentiles and based on Waist-to-Height-Ratio (WHtR; central obesity), respectively. Their parents filled in a questionnaire on health care use, days of absence from school or work and health-related quality of life (HRQoL). Further data on sociodemographic features, lifestyle, early development and parents’ health were assessed via parental questionnaire. In a subsample of 498 children a cognitive testing took place. Associations between scores in inhibitory control, cognitive flexibility, sustained attention and BMI percentiles were analysed via hierarchical linear regression controlling for potential confounders. Differences in inhibitory control between obese, overweight and non-overweight children were calculated via ANOVA and differences between centrally obese and non-obese children in sick days, visits to a physician and HRQoL were analysed via Mann-Whitney-U-Test.

Results: Inhibitory control was significantly associated with BMI percentiles. Obese children displayed lower inhibitory control than overweight and non-overweight children. Besides inhibitory control, cognitive flexibility was also associated with body weight but not sustained attention. Centrally obese children (WHtR ≥ 0.5) had significantly more sick days, more visits to a physician and a lower HRQoL than non-obese children.

Conclusions: Cross-sectional results indicate an association between cognitive abilities such as inhibitory control and cognitive flexibility, also known as executive functions, and
Summary

body weight in primary school children. The findings further suggest that paediatric obesity is linked to poorer inhibitory skills, thus, deficits in inhibitory control may constitute a risk factor especially for extreme weight gain. As previous research in the field of executive functions highlights their role in social and emotional development, academic success and also health behaviour, health promotion and prevention efforts might benefit from integrating cognitive training. Future longitudinal and intervention studies, however, are necessary first to gain more insight in the directionality of the association and to evaluate the impact of cognitive training units. Higher rates of absence, more visits to a physician and lower HRQoL were found in centrally obese children. This emphasises the negative consequences of central obesity already in early school age: academic disadvantages, an impaired subjective well-being, higher health care costs. Early intervention measures are necessary to establish a healthy lifestyle and self-controlled behaviour from the beginning and to avoid negative health outcomes.
6 References


Appendix
Publications

Hereinafter, the corresponding publications referring to the current research project are attached. The articles are included in full based on the license and author’s agreement of each publisher.


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Appendix

Eating Behaviors 15 (2014) 9–12

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Eating Behaviors

ASSOCIATIONS BETWEEN INHIBITORY CONTROL AND BODY WEIGHT IN GERMAN PRIMARY SCHOOL CHILDREN

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Overweight
Obesity
Child

A B S T R A C T

Deficits in inhibitory control are supposed to be a risk factor for overweight but literature concerning childhood and beyond the clinical setting is scarce. The objective of this study was to investigate the role of inhibitory control in regards to body weight in a large non-clinical sample of primary school children. Baseline data of 498 children (1st and 2nd grade; 70 ± 60 years; 48.8% boys) participating in a school-based intervention study in Germany were used. Children performed a Go-NoGo task to assess inhibitory control. Height and weight were collected and converted to BMI percentiles based on national standards. Relevant influencing factors (sociodemographic data, health characteristics of parents, children’s health behavior) were assessed via parental questionnaire. Inhibitory control was significantly associated with body weight and contributed to the statistical prediction of body weight above and beyond parent education, migration background, parent weight, TV consumption and breakfast habits. Moreover, obese children displayed significantly lower inhibitory control compared to non-obese and overweight children. The findings suggest that deficits in inhibitory control constitute a risk factor for pediatric obesity.

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1. Introduction

The increasing prevalence of paediatric obesity in industrialised countries has become a major topic of public health in recent decades. The German Health Interview and Examination Survey for Children and Adolescents (KiGGS) indicates an overweight prevalence of 14.8% with a profound increase at the age of school entry (Hirth & Schaffatal Rossi, 2010). There is a high risk for several chronic diseases (e.g. hypertension, type 2 diabetes, pulmonary and musculoskeletal complications) as well as psychosocial repercussions associated with childhood overweight (Birkeland, Pavlik, & Ludvig, 2002; Reilly et al., 2003; Schwarzner, Burwinkle, & Vanni, 2003). Besides genetic predisposition certain behavioural and lifestyle factors such as unfruitful dietary habits and preferences of sedentary activities have been identified to contribute to excessive weight gain (Nagel et al., 2005; Proctor et al., 2003; Reilly et al., 2005).

Recently, the importance of deficits in self-regulating skills for the development of overweight has been acknowledged. One essential cognitive regulatory function is inhibitory control defined as the ability to withhold prepotent inappropriate responses (Miyake, Friedman, Emerson, Witzki, & Howarter, 2000; Wagner, 2010). Deficits in inhibitory control are linked to impulsive and less self-controlled behaviour (Barkeley, 1997; Logan, Schachar, & Tannock, 1997; Nederkoorn, Braet, Van Eijij, Tanghe, & Jansen, 2006) and associations between impulsivity respectively self-control and body weight or weight change have been shown previously (Braet, Claes, Verhezen, & Vlerick, 2007; Duckworth, Tsakayama, & Grier, 2010; Nederkoorn, Jansen, Mulkins, & Jansen, 2006). Further, numerous studies are indicating a comorbidity between attention deficit / hyperactivity disorder (ADHD) and obesity (Cortese et al., 2008). As one explanation a deficient inhibitory control and delay aversion in ADHD leading to unusual eating behaviours are discussed (Cortese et al., 2008; Davis, Levitan, Smith, Tweed, & Curtis, 2006). The direct role of inhibitory control in regards to body weight and weight status has been shown in preschool as well as in school children (Czarny, Cullis, & Keane, 2010; Paulis-Poll, Albayrak, Hebebrand, & Pott, 2010). Paulis-Poll et al. found significant interactions with age showing this link exclusively in younger school children and assumed an especially important developmental period around the age of 8 years. Regarding the underlying mechanisms researchers assume that maladaptive eating behaviour (e.g. overeating, impulsive eating) may play a role (Davis et al., 2006; Graziano et al., 2010). Children with low impulse control are more vulnerable for food temptations, seek...
Immediate gratification, fail to think their responses through and tend to overeat (Jansen et al., 2003; Nederkoorn, Jansen, et al., 2006). Riggs, Chou, Spruijt-Metz, and Pente (2010) pointed out the importance of inhibitory control and further executive functions in planning, implementing, and maintaining healthy goal-directed behavior including food intake and physical activity.

Nevertheless, there is a lack of research especially for children in early school age when excessive weight gain is particularly pronounced and great progress in self-regulating skills are made. Studies predominantly examined clinical populations who possibly suffer more intense impulsivity problems, comorbid psychopathology or extreme weight problems and sample sizes are often limited. The objective of the present study was to investigate directly the role of inhibitory control in body weight and in the development of weight problems in a large nonclinical sample of primary school children. The continuous spectrum of body weight was considered as well as the classification in clinically meaningful weight groups. Positive confounders (sociodemographic features, parent weight, children’s health behavior) were taken into account. It was hypothesized that inhibitory control contributes significantly to the prediction of body weight and that children with poorer inhibitory control are more likely to be overweight or obese.

2. Material and methods

2.1. Overview

The study was conducted within the context of the Baden-Württemberg Study which is evaluating the effects of a school-based health promotion programme for children implemented in southwest Germany. The Baden-Württemberg Study was approved by the institutional ethics committee and is registered in the German Clinical Trials Register (DRKS00000834). A detailed description has been published elsewhere (Dreyhaupt et al., 2012). Teachers volunteered to participate and written informed consent was obtained from parents. Baseline measurements including the assessment of anthropometric and cognitive data were taken in autumn 2010. All measurements were performed on site at school. After the measuring period a parental questionnaire was issued and returned within six weeks.

2.2. Participants

Overall, n = 496 children from ethnically and socioeconomically diverse primary schools in the federal state of Baden-Württemberg, Germany, provided anthropometric and cognitive data. Children attended 1st grade (57.0%) or 2nd grade and averaged 7.0 ± 0.6 years of age; 49.8% were boys. Exclusion criteria were colour blindness and motor impairments.

2.3. Cognitive measures

Inhibitory control was measured via the Go-Nogo-task of the computer-based test battery of attention for children (KITAP; Zimmermann, Gordan, & Füllen, 2002). The KITAP is valid for the age range 6 to 10 years and has been used in paediatric, basic and cross-cultural research (Drechsler, Rizzo, & Steinhausen, 2009; Eikelmann, Petermann, & Daechning, 2008; Koller, Langguth, Ganschow, Nischan, & Schulte, 2010; Sobe, & Speijers, 2003; Trautmann & Zepf, 2012). The test was administered during the first school hours by trained examiners in small groups; instructions were standardised. Comprehension and willingness of the children were assured by short preceding practice trials.

A total score based on number of errors and reaction time was calculated (errors standard scores minus reaction time standard scores) and reversed to improve interpretability. A positive total score therefore indicates high inhibitory control (less number of errors; slower, more reflexive reactions), a negative score low inhibitory control (higher number of errors; faster, more impulsive reactions).

2.4. Anthropometric measures

Height and weight of the children were taken by trained staff according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK; Murilli-Jones, Dils, Stewart, & Carter, 2006). Children’s body mass index (BMI) was calculated (kg/m²) and converted to BMI percentiles using national age- and sex-specific reference data (Kromeyer-Hauschild et al., 2001). Subjects were categorized as overweight (≥85th percentile, ≥97th percentile), obese (≥97th percentile) and non-overweight (<85th percentile).

2.5. Co-variables

Sociodemographic data, health characteristics of parents and children’s health behaviour were assessed via parental questionnaire. Parent education was assigned according to the CASMIN classification (Brauns, Scherer, & Steinmann, 2003). Due to the small number of cases with primary education level parent education was dichotomised with primary and secondary versus tertiary education level. Migration background was defined as at least one parent born abroad or mainly having spoken a foreign language with the child during its first years of life. Self reported parental height and weight were used to calculate BMI of mother and father. Additionally, parents estimated their child’s TV consumption and breakfast habits. The mean time spent watching television per day was dichotomised using a cut-off-point at 1 h as the American Academy of Paediatrics (2001) recommends less than 1 - 2 h of screen time per day. For statistical analysis frequency of having breakfast prior to going to school was also dichotomised with “never” / “rarely” versus “often” / “always”.

2.6. Statistical methods

Hierarchical multiple regression analysis was performed to determine the predictive value of inhibitory control on BMI percentiles controlling for potential confounders. To determine whether children with poor inhibitory control are more likely to have weight problems ANOVA and Tukey-HSD post-hoc analysis across different weight groups were used. Due to incomplete data sample size varies for different analyses. Statistical analyses were carried out using SPSS 19, statistical significance was set at α = 0.05.

3. Results

Inhibitory control of children averaged −0.01 ± 1.68 (total score), with a mean number of errors of 5.28 ± 3.26 and a mean reaction time of 511.14 ms ± 76.34 ms. Average BMI percentile of children was 48.21 ± 26.52 and 5.46% were classified as overweight or obese. Average BMI of mothers was 23.86 ± 4.47, BMI of fathers 27.90 ± 3.93. Sociodemographic, behavioral and further weight group characteristics are shown in Table 1.

Results of the hierarchical regression are presented in Table 2. Model 1 was established including parent education, migration background, BMI of mother and father, children’s TV consumption and breakfast habits as co-variables. In Model 2 inhibitory control was added and contributed significantly to the prediction of BMI percentiles.

Furthermore, there was a significant difference in inhibitory control between weight groups (F(2, 2474) = 6.46, p = .002, η² = .03) with a significant lower total score in obese children compared to non-overweight (MD = 1.52, SE = 0.42, p = .001) and overweight children (MD = 1.39, SE = 0.54, p = .027). Overweight children did not differ significantly from non-overweight children. Obese children showed more errors than the other two groups (F(2, 2795) = 5.09, p = .013, η² = .03; MD = 3.05, SE = 1.15, p = .05 and MD = 3.33, SE = 1.28, p = .04)
and the shortest reaction time, just failing significance level compared to non-overweight children \( (F(2, 474) = 3.12, p = .045, \tau^2 = .01; MD = 44.77, SE = 19.39, p = .06) \).

4. Discussion

In a sample of primary school children inhibitory control contributed significantly (1.4% additional variance accounted) to the statistical prediction of body weight above and beyond parent education, migration background, parent weight, children's TV consumption and breakfast habits. Considering that BMI is a complex construct influenced by multiple genetic, behavioral and environmental factors this can be interpreted as a distinct contribution of inhibitory control. Previous studies reported similar values (Zen, Paul-Pott et al., 2010). In infants Graziano et al. (2010) found larger ones for inhibitory control in terms of reaction time \( (85) \) but only controlled for behavioral problems.

Comparing weight groups only obese but not overweight children showed poorer inhibitory control compared to non-overweight children. The more impulsive responses could be seen in the highest error rate as well as the shortest reaction time supporting previous findings of higher impulsivity in obese children (Brat et al., 2007; Nederkoorn, Jansen et al., 2006). Of particular interest is the finding that the effect was limited only to the obese suggesting that inhibition plays a role especially in extreme overweight. As in most studies only two weight groups are compared, further research is needed to confirm this assumption. There might even be a critical cut-off point from which inhibitory control gets relevant for body weight.

Table 2

<table>
<thead>
<tr>
<th>Predictor</th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>BM 0</td>
<td>4.26</td>
<td>3.98</td>
</tr>
<tr>
<td>Migration background</td>
<td>4.01</td>
<td>3.51</td>
</tr>
<tr>
<td>BMI mother</td>
<td>1.11***</td>
<td>1.03**</td>
</tr>
<tr>
<td>BMI father</td>
<td>1.02**</td>
<td>1.02**</td>
</tr>
<tr>
<td>TV consumption</td>
<td>3.86</td>
<td>3.26</td>
</tr>
<tr>
<td>Breakfast habits</td>
<td>2.53</td>
<td>2.53</td>
</tr>
<tr>
<td>Inhibitory control</td>
<td>-1.91</td>
<td>-3.52</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>.11</td>
<td>.12</td>
</tr>
<tr>
<td>( \Delta R^2 )</td>
<td>.00***</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note: \( N = 340, CI = \text{confidence interval} \). * \( p < .05 \); ** \( p < .01 \); *** \( p < .001 \).

It should be noted that the cross-sectional study design precludes any causal interpretation of the findings. Besides the assumption that inhibitory control influences healthy (eating) behavior and therefore body weight the relationship could be reverse or bidirectional as well. Variations in food intake or physical activity could also influence cognitive functions and brain development (Riggs et al., 2010). Further, the low number of obese children did not allow controlling for potentially confounding variables in the weight group comparison. Conclusions on inhibitory control in obese children must be drawn carefully and further analyses such as the identification of potential subgroups are needed. Taking BMI percentile as measure for body weight might not reflect actual body fat content. However, it is an accepted measure for population research, clinically meaningful (Reilly et al., 2003) and enables comparability with other studies. Regarding the behavioral aspects assessed via parent questionnaire not taking into account the objective standardised measurements of cognitive and anthropometric data, however, can be considered as strength of the study.

The current findings provide support for an association between inhibitory control and body weight in children entering primary school and suggest that paediatric obesity is linked to poorer inhibitory abilities. Further work is needed to clarify the direction and underlying mechanisms. In addition, other cognitive functions and self-regulating skills should be considered to prove whether this link is specific to inhibitory processes. As an implication obesity intervention and prevention should also consider cognitive regulation of health behaviour and include for example measures to strengthen inhibition of impulsive eating (e.g. perception of satiation, resistance for food temptations, prevention of overeating) as well as changes in environment for those with poorer inhibition.

Role of funding sources

Funding for this study was provided by the Baden-Württemberg Stiftung (Baden-Württemberg foundation). The Baden-Württemberg Stiftung had no role in the study design, collection, analysis or interpretation of the data, writing the manuscript, or the decision to submit the paper for publication.

Contributors

Tamar Wirt designed the study and wrote the first draft of the manuscript. Verena Henseläwer, Anna Scheiber, and Donatella Koczyla were involved in statistical analysis and drafting the manuscript. Jürgen M. Neubauer is the principal investigator of the Baden-Württemberg Study and director of the programme “Kinder mit in das gesunde Kind – Grundschule”. Tamar Wirt, Verena Henseläwer, Anna Scheiber, Donatella Koczyla, and the research team organized the Baden-Württemberg Study and were involved in carrying out the measurements. All authors contributed to and have approved the final manuscript.

Conflict of interest

All authors declare that they have no conflicts of interest.

Acknowledgments

The study was conducted within the context of the health promotion programme “Kinder mit in das gesunde Kind – Grundschule”. The authors would like to thank all members of the research group for their input, especially Susanne Brandstätter for her contribution to the study design, all assistants who were involved in the performance of measurements and all teachers and families for their participation.

References

Appendix
Research Article

Early Life Cognitive Abilities and Body Weight: Cross-Sectional Study of the Association of Inhibitory Control, Cognitive Flexibility, and Sustained Attention with BMI Percentiles in Primary School Children

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The objective of this study was to investigate the association of different cognitive abilities with children's body weight adjusted for further weight influencing sociodemographic, family, and lifestyle factors. Cross-sectional data of 498 primary school children (70 ± 0.6 years; 49.8% boys) participating in a health promotion programme in southwest Germany were used. Children performed a computer-based test battery (KITAP) including an inhibitory control task (Go-Nogo paradigm), a cognitive flexibility task, and a sustained attention task. Height and weight were measured in a standardized manner and converted to BMI percentiles based on national standards. Sociodemographic features (migration background and parental education), family characteristics (parental body weight), and children's lifestyle (TV consumption, physical activity, consumption of sugar-sweetened beverages and breakfast habits) were assessed via parental questionnaire. A hierarchical regression analysis revealed inhibitory control and cognitive flexibility to be significant cognitive predictors for children's body weight. There was no association concerning sustained attention. The findings suggest that especially cognitive abilities known as executive functions (inhibitory control and cognitive flexibility) are associated with children's body weight. Future longitudinal and intervention studies are necessary to investigate the directionality of the association and the potential of integrating cognitive training in obesity prevention strategies. This trial is registered with ClinicalTrials.gov DRKS00000494.

1. Introduction

The dramatically increased prevalence of childhood obesity in industrialised nations has been declared as a major topic of public health in the recent decade [1, 2]. In Germany, 14.8% of children aged 2 to 17 years are overweight or obese [3]. An increase of overweight and obesity is particularly evident at the age of school entry, between 5 and 8 years [3, 4]. Given the significant adverse biopsychosocial consequences of paediatric overweight, its relatively stable course, and the enormous economic costs to the healthcare system, effective prevention strategies are needed [1, 5–8]. It is therefore important to better understand correlates of paediatric overweight and to identify risk factors. Besides a genetic predisposition, increased body weight is influenced by certain behavioural and lifestyle factors such as unfavourable dietary habits, for example, high consumption of sugar-sweetened beverages or skipping breakfast, low levels of physical activity, and preference of sedentary activities, for example, screen media use [9–12]. Furthermore, cultural and family characteristics such as migration background, low socioeconomic position, low parental education, and parental obesity are associated with childhood overweight [3, 11, 13, 14].

Additionally, there is a growing body of evidence suggesting an association between increased body weight and altered cognitive functioning in children. Overweight children show, for example, worse school performance compared to their normal-weight counterparts [15–17]. Moreover, a negative
association between obesity and executive functions has been reported [18]. Executive functions are defined as higher-order control processes of the cognitive system that are related to self-regulation and underlie goal-directed and adaptive behaviour [19, 20]. These processes have already been positively related to social and emotional skills, school success, mental and physical health, and social status in adulthood [20, 21]. Different components of executive functions such as inhibitory control (the ability to withhold inappropriate actions) or cognitive flexibility (the ability to adjust to changed circumstances or demands) are usually distinguished [20]. Regarding the association between obesity and executive functions studies have mainly focussed on inhibitory control which is significantly related to body mass index in children and adolescents [18, 22, 23]. Concerning other executive functions (e.g., cognitive flexibility) or further cognitive domains (e.g., attention, memory, and general cognitive function), however, findings are scarce and inconsistent [18, 24, 25].

Assuming an association between children’s body weight and cognitive functioning one possible underlying mechanism may be that certain cognitive abilities play a role in learning, adopting, and maintaining health behaviour [26, 27]. As previously mentioned executive functions and most of all the inhibitory components are related to cognitive self-regulation and to disciplined behaviour [20]. In the context of paediatric obesity inhibitory control may be important for young children to regulate their physical activity level and their food intake in terms of appreciating rules from parents or teachers, resisting temptations (e.g., consumption of sweets when not allowed and watching TV or video games when otherwise engaged), controlling distracting thoughts and negative emotional states which may increase appetite, and staying focused on activities such as playing games. Cognitive flexibility may be critical for children when trying out new behaviour and dealing with changes, barriers, or different settings throughout their day and when deliberating attention control (focusing and switching) is necessary. Appreciating healthier food and beverages and active ways of transport when introduced by caregivers, coping with school entry and the related changes, switching between sedentary activities such as homework and active play, and finding ways of being physically active despite bad weather or without any toys may be that examples. Besides these control functions further abilities such as sustained attention may play a role in terms of maintaining the focus of attention on specific activities over a certain period of time. Thus, it is important for children not only to cope with immediate distractions, changes, and temptations, but also to stay focused in the long run.

However, the small body of literature regarding childhood and specifically early school age can be criticised. Most studies focused only on older children or adolescents. Selectivity, small size of study samples, and the use of self-reporting measures further limit validity of research results. Moreover, researchers addressing paediatric obesity always emphasise the importance of controlling for social factors such as parental income or education [15]. The objective of the present study, therefore, was to investigate the association between different cognitive abilities (inhibitory control, cognitive flexibility, and sustained attention) and body weight in a large nonclinical sample of primary school children. To consider the outlined methodical issues objective standardised tests and assessment methods were used and potentially confounding factors including sociodemographic features, family, and lifestyle were controlled.

2. Materials and Methods

2.1. Overview. In the context of a large evaluation study of a school-based health promotion programme in south-west Germany (the Baden-Württemberg Study) cognitive, anthropometric, sociodemographic, and behavioural data of primary school children were collected. The Baden-Württemberg Study was approved by the institutional ethics committee and is registered at the German Clinical Trials Register (DRKS00000494). Teachers of school classes in the federal state of Baden-Württemberg volunteered to participate in the study and written informed consent was obtained from parents prior to data collection. The Baden-Württemberg Study is a longitudinal study and is designed as a randomised controlled trial. A detailed description of the study has been published by Dreyhaupt et al. [28]. For the present analysis only baseline data of the control and intervention group were used. Baseline assessment took place in autumn 2010 (within a 3-month period from the end of summer vacation in September to the beginning of autumn vacation in November). During this time a research group from the University of Ulm visited the participating school classes (one or two classes each day). Thus, all measurements were performed on-site at school during one school day. On the day of a school visit, children were assigned to small groups based on gender and class to perform the different measurements (e.g., cognitive testing and anthropometric measurement). To obtain information about sociodemographic and lifestyle characteristics a parental questionnaire was issued directly after the measuring period (November 2010) and returned within six weeks.

2.2. Participants. The total sample of the Baden-Württemberg Study consisted of \( n = 1944 \) children from ethnically and socioeconomically diverse primary schools in the federal state of Baden-Württemberg, Germany. Primary school classes were recruited using a number of different public relations activities such as written information for schools, education and health authorities, adverts in training catalogues for teachers, informative events, or participation at pedagogic trade shows. For logistical reasons (distances between schools, scope of measurements of the Baden-Württemberg Study, and technical equipment) cognitive testing was only carried out in the southern part of Baden-Württemberg at a convenient distance of the research centre in Ulm. Furthermore, children who were absent on the day of school visit were not retested. Cognitive data collection took place in a subsample of \( n = 513 \) children. After exclusion of \( n = 15 \) children due to motor impairment, colour blindness, or lack of compliance the sample for the present analysis amounts to \( n = 498 \) participants. Children attended either
1st grade (57.0%) or 2nd grade and averaged 7.0 ± 0.6 years of age (range 5–9); 49.8% were boys. Sample size for each cognitive subtest varies due to further missing or invalid data: n = 479 children provided valid data for inhibitory control, n = 445 for cognitive flexibility, and n = 466 for sustained attention. Reasons for further subtest dropouts were, for instance, time restriction at school and lack of comprehension or compliance or implausible data concerning only one subtest. Anthropometric data was available for n = 496, and the parental questionnaire was filled out for n = 441 children. Complete data including all cognitive measures, anthropometric measures, and parental questionnaire was available for n = 297. Figure I provides an overview of the sample and subsample selection.

2.3. Cognitive Measures. Cognitive abilities were assessed using the computer-based test battery of attention for children (KITAP) [29]. The KITAP is validated for children aged 6 to 10 years and consists of a broad range of nonverbal subtests measuring different basal as well as higher-order components of the cognitive system (attention and executive functioning). Each component can be assessed separately. To ensure optimal motivation and compliance all subtests are designed in the form of short games with an enchanted castle theme. This allows the KITAP to be particularly accessible to young children in comparison to other known test batteries based on more abstract stimuli. Furthermore, a computer-based test was preferable to a paper pencil test as preliminary trials demonstrated that children just entering school had difficulties in turning pages and handling a pencil. Due to the child-friendly character, the feasibility in the school and group setting, and the possibility to measure differentially cognitive functioning (including executive control components) the KITAP constituted a suitable assessment tool for the present study purposes. In terms of validity the test battery has been especially used in neuropsychological and other paediatric researches [30–32] as well as in research with healthy children and in cross-cultural studies [33, 34]. Significant correlations with school outcomes [34], intellectual abilities [32], and behavioural questionnaires [35] could be found. Factorial analysis confirmed the construct validity [29], and group comparisons (e.g., children with versus without attention deficit hyperactivity disorder) demonstrated criterion validity [30]. The reliability of the test battery can be considered as satisfactory [29].

Three subtests of the KITAP were administered: an inhibitory control task (Go/NoGo paradigm), a cognitive flexibility task, and a sustained attention task. For each task number of errors (incorrect response to a noncritical stimulus), number of omissions (missed response to a critical stimulus), and reaction time (milliseconds in median) were recorded. For statistical analysis and to overcome the right skewed distributions of errors and omissions total scores were calculated for each subtest based on the key parameters recommended in the test manual.

(1) Inhibitory Control. The Go/NoGo task examined the ability to respond as quickly as possible to a certain critical stimulus by pressing a button and to withhold the response when another noncritical stimulus emerged. The task lasted 3 minutes. Key parameters were errors and reaction time. Errors could range from 0 to 20 and reaction time from 0 ms to 2700 ms (maximum time interval between two stimuli). The total score was calculated as follows:

$$\text{Total score} = \text{errors standard scores} - \text{reaction time standard scores}$$

To improve interpretability the score was reversed with a positive total score indicating an overly high inhibitory control (low number of errors and slow reflexive reactions) and a negative score indicating low inhibitory control (high number of errors and fast impulsive reactions). A score around 0 represented an average inhibitory ability.

(2) Cognitive Flexibility. The task examined the ability to deliberately control the attention focus and to adapt responses to changing conditions as quickly as possible. Children had to consider different features simultaneously (colour and location of the stimulus), to switch their attention continuously between these features, and to react appropriately according to the target feature in each trial. In detail, two stimuli in different colours were presented simultaneously on the right and the left sides of the screen. Children had to press one out of two buttons (left button for the left side or right button for the right side) depending on the colour of the stimuli in an alternate sequence (colour A, colour B, colour
A, colour B, ...). On each trial, the stimulus with the target colour could be presented on the same side of the screen as before or on the other side; thus, children had to change their response behaviour or not. Duration of the whole task varied depending on reaction times (approximately 3 minutes). Key parameters were errors and reaction time. Errors could range from 0 to 50 and reaction time from 0 ms to 6000 ms (maximum time interval between two stimuli if no reaction occurred). Contrary to the other subtests, a total score was automatically computed by the KITAP based on standardised number of errors and reaction time [29]. A positive score represented overly high flexibility (low number of errors and fast reactions) and a negative score low flexibility (high number of errors and slow reactions). A score around 0 represented average cognitive flexibility.

(3) Sustained Attention. The task examined the ability to maintain attention over an extended period of time (10 minutes). During this time, children had to compare subsequent stimuli in terms of a specific feature (colour) and to determine whether two stimuli were matching. Key parameters were errors (two stimuli incorrectly indicated as matching) and omissions (two stimuli incorrectly indicated as nonmatching). Errors could range from 0 to 250 and omissions from 0 to 50. The total score represented the number of correct responses and was calculated as follows:

\[
\text{Total score} = \frac{\text{total number of stimuli}}{\text{(number of errors + number of omissions)}}.
\]

To consider the different number of errors and omissions possible (250 versus 50) the number of errors was relativised (divided by 5):

\[
\text{Total score} = \frac{100}{\left(\frac{\text{number of errors}}{5}\right) + \text{number of omissions}}.
\]

Thus, the total score ranged from 0 to 100 with a high total score indicating high sustained attention and a low score indicating low sustained attention. A score around 0 represented no sustained attention at all.

Procedure. On the day of a school visit the cognitive tests were administered during the first school hours. Cognitive testing took place in one or two separate quiet classrooms and was carried out by trained examiners using laptops (screen size: 15 inches). As previously mentioned children performed the tests in small groups (up to 8 children). Per group 4 examiners supported and supervised the children (with a maximum of 2 children per examiner). While one testing session took place, which lasted in total 30 minutes, the other groups were assigned either to anthropometric measurement or to other parts of the Baden-Württemberg Study. The subtests of the KITAP were administered in a fixed order and instructions were given in a standardised manner. Comprehension and willingness of the children were assured by short preceding practice trials according to the test manual. These practice trials could be repeated if necessary—especially the cognitive flexibility task required several preceding trials. The main testing started when it was clear that each child of the group understood the instructions. When the examiner was sure that a child was not able to perform a task, lack of comprehension was documented. The main testing was administered once. Further irregular and disruptive behaviour was documented and later considered during data preparation. Children who were absent on the day of testing were excluded from the analysis as there was no repetition of the testing at a later point in time.

2.4 Anthropometric Measures. Anthropometric measurement took place in a separate room provided by the teacher. Gender segregation of the groups was considered. Body height and weight of the children were taken by trained staff according to the guidelines of the International Society for the Advancement of Kinanthropometry (ISAK) [36]. Height was measured using a portable stadiometer (Seca model 217, Seca, Germany), without wearing shoes, with an accuracy of 0.1 cm. Weight was measured using a calibrated electronic scale (Seca model 862, Seca, Germany), wearing underwear, with an accuracy of 0.05 kg. Children’s body mass index (BMI) was calculated as weight divided by height squared (kg/m²) and converted to BMI percentiles using national age- and sex-specific reference data [37]. To allow international comparisons, weight status was also calculated according to international reference data [38].

2.5 Parental Questionnaire. Sociodemographic data, body weight of parents, and different lifestyle factors of children were assessed via parental questionnaire. Parent education was assigned to the respective level according to the CASMIN classification [39]. The CASMIN (Comparative Analysis of Social Mobility in Industrial Nations) is the most widely used international instrument to classify education considering length, quality, and value of general education as well as vocationally oriented schooling or training. The classification distinguishes primary, secondary, and tertiary education levels. In the present study parent education was determined as the highest level of two parents or the level of a single parent who cares for the child. Due to the small number of cases with primary education level (1.0%) parent education was dichotomised with primary and secondary education levels in one group and tertiary education level in another. Migration background was defined as at least one parent born abroad or at least one parent mainly having spoken a foreign language with the child during its first years of life. Self-reported parental height and weight were used to calculate BMI of mothers and fathers (kg/m²). Concerning children’s lifestyle, TV consumption, physical activity, consumption of sugar-sweetened beverages, and breakfast habits were assessed. The mean time spent watching television per day was rated on a 7-point Likert scale (“never” to “more than 4 hours”). As the American Academy of Paediatrics [40] recommends less than 1-2 hours of total screen time per day, TV consumption
was dichotomised using a cut-off point at 1 hour. Further, parents were asked on how many days per week their child was engaging in at least 60 minutes of moderate to vigorous physical activity (range 0 to 7 days) and how often their child was consuming sugar-sweetened beverages (6-point Likert scale: “never” to “more than once per day”). The frequency of having breakfast prior to going to school was rated on a 4-point Likert scale and, for statistical analysis, dichotomised as “never”/“rarely” versus “often”/“always.”

2.6. Statistical Methods. To determine the additional predictive value of each of the three cognitive variables on children’s BMI (percentiles) hierarchical multiple linear regression analysis was performed. First, a basic model (model 1) was established which included parent education, migration background, BMI of mother and father, children’s TV consumption, physical activity, consumption of sugar-sweetened beverages, and breakfast habits. In the next steps inhibitory control, cognitive flexibility, and sustained attention were added successively as predictors (models 2 to 4). Statistical analysis was carried out using SPSS 19 and statistical significance was set at α = 0.05. As missing data may have had an impact on the results, differences between the samples and subsamples (the Baden-Württemberg Study sample, n = 1944, the cognitive subsample, n = 498, and the final sample with complete and valid data, n = 297) were analysed using t-test for continuous data and Fisher’s exact test for categorical data.

3. Results

3.1. Descriptive Characteristics. Sociodemographic, lifestyle, and weight group characteristics of the different samples are shown in Table 1. In the cognitive subsample (n = 498) the average BMI percentile of children was 48.21 ± 26.92, and 8.4% were classified as overweight or obese and 7.3% were classified as underweight according to national standards [37]. The prevalence for overweight and for underweight was slightly higher according to international cut-off points [38] (Table 1). Parental BMI averaged 23.86 ± 4.47 (mothers) and 27.90 ± 3.93 (fathers), respectively. Means and standard deviations for all cognitive subtests (total scores, number of errors, number of omissions, and reaction time) are illustrated in Table 2.

3.2. Prediction of Body Weight. To determine whether different cognitive abilities are associated with children’s BMI, hierarchical regression analysis was conducted. Results are presented in Table 3. First, model 1 revealed migration background, body weight of mother, and body weight of father as significant predictors of children’s BMI. No relationship between parental education or the different lifestyle factors and children’s BMI was found. As it is shown in models 2 to 4 inhibitory control and cognitive flexibility were significant cognitive predictors over and above all other variables whereas sustained attention did not significantly contribute to the prediction. Inhibitory control and cognitive flexibility together explained an additional amount of 4.5% of variance in the criterion.

3.3. Missing Data. Children of the cognitive subsample (n = 498) differed from children of the total study population in terms of migration background and father’s BMI. A significantly higher percentage of migration background (P = 0.022) and a significantly lower father’s BMI (P = 0.001) were found in children who performed the KITAP compared to those who did not. There were no significant differences concerning age, sex, BMI percentiles, weight group, TV consumption, physical activity, consumption of sugar-sweetened beverages, breakfast habits, parental education, and mother’s BMI. Children of the final subsample with complete data (n = 297) differed significantly from children of the total study population in terms of BMI percentiles, parental education, consumption of sugar-sweetened beverages, and father’s BMI. Lower BMI percentiles (P = 0.008), a higher percentage of tertiary parental education level (P = 0.009), a lower percentage of soft drink consumption (P = 0.031), and a lower father’s BMI (P = 0.000) were found in children with complete data compared to those without. There were no significant differences concerning any other variable. Although the percentage of migration background was increased in the cognitive subsample, more children with migration background dropped out in the further data process. Thus, the final subsample did not differ anymore from the total study sample in this respect.

4. Discussion

The present study examined the association between different cognitive abilities and body weight in primary school children. The findings suggest that especially cognitive abilities known as executive functions such as inhibitory control and cognitive flexibility are associated with children’s body weight. In the past decade particularly the influence of inhibitory control was investigated in children and adolescents using a variety of assessment tools [18]. Methods ranged from behaviour questionnaires, ratings, and self-reports to different tasks and computerised tests (e.g., Stroop test, Go-Nogo test, and delay-of-gratification task). In line with the results reported here all studies showed a significant relationship between body weight and inhibitory control in that a higher body weight was associated with poorer inhibition performance. Additionally, a few longitudinal studies indicated that inhibitory control at a younger age can predict children’s BMI at an older age [18, 22, 41]. Group analyses revealed less inhibitory control in overweight adolescents compared to their normal weight peers [18, 42]. Paul-Pott et al. [23] further pointed out a significant interaction with age and assumed that there might be an especially important developmental period at early school age when inhibitory control is particularly important for self-regulation.

Few studies can be found examining the association between cognitive flexibility and body weight. Cserjesi et al. [24], for example, found a significant negative correlation in adolescent boys, and obese boys significantly performed
Appendix

Table 1: Descriptive characteristics of the Baden-Württemberg Study sample and the KITAP subsamples.

<table>
<thead>
<tr>
<th>Child characteristics</th>
<th>Baden-Württemberg Study sample (n = 1944)</th>
<th>Missing values</th>
<th>Cognitive subsample (n = 498)</th>
<th>Missing values</th>
<th>Final subsample* (n = 297)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age, m (sd)</td>
<td>71 (6.6)</td>
<td>0</td>
<td>70 (6.6)</td>
<td>0</td>
<td>71 (6.6)</td>
</tr>
<tr>
<td>Female, %</td>
<td>949 (48.8)</td>
<td>0</td>
<td>250 (50.2)</td>
<td>0</td>
<td>141 (47.5)</td>
</tr>
<tr>
<td>BMI percentiles, m (sd)</td>
<td>49.0 (27.9)</td>
<td>51</td>
<td>48.2 (26.9)</td>
<td>2</td>
<td>45.2 (26.9)</td>
</tr>
<tr>
<td>Weight group, national reference data, n (%) [37]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight (&lt;10 BMI percentile)</td>
<td>148 (78)</td>
<td>51</td>
<td>36 (73)</td>
<td>2</td>
<td>25 (8.4)</td>
</tr>
<tr>
<td>Overweight (&gt;90 and &lt;97 BMI percentile)</td>
<td>108 (5.7)</td>
<td>51</td>
<td>25 (5.0)</td>
<td>2</td>
<td>14 (4.7)</td>
</tr>
<tr>
<td>Obese (&gt;97 BMI percentile)</td>
<td>82 (4.3)</td>
<td>17</td>
<td>17 (3.4)</td>
<td>6</td>
<td>6 (2.0)</td>
</tr>
<tr>
<td>Weight group, international reference data, n (%) [38]</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Underweight</td>
<td>78 (4.0)</td>
<td></td>
<td>50 (10.0)</td>
<td></td>
<td>35 (11.8)</td>
</tr>
<tr>
<td>Overweight</td>
<td>190 (10.0)</td>
<td></td>
<td>46 (9.2)</td>
<td></td>
<td>22 (7.4)</td>
</tr>
<tr>
<td>Obese</td>
<td>74 (3.9)</td>
<td></td>
<td>15 (3.0)</td>
<td></td>
<td>4 (1.3)</td>
</tr>
<tr>
<td>TV consumption &gt; 60 minutes/day, n (%)</td>
<td>242 (14.3)</td>
<td>254</td>
<td>65 (14.9)</td>
<td>61</td>
<td>37 (12.5)</td>
</tr>
<tr>
<td>Days/week with at least 60 minutes MVPA, m (sd)</td>
<td>2.7 (1.7)</td>
<td>321</td>
<td>2.8 (1.7)</td>
<td>81</td>
<td>2.8 (1.7)</td>
</tr>
<tr>
<td>SSB consumption &gt; once/week, n (%)</td>
<td>416 (24.4)</td>
<td>242</td>
<td>95 (21.6)</td>
<td>58</td>
<td>58 (19.9)</td>
</tr>
<tr>
<td>Never/rarely having breakfast, n (%)</td>
<td>223 (13.0)</td>
<td>237</td>
<td>60 (13.7)</td>
<td>58</td>
<td>35 (11.8)</td>
</tr>
</tbody>
</table>

Parental characteristics

| Tertiary education level, n (%) | 522 (32.2) | 324 | 148 (35.4) | 80 | 111 (38.7) |
| Migration background, n (%)    | 525 (31.9) | 298 | 156 (34.6) | 70 | 97 (32.7)  |
| Mother's BMI                   | 241 (4.5)  | 361 | 23.9 (4.5)  | 89 | 241 (4.8)  |
| Father's BMI                   | 28.5 (4.1) | 481 | 27.9 (4.0)  | 121 | 278 (4.0)  |

Note. *Cases with complete data on cognitive, anthropometric, sociodemographic, family, and lifestyle variables. MVPA = moderate to vigorous physical activity; SSB = sugar-sweetened beverages.

Table 2: Mean, standard deviation, and range for cognitive test scores.

<table>
<thead>
<tr>
<th>Inhibitory control</th>
<th>M</th>
<th>SD</th>
<th>Minimum</th>
<th>Maximum</th>
<th>n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total score</td>
<td>-0.01</td>
<td>1.68</td>
<td>-5.48</td>
<td>4.51</td>
<td>479</td>
</tr>
<tr>
<td>Number of errors</td>
<td>5.28</td>
<td>3.26</td>
<td>0</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>Reaction time (ms)</td>
<td>531.14</td>
<td>76.34</td>
<td>298.00</td>
<td>778.00</td>
<td></td>
</tr>
</tbody>
</table>

Cognitive flexibility

| Total score                | -0.60  | 9.56  | -30.40  | 22.62   | 445 |
| Number of errors           | 6.42   | 3.73  | 0       | 16      |     |
| Reaction time (ms)         | 1261.66| 305.14| 445.00  | 2290.00 |     |

Sustained attention

| Total score                | 82.74  | 8.86  | 60.60   | 100.00  | 466 |
| Number of errors           | 16.26  | 16.69 | 0       | 72      |     |
| Number of omissions        | 14.00  | 7.87  | 0       | 37      |     |

Note. ms = millisecond.

worse than their healthy weight counterparts. Verdejo-Garcia et al. [42] used a whole battery of executive functioning tests including response inhibition and flexibility. Similarly, the authors reported significant group differences in the flexibility task and a significant relationship between BMI and flexibility. These findings are supported by further studies focusing mainly on adolescents [43, 44], whereas Gunstad et al. [25, 45] demonstrated a link between cognitive flexibility (switching-of-attention task) and body weight only in adults but neither in children nor in adolescents. The results reported here conform to most of the existing research literatures even though these studies have been conducted
Appendix

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Table 3: Hierarchical multiple regression model predicting children's body weight from parental, behavioural, and cognitive variables.

<table>
<thead>
<tr>
<th>Predictors</th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parent education</td>
<td>-4.61*</td>
<td>-4.00*</td>
<td>-3.91*</td>
<td>-4.33*</td>
</tr>
<tr>
<td>Migration background</td>
<td>7.32***</td>
<td>6.68***</td>
<td>6.87***</td>
<td>6.61***</td>
</tr>
<tr>
<td>BMI of mother</td>
<td>1.22***</td>
<td>1.13***</td>
<td>1.18***</td>
<td>1.20***</td>
</tr>
<tr>
<td>BMI of father</td>
<td>1.15**</td>
<td>1.20**</td>
<td>1.13**</td>
<td>1.11**</td>
</tr>
<tr>
<td>TV consumption</td>
<td>-0.58*</td>
<td>-1.99*</td>
<td>-2.52*</td>
<td>-2.53*</td>
</tr>
<tr>
<td>Physical activity</td>
<td>1.4</td>
<td>1.18</td>
<td>0.99</td>
<td>0.94</td>
</tr>
<tr>
<td>SSB consumption</td>
<td>-2.31</td>
<td>-2.37</td>
<td>-2.39</td>
<td>-2.44</td>
</tr>
<tr>
<td>Breakfast habits</td>
<td>4.69</td>
<td>5.05</td>
<td>6.67</td>
<td>6.53</td>
</tr>
<tr>
<td>Inhibitory control</td>
<td>-1.98**</td>
<td>-1.94*</td>
<td>-1.94*</td>
<td>-1.94*</td>
</tr>
<tr>
<td>Cognitive flexibility</td>
<td>-0.46**</td>
<td>-0.50**</td>
<td>-0.50**</td>
<td>-0.79**</td>
</tr>
</tbody>
</table>

Sustained attention

<table>
<thead>
<tr>
<th>R²</th>
<th>0.14</th>
<th>0.16</th>
<th>0.19</th>
<th>0.19</th>
</tr>
</thead>
<tbody>
<tr>
<td>F</td>
<td>5.78***</td>
<td>5.77***</td>
<td>6.37***</td>
<td>5.86***</td>
</tr>
<tr>
<td>ΔR²</td>
<td>0.02</td>
<td>0.03</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>ΔF²</td>
<td>5.01*</td>
<td>10.05**</td>
<td>0.77</td>
<td>0.77</td>
</tr>
</tbody>
</table>

Note: N = 297. CI = confidence interval. SSB = sugar-sweetened beverages. *P < 0.05; **P < 0.01; ***P < 0.001.

mainly in older children. Thus, besides inhibitory control another executive functions domain seems to be associated to body weight and weight gain and, according to the present finding, this seems to be true in younger children, too.

On the other hand, the third cognitive domain, sustained attention, was not related to BMI percentiles in the current investigation. Previous findings concerning cognitive abilities other than executive functions are inconsistent. The literature review of Reinert et al. [18] reports six studies focusing on the association between obesity and general cognitive function with half of them demonstrating no relationship. Graziano et al. [22] considered sustained attention besides inhibitory control as part of cognitive self-regulation. Body weight of their preschool children, however, was only associated with the inhibitory performance but not with the attention performance. On the contrary, Cserjesi et al. [24] showed the same result as for flexibility in their adolescent sample: a significant correlation of performance in the D2 sustained attention test with BMI and a significant group difference to the disadvantage of the obese. The existing inconsistencies in research literature might be due to the different age groups and to the use of different concepts and methods of the studied cognitive abilities. Hence, standardisation concerning the understanding and measurement of certain cognitions should be targeted and changes in outcomes according to stages of development should be taken into account when addressing this issue.

Besides the cognitive variables, parental body weight, BMI of mothers as well as BMI of fathers, was significantly associated with children's body weight. This finding is not surprising as it is consistent with the literature [11, 12, 14] and may be explained by genetic mechanisms as well as the shared environment. Family characteristics such as knowledge of risk factors of overweight, eating habits, and food preferences but also physical activity patterns [46] may influence children's health behaviour and body weight. Migration background was revealed to be significantly associated with body weight as well. This finding is in line with previous national investigations [3, 11, 13]. The prevalence of overweight and obesity is found to be higher in children with migration background and the odds of overweight increased. Cultural attitudes and traditions concerning body weight and weight related behaviours (physical activity, TV consumption, and dietary habits), social integration (e.g., influencing recreational activities), and the knowledge of risk factors hampered by language barriers may explain this relationship.

Executive functions are seen to be crucial for self-regulatory behaviour [47]. They have already been related to health behaviour such as physical activity, snack food consumption, and fruit/vegetable intake in fourth graders [26]. Thus, the association with children's body weight may be mediated through more physical activity and healthy diet and less sedentary behaviour. As children just starting school are still more dependent on their parents and not completely autonomous in their planning and decision-making executive functions may, however, be crucial to appreciate and maintain new and healthy behaviour introduced by their caregivers, to control their thoughts, their behavioural impulses, and their feelings. Assuming this directionality, potential implications would be to integrate the promotion of executive functions in early obesity prevention efforts. Riggs et al. [48] suggested developing specific programme contents tailored to different obesity-risk profiles depending on
certain behaviour patterns, weight consciousness (especially as children get older), and deficits in executive functions. Beyond the overweight and obesity issue, it has been shown that executive functions play an important role for success and health throughout the whole life. They are crucial for the social and emotional development, school readiness, and further academic and job success, as well as wealth and mental and physical health even in the long term [20, 21, 49, 50]. Regulating emotions in social conflicts, staying in control of oneself, adapting to rules when necessary, adopting effective problem-solving, and learning strategies are just a few examples when executive control is required. On the contrary, deficits are linked to social and health problems such as attention deficit hyperactivity disorder, obsessive compulsive disorder, depression, early school leaving early pregnancy, addiction, and criminality [20, 21]. Hence, strategies focusing on the improvement of these abilities would probably lead to positive effects in more than one health and life domain and even on a more public level (e.g., public safety and economic costs). In return, learning to cope with the different challenges in life successfully and to reduce emotional and social stress means reducing psychological risk factors for excessive weight gain again and starting a virtuous circle. There have already been national and international efforts aiming at an early improvement of executive functions in general [20, 50, 51]. These include school-based programmes and the integration of the promotion of these abilities in the official curriculum of primary schools in Germany. Thus, cognitive training in general and the integration of cognitive improvement in obesity interventions may be helpful ways to improve future generation's health and overall quality of life.

4.1. Strengths and Limitations. Results, however, should be interpreted in light of study limitations. First, the cross-sectional study design precludes any causal interpretation of the findings. Therefore, directionality of the association between cognitive functions and body weight still remains unclear: on the one hand, cognitive functions such as inhibitory control or cognitive flexibility may influence health behaviour and consequently weight development. On the other hand, body weight and variations in food intake, physical activity, and sedentary activities, for example, may also affect cognitive performance and brain development or the relationship may be bidirectional as well. Further studies are needed to clarify causality and underlying mechanisms in order to derive any implications.

Secondly, there are some limitations concerning missing data and selection bias in the present study. Due to the subsample and the missing or invalid data in the cognitive subtests and the parent questionnaire the number of subjects decreased from 1944 (in the Baden-Württemberg Study sample) to 297 in the final regression analysis. Missing data may have led to a form of selection bias. The cognitive subsample included, for example, more children with migration background. However, more children with migration background and with lower parental education level dropped out in the further data processing maybe partly due to comprehension difficulties. Furthermore, more children with higher BMI percentiles, higher consumption of sugar-sweetened beverages, and higher father’s BMI were among those with missing data. Thus, children who entered the final analysis showed a more favourable profile in critical variables. Although migration background is still representative for school children in Germany, the final sample consisted of more children with higher parental education indicating a higher social status and lower body weight than usually found in the population (as reference, official statistics concerning German school children report 32.1% migration background, 23.9% tertiary parental education level, and 13.9% overweight or obesity [3, 52, 53]). On the contrary, the reduced sample size and statistical power may have led to an underestimation of significances. The inclusion of these missing cases could have potentially strengthened the final results. Furthermore, this may in part explain why no significant association between parental education and children’s body weight was found.

Finally, underreporting in terms of recall bias or social desirability regarding children’s lifestyle which was assessed via parental questionnaire should be taken into account and might explain the missing significant association of these variables with body weight. The objective standardised and direct measurements of cognitive and anthropometric data, on the other hand, as well as the large sample size constitute a strength of the study. Further, the focused age group is highly relevant as excessive weight gain is particularly pronounced at the age of school entry and important cognitive developments especially in executive functions relevant for a wide variety of behaviour and health outcomes take place.

5. Conclusions

In summary, cognitive abilities were significantly related to body weight of primary school children controlling for further weight influencing sociodemographic and lifestyle factors. This relationship concerns inhibitory control and cognitive flexibility, both processes considered as executive functions. As executive functions are crucial for self-regulation and disciplined behaviour including health behaviour, the finding indicates that promoting executive functions may assist in developing a healthy body weight and avoiding excessive weight gain in addition to already existing obesity prevention efforts. However, further research is necessary first, in particular longitudinal and intervention studies, to confirm the present findings, to determine the directionality of the association, and to investigate the impact of cognitive training on weight related outcomes.

Conflict of Interests

The authors declare that there is no conflict of interests.

Acknowledgments

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References


Is central obesity associated with poorer health and health-related quality of life in primary school children? Cross-sectional results from the Baden-Württemberg Study

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Abstract

Background: Childhood obesity and its consequences are a growing threat to national economies and health services. The aim of this study was to determine associations between waist-to-height ratio (WHtR) as a measure of central obesity, and health-related quality of life (HRQoL) and absenteeism of primary school children in the state of Baden-Württemberg, Germany.

Methods: Cross-sectional data from 1888 first and second grade children (7.1 ± 0.6 years) participating in the baseline measurements of the Baden-Württemberg Study were analyzed. Parents completed questionnaires including a rating of their children's HRQoL using KINDL® and EQ5D-Y VAS. Days of absence because of illness, and number of visits to a physician during the last year of school/kindergarten were asked, as well as the number of days parents took off work to care for their sick child. Anthropometric measurements were taken by trained staff. The Mann-Whitney-U test was used for statistical analysis of differences between WHtR groups. Logistic regression models were used to identify factors associated with sick days.

Results: A total of 156 (8.4%) children were centrally obese (WHtR ≥ 0.5). These children had significantly more sick days (9.05 vs. 6.84, p < 0.001) and visits to a physician (3.38 vs. 2.91, p < 0.05), but not days of parental absence than other children. According to regression analysis, sick days were also associated with age, migration status, physical activity pattern, maternal health awareness and family education level. Parent-rated HRQoL was significantly lower in centrally obese children for the EQ5D-Y VAS (88.1 vs. 91.6, p < 0.001), and the KINDL® subscales 'school' (79.9 vs. 82.5, p < 0.05) and 'friends' (75.4 vs. 78.3, p < 0.05), but not for the total score.

Conclusions: Cross-sectional results show higher rates of absence, more visits to a physician and lower HRQoL in children with central obesity. Each missed day at school implies a hazard to academic achievement and each additional visit to a physician is related to higher health care costs. Thus, the negative impact of central obesity is already measurable in primary school children, which emphasizes the urgent need for early delivery of health promotion and targeted prevention.
Background
Overweight and obesity and their associated health outcomes threaten economies and health-care systems all over the world [1-5]. As there is some evidence that the origin of overweight and obesity is often established in childhood [6], primary school children are increasingly the focus of research. Data from the German KIGGS study (German Health Interview and Examination Survey for Children and Adolescents) showed that for both boys and girls the proportion of overweight increased from 10% in 2–6-year-olds to over 15% in 7–10-year-olds up to 17% in 14–17-year-olds [7]. According to this, the greatest increase in the development of overweight takes place at an age between 7 and 10 years, when children in Germany are attending primary school.

Economic consequences of the childhood obesity epidemic, particularly medical costs, have been addressed by several authors [1-5]. The direct costs of childhood obesity, including annual drug prescription, emergency room, and outpatient costs, in the US amount to $14.1 billion annually [2], plus inpatient costs of $237.6 million (all quotations in 2005 dollars) [3]. These sums correlate with the findings of an Israeli work group, providing objective, clinical evidence that obesity in children is associated with increased health care use [4]. Results from other studies in Germany and the Netherlands confirm this association [8,9].

Only a few authors have addressed health-related absence from school in overweight and obese children, with heterogeneous conclusions. Wiiga et al. found obesity to be significantly associated with more school absenteeism [9], while Rappaport et al. only detected strong associations among extremely obese children [10]. Baxter et al. saw no significant relationship between children’s absenteeism and body mass index (BMI) [11], but Li et al. showed that increased body weight was independently associated with severe school absenteeism in children [12]. Data on parental work absenteeism because of illnesses in their overweight or obese children were only found in one study, dealing with another age group (9 to < 12 years) [13].

Sick days and illness have an impact on health-related quality of life (HRQoL). Obesity in adults is associated with impaired HRQoL [14]. There is also some evidence that HRQoL in overweight and obese children is lower than in their normal weight peers, but differences are not always significant and seem to depend on the method of rating HRQoL [15-17]. Parent-rated HRQoL is often poorer than self-rated HRQoL in overweight and obese children [17]. The KINDL® (Revidierte KINDer Lebensqualitätsfragebogen) questionnaire is currently the most broadly used HRQoL instrument for children and adolescents in Germany, and has been translated into many languages ([www.kindl.org] [18]. The KINDL® includes indicators for physical, psychological, family, social and school well-being, and self-esteem [18]. Arif et al. found that overweight children have lower proxy-rated HRQoL in KINDL® total score, and scores for subscales self-esteem and friends' [19]. In their review, Tostros et al. stated that increasing weight status had a negative impact on overall pediatric HRQoL, in which physical and social functioning appeared to be most affected [17]. Only a little information about HRQoL in children with central obesity is available, but like in obesity classified by BMI [15-17], HRQoL can be expected to be lower.

The aims of this cross-sectional study were to examine the basic measurements of the Baden-Württemberg Study carried out in fall 2010 with regard to visits to a physician, absenteeism, and HRQoL of centrally obese primary school children. The focus was on central obesity, not only because of some practical advantages of this measure [20], but mainly because waist-to-height ratio (WHtR) and waist circumference (WC), seem to be better predictors of weight-related health risks in children (5–16 years) than obesity as determined by BMI [21,22]. Furthermore, central body fat is associated with various cardiometabolic risk factors such as insulin resistance, higher blood pressure, unfavorable lipid levels, and elevated high-sensitivity C-reactive protein concentration even in childhood and adolescents [23-26]. Indeed there is some evidence that the epidemic of obesity defined by BMI is plateauing [27], but at the same time there is doubt the same applies to central obesity [28].

Methods
"Komm mit in das gesunde Boot - Grundschule" (Join the Healthy Boat - Primary School)
Based on the positive results of the URMEL-ICE study regarding a reduction in the increase in waist circumference and favorable cost-effectiveness [29,30], a health-promotion program for primary schools in the state of Baden-Württemberg (South-Western Germany) was developed at Ulm University and has been implemented from 2009. Primary school children in grades 1 to 4 are included. The program combines behavioral and environmental measures, with the aim of changing children’s behavior and focusing on the prevention of overweight and obesity among other health-related outcomes. The lecture material is integrated into the usual curriculum and does not require additional lessons. Three crucial risk factors for childhood overweight and obesity are targeted: physical activity, consumption of sweetened beverages, and use of screen media [31]. The intervention consists of 20 units of regular teaching time spread over 36 weeks in one school year including regular activity breaks, six family homework assignments to be completed by the children and their parents, and information material for
parents. Teachers are trained in three courses to familiarize themselves with the material and the implementation of the intervention. To assess the initial situation and to study the impact of the teacher-driven intervention, a randomized, controlled trial started in 2010. Only schools who had not yet participated in the program were included. The study protocol was approved by the ethics committee of Ulm University in June 2009 (Application No. 126/10). The Baden-Württemberg Study is registered at the German Clinical Trials Register (DRKS), Freiburg University, Germany, under the DRKS-ID: DRKS00000494. A detailed description of this study ("Baden-Württemberg Study") has already been published elsewhere [32].

Participants and data
Written informed consent was obtained from parents of 1968 pupils, representing about 62% of all eligible children. Baseline measurements of height, weight and WC were taken in 1947 children prior to the start of the intervention and the subsequent parental questionnaire was available from 1714 participants. All subsequent analyses are based on a sample size of 1888 participants providing data on sex, age, weight, height, and WC.

Demographics
The parental level of education was assessed and assigned to the respective level according to the CASMIN classification [32]. Family education level was determined as the highest level of two parents or the level of a single parent who cared for the child. Family education was dichotomized for analysis; elementary and intermediate education levels were clustered together in one group; tertiary level in another. The child’s migration background was defined as at least one parent being born abroad or at least one parent mainly having spoken a foreign language during the child’s first years of life.

Health behaviors
Parents gave information about maternal smoking during pregnancy, gestational diabetes, gestational age at delivery, birth weight and breastfeeding. They were asked to rate the sporting activity of their children, how much time a day they spent playing outside, on how many days a week they were physically active on a moderate to vigorous level for at least 60 minutes a day, the frequency of consumption of soft drinks at school and at home, and whether they had breakfast before school. Parents gave information about their own health behavior such as smoking, and were asked to rate their health awareness.

Anthropometric measurements
Anthropometric measurements of the children were taken by staff trained to ISAQ-standard [34] in a consistent manner [32]. The children’s BMI was calculated as weight divided by height squared (kg/m²), and percentiles were allocated according to German reference data with 90th and 97th age- and sex-specific percentiles used as cut-off points to define overweight and obesity, and the 10th percentile was used to define underweight [35]. WHR was calculated as the ratio of WC to height in centimeters; participants with WHR ≥ 0.5 were categorized as centrally obese [21].

Parental BMI was calculated from self-reported weight and height data in the questionnaires, and categorized as overweight (BMI > 25.0) and obese (BMI > 30.0), according to the international classification of the World Health Organization (WHO) [36]. Parental WHR was calculated as the ratio of self-reported WC to height.

Health and health-related quality of life
Parents were asked to recall the number of days their children were absent from school or kindergarten because of illness, and the number of visits to a physician during the past year. Working parents indicated the number of days they had to take off work to care for their sick child.

To assess the HRQoL of the children, parents were asked to complete the KINDL² proxy version [37] and a visual analogue scale (VAS) taken from the EQ5D-Y Proxy Version [38], both scales ranging from 0–100. The KINDL² questionnaire is a frequently used, validated instrument for the measurement of HRQoL in children [39]. The discriminative ability of the EQ5D-Y VAS in terms of obesity has already been successfully tested by Sach et al. [40].

Missing data
Common to observational studies is the problem of missing data. To examine baseline differences between records with and without missing outcome variables (WHR, absenteeism, visits to the physician, KINDL² total score, VAS) the Mann-Whitney-U test for continuous data or the Fisher exact test for categorical data were used. The same applied for differences between records with and without missing independent variables.

Statistical analysis
Baseline characteristics for anthropometric measurements were available from 1888 participants including information on WHR. Pregnancy and birth characteristics, parental characteristics, children’s lifestyle and health characteristics were available from 1714 parental questionnaires. Correlations between parental and children’s weight measurements were calculated using Pearson’s r-statistic. Sample size in the analyses varied because of incomplete data. All analyses were carried out using the statistical software packages IBM SPSS release 19.0.0.2
Appendix

for Windows (SPSS Inc, Chicago, IL, USA) and R release 2.13.0 for Windows (http://cran.r-project.org).

**Differences between WHtR groups**

Differences between the WHtR groups for all variables were tested (according to scale level and distribution of the data) using Fisher's exact test for categorical data and Mann-Whitney-U test for continuous data. The significance level was set at \( \alpha < 0.05 \) for two-sided tests.

**Analysis of differences in health-related quality of life**

Mean values of EQ5D-Y VAS and KINDL\(^2\) total score and subscale scores were compared between WHtR groups. Because of the marginal non-normality of the underlying distributions, the Mann-Whitney-U test was applied to determine differences.

**Analysis of absenteeism**

The number of children's sick days was dichotomized by the median value of 5 days into a group with a lower amount of sick days (\( \leq 5 \)) and a group with a higher amount of sick days (\( > 5 \)), because of the non-classifiable distribution of this variable. Stepwise backward elimination was used in the logistic regression to identify factors associated with sick days, and to compute adjusted odds ratios and 95% confidence intervals (95% CI).

**Results**

**Baseline characteristics**

The mean age of the included first and second grade children was 7.1 ± 0.6 years, ranging from 6.4–9.8 years, and 51.2% were boys. Table 1 presents the characteristics of the participants, including information about missing values. Significant differences between the WHtR groups were found for a number of variables. There were more children with a migration background in the group with high WHtR (\( p < 0.001 \)), BMI, BMI percentile and WC were higher in the high WHtR group (\( p < 0.001 \)), with no overweight and fewer normal weight but more overweight and obese children in the high WHtR group (\( p < 0.001 \)). More mothers had smoked during pregnancy (\( p < 0.01 \)) and children were less often breastfed in the high WHtR group (\( p < 0.05 \)). Children with a high WHtR more often had a single parent (\( p < 0.05 \)) and a lower family education level (\( p < 0.01 \)). Parental overweight and smoking were more often present in the high WHtR group (\( p < 0.001 \)). Maternal WHtR was higher (\( p < 0.001 \)) in the high WHtR group, as was paternal WHtR (\( p < 0.01 \)). Absenteeism from school (\( p < 0.001 \)) and the number of visits to a physician (\( p < 0.05 \)) were higher in the high WHtR group. Children in the high WHtR group were less often rated as sporting active (\( p < 0.05 \)), more often consumed soft drinks outside school (\( p < 0.01 \)) and more often had no breakfast before school (\( p < 0.001 \)). Figure 1 illustrates the differences in the distributions of absenteeism between the two WHtR groups using box and whisker plots. Maternal and paternal BMI correlated with children's BMI (\( r = 0.28 \) and 0.25, respectively), and maternal and paternal WHtR were associated with children's WHtR (\( r = 0.21 \) and 0.17, respectively, all \( p < 0.01 \)).

**Missing data**

Participants with missing data in the outcome variables were significantly more likely to have a migration background. Their working mothers stayed at home more often to care for their sick child, they were less often breastfed, had lower family education level, their mothers were more often overweight and smoked, they were less often categorized as sporting active, they consumed soft drinks more often at school and at home and had breakfast less often before school.

Participants with missing data in the independent variables differed significantly in the KINDL\(^2\) total score, had more days of absence from school, their working mothers stayed at home more often to care for their sick child, they had more visits to a physician, they more often had a migration background, and their mothers were more likely to have smoked during pregnancy, they were less likely to have been breastfed, they were more likely to have a single parent and a lower family education level, parents smoked more often, they were less often sporting active, and they consumed soft drinks at school more often.

For both groups, i.e., those with missing data in the outcome variables and those with missing data in the independent variables, there was a lower proportion of normal weight participants and higher proportion of overweight, obese and centrally obese participants.

**Health-related quality of life**

HRQoL measured by EQ5D-Y VAS was significantly lower in children with higher WHtR (\( p = 0.010 \)). These differences were also found in the KINDL\(^2\) subscales 'school' (\( p = 0.038 \)) and 'friends' (\( p = 0.029 \)). However, the KINDL\(^2\) total score did not show lower values in children with central obesity. Table 2 shows the mean values and standard deviations of the various measures. The differences in the underlying distributions of EQ5D-Y VAS ratings between the two WHtR groups are shown in the box and whisker plots of Figure 2.

**Odds ratios from stepwise logistic regression analysis of higher level of child absenteeism**

All variables included in Table 1, except HRQoL because of its mutual relationship with the outcome variable, were tested for significant association with child absenteeism in a logistic regression model using stepwise backward
<table>
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<tr>
<th></th>
<th>Missing values</th>
<th>WHr &lt; 0.5 n = 1730</th>
<th>WHr ≥ 0.5 n = 158</th>
</tr>
</thead>
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<tr>
<td>Boys, n (%)</td>
<td>0</td>
<td>894 (51.7)</td>
<td>73 (46.2)</td>
</tr>
<tr>
<td>Age, years [m (sd)]</td>
<td>0</td>
<td>7.07 (0.63)</td>
<td>7.16 (0.71)</td>
</tr>
<tr>
<td>Migration, %</td>
<td>293</td>
<td>30.4</td>
<td>48.3***</td>
</tr>
<tr>
<td><strong>Anthropometric measures</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BMI, kg/m² [m (sd)]</td>
<td>0</td>
<td>15.37 (1.42)</td>
<td>21.00 (2.76)***</td>
</tr>
<tr>
<td>BMI percentile [m (sd)]</td>
<td>0</td>
<td>44.85 (25.23)</td>
<td>94.23 (7.63)***</td>
</tr>
<tr>
<td>WC cm [m (sd)]</td>
<td>0</td>
<td>54.37 (3.83)</td>
<td>68.86 (7.74)***</td>
</tr>
<tr>
<td>Underweight, %</td>
<td>0</td>
<td>8.6</td>
<td>1.0***</td>
</tr>
<tr>
<td>Normalweight, %</td>
<td>0</td>
<td>88.0</td>
<td>17.1***</td>
</tr>
<tr>
<td>Overweight, %</td>
<td>0</td>
<td>3.2</td>
<td>32.0***</td>
</tr>
<tr>
<td>Obesity, %</td>
<td>0</td>
<td>0.2</td>
<td>50.3***</td>
</tr>
<tr>
<td><strong>Pregnancy and birth characteristics</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Week of gestation, [m (sd)]</td>
<td>291</td>
<td>39.12 (2.94)</td>
<td>38.99 (2.23)</td>
</tr>
<tr>
<td>Gestational diabetes, %</td>
<td>247</td>
<td>3.8</td>
<td>7.3</td>
</tr>
<tr>
<td>Birth weight, gr [m (sd)]</td>
<td>226</td>
<td>3328.0 (561.7)</td>
<td>3309.4 (538.3)</td>
</tr>
<tr>
<td>Smoking during pregnancy, %</td>
<td>238</td>
<td>9.5</td>
<td>19.0**</td>
</tr>
<tr>
<td>Breastfeeding, %</td>
<td>236</td>
<td>94.7</td>
<td>76.4*</td>
</tr>
<tr>
<td><strong>Parental characteristics</strong></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Single parent, %</td>
<td>262</td>
<td>10.0</td>
<td>13.8</td>
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<tr>
<td>Tertiary family education level, %</td>
<td>365</td>
<td>33.4</td>
<td>163.8**</td>
</tr>
<tr>
<td>Maternal overweight/obesity, %</td>
<td>357</td>
<td>29.1</td>
<td>53.3**</td>
</tr>
<tr>
<td>Paternal overweight/obesity, %</td>
<td>457</td>
<td>59.3</td>
<td>78.1***</td>
</tr>
<tr>
<td>Maternal WHr, [m (sd)]</td>
<td>793</td>
<td>0.50 (0.01)</td>
<td>0.50 (0.01)</td>
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<tr>
<td>Paternal WHr, [m (sd)]</td>
<td>876</td>
<td>0.54 (0.01)</td>
<td>0.57 (0.01)*</td>
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<tr>
<td>Smoking (mother), %</td>
<td>281</td>
<td>19.4</td>
<td>37.5***</td>
</tr>
<tr>
<td>Smoking (father), %</td>
<td>349</td>
<td>28.2</td>
<td>51.8***</td>
</tr>
<tr>
<td>Maternal health awareness, %</td>
<td>282</td>
<td>58.9</td>
<td>55.9</td>
</tr>
<tr>
<td>Paternal health awareness, %</td>
<td>388</td>
<td>44.8</td>
<td>45.4</td>
</tr>
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<td><strong>Lifestyle and health characteristics</strong></td>
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<td></td>
</tr>
<tr>
<td>Absenteeism at kindergarten/school</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>because of illness last year, [m (sd)]</td>
<td>335</td>
<td>6.94 (6.70)</td>
<td>9.05 (6.70)***</td>
</tr>
<tr>
<td>Mothers absenteeism at work because of child’s illness last year, [m (sd)]</td>
<td>823</td>
<td>2.53 (4.07)</td>
<td>3.16 (6.01)</td>
</tr>
<tr>
<td>Fathers absenteeism at work because of child’s illness last year, [m (sd)]</td>
<td>1053</td>
<td>0.56 (3.72)</td>
<td>0.92 (2.23)</td>
</tr>
<tr>
<td>Number of visits to a physician last year, [m (sd)]</td>
<td>348</td>
<td>2.91 (2.88)</td>
<td>3.58 (3.83)*</td>
</tr>
<tr>
<td>Sporting activity, %</td>
<td>289</td>
<td>88.4</td>
<td>81.1*</td>
</tr>
<tr>
<td>Playing outside ≥ 60 min/day, %</td>
<td>293</td>
<td>69.1</td>
<td>63.9</td>
</tr>
<tr>
<td>≥ 4 times a week active for ≥ 60 min/day, %</td>
<td>316</td>
<td>27.1</td>
<td>27.8</td>
</tr>
</tbody>
</table>
elimination. The final model consisted of age (years), WHIR (≥ 0.5), physical activity (≥ 60 for at least 4 days a week), migration background, tertiary family education level and high level of maternal health awareness. Parental weight status and WHIR were excluded to avoid collinearity with children's weight status and WHIR, and allow use of parental health awareness as a more direct measure of parental health behavior. Unadjusted and adjusted odds ratios and confidence intervals are reported in Table 3. Age (p = 0.001), physical activity (p = 0.001), tertiary family education level (p = 0.001), and high level of maternal health awareness (p = 0.049) were associated with a lower level of child absenteeism. In addition, WHIR (p = 0.010), and migration background (p = 0.001) were associated with a higher level of child absenteeism.

Discussion

Critical interpretation and meaning

Children with central obesity in this cross-sectional study showed higher rates of school absenteeism, more visits to a physician, and lower HRQoL. Central obesity and migration status increased the odds of children having more than 5 days of sickness absence to 182%, and 155%, respectively. On the other hand, regular physical activity (≥ 60 min/day for at least 4 days a week) reduced the odds of a higher level of absence by 52%. Further factors reducing the odds of a high level of sickness absence were age (92% lower odds per year), maternal health awareness (25% lower odds) and family education level (47% lower odds). Regarding a higher level of sick days, parents of centrally obese children recalled significantly more visits to a physician than parents of children without central obesity. In addition, children with central obesity showed significantly lower scores for HRQoL, EQ5D-Y VAS as well as KINDL subscales friends' and school.

With regard to WHIR, no German reference data were available for the age group presented here. However, the overweight and obesity rates found in this study (5.7% and 4.4%, respectively) for children in Baden-Württemberg entering elementary school differed only marginally from the data of the reference groups collected from 1985 to 1999 [35]. Nonetheless, it is to be feared that the increase in BMI and WHIR in first and second graders has just started, as the data of the KiGGS study implied [7]. Because of the close relationship between WHIR and health risks, mainly cardiometabolic risks [22], this trend needs to be stopped. According to data published by the WHO, cardiovascular diseases are the leading cause of death in the world and diabetes mellitus is among the top ten causes in middle and high income countries [41]. In the present study, signs of morbidity, such as higher rates of absenteeism, more visits to a physician, and lower HRQoL could already be measured in primary school children.

More frequent visits to a physician imply higher health care expenses for centrally obese children. This is consistent with findings from Germany and the Netherlands, which found that obese children had significantly higher physician costs and a higher probability of being high utilizers of health care services [8]. Furthermore, Wuja et al. reported that childhood obesity was significantly associated with more visits to the general practitioner [9].

The present results indicated that parent-rated child HRQoL in the EQ5D-Y VAS was at a high level for both, centrally obese children and non-obese children. The rating for the KINDL total score, however, tended to be slightly higher than in the age-related reference group in
Table 2 Children's health-related quality of life by WHR

<table>
<thead>
<tr>
<th></th>
<th>Missing values</th>
<th>WHR &lt; 0.5</th>
<th>WHR &gt; 0.5</th>
</tr>
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<tbody>
<tr>
<td>EQSD-Y VAS</td>
<td>261</td>
<td>91.63 (9.71)</td>
<td>88.12 (13.24)***</td>
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<tr>
<td>KINDL® physical well-being</td>
<td>276</td>
<td>83.72 (13.43)</td>
<td>81.49 (14.10)</td>
</tr>
<tr>
<td>KINDL® psychological well-being</td>
<td>265</td>
<td>84.88 (11.10)</td>
<td>82.71 (13.16)</td>
</tr>
<tr>
<td>KINDL® self-esteem</td>
<td>226</td>
<td>74.01 (13.23)</td>
<td>74.69 (13.27)</td>
</tr>
<tr>
<td>KINDL® family</td>
<td>2/2</td>
<td>80.33 (12.27)</td>
<td>79.06 (15.64)</td>
</tr>
<tr>
<td>KINDL® friends</td>
<td>264</td>
<td>78.79 (12.05)</td>
<td>75.38 (13.44)**</td>
</tr>
<tr>
<td>KINDL® school</td>
<td>223</td>
<td>82.47 (14.35)</td>
<td>79.93 (14.12)**</td>
</tr>
<tr>
<td>KINDL® total score</td>
<td>331</td>
<td>80.72 (8.65)</td>
<td>79.47 (9.04)</td>
</tr>
</tbody>
</table>

m (sd): mean value (standard deviation).

*** p < 0.001, ** p < 0.01, * p < 0.05.

the above-mentioned KiGGS study (80.6 vs. 79.0) [42]. Lower HRQoL found in the subscales ‘school’ and ‘friends’ may be related to more visible signs of central obesity such as a large belly, and children can be very cruel in pointing out what makes other children different from themselves [43]. Lower values in the KINDL® subscale ‘friends’ for overweight children have already been found in a previous study [19]. Another reason for lower values in the subscales ‘school’ and ‘friends’ may be the stigmatization of overweight and obese children, with negative social and emotional consequences [44]. Additionally, central obesity may slow down children or discourage them from taking part in active play during break time and physical education lessons [45].

The strongest factor associated with a higher level of sickness absence besides age was central obesity, according to WHR beyond the cut-off point. Children's physical activity level was another modifiable factor identified in this study. According to Kim and Lee, leisure time physical activity is associated with abdominal obesity in youth [46], so it is understandable that both variables were significantly associated with higher levels of sickness absence. Furthermore, many authors have already addressed physical activity as an important determinant of physical and psychological health, suggesting a dose-response relationship in observational studies with more physical activity resulting in greater health benefits [47,48]. Maternal health awareness, a further modifiable factor identified in the present research, may directly influence a child’s health, as the mother usually is the most important caregiver in maintaining the well-being of the child for whom she cares. Migration status and family education level are unchangeable components, and both are also known risk factors for childhood overweight and obesity [49]. Migration and lower levels of education may lead to less concern about health behaviors, resulting in a greater chance of more sick days. Age is constantly increasing and as children grow older, their immune system is believed to grow stronger so that their parents may have fewer concerns about their health.

BMI and age- and sex-adjusted BMI percentiles, in contrast to WHR, showed no significant relationship with a higher level of sickness absence. This finding correlates with a study of more than 20,000 workers in Belgium where central abdominal fatness, but not BMI, was found to be an independent predictor of sick leave [50]. Rappaport et al. found that race and poverty appeared to affect sickness absence to a greater extent than overweight and obesity as classified by BMI in Philadelphia.
school children, grades 1–12 [10]. Baxter et al. did not find significant relationships between absenteeism and age- and sex-specific BMI percentiles, and socio-economic status, but found a significant inverse relationship between absenteeism and academic achievement in fourth grade children [11]. Obesity was significantly associated with a lower general health score, more visits to a physician, more school absenteeism and more health-related limitations in a Dutch study with 8-year old children [9]. These heterogeneous findings underscore the need for further investigation of the relationship between anthropometric measures and absenteeism.

Central obesity seems to encapsulate the health risks of obesity [51], otherwise one would not expect to find the reported associations at an early stage in such a young population. Children starting school are subjected to a change of lifestyle with increasing sedentary behavior and decreasing physical activity levels [52], because of the essential demands of the current character of schooling. Higher levels of sickness absence are substantially consistent with lower levels of HRQoL, and do not need to be explained any further. Thus, by promoting physical activity in school and reducing time spent sedentary, central obesity may be reduced as well as sick days, and consequently HRQoL may be increased.

Strengths and limitations
One strength of the study presented in this article is the inclusion of a complete federal state of Germany. Spread over the entire territory of the state of Baden-Württemberg, a school-based health-promotion program, developed and disseminated by Ulm University Medical Center, was evaluated in fall 2010 and 2011. Teachers of 157 classes with 1968 pupils at 84 schools decided to take part in this study. Data from all parts of the state could be collected to provide a descriptive picture of the situation of primary school children today. Another strength is the quality of the target group’s anthropometric measurements according to ISAQ-standards. A further strength is the high return rate of parental questionnaires (87%). In addition, the application of two independent instruments for the assessment of children's HRQoL enabled differentiated valuation. The EQSD-Y VAS offers an overall measure of global health whereas the KINDL® results in a profile of HRQoL, allowing the examination of aspects such as physical and emotional well-being, self-esteem, family, friends and school.

There are restrictions in an observational study compared with a clinical study, and the present research shows some limitations concerning missing data and selection bias. Missing data in various variables diminished the number of subjects in the logistic regression from 1888 to 1331 (70.9%). Missing data may have led to a form of selection bias but, in the best case, would only lessen the precision of the study [53], and according to the differences observed in the analyses of missing data in this study, would have underestimated the scale and significance of the results. As the analysis of missing data implied, participants with missing data predominantly showed an unfavorable profile in the critical variables, higher proportion of migrants, lower family education level, more absence of working mothers, children less often sporadically active and a higher proportion of mothers who smoked. If those participants could have been included in the analysis, this probably would have meant stronger evidence for the present results.

Another limitation concerns the quality of the parent-reported data. Parents may retrospectively have forgotten the actual number of days their child could not go to school or kindergarten during the past year because of illness, and the correct number of visits to a physician, especially if they had more than one child. Parents self-reported weight, height and WC may also have been less exact than the according-to-protocol anthropometric measurements of their children. Physical activity patterns of the children asked in the parental questionnaire were only vague approximations of real activity levels measured by accelerometers as the objective method of choice. Furthermore, pediatric HRQoL based on a proxy perspective is controversial, but analysis of the KINDL® revealed an acceptable accordance between parental and child reports [37]. Whenever possible, both sources of information should be used. Since more than half of the children in this study were aged 7 years and younger, and had just started school, the researchers abstained data from self-reported HRQoL in the baseline measurements in 2010. All teachers opted in voluntarily and were likely to be engaged in health-promotion from the outset, thus it can be assumed that the study population differed from the basic population. The teachers would particularly influence longitudinal data and effects, but were likely to have less influence on this cross-sectional baseline analysis.

Conclusions
Considering all the consequences of the overweight and obesity epidemic, and the fact that the development of overweight starts in childhood, the early introduction of preventive measures for all subjects at risk, which means all children exposed to a modern lifestyle, is called for. The impact of central obesity on health and HRQoL can already be seen in first and second grade school children before or at the very start of the upward trend in weight gain [7]. Also higher rates of school absenteeism, like those found in the present study, are associated with lower academic achievement [11]. Moreover, childhood obesity is generally associated with lower parental education level and socio-economic status [6–8], thus without early
school-based measures may become a vicious cycle of obesity and low education attainment [54]. Primary school children, especially prepubertal children, may still be in a more impressionable phase with a good chance of establishing a healthy lifestyle, for example because parents have a greater amount of control regarding food choices inside and outside the home [55]. Because it would involve much effort and cost for governmental authorities or health authorities to directly provide health information for each family, a cost-effective solution to teach children sustainable healthy living is to include health education into the regular curriculum in schools, especially in primary schools and to address parents as well. Teachers are key players and need to receive a science-based education emphasizing health promotion and health awareness at university to enable them to embed health education in the everyday routine of any type of school, thus implementing the request of the EU for “health in all policies” [56]. More research, preferably from representative unbiased samples, is needed to examine the association between school absenteeism, HRQoL and central obesity.

Competing Interests
The authors declare that they have no competing interests.

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Appendix

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For data protection reasons the curriculum vitae has been removed.