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Estimated and measured BMI and self perceived body image of adolescents in Germany:

Part 1: General implications for correcting prevalence estimations of overweight and obesity

Short title: **How to correct prevalence estimations of obesity**

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Summary

Objective: This study examines the degree of divergence between body mass index (BMI) calculated from subjective assessments and BMI calculated from measured height and weight as a function of gender and body image. **Methods**: In the German National Health Interview and Examination Survey for Children and Adolescents (KiGGS) the height and weight of 17,641 children and adolescents aged 0 to 18 years were measured. Participants were also questioned about their subjective body image (whether they considered themselves much too thin, a bit too thin, exactly the right weight, too fat, or much too fat). A representative subsample of adolescents between 11 and 17 years old (N= 3,436: 1,663 boys and 1,773 girls) was asked additionally to self-report their body weight and height before being measured. **Results**: The bias in the self-reported BMI yielded an underestimation of overweight and obesity prevalence. Girls who considered themselves much too fat or too fat and boys who considered themselves as much too fat underestimated their BMI. This was taken into account using a correction procedure for prevalence estimates of overweight and obesity based on the concept of conditional probabilities. **Conclusion**: The proposed correction formula using data from the KiGGS study can be applied to other German studies of adolescents in which weight, height and body image are only determined by self-report. Furthermore the correction procedure in principle can be transferred to other studies in other countries as long as a parallel validation study has been conducted to assess both subjective and objective BMI and body image.

Introduction

There is considerable evidence in specialist literature that subjectively determined body mass index (BMI) data shows distortions compared to objectively ascertained BMI data, particularly among adults. All publications on this topic have observed that subjective BMI tends to underestimate objective BMI and that estimates of the prevalence of overweight and obesity consequently tend to be too low. The conclusions drawn from these observations range from a general rejection of determining height and weight by self-report [1], [2] to suggesting corrective procedures for subjective BMI [3], [4] to recommending the use of subjective data only from certain age and population groups where distortions are lower [5], [6], [7]. Furthermore, a European study comparing the correlations between subjective and objective BMI in different European countries concluded that the level of correspondence between the subjective and objective BMI varies from country to country, and that no comparable estimates of the prevalence of overweight and obesity can therefore be made on the basis of subjectively collected BMI data [8]. The reasons for these variations may be different cultural backgrounds or perhaps different "ideals of beauty". Whichever is the case, national validation studies are necessary.

Results among children and adolescents are analogous to those from adults, although the number of published studies is smaller [9]. The degree of divergence between subjective and objective BMI as a function of age and gender has been described in different countries. In NHANES III (USA), subjective data on the height and weight of 1,657 adolescents aged between 12 and 16 years were compared with measured data. The degree of BMI underestimation tended to be highest among obese adolescents. Furthermore, girls showed a larger bias than boys [10].

In the "National Longitudinal Study of Adolescents' Health" (USA) the subjective height and weight assessments made by 15,483 adolescents aged between 13 and 17 years were compared with objective measurements. There was a high correlation between subjective and objective BMI, although the subjective BMI underestimated the objective BMI [11]. A correction of the subjective BMI was recommended in [12]. The proposed correction procedure was developed using the subjectively and objectively assessed BMIs of only 143 pupils in Sienna and does not seem to be generally applicable.

Some studies have shown that boys and girls who felt 'too fat' or wished to be leaner under-reported their weight to a greater extent than those who were satisfied with their body size [13], [14]. The Cross National Student Health Survey (CNSHS) consisting of

5,900 records of university students from Bulgaria, Germany, Lithuania, Poland, Spain and Turkey came to the same conclusion [15].

In the German Health Survey for Children and Adolescents (KiGGS), a random subsample of adolescents between the ages of 11 and 17 years (N=3,473: 1,678 boys, 1,795 girls) were asked to report their body weight and height before being measured and weighed at the study centre. Comparing self-reports with the subsequent measurements makes it possible to examine the degree of divergence between the two assessment methods. The participants were also questioned about their subjective body image (whether they considered themselves to be much too thin, a bit too thin, exactly the right weight, too fat or much too fat). The aim of this paper is to identify a correction procedure using this additional information.

Methods

Study Design and Sample

The aim of the KiGGS study was to collect comprehensive nationwide representative information on the health of children and adolescents aged between 0 and 17 years living in Germany. Participants were enrolled in two steps: First, 167 study locations (sample points) were chosen. Second, subjects were randomly selected from the official registers of local residents. A total of 17,641 children and adolescents were surveyed (8,965 boys and 8,656 girls). Survey participants were given a medical and physical examination, and those over the age of 11 also completed a written questionnaire. In addition, the parents of all participating children and adolescents filled in a questionnaire and took part in a standardized, computer-assisted medical interview. Comprehensive laboratory diagnoses were carried out on the blood and urine samples obtained. The study was approved by the Charité/Universitätsmedizin Berlin ethics committee and the Federal Office for the Protection of Data. Each subject´s informed consent was a precondition for all investigations. Details have been published on the study design, including the sampling procedure, the execution and procedure of the study, data management, quality assurance and the inclusion of migrants [16].

Anthropometric Measures

Standard methods were used at each study location to determine height and weight. Each subject's height was measured, while standing, to an accuracy of 0.1 cm using a calibrated stadiometer. Weight (in underwear) was determined on calibrated scales to the nearest 0.1 kg.

Objective BMI

BMI was calculated by dividing the measured body weight in kg by the square of the measured height in metres.

BMI = weight/ height²

BMI is used internationally to assess population-specific prevalence of overweight and obesity.

Kromeyer-Hauschild's BMI reference values [17] are currently used to define overweight and obesity in children and adolescents in Germany in line with the recommendations of the Study Group on Obesity in Childhood and Adolescence (AGA) (see www.a-g-a.de). The latest evidence from the KiGGS study on the prevalence of overweight and obesity in children and adolescents was determined on the basis of these reference values (see [18]). According to this, children are considered overweight if they have a BMI above the 90th age- and gender-specific percentile of the reference system of Kromeyer-Hauschild. They are deemed obese if their BMI is above the 97th percentile. Children or adolescents with a BMI below the age- and gender-specific 10th percentile are defined as underweight; those below the third percentile are considered extremely underweight.

Perceived Obesity / Body Image

In the KiGGS questionnaire, all 11- to 17-year-olds (N=6,697: 3,426 boys and 3,271 girls) were asked to report their body image on a 5-point Likert-type scale: "Do you think you are

- ➜ much too thin
- ➜ a bit too thin
- ➜ exactly the right weight
- ➜ a bit too fat
- ➜ much too fat?"

This instrument was implemented in the international HBSC-Study (Health behaviour in school-aged children) conducted by the WHO [19]. For the KiGGS study, the official German translation was used [20].

Subjective BMI

When they arrived at the study centre, a random selection of boys and girls aged between 11 and 17 years (N= 3,473: 1,678 boys and 1,795 girls, average age 14,7 years) were asked to self-report their height and weight before being measured and weighed.

With the help of these subjective statements on height (height$_{sub}$) and weight (weight$_{sub}$), a "subjective" BMI was determined for the subsample.

$$BMI_{sub} = weight_{sub}/ height_{sub}^2 \qquad (1)$$

Data Analysis

In the subsequent analyses, to characterize deviations between the subjective statements and the objective measurements, the respective differences were defined as follows:

$$Diff\ (weight)\ = weight_{sub} - weight$$
$$Diff\ (height)\ = height_{sub} - height$$
$$Diff\ (BMI)\ \quad = BMI_{sub} - BMI \qquad (2)$$

A negative value of these differences indicates a subjective underestimation and a positive value an overestimation of the respective measurement. For these differences descriptive statistics are shown as means and 95% confidence intervals (95%-CI). If the 95%-CI did not include 0 the difference was regarded as significant. To determine significant deviations between boys and girls, Student's t-test was performed. The level of significance was set at $p < 0.05$ (two-sided). In linear regression models adjusted for age (as a categorical variable), the effect of measured BMI-categories and Body Image-categories on the difference between self-reported and measured height, weight and BMI was examined, separately for boys and girls.

Participants were classified as underweight, overweight, or normal weight on the basis of both the objectively measured BMI and the subjective BMI.

All analyses of KiGGS data were carried out with a weighting factor to correct for population structure deviations between the study sample and the German population (as of 31 December 2004) with regard to age (in years), gender, region (East/West) and German/non-German nationality. To allow for the correlation of test persons

sampled from the same municipality, the confidence intervals (at the 95% level) were determined using the SPSS-14 procedure for complex samples.

Probabilities and Conditional Probabilities

The following terms are used:

Let $P(BMI \in I)$ be the probability that the true BMI of a person belonging to an age- and gender-specific population subgroup of children and adolescents falls within a certain interval I. Then

$$P_i = P(BMI \in I_i), (i=1...5) \quad \text{where} \tag{3}$$

- $I_1 = (-\infty, Pz_3)$
- $I_2 = [Pz_3, Pz_{10})$
- $I_3 = [Pz_{10}, Pz_{90})$
- $I_4 = [Pz_{90}, Pz_{97})$
- $I_5 = [Pz_{97}, \infty)$,

(Pz_x: x^{th} percentile of the BMI reference data according to Kromeyer-Hausschild [17])

This means, for example, that a child whose BMI falls within the category I_4 is overweight but not obese. Therefore, P_4 is the prevalence of overweight without obesity.

By analogy, the probability that the subjective BMI reported by a person belonging to an age- and gender-specific population subgroup falls within an interval I is

$$Q_i = P(BMI_{sub} \in I_i), (i=1...5). \tag{4}$$

Then by definition of conditional probabilities [21]:

$$P_i = \sum_{j=1}^{5} a_{ij} Q_j \qquad (i=1...5). \tag{5}$$

with

$$a_{ij} = P\left(\left.BMI \in I_i \middle/ BMI_{sub} \in I_j\right.\right) \tag{6}$$

The correlations between P_i and Q_i are examined as a function of age, gender and the adolescents' body image.

The variable BI (Body Image) assumes values from 1 to 5. In this context,

- BI=1: test person considers him/herself to be much too thin
- BI=2: test person considers him/herself to be a bit too thin
- BI=3: test person considers him/herself to be exactly the right weight
- BI=4: test person considers him/herself to be too fat
- BI=5: test person considers him/herself to be much too fat

By analogy to (3) and (4), R_i is defined by

$$R_i = P(BI=i), \text{ (i=1...5).} \tag{7}$$

And by analogy to (5)

$$P_i = \sum_{k=1}^{5} p_{ik} R_k \qquad \text{(i=1...5),} \tag{8}$$

Where $p_{ik} = P\left(\left.BMI \in I_i \middle/ BI = k\right.\right) \tag{9}$

Furthermore, Q_{jk} is defined as the probability of the subjective BMI categories j in the group of people with Body Image BI=k,

$$Q_{jk} = P\left(\left.BMI_{sub} \in I_j \middle/ BI = k\right.\right), \tag{10}.$$

Then we can define a_{ijk} as the conditional probability that the measured BMI of a person falls within the interval I_i under the condition that the subjectively assessed BMI falls within the interval I_j and the body image has value k:

If $a_{ijk} = P\left(BMI \in I_i \middle/ BMI_{sub} \in I_j, BI = k\right)$ (11)

From definition (9) follows

$$p_{ik} = \sum_{j=1}^{5} a_{ijk} Q_{jk},$$ (12)

and consequently $P_i = \sum_{k=1}^{5}\left[\sum_{j=1}^{5} \alpha_{ijk} Q_{jk}\right] R_k.$ (13)

Results

Comparison of self-reported and measured BMI

In the subsample of 1,663 girls and 1,773 boys it was possible to compare the measured data with the subjective statements on height and weight (see Table 1).

Normal-weight girls and overweight and obese girls and boys underestimated their BMI significantly, whereas underweight boys significantly overestimated their BMI. The tendency to underestimate BMI evident among overweight and obese adolescents increased with "true" BMI. This underestimation was mostly due to an underestimation of weight: for example, 11- to 17-year-old obese boys underestimated their weight by an average of 3.4 kg, girls by 2.9 kg, whereas height was overestimated by only 1.1 and 1.6 cm, respectively (Table 1).

Body Image and Bias of the Subjective BMI

Adolescents' body image (BI) had an impact on the incorrect estimation of their height and weight and therefore their subjective BMI. Girls who considered themselves "much too fat" or "too fat" underestimated their BMI; among boys underestimation was only significant for those who considered themselves "too fat". Both boys and girls who regarded themselves as much too thin overestimated their BMI (Table 2), but this was not significant.

These deviations resulted in different prevalence estimates for the five weight categories, as shown in Table 3.

Misclassification

The deviations between subjective and objective BMI led to misclassifications within the five weight categories as described in Table 4. The table indicates whether objective BMI classification can be made on the basis of the subjective BMI classification. For each of the five categories of subjective BMI, there are underlying categories of the measured BMI. The coefficients a_{ij} from Table 4 are the (conditional) probabilities that a survey participant should be in the objective BMI class i, given that their subjective statements led to classification in category j (see definition (6)).

The overall prevalence P_i of an objective BMI class I is thus made up of the shares that are "hidden" respectively in the five subjective BMI categories. Using formula (5) we give for illustration two examples derived from table 4:

EXAMPLE 1:

The prevalence of overweight-but-not-obese people and of obese people is calculated as follows (the a_{ij} can be taken from Table 4, the Q_i from Table 3):

P_4 = **9.6** = *0.015 * ***3.5*** + 0* ***6.3*** + 0.051 * ***75.2*** + 0.575 * ***8.8*** + 0.101 * ***6.2***

P_5 = **7.7** = *0 * ***3.5*** + 0* ***6.3*** + 0.004 * ***75.2*** + 0.264 * ***8.8*** + 0.824 * ***6.2***

EXAMPLE 2:

If, additionally, the calculations are stratified by gender, this leads to slightly different probabilities for boys and girls as again can be concluded from the information in tables 3 and 4.

P_4^m = **9.7** = *0.023 * ***4.4*** + 0 * ***6.0*** + 0.049 * ***73.4*** + 0.533 * ***9.6*** + 0.134* ***6.6***

the prevalence of overweight, but not obese male adolescents,

P_4^f = **9.4** = *0 * ***2.5*** + 0 * ***6.7*** + 0.052 * ***77.1*** + 0.629 * ***8.0*** + 0.062 * ***5.7***

the prevalence of overweight, but not obese female adolescents,

P_5^m = **7.8** = *0 * ***4.4*** + 0 * ***6.0*** + 0.002 * ***73.4*** + 0.265 * ***9.6*** + 0.768 * ***6.6***

the prevalence of obese male adolescents,

P_5^f = **7.7** = *0 * ***2.5*** + 0 * ***6.7*** + 0.007 * ***77.1*** + 0.263 * ***8.0*** + 0.891 * ***5.7***

the prevalence of obese male adolescents.

Correction procedure I

If the conditional probabilities a_{ij} between subjective and objective weight classifications found on the basis of a representative survey can be generalized, this would allow – for studies S based only on subjective statements – an estimation of the (unknown) prevalence of overweight, normal weight and underweight, that corrects (in a gender- and age-specific manner) the bias introduced by self-reporting BMI.

Replacing in formula (5) the Qj of the validation study (here the KiGGS study) by the subjective BMI categories Q_j^S of a second study S we obtain

$$\hat{P}_j^S = \sum_{j=1}^{5} a_{ij}\, Q_j^S \qquad \text{(i=1...5)} \qquad (14)$$

This estimation can be applied to every study S where the conditional probabilities $a_{ij}{}^V$ are known from a parallel representative validation study V.

Misclassification, modified by Body Image

As the data from the KiGGS study show, the relationships between subjective and objective BMI classifications again differ by self-assessed body image group.

Table 5 shows the conditional probabilities of BMI classification as a function of BMI_{sub}, subjective body image, and gender. Because of the sample size, here only three categories of body image were used. We combined BI category 1 with 2 and category 4 with 5 such that

$\overline{BI} = 1$ if BI = 1 or BI = 2

$\overline{BI} = 2$ if BI = 3

$\overline{BI} = 3$ if BI = 4 or BI = 5.

Then

$r_1 = P\,(\overline{BI} = 1) = R_1 + R_2 = 0.148$

$r_2 = P\,(\overline{BI} = 2) = R_3 = 0.399$

$r_3 = P\,(\overline{BI} = 3) = R_4 + R_5 = 0.453$ (see definition (7) and Table 3). $\qquad (15)$

According to this, the accuracy of the subjective BMI classification depends on the test person's body image. This makes it possible to determine the objective BMI class more exactly by incorporating information on body image with the subjective BMI category (formula 13).

EXAMPLE 3*:*

The following examples illustrate the use of coefficients a_{ijk} and Q_{jk} from Table 5 in formula (13) to calculate the prevalence of overweight and obesity.

$$P_4 = \mathbf{9.6} = \mathbf{0.148}^*(0^*\mathbf{14.4}+0^*\mathbf{18.7}+0^*\mathbf{65.3}+0.269^*\mathbf{1.1}+0^*\mathbf{0.5})$$
$$+ \mathbf{0.399}^*(0^*\mathbf{3.0}+0^*\mathbf{7.6}+0.015^*\mathbf{85.9}+0.416^*\mathbf{2.8}+0.186^*\mathbf{0.7})$$
$$+ \mathbf{0.453}^*(0.38^*\mathbf{0.3}+0^*\mathbf{1.2}+0.105^*\mathbf{69.0}+0.605^*\mathbf{16.6}+0.098^*\mathbf{12.8})$$

the prevalence of overweight but not obese subjects,

$$P_5 = \mathbf{7.7} = \mathbf{0.148}^*(0^*\mathbf{14.4}+0^*\mathbf{18.7}+0^*\mathbf{65.3}+0.349^*\mathbf{1.1}+0^*\mathbf{0.5})$$
$$+ \mathbf{0.399}^*(0^*\mathbf{3.0}+0^*\mathbf{7.6}+0^*\mathbf{85.9}+0.061^*\mathbf{2.8}+0.076^*\mathbf{0.7})$$
$$+ \mathbf{0.453}^*(0^*\mathbf{0.3}+0^*\mathbf{1.2}+0.01^*\mathbf{69.0}+0.293^*\mathbf{16.6}+0.871^*\mathbf{12.8})$$

the prevalence of obese subjects.
These prevalences again differ by gender.

EXAMPLE 4*:*

The prevalences for male and female adolescents are calculated according to tables 3 and 5:

$$P_4^m = \mathbf{9.7} = \mathbf{0.209}^*(0^*\mathbf{12.4}+0^*\mathbf{15.9}+0^*\mathbf{69.8}+0.269^*\mathbf{1.5}+0^*\mathbf{0.4})$$
$$+ \mathbf{0.435}^*(0^*\mathbf{3.6}+0^*\mathbf{5.7}+0.021^*\mathbf{86.0}+0.293^*\mathbf{3.6}+0.146^*\mathbf{1.0})$$
$$+ \mathbf{0.356}^*(0.47^*\mathbf{0.6}+0^*\mathbf{0.4}+0.132^*\mathbf{60.2}+0.591^*\mathbf{21.8}+0.134^*\mathbf{17.1})$$

$$P_4^f = \mathbf{9.4} = \mathbf{0.083}^*(0^*\mathbf{19.7}+0^*\mathbf{26.1}+0^*\mathbf{53.4}+0^*\mathbf{0}+0^*\mathbf{0.8})$$
$$+ \mathbf{0.362}^*(0^*\mathbf{2.2}+0^*\mathbf{9.8}+0.009^*\mathbf{85.8}+0.715^*\mathbf{1.8}+0.342^*\mathbf{0.3})$$
$$+ \mathbf{0.555}^*(0^*\mathbf{0.1}+0^*\mathbf{1.8}+0.09^*\mathbf{75.0}+0.621^*\mathbf{13.2}+0.057^*\mathbf{10.0})$$

$$P_5^m = \mathbf{7.8} = \mathbf{0.209}^*(0^*\mathbf{12.4}+0^*\mathbf{15.9}+0^*\mathbf{69.8}+0.349^*\mathbf{1.5}+0^*\mathbf{0.4})$$
$$+ \mathbf{0.435}^*(0^*\mathbf{3.6}+0^*\mathbf{5.7}+0^*\mathbf{86.0}+0.086^*\mathbf{3.6}+0.094^*\mathbf{1.0})$$
$$+ \mathbf{0.356}^*(0^*\mathbf{0.6}+0^*\mathbf{0.4}+0.005^*\mathbf{60.2}+0.298^*\mathbf{21.8}+0.829^*\mathbf{17.1})$$

$$P_5^f = \textbf{7.7} = \quad \textbf{0.083}^*(0^*\textbf{19.7}+0^*\textbf{26.1}+0^*\textbf{53.4}+0^*\textbf{0}+0^*\textbf{0.8})$$

$$+ \textbf{0.362}^*(0^*\textbf{2.2}+0^*\textbf{9.8}+0^*\textbf{85.8}+0^*\textbf{1.8}+0^*\textbf{0.3})$$

$$+ \textbf{0.555}^*(0^*\textbf{0.1}+0^*\textbf{1.8}+0.013^*\textbf{75.0}+0.287^*\textbf{13.2}+0.919^*\textbf{10.0})$$

Correction Procedure II

Information on subjective body image could improve the accuracy of prevalence estimates of overweight and obesity in study S without objective height and weight measurements. Estimation by Equation (14) can be improved by knowledge of participants' subjective body image.

By using the conditional probabilities a_{ijk} (see equation (11)) of a validation study that assesses information about the body image of participants in addition to the measured and subjectively assessed BMI, the bias introduced by the subjective BMI can be reduced.

Replacing Q_{jk} and R_k in formula (13) by the corresponding prevalences Q_{jk}^S and R_k^S from the study S the resulting correction formula is

$$\tilde{P}_i = \sum_{k=1}^{5}\left[\sum_{j=1}^{5}\alpha_{ijk}Q_{jk}^S\right]R_k^S \qquad (i=1\ldots5), \tag{16}$$

where $a_{ijk} = P\left(\frac{\mathrm{BMI}\in\mathrm{I}_i}{\mathrm{BMI}_{sub}\in\mathrm{I}_j,\, BI=k}\right)$ (17)

is determined by a validation study,

R_k^S is the prevalence of the body image category k in the study S,

and $Q_{jk}^S = P\left(\frac{\mathrm{BMI}_{sub}\in\mathrm{I}_j}{BI=k}\right)$ (18)

are the prevalences of the subjective BMI categories j in the group of people with Body Image BI=k in the study S.

Equation (16) is valid for any study that only has information on subjective body image and subjective BMI, as long as a parallel validation study V is conducted to estimate the conditional distribution of objective BMI according to subjective BMI for different body image groups. It has to be mentioned that even the coefficients a_{ijk} may differ by time, by gender, and by cultural background of the participants. Therefore we used a_{ijk}^V to indicate the results of a representative, up-to-date validation study V.

Discussion

For practical and economic reasons, height and weight are frequently ascertained only by self-report in epidemiological studies. The extent to which subjective estimation of BMI leads to a bias in estimates of the prevalence of overweight and obesity has been examined in specialist literature. A review article examined mistakes in the prevalence estimates of overweight and obesity in adolescents presented in 11 studies from 11 countries [9]. The review concluded that the prevalence of overweight and obesity among adolescents is grossly underestimated when subjective data are used. Furthermore, misclassification is more frequent among people who are truly overweight or obese as well as among girls. The authors recommended that the level of bias in subgroups of children and adolescents be examined more closely.

Among 418 pupils in Wales (participating in the WHO Health Behaviour in School-Aged Children Survey – HBSC), measurements of height and weight were carried out parallel to collecting data from questionnaires [22]. It was noted that, in order to assess the public health relevance of overweight and obesity, measured data must be considered to assess the extent of misclassification by subjective data. A study of Greek schoolchildren came to the same conclusion [23]. Regular national validation studies are called for in order to be able to assess the validity of subjective assessments.

Precisely this has been implemented with the KiGGS study in Germany. Asking 11- to 17-year-old KiGGS participants their height and weight and measuring it at the same time opens up the possibility to determine bias more accurately as a function of various influence factors.

Normal-weight adolescents in the KiGGS study gave a realistic assessment of their height and weight and therefore also of their BMI. Overweight participants tended to underestimate their weight. This led to a misclassification of their BMI and consequently to an underestimation of the prevalence of overweight and obesity. This did not depend on education or social status [24]. These results are highly valuable in the international context because they are based on a representative study with a large sample size.

This paper shows that, for studies S of a special age group of adolescents that only assess self-reported weight and height and therefore only obtain subjective BMI, there exists a correction procedure for the biased prevalence estimations of overweight and

obesity. The only condition is that a validation study V exist, which is representative for the same age group of adolescents as the study S and can be used to calculate the conditional distributions of objective BMI according to subjective BMI. The corresponding correction procedure is described in equation (14).

Furthermore, the KiGGS data have shown that the deviations between subjective and measured BMI differ not only between the sexes, but also between groups with different subjective body images (similar results are found in [8] and [9]).

A large percentage of both girls and boys in the KiGGS study whose BMI is actually normal consider themselves too fat. Although this occurs more frequently among girls than boys it is encountered in both sexes. The reverse is true among obese participants. Here, girls are more realistic than boys. 60.6% of obese girls, but only 32.2% − i.e. under one third − of boys recognize that they are "much too fat". Most obese participants considered themselves "a bit too fat". When it comes to subjective statements on height and weight, false self-perception of body image influences the bias in the opposite direction: adolescents who consider themselves much too fat report their weight as being lower than it really is, and young people who consider themselves too thin correspondingly "adjust" their weight upwards. Adolescents who consider themselves "exactly right" also provide more realistic information on their height and weight than other groups.

In this paper a correction procedure is proposed for prevalence estimation of overweight and obesity obtained through subjective BMI assessments. The procedure calls for simultaneously recording both the subjective and the objective BMI and asking for the subjective body image. For example this correction procedure can be applied to the German HBSC study [20], where adolescents were asked their body image as well as their height and weight. In this case the German KiGGS study will serve as the validation study for correcting the bias in the subjective BMI. The KiGGS study, as a representative study of German adolescents aged between 11 and 17 years old, overlaps the age groups of the HBSC study and was carried out in the same time period. Therefore, the KiGGS study can provide the coefficients a_{ijk} in equation (16). In a future part II of this paper, the corrected estimates of the prevalence of overweight and obese pupils in Germany will be published.

Conclusions

The correction procedure described in this paper can also be used in the international context, if a representative study exists that collected information about measured and self-reported BMI as well as self-perceived body image. With the data from this study, the dependence of the bias in the self-reported BMI on the self-perceived body image can be assessed. Applying the properties of conditional probabilities, the correction formula (16) can be applied to any epidemiological study S that collected information only on self-reported BMI and self-perceived body image at approximately the same time. Although the coefficients a_{ijk} will differ by time, age groups, gender, and nationality, the general principle remains valid. Considering the body image of study subjects can improve prevalence estimates of overweight, obesity and other BMI categories.

Competing Interests

The authors declare that they have no competing interests.

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