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Title: Relevance of age-related growth references: Variations in body measurements among girls in relation to their menarche status

Short title: **Body measurements among adolescent girls**

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Abstract

Aim: The objective of this study is to fill the information gap by providing detailed information on the development of girls' BMI and hip and waist circumferences in correlation with their menarche status and to examine the impact of considering menarcheal age in addition to numerical age in the assessment of overweight and abdominal overweight.

Subjects and Methods: The description of data is based on two recently conducted cross-sectional surveys: the *German Health Interview and Examination Survey for Children and Adolescents* (KiGGS, n=1,942) and the *Berlin School Children's Cohort* (BSCOC, n=1,606). Anthropometric data are presented stratified by age in years (11-14) and menarche status. The frequency distribution of overweight and abdominal overweight was calculated according to German reference data. Group comparisons were performed with non-parametric tests.

Results: Changes regarding body composition occur mainly during pre-menarche and menarche. In girls in whom menarche had occurred more than 6 months ago, waist circumference and, to a lesser extent, BMI attained stable values, while the values for hip circumference were higher in post-menarche girls. The frequency distribution of overweight and abdominal overweight among post-menarche girls shows that they are more than twice as likely to be overweight and/or abdominally overweight as pre-menarche girls within the same age group.

Conclusion: The frequency distribution of overweight and abdominal overweight among girls in a similar age group but with a different menarche status demonstrates that misclassification of girls can arise when only age is taken into account. The progress of maturation is an important factor in assessing the growth and health of adolescents.

Key words: BMI, waist circumference, hip circumference, menarche, adolescent girls

Introduction

Children's growth and body development vary during their lifetimes, and age-based percentiles for body measurements are known and described in many studies (Kromeyer-Hauschild et al. 2001 and 2008; Fredriks et al. 2003 and 2005; Moreno et al. 1999; Stolzenberg et al. 2007; Kurth et al. 2007; Tanner et al. 1966; Cole 2000). Variations in development start at birth (sex-dimorphism). During puberty, body measurements and composition, as well as growth velocity, change significantly throughout the various biological development stages (Marshall and Tanner 1969; Cole 2003).

Therefore the World Health Organisation Expert Committee recommends that maturational status should be taken into account when interpreting anthropometric data based on chronological age (de Onis and Habicht 1996). In addition, pubertal body measurements are important as they are linked directly to the possible onset of metabolic cardiovascular chronic disease later in life (Jordan et al. 2005; Lakshman et al. 2008). Studies have shown that the risk factors of fat patterning are difficult to detect in childhood and are seen only after sexual maturation (Freedman et al. 1999). Waist circumference as a sign of central fat accumulation, rather than BMI, has come into the focus to characterize fat frequency distribution (McCarthy et al. 2008). In Europe there are comparatively few population studies on maturational status and anthropometric data during puberty. The main reason for this is that it is difficult to assess puberty age and to measure anthropometric data close to the puberty event. Therefore this study has two main aims: first, to fill the information gap by providing detailed information on the development of subjects' BMI and hip and waist circumferences in correlation with their pubertal stage (respectively three menarche stages: pre-menarche, recent menarche and post-menarche); and secondly, to determine the impact of considering menarcheal age in addition to numerical age when defining overweight / obesity and abdominal overweight ("overwaist"). The description of data and comparison are based on two cross-sectional surveys recently conducted in Germany.

Methods

Sub-samples of 11- to 14-year-old girls were selected from two surveys: the nationwide representative *German Health Interview and Examination Survey for Children and Adolescents* (KiGGS), conducted by the Robert Koch-Institute (RKI) from 2003 to 2006 (Kurth et al. 2008); and the *Berlin School Children's Cohort* (BSCOC), performed by the Institute for Experimental Paediatric Endocrinology of Charité University Medicine 2006-2007 (Bau et al. 2009).

1,942 KiGGS girls were extracted from 17,641 children and adolescents (age range 0-17 years). This sample was then compared with 1,606 BSCOC girls, extracted from 1,842 girls between 10 and 16 years of age. KiGGS recruited the participants in two steps: first, 167 study locations (sample points) were chosen; then subjects were randomly selected from the official registers of local residents. The response rate was 66.6%. BSCOC is a school study in Berlin. In selecting schools, the various school types, migration background and social structure in the city were all taken into consideration. 1,842 (40.8%) girls agreed to participate. Both studies were approved by the local ethics committee.

Anthropometric measurements in both studies were performed by trained nurses. Girls' *height and weight* were measured in underwear with calibrated scales and stadiometers. Body Mass Index (BMI) and BMI standard deviation score (SDS) were calculated according to German reference data (Kromeyer-Hauschild et al. 2001). Girls over 1.4 BMI-SDS were classified as overweight; those between 1.4 and (-)1.4 BMI-SDS were classified as having normal weight; and those under -1.4 BMI-SDS were considered underweight. *Waist circumference* was measured with an inelastic measuring tape over the bare skin at the narrowest point between the lowest rib and the top of the iliac crest (Stolzenberg et al. 2007). Waist standard deviation score (waist-SDS) was calculated according to German reference data (Kromeyer-Hauschild et al. 2008). Girls over 1.3 waist-SDS, as recommended by Fredriks et al. (2005), were classified as abdominally overweight ("overwaist"); those between 1.3 and (-)1.3 waist-SDS were classified as having a normal waist; and those under -1.3 waist-SDS were considered abdominally underweight ("underwaist"). *Hip circumference* was measured over underwear over the great trochanters and at the widest circumference. The circumference was noted to the nearest 0.1 cm in KiGGS and 0.5 cm in BSCOC.

In both studies the sexual maturity of the girls was determined in an interview regarding their first menstrual period (menarche). KiGGS used the status-quo method (Kahl et al. 2007), asking girls simply whether they had or had not reached menarche. The *menarche status* was thus defined as pre-menarche or post-menarche. This method is also used in most of the current epidemiological studies concerning menarche status (Kaplowitz et al. 2001; Himes et al. 2009). Mean menarcheal age was calculated by means of a logit –analysis (Kahl et al. 2007). The *KiGGS data* is stratified in pre-menarche (n=913, 47.0%) and post-menarche (n=1,029, 53.0%) girls.

In BSCOC, in contrast, age at menarche was calculated from each girl's birthday and month and year of occurrence of the first menstruation (Koo and Rohan 1997, Bau et al. 2009). The girls were asked to recall the age at or the date of occurrence of their first menstruation. More than 50% of the girls were able to remember the month and the year of their menarche exactly. For those girls who could not exactly remember, the date was narrowed by seasonal calendar. This retrospective assessment method made it possible to stratify menarche

status into *pre-menarche*, *recent menarche* (menarche reached $\leq$ six months ago) and *post-menarche* (menarche reached more than 6 months ago). The anthropometric data of girls who reached menarche within the last 6 months are comparable with data from longitudinal surveys, since the assessment interval is also between 3 and 6 months in longitudinal studies (Siervogel et al. 2003). The *BSCOC data* is presented separately for pre-menarche (n=712, 44.4%), recent menarche (n=231, 14.4%) and post-menarche (n=661, 41.2%) girls.

The two studies are comparable regarding sample size and mean age distribution; they differ in terms of migration background (Schenk et al. 2007), school type attendance, weight status and abdominal overweight. This variance is attributable to the difference in regions studied, Germany and Berlin respectively. Nevertheless, the anthropometric measurements of median weight, height, and waist and hip circumference of pre-menarche girls are comparable. An overview of the two sub-samples, KiGGS and BSCOC, is presented in Table 1.

Please insert Table 1 here

All *data analysis* was performed using SPSS Version 17.0. All anthropometric data are presented stratified by study, menarche status and age. Group comparisons were performed by means of a non-parametric test to evaluate differences between menarche stages and age groups with respect to median BMI and waist and hip circumferences (Mann-Witney-Test, M-W, and Kruskal-Wallis-Test, K-W). The level of significance was 0.05 (two-sided) for all statistical tests.

Results

The median BMI and waist and hip circumferences, stratified by menarche status and age group, are presented in Table 2 for the KiGGS girls; the same information for the BSCOC girls is presented in Table 3. The KiGGS results show that *girls similar in age but at different menarche stages* have different body measurements. Post-menarche girls have a higher median BMI (about 2-3 kg/m²) and a larger median waist circumference (about 4-5 cm) and hip circumference (about 8-10 cm) than girls who are not yet menstruating. With regard to *girls at the same menarche stage but in different age groups*, KiGGS data show that median hip circumference, (as well as height and weight – data not shown) is significantly higher in older age groups (K-W $p < 0.001$), among both pre-menarche girls (about 4-5 cm) and post-menarche girls (about 2-3 cm). This also holds for median waist circumference in pre-menarche girls (about 1 cm), but not for waist circumference in post-menarche girls, and not for median BMI in either pre- or post-menarche girls.

Please insert Table 2 here

The BSCOC results (Table 3) allow for further differentiation. *Girls similar in age but at different menarche stages*: Recent menarche girls have a higher median BMI (about 2-3 kg/m²), and larger median waist (about 3-4 cm) and hip circumferences (about 4-5 cm) than girls who are not yet menstruating. Post-menarche girls (menarche more than six months ago) have a median hip circumference that is significantly higher (about 3-4 cm) than in recent menarche girls; waist circumference, however, is not significantly higher. In general the differences from pre-menarche to recent menarche are greater than those from recent menarche to post-

menarche, and the latter tend to increase with age. For *girls at the same menarche stage but in different age group* shows that BSCOC girls have the same median BMI, waist circumference and hip circumference, irrespective of their age, with the exception of hip circumference of pre-menarche girls.

Please insert Table 3 here

Table 2 (KiGGS) and Table 3 (BSCOC) also show the 10th and 90th percentiles for BMI, waist and hip circumference, which are the supposed limits for general underweight and overweight respectively. Figure 1 presents the frequency distribution of *overweight*; Figure 2 presents the frequency distribution of *overwaist* stratified by study, menarche status and age. The prevalence of *overweight* is about twice as high in post-menarche girls as in pre-menarche girls regardless of age. The prevalence of *overweight* is lower in older age groups when girls of the same menarche status are compared.

Please insert Figure 1 here

This frequency distribution is analogous for *overwaist* (Figure 2). Girls at the onset of menarche (see BSCOC data, Figure 2) are less *overwaist* than post-menarche girls who had their first menstruation more than six months ago. The frequency distribution of *overwaist* is in general higher than *overweight*.

Please insert Figure 2 here

Discussion

For the first time representative body measurements comprising median BMI and waist and hip circumferences and stratified for menarche status for German female adolescents (KiGGS) are available. The stratification of anthropometric measurements shows that girls similar in age who have not yet reached menarche have significantly lower BMI and hip and waist circumferences, while girls who have recently experienced menarche (BSCOC) show higher BMI and hip and waist circumference. The observation of higher data is comparable also for post menarche girls with exception of waist circumference (BSCOC girls) in comparison to recent menarche. With regard to girls at the same menarche stage but in different age groups, BMI and waist circumference show stable values in girls whose menarche occurred recently and more than six months ago. The analysis demonstrates that puberty changes affecting body composition (expressed by BMI and waist circumference) occur mainly during pre-menarche and menarche; few changes appear more than six months after menarche.

Neither the German anthropometric reference data (Kromeyer-Hauschild et al. 2001, Schaffrath Rosario et al. 2010) nor the reference data in Europe take menarche status into account. These reference data show a positive correlation between body measurements and age. The data presented here show no or only a weak correlation with age, but reveal significant differences in body measurements by considering menarcheal status. These results have two possible implications.

First, in view of the general anthropometric reference data, it seems we are more likely to misclassify girls with an early menarche as overweight if their menarche status is not factored in. A look at the 90th BMI percentile of

the twelve-year-old post-menarche KiGGS girls shows that the limit is set at 27.3 kg/m² (Table 2), whereas the German reference is 22.48 (Kromeyer-Hauschild et al. 2001). These trends decrease with age because the stable values of BMI and waist circumference in post-menarche girls become more in line with the average anthropometric reference data as they grow older.

On the other hand, the observation may simply further illustrate the secular trend of overweight and abdominal overweight over the last 20 years; thus, the percentiles are higher in the younger populations studied in KiGGS and BSCOC. But even if we consider the secular trend in overweight, the development gap among girls in the same age group but at different menarche stages is obvious.

Unfortunately we cannot observe the long-term development of the girls, and we have an age limitation of 11-14 years. Nevertheless, the (BSCOC) data also seems to implicate that the differentiation of body shape after menarche is of particular importance. Kromeyer-Hauschild et al. (2008) show that waist circumference increases between the age of 6 and 13 years and changes only slightly after this age. These waist circumference variations can also be observed in BSCOC. From pre-menarche to recent menarche, the difference is an average of 4-5 cm, while the increase from recent menarche to post-menarche is on average only 1-2 cm. The hip circumference is still higher with time elapsed after menarche. This means that the “female body shape” becomes more obvious and, consequently, BMI might also continue to increase slightly with time elapsed after menarche. The data imply that girls reach their individual waist circumference with post-menarche – a median value of 68 cm and a 90th percentile of 80 cm. Maffeis et al. (2001) observed that children with a waist circumference greater than the 90th percentile are more likely to have multiple risk factors than children with a waist circumference less than the 90th percentile, and that waist circumference is a better predictor of cardiovascular diseases risk factors than BMI (Savva et al. 2000; Csábi et al. 2000). Therefore, health professionals should incorporate the use of waist circumference measurements in their routine clinical examination of adult patients (cut-off point ≥ 80 cm for women) (Dobbelsteyn et al. 2001) and also for adolescents (Kromeyer-Hauschild et al. 2008; Fredriks et al. 2005; Moreno et al. 1999 and 2002; McCarthy et al. 2008). The cut-off point is not yet set for children and adolescents, but according to the results presented here, the 90th percentile of post-menarche girls is close to 80 cm. Moreno et al. (1999) have called for more research to establish adequate age-specific and gender-specific cut-off-points for reasons of health promotion and clinical practicality.

The strength of the BSCOC study is that it demonstrates variations in body measurements over time, especially those of girls who have already experienced menarche. The comparison of the two data sets performed in this study reveals that changes in body composition occur mainly during pre-menarche and recent menarche, and that few changes appear in the post-menarche phase; this is especially true for waist circumference. The frequency distribution of overweight and abdominal overweight among girls in similar age groups but at different menarche stages demonstrates that misclassification of girls can arise. Evaluation of menarche or the progress of maturation is important for assessing the growth and health of adolescents.

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Conflict of interest

There is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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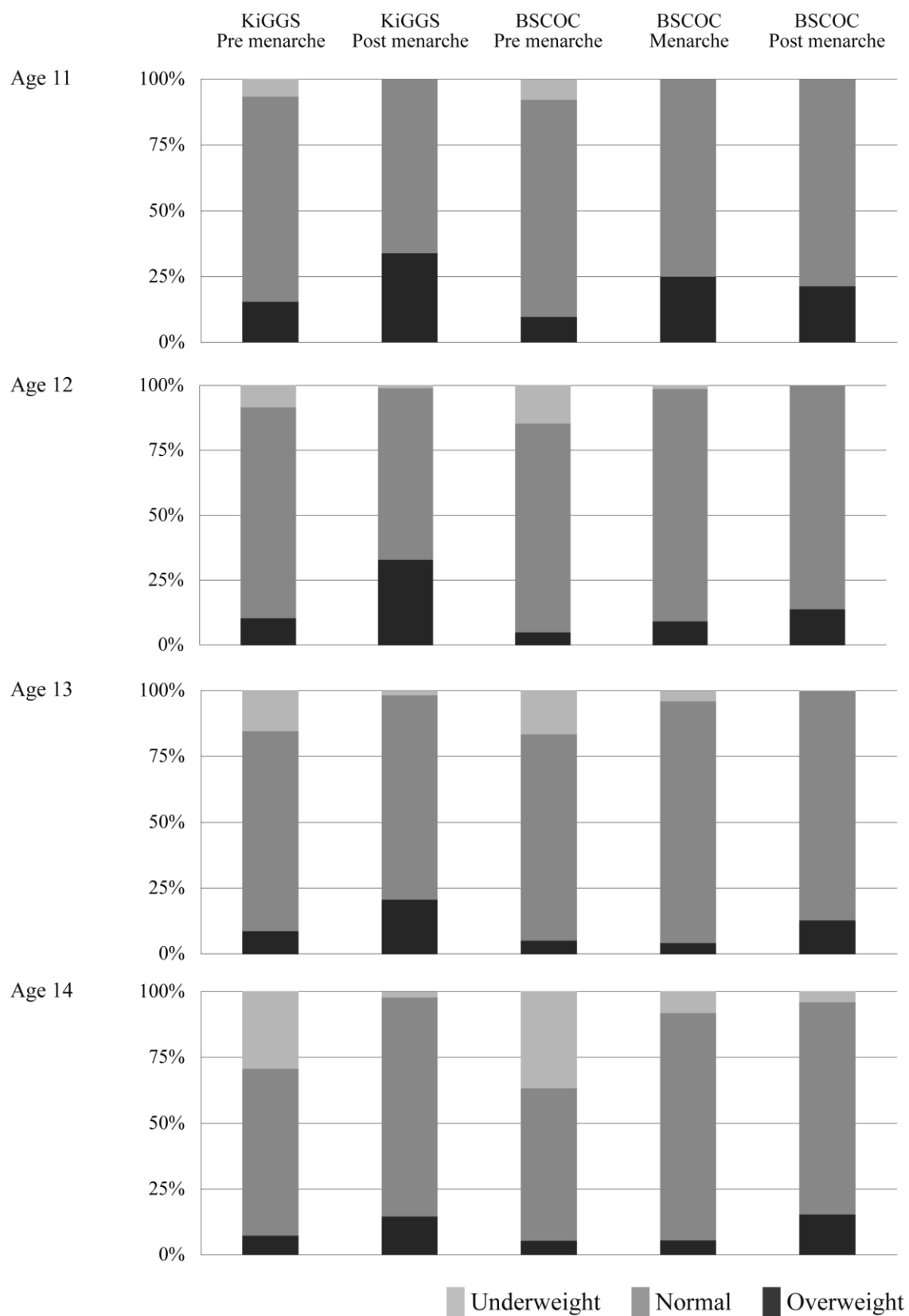
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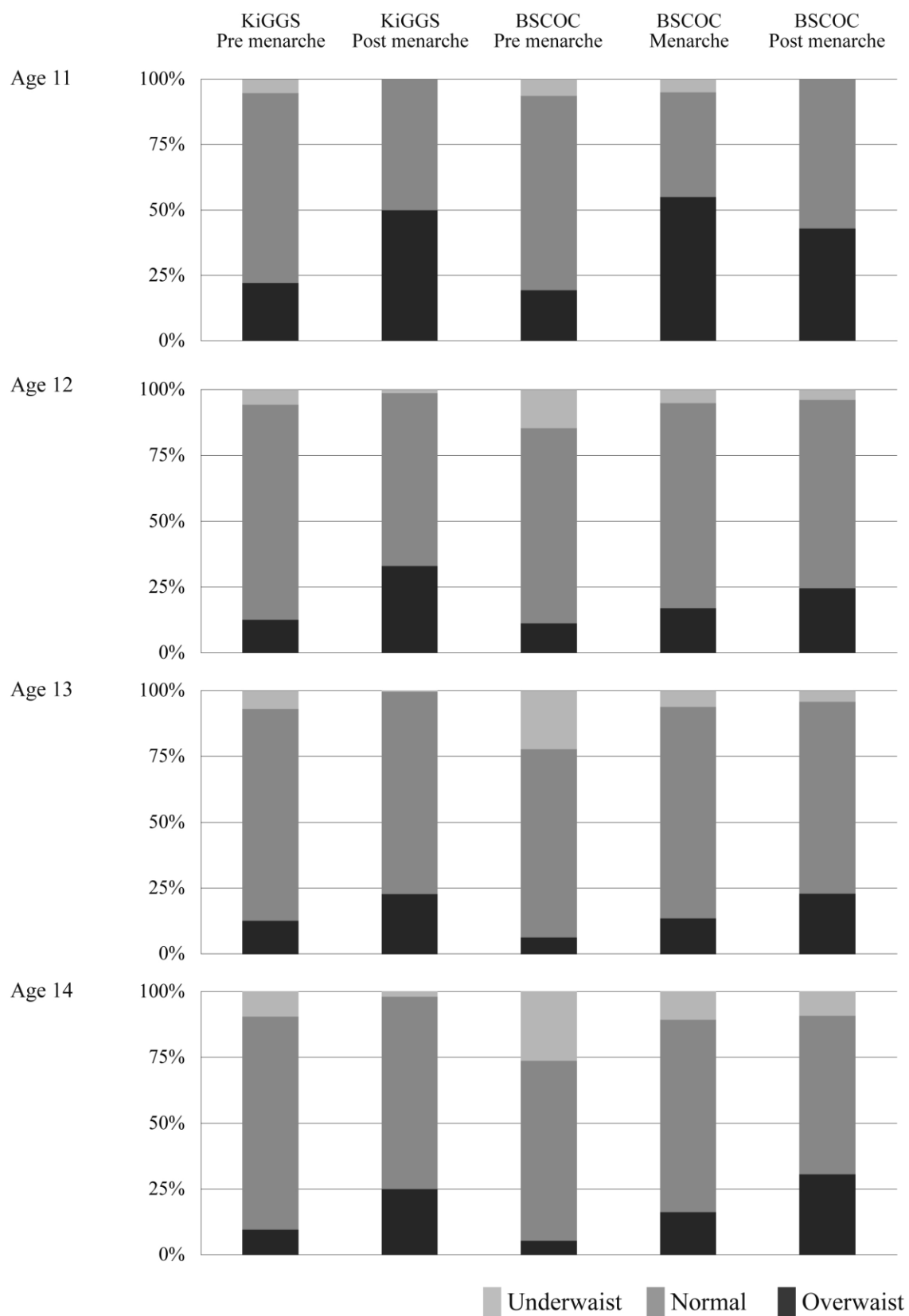
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Figure 1: Frequency distribution (%) of under-, normal- and overweight in KiGGS and BSCOC data (according to German reference Kromeyer-Hauschild et al. 2001) similar in age group but at different menarche stages



Statistically significant difference ($p < 0.001$) in frequency distribution of under-, normal- and overweight according to menarche status in KiGGS and BSCOC data

Figure 2: Frequency distribution (%) of under-, normal- and overwaist in KiGGS and BSCOC data (according to German reference Kromeyer-Hauschild et al. 2008) similar in age group but at different menarche stages



Statistically significant difference ($p < 0.001$) in frequency distribution of under-, normal- and overwaist according to menarche status of KiGGS and BSCOC data

Table 1: Frequency distribution of age, migration background and school type attendance of studied populations, KiGGS and BSCOC

Characteristics, 11-14 years old	KiGGS girls N=1,942	BSCOC girls N=1,606
Age (mean, SD)	13.1 (1.2)	13.0 (1.0)
Migration background (%)		
None	78.6	63.4
One-sided	6.1	9.1
Two-sided	15.3	27.5
School type (%)		
Primary school/ Grundschule	8.9	20.9
Secondary general school/ Hauptschule und Sonderschule	17.2	4.2
Intermediate secondary school/ Realschule	28.2	16.5
Comprehensive school/ Gesamtschule	9.0	14.6
Grammar school/ Gymnasium	36.7	43.8
Menarche age in years (mean and 95%CI)	12.8 (12.8-12.9)*	12.8 (12.75-12.9)**

* Kahl H, Schaffrath Rosario A, Schlaud M (2007) Sexuelle Reifung von Kindern und Jugendlichen in Deutschland. Ergebnisse des Kinder- und Jugendgesundheitssurvey. Bundesgesundheitsblatt-Gesundheitsforschung-Gesundheitsschutz 50:677-685

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Table 2: KiGGS data: BMI and waist and hip circumferences (median; 10; 90 percentile) according to pre- and post- menarche per age group

	N	Pre-Menarche (median; 10; 90 percentile)	N	Post-Menarche (median; 10; 90 percentile)	P-value ↔
Age	BMI (kg/m2)				
11	459	18.0 (15.2; 23.5)	53	21.1 (17.9; 26.7)	**
12	282	18.4 (15.5; 23.2)	210	20.6 (17.4; 27.3)	**
13	129	18.0 (15.6; 23.5)	341	20.6 (17.5; 25.9)	**
14	41	17.9 (15.6; 23.7)	420	20.9 (18; 26)	**
P-value ↑		n.s.		n.s.	
	Waist circumference (cm)				
11	456	62.0 (55.7; 74.8)	54	68.0 (59.8; 81.2)	**
12	279	63.2 (57.4; 72.9)	209	67.7 (60.8; 82.1)	**
13	128	62.9 (58.5; 77.2)	340	67.5 (61.2; 79.2)	**
14	42	63.1 (58.5; 72.6)	420	67.8 (61.6; 79)	**
P-value ↑		*		n.s.	
	Hip circumference (cm)				
11	457	78.8 (70.8; 91.2)	54	89.1 (90; 98)	**
12	279	82.2 (74.1; 91.1) ↑**	209	89.9 (82.5; 102.2)	**
13	128	82.7 (76.3; 96.5) ↑*	340	90.8 (82.7; 101.2)	**
14	42	83.4 (75.3; 91.8)	419	91.9 (84.9; 102.3)	**
P-value ↑		**		**	

↔ M-W (Mann-Withney Test) : horizontal (similar age groups but at different menarche stages): significant difference (* p<0.05, ** p<0.001) between pre- and post-menarche

↑ M-W, K-W (Kruskal-Wallis-Test): vertical (similar menarche status but at different ages): significant difference (* p<0.05, ** p<0.001) from the previous age

Table 3: BSCOC data: BMI and waist and hip circumference (median; 10; 90 percentile) according to pre-, recent and post-menarche per age group

	Pre-menarche			Recent menarche			Post-menarche		P-value
	N	(median; 10; 90 percentile)	N	(median; 10; 90 percentile)		N	(median; 10; 90 percentile)		↔
Age	BMI (kg/m2)								
11	279	17.7 (15.2; 22.4)	20	20.8 (16.2; 25.6) ↔**		14	19.6 (18; 24.4)		**
12	251	17.7 (15.3; 21.7)	77	19.7 (17.3; 23.3) ↔**		102	20.3 (17.6; 24.1)		**
13	162	17.9 (15.6; 21.9)	97	19.4 (17; 22.8) ↔**		349	20.5 (17.8; 24.8) ↔**		**
14	19	17.6 (14.6; 19.8)	37	19.2 (16.5; 22.1) ↔*		196	20.5 (18; 26.5) ↔**		**
P-value ↑		n.s.		n.s.			n.s.		
	Waist circumference (cm)								
11	279	61.5 (55; 75)	20	70.5 (61; 83.8) ↔**		14	68.8 (64; 82.5)		**
12	251	62 (55; 72.8)	77	66 (61; 75) ↔**		102	67 (58; 79)		**
13	162	63 (55.3; 71)	97	66 (58; 75) ↔**		349	68 (59; 80) ↔*		**
14	19	62 (56; 72)	37	66 (58; 78) ↔*		196	68 (59; 83.3)		*
P-value ↑		n.s		n.s			n.s		
	Hip circumference (cm)								
11	278	78 (70; 89)	20	86 (76.2; 97.7) ↔**		14	88 (81.5; 96)		**
12	251	81 (72; 89) ↑**	77	85 (79.2; 93.2) ↔**		102	88 (81; 95) ↔*		**
13	162	81.5 (76; 90) ↑*	97	86 (79.8; 93.2) ↔**		349	90 (82; 99) ↔** ↑*		**
14	19	81 (74; 90)	37	86 (80; 92.4) ↔*		196	90 (83; 101) ↔**		**
P-value ↑		**		n.s.			n.s.		

↔ M-W (Mann-Withney Test) : horizontal (similar age groups but at different menarche stages): significant difference (* p<0.05, ** p<0.001) between pre- and post-menarche

↑ M-W, K-W (Kruskal-Wallis-Test): vertical (similar menarche status but at different ages): significant difference (* p<0.05, ** p<0.001) from the previous age

