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Determinants of BMI category changes during middle childhood and adolescence in girls

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Abstract: The aim of the study was to analyse the changes in BMI category between 7 and 16–18 years of age on the basis of continuous studies and evaluate which factors are related to the increase and decrease in BMI category.

Data were collected from 1008 secondary school students aged 16–18 y. Body height and weight were measured and BMI was calculated. Information on height and body mass in earlier periods of life was retrieved from medical records. Age at menarche and socio-economic status was established on the basis of a questionnaire.

Most girls who were underweight at 7 y. as well as those who were overweight or obese at 7 y. at the age of 16–18 y. reach correct body weight. The probability of the BMI category changing to higher one at 16–18 y. was related to short stature at 7, 9 and 14 y., low socio-economic status, living in the village and primary level of mother education. A drop in the BMI category was linked to the incidence of overweight and obesity at the age of 9 and 14 y. and tall stature at the age of 7 and 9 years. High socio-economic status was connected with a change in the category from "correct weight" at the age of 7 y. to "underweight" at 16–18 y., whereas the socio-economic status did not have a significant effect on the change of the category "overweight & obesity" at 7 y. to "correct weight" at 16–18 y.

Key words: BMI, SES, underweight, overweight, obesity.

Introduction

Obesity is considered the greatest epidemic of the 21st century. According to WHO, in 2014 globally 39% adults were overweight (BMI ≥ 25 kg/m^2) and 13% obese (BMI ≥ 30 kg/m^2). The prevalence of obesity doubled from 1980 to 2014 [1]. In 2013, 42 million children under 5 were either overweight or obese. In recent years the epidemic of obesity among children and teenagers has become an issue both in highly-developed and developing countries. Currently the rate of increase of childhood overweight and obese in developing countries is 30% higher than in highly-developed countries [1].

The prevalence of obesity and related condition leads to an intensification of health campaigns. Mass media also promote slim, sometimes even extremely slim figure. In many groups such activities have sparked a trend for a healthy lifestyle. This is reflected in a decrease in the prevalence of overweight and obesity. A meta-analysis of data from 1999 to 2010 by Rokholm *et al.* revealed than in most European countries the prevalence of obesity in children either remained on a steady level or decreased over the analysed period. A rising number of obese children was observed only in Germany [2].

Results of cross-sectional studies involving children and teenagers of various ages also indicate that significant differences in the prevalence of excess body mass may occur depending on the subject's age [3–8]. This is particularly true for girls, for whom the prevalence of overweight and obesity is often lower after puberty than in younger age categories [8]. The phenomenon could be explained by overwhelming social pressure for a slim figure presented in the media as a determinant of attractiveness and social success. Body mass and the related BMI are ecosensitive and may vary over short periods of time depending on lifestyle, which in turn is related to the socio-economic status (SES). Moreover, weight-to-height proportions change along with age, and the pattern and magnitude of BMI change is strictly correlated with the maturation rate [8–12].

Studies on changes in the incidence of obesity are usually cross-sectional, and they are aimed at determining the prevalence of obesity and overweight at various points in time. Apart from establishing the frequency of a specific phenomenon, longitudinal studies allow researchers to trace BMI changes with age in each individual. If analysis is based on data obtained in cross-sectional studies, new cases of overweight and obesity will be reported only if their number exceeds the number of individuals who have lost weight.

The present study contains an analysis of changes in BMI category between 7 and 16–18 years of age on the basis of continuous studies. We verified which factors are related to the increase and decrease in BMI category.

Material and methods

Data were collected from 1008 secondary school female students aged 16–18 y. (born in years 1992–1994). Measurements included body weight and height, on the basis of which BMI was calculated. Information on height and body weight in earlier periods of life was retrieved from medical records. Each girls was examined in the 1st, 3rd and the final grade of primary school at the ages of respectively 7 (6.5–7.49), 9 (8.5–9.49) and 14 (13.5–14.49) years. Height and weight were measured with standard anthropometric methods. The measuring procedure was identical in all schools, with surgeries equipped with the same measuring instruments. Measurements at 16–18 years were also made according to the same procedure.

The prevalence of underweight, overweight and obesity was defined on the basis of international cut-points defined by Cole *et al.* [13, 14]. Subjects were categorized on the basis of Z-scores height for age as short (below –1s), average (–1 s to 1s) or tall (above 1s).

Socio-economic status was established on the basis of a questionnaire on the level of urbanisation of the subject's place of residence, parents' levels of education and number of siblings. "Place of residence" was categorised as 1. village, 2. city with up to 100,000 inhabitants, 3. city with more than 100,000 inhabitants; "parents' education" was categorised as: 1. primary or vocational, 2. secondary, 3. higher; "number of children in the family": 1. four and more, 2. three, 3. two, 4. one. Numerous reports indicate that the above variables serve as good indicators of standard of living in Poland, while not compromising the right to privacy of the study participants [15]. On the basis of all variables, a complex socio-economic status indicator was generated and subjects were qualified as belonging to families of low, average and high socio-economic status (SES). The division was introduced on the basis of the value of the first component obtained in the principal components method (PCA). The loadings of analysed variables on the SES index were as follow: 0.43 — place of living, 0.59 mother education, 0.58 — father education and –0.36 — number of children in family. The eigenvalue of the factor reached 2.78 and explained 62.1% of common variation in SES.

In addition, age at first menstruation was determined by means of a retrospective method. The subjects were split into three groups: early adolescents, whose age at menarche was lower than 12.5 years ($\bar{x}$–1sd), average adolescents, i.e. at the age of 12.5–14 years, and late adolescents, whose age at menarche was higher than 14 years ($\bar{x}$+1sd).

Statistical methods

The subjects were divided into 3 groups for further analysis: persons whose BMI category at age 16–18 y. was lower than at the age of 7 y., persons whose BMI category at the age of 16–18 was the same as at the age of 7 y., and persons whose BMI category increased.

In order to determine factors conducive to a change in BMI category odds ratio (OR) and 95% confidence interval (CI) for each of the factors separately were calculated using a logistic regression analysis. Regression models were constructed separately for changes BMI to higher and lower category. Significance of the differences was set at the level of $p < 0.05$. All statistical analyses were performed using STATISTICA 10 software package.

Results

Underweight at the age of 7 y. was reported in 107 subjects (10.63%), overweight in 111 subjects (11.02%), and obesity in 24 subjects (2.38%). At the age of 16–18 y., 127 subjects (12.61%) were underweight, 34 (3.38%) overweight, with only 6 (0.60%) obese subjects. Therefore, in middle childhood and adolescence a marked drop in the prevalence of overweight and obesity could be observed ($\chi^2 = 37.22$, $p < 0.001$).

Table 1 shows the prevalence of incorrect body weight at the age of 16–18 y. depending on the body mass category at the age of 7 y. Most underweight 7-year-old girls display an increase in the BMI category, whereas overweight and obese girls enter a lower BMI category at the age of 16–18 y. Most girls who were underweight at 7 y. as well as those who were overweight or obese at 7 y. in later life stage, at the age of 16–18 y. reach correct (healthy) body weight.

Table 1. BMI category at 16–18 y. in relation to BMI at 7 y.

	Underweight at 7 y.	Correct weight at 7 y.	Overweight at 7 y.	Obesity at 7 y.
Underweight at 16–18 y.	15 (14.02%)	107 (13.99%)	5 (4.5%)	0 (0.00%)
Correct weight at 16–18 y.	90 (84.11%)	634 (82.88%)	94 (84.68%)	22 (91.67%)
Overweight at 16–18 y.	2 (1.97%)	23 (3.01%)	8 (7.21%)	1 (4.17%)
Obesity at 16–18 y.	0 (0.00%)	1 (0.13%)	4 (3.60%)	1 (4.17%)

Among subjects with correct body weight at 7 y., for 14% the value of BMI was in category underweight, and for 3% the value of BMI was in category overweight and obesity at the age of 16–18 y. Results of logistic regression indicate that for persons with correct body weight at 7 y. the risk of being underweight at 16–18 y. is greater when their socio-economic status is higher (low SES OR = 0.42, 95% CI = 0.10–1.34; high average SES OR = 0.63, 95% CI: 0.12–1.76; high SES OR = 1 ref.), whereas

the risk of overweight and obesity is higher in persons from families of low socio-economic status (low SES OR = 2.53, 95% CI = 1.53–4.38 average SES OR = 0.48 95% CI = 0.12–1.62; high SES OR= 1 ref.).

The BMI category was more likely to change to a higher one in persons who were underweight as children than in those with correct body mass in their childhood. The probability of the BMI category changing to higher one at 16–18 y., both for underweight girls and girls with normal body mass at the age of 7 y., was related to short stature ($<\bar{x}-1$sd) at 7 y., 9 y. and 14 y. (Table 2). Low socio-economic status, living in the village and primary level of mother education increased the likelihood of the category shifting up the scale (Table 2).

Table 2. Odds ratio for being in the higher BMI category in the age of 16–18 y. than in the age of 7 y.

Factor	Category	OR	CI	p
BMI at 9 y.	Underweight	6.17	4.57–9.78	<0.001
	Correct weight		Ref.	
	Overweight and obesity	1.42	0.61–3.29	NS
BMI at 14 y.	Underweight	3.37	2.02–5.31	<0.01
	Correct weight		Ref.	
	Overweight and obesity	1.32	0.66–2.62	NS
Body height at 7 y.	Short ($<\bar{x}-1$sd)	1.66	1.03–2.67	<0.05
	Average ($\bar{x}\pm1$sd)		Ref.	
	Tall ($>\bar{x}+1$sd)	0.72	0.37–1.41	NS
Body height at 9 y.	Short ($<\bar{x}-1$sd)	2.41	1.51–3.83	<0.01
	Average ($\bar{x}\pm1$sd)		Ref.	
	Tall ($>\bar{x}+1$sd)	0.80	0.41–1.52	NS
Body height at 14 y.	Short ($<\bar{x}-1$sd)	1.38	0.85–2.25	<0.05
	Average ($\bar{x}\pm1$sd)		Ref.	
	Tall ($>\bar{x}+1$sd)	0.61	0.36–1.12	NS
Maturation rate	Early	1.48	0.64–2.86	NS
	Average		Ref.	
	Late	0.86	0.45–1.54	NS
Dwelling place	Village	2.12	1.11–4.40	<0.05
	Town	1.76	0.81–2.70	<0.05
	City		Ref.	
Mother's education	Primary	2.12	0.98–3.58	<0.05
	Secondary	1.52	0.85–2.70	NS
	University		Ref.	

Factor	Category	OR	CI	p
Father's education	Primary	1.28	0.76–2.15	NS
	Secondary	0.95	0.56–1.64	NS
	University		Ref.	
The number of siblings	0	0.86	0.48–1.27	NS
	1	1.01	0.59–1.68	NS
	2	1.13	0.65–2.00	NS
	3 and more		Ref.	
Socio-economic status	Low	2.48	1.25–4.25	<0.05
	Average	1.48	0.86–2.56	NS
	High		Ref.	

A drop in the BMI category was linked to the incidence of overweight and obesity at the age of 9 and 14 and a body height above the values of $\bar{x}\pm1s$ at the age of 7 and 9 years (Table 3). High socio-economic status was connected with a change in the category from "correct weight" at the age of 7 y. to "underweight" at 16–18 y. (low SES OR = 0.41, 95% CI = 0.08–1.89; average SES OR = 0.62, 95% CI = 0.10–1.96; high SES OR = 1 ref.), whereas the socio-economic status did not have a significant effect on the change of the category "overweight & obesity" at 7 y. to "correct weight" at 16–18 y. (low SES OR = 0.87, 95% CI = 0.22–2.01; average SES OR = 0.94, 95% CI = 0.26–2.57; high SES OR = 1 ref.).

The effect of maturation ratio on the changing of BMI category was very week. The OR for being at the age of 16–18 y. in the lower BMI category than at the age of 7 y. was higher in late maturing girls (Table 2), whereas the OR for being in the higher category was a slightly higher in early maturing girls (Table 3).

Discussion

Cross-sectional studies constitute an overwhelming majority of research on BMI changes during puberty. This is caused by the fact that maintaining contact with a large number of subjects for a longer period of time is very difficult. With each year persons are increasingly less willing to participate in tests. Among the longitudinal studies on changes in BMI and adiposity [16–18] a large proportion of them concerns intervention studies involving measures aimed at adiposity reduction in subjects and constantly monitoring the effect of such measures [19, 20]. Data obtained in this way do not reflect actual changes occurring in general population.

Many studies indicate that obesity in childhood increases the risk of obesity and obesity-related conditions in adulthood. Obese children become obese individuals at a later age [21–25]. Researchers agree that children with excessive body mass enter

Table 3. Odds ratio for being in the lower BMI category in the age of 16–18 y. than in the age of 7 y.

Factor	Category	OR	CI	p
BMI at 9 y.	Underweight	1.67	0.56–1.57	<0.05
	Correct weight		Ref.	
	Overweight and obesity	7.79	4.86–10.17	<0.001
BMI at 14 y.	Underweight	1.87	1.09–2.99	<0.05
	Correct weight		Ref.	
	Overweight and obesity	2.47	1.63–3.75	<0.01
Body height at 7 y.	Short (<$\bar{x}$–1sd)	1.13	0.75–1.83	NS
	Average ($\bar{x}$±1sd)		Ref.	
	Tall (>$\bar{x}$+1sd)	1.76	1.30–2.87	<0.05
Body height at 9 y.	Short (<$\bar{x}$–1sd)	1.01	0.64–1.60	NS
	Average ($\bar{x}$±1sd)		Ref.	
	Tall (>$\bar{x}$+1sd)	1.93	1.32–2.84	<0.05
Body height at 14 y.	Short (<$\bar{x}$–1sd)	0.92	0.60–1.41	NS
	Average ($\bar{x}$±1sd)		Ref.	
	Tall (>$\bar{x}$+1sd)	1.23	0.82–1.85	NS
Maturation rate	Early	1.37	0.88–2.14	NS
	Average		Ref.	
	Late	1.63	1.09–2.46	<0.05
Dwelling place	Village	0.76	0.50–1.16	NS
	Town	0.78	0.28–2.12	NS
	City		Ref.	
Mother's education	Primary	0.73	0.47–1.13	NS
	Secondary	0.75	0.66–1.18	NS
	University		Ref.	
Father's education	Primary	0.79	0.53–1.16	NS
	Secondary	0.83	0.57–1.22	NS
	University		Ref.	
The number of siblings	0	1.57	0.87–2.80	NS
	1	1.52	0.99–2.36	NS
	2	1.33	0.82–2.17	NS
	3 and more		Ref.	
Socio-economic status	Low	0.67	0.31–1.03	NS
	Average	0.96	0.67–0.38	NS
	High		Ref.	

puberty earlier, and also face a greater risk of developing diabetes or metabolic syndrome later in their lives [26–29].

Nevertheless, there are also scientific publications which report that overweight and obese children tend to lose weight, whereas slim children tend to gain weight later in their lives [30]. The authors of the present study obtained results similar to publications referred to above. Most girls who were underweight at 7 y. achieved correct body weight at the age of 16–18 y. Also, most girls who were overweight at 7 y. had correct body weight at the age of 16–18 y.

This particular phenomenon could be explained in different ways, by biological and cultural factors.

Body weight change along with age is related to rate of maturation. Early maturing individuals have a greater body weight and height than their peers, even at the age of 7–9 years, before the onset of sexual maturity. Their BMI is on average higher than in average maturing and late maturing persons [22, 31–33]. Rate of maturation and body weight, BMI and adiposity level are interrelated. Early onset of sexual maturation means an earlier growth spurt of body weight and height, making such girls taller and heavier than their peers, on the other hand excessive amount of adiposity in adolescence stimulates earlier maturation [34–36]. Age at menarche is strongly correlated with the risk of obesity, both pre- and post-adolescence, but seems to have little effect on the magnitude of BMI value changes with age. According to many works published in scientific literature, early maturing persons have a higher BMI and higher prevalence of overweight, while late maturing person have a lower BMI and are more frequently underweight in comparison to average maturing person [9, 12. 32, 37–39]. Such relationship does not vary with age, as it is noticeable both in childhood and adulthood. The results we obtained demonstrated that the effect of age at menarche on changes in BMI category proved statistically insignificant.

Age-dependent BMI category shifts could also be explained by cultural variables. Under peer pressure, children with excessive body weight strive to reduce it by changing their lifestyle and nutritional habits. This phenomenon intensifies and is particularly marked in girls who want to achieve the 'perfect' (i.e. extremely slim) figure. Nowadays not only obese girls but also those with normal body mass tend to slim down, and we may speak of the so-called 'unjustified slimming' [40–46].

Although a decrease in body mass, particularly in overweight and obese persons, is a positive phenomenon, we must consider methods used to this achieve this aim. Using ill-balanced diets or drastic methods such as fasting or pharmaceuticals may have a strongly negative impact on health. As for slim children, their parents and children themselves do not see the need to restrict the intake of high-calorie products and fail to form healthy lifestyle habits, which may lead to gaining weight later on. Parents may have a considerable influence on their children gaining weight, introducing high-calorie foods (often appetite stimulants) to children's diet so

that their offspring could achieve normal weight. Cross-sectional studies indicate a significant effect of the family context on BMI and the incidence of incorrect body mass [36, 47–50]. In contrast, there is not enough data on the magnitude of BMI changes with age depending on the family's socio-economic status; in addition, most information has been collected by monitoring obese children from groups involved in weight-reduction programmes. In the present study we reported the effect of socio-economic status on the direction of BMI changes in children with correct body mass at the age of 7. High socio-economic status favoured a decrease, and low SES — an increase in the category. In persons from families with high SES this is probably due to peer pressure and a desire for the perfect figure. In families of low SES, a change to a higher BMI category may be caused by lack of knowledge on healthy nutrition as well as economic factors: ingredients of cheapest food products are often responsible for weight gain.

Conclusions

The results of this study confirm the hypothesis that the scale of BMI changes in childhood and adolescence depends to a large extent on BMI in childhood. Most girls who were overweight or obese at 7 y. and those who were underweight at 7 y. reach correct BMI at the age of 16–18 y. The probability of the BMI category changing to lower at 16–18 y. was related to tall stature at the age of 7 and 9 years and the incidence of overweight and obesity at the age of 9 and 14 y. An increase of the BMI category was linked to short stature at 7, 9 and 14 y., low socio-economic status, living in the village and primary level of mother education.

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