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ORIGINAL ARTICLE

Polish 2012 growth references for preschool children

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Abstract Growth references are useful in monitoring a child's growth, which is an essential part of child care. The aim of this paper is to provide updated growth references for Polish preschool children and to assess how well children in Poland match or diverge from the World Health Organization (WHO) growth standards/references and recent German height-for-age references. The height-, weight-, body mass index-for-age, and weight-for-height references were constructed with the LMS method using data from a recent, large, population-representative sample of 4,941 preschool children aged 3 to 6 years (the OLA study). In the case of boys, the third, 50th, and 97th height percentiles of new Polish and German references overlap almost completely, whereas the WHO growth standards/references percentiles are systematically lower. In the case of girls, comparison between the new Polish and German height references showed conformity on the third and 50th percentile, whereas body height values of the WHO standards/references are shorter. Polish children aged 3 to 6 years from for the nation representative sample, had significantly greater than zero mean *z* scores of height-, weight-, and BMI-for-age and weight-for-height, relative to the WHO growth standards/-references. The number of children in the sample with height-for-age below −2 SD was significantly lower than expected and number of children with height-for-age above +2 SD was significantly higher than expected. *Conclusion*: The OLA study growth references can be recommended as national references for preschool children in Poland.

Keywords Preschool children · Growth references · LMS method

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Introduction

Children's growth monitoring to identify medical disorders or nutrition-related problems is an important task of medical professionals providing health care for children. Optimal growth monitoring requires up-to-date reference growth data on representative samples from the population and growth references constructed according to the state-of-the-art statistical methodologies [5]. Reference charts for preschool children that were until recently used in Poland were based on the sample representative for capital city (Warsaw) and were constructed without accounting for skewness of weight and body mass index (BMI) [18]. In 2006, the World Health Organization (WHO) published results of the Multicentre Growth Reference Study (MGRS) and new international growth standards based on measurements taken from healthy breastfed infants and children under 5 years, living in six countries on different continents "under conditions likely to favor the achievement of their full genetic growth potential" [24]. Therefore the MGRS sample could be regarded as universal reference population and there is a noticeable interest for the idea of implementing these charts

[9]. However, children's development depends on various genetic and socio-economic factors which are different in different parts of the world and typical for ethnic groups. Thus, growth references should be not only specific for ethnic group but also should be periodically actualized to adjust to changes in socio-economical situation. In previous studies on distribution of height, weight, and BMI in Polish school-aged children, significant differences from international growth references including the WHO growth references for children and adolescents aged 5–19 years were found [15, 16]. Similar observations on taller children in nationally representative sample than children representing the WHO growth standards/references came recently from Germany [21].

In this paper, we present cross-sectional height-, weight-, BMI-for-age, and weight-for-height references for preschool children in Poland using data from a current, representative sample of Polish children aged 3−6 years. We also took advantage of a recent, large sample of preschool children to assess how well children in Poland match or diverge from the WHO Child Growth Standards and recent German height-for-age references.

Materials and methods

Design, setting, and subjects

We analyzed anthropometric data collected in the course of population-based cross-sectional OLA study (N R13 0002 06), which main purpose was to assess distribution of blood pressure and construct blood pressure percentiles for Polish preschool children. Field examinations were conducted in 81 primary health care practices in all regions of Poland between November 2010 and May 2012. Approval of the Children's Memorial Health Institute Ethics Committee to conduct the study was obtained before the study commenced. Informed consent was obtained in written form from parent of each participating child. Study participants (children 2.5−6.5 years of age) were randomly selected using two-stage sampling. The sampling frame at the first stage consisted of a list of primary health care practices obtained from regional offices of National Health Fund. Sampling was stratified by province. In the second stage, all children in the required age range within the sampled primary health care setting comprised the sampling frame. The information on date of birth, pregnancy duration, and birth weight (BW) was obtained from the Child Health Handbooks. Parents were interviewed on duration of breastfeeding, introduction of complementary feeding, child's pharmacotherapy in the month preceding the survey, and on medical history of the child. The general health status including medical history and physical examination of each subject was assessed by a physician. Children with disorders possibly affecting growth were excluded from the study; exclusion criteria were: postural deficiencies, genetic syndromes (Down syndrome, Turner syndrome), cancer, or other chronic disease influencing height, including children treated with growth hormone or diagnosed with growth hormone deficiency, children treated with systemic steroids for any reason, diabetes, cerebral palsy, thyroid hormone supplementation, cystic fibrosis, renal disease, congenital adrenal hyperplasia, and congenital heart defect with impairment of physical fitness.

Anthropometric techniques

Height and weight were recorded in duplicate. Height was measured using a SECA 214 stadiometer. The subject was in the standing upright position (no shoes), with hips and shoulders perpendicular to the central axis, heels against the footboard, knees together, arms hanging loosely at the sides, and the head in the Frankfurt plane. Height was recorded to the nearest millimeter, if a difference between measurements exceeded 4 mm, a third measurement was performed. Body weight was recorded in light underwear to the nearest 0.05 kg, using a digital medical scale (Radwag WPT 100/200, Poland). In the case of a difference between measurements equal to or exceeding 0.3 kg, a third measurement was taken. Body mass index was calculated as body weight divided by height in meters squared.

All measurements were taken by trained staff: anthropologists, nurses, public health professionals, and physicians using standard and calibrated equipment. The training consisted of presentation of the standardized measuring techniques and practical exercises supervised by the trainer. Following the training, standardization sessions were conducted according to the standardization protocol. Reliability of anthropometric measurements between the trainer and the trainee (study staff) was documented.

Statistical analysis

Statistical analyses were performed separately for boys and girls using SAS 9.2 software. Exact age was calculated by subtracting the date of birth from the date of examination. Outliers were identified by inspecting the *z* score plot of the variable under consideration, and were checked carefully for possible mistakes of data recording and/or transfer. None of the outliers was considered to be biologically implausible and there were no outlier exclusions from the dataset.

Height-for-age, weight-for-age, BMI-for-age, and weight-for-height percentile curves were constructed separately for each sex using the LMS method [3] and LMSChartMaker Pro version 2.42 software [19]. In order to provide a smooth transition from the Polish 2012 preschool growth references

curves beyond age of 6 years, data of the OLA study were merged with data of the OLAF study, which provided Polish 2010 growth references for school-aged children and adolescents [15]. A Box-Cox power transformation was used to normalize the data at each age. Natural cubic splines with knots at each distinct age t were fitted by maximum penalized likelihood to create three smooth curves: $L(t)$ the Box-Cox power, $M(t)$ the median, and $S(t)$ the coefficient of variation percentile curves at age were then obtained as

$$C_{100\alpha}(t) = M(t)[1 + L(t)S(t)Z_\alpha]^{1/L(t)}$$

where Z_α is the normal equivalent deviate for tail area$_\alpha$, and C100$_\alpha$ (t) is the percentile corresponding to Z_α. Equivalent degrees of freedom (edf) $L(t)$, $M(t)$, and $S(t)$ measure the complexity of each fitted curve. With the use of the LMS method each observation can be converted to its standard deviation score (Z) with the formula: $Z = \frac{\left[\frac{\text{measurement}}{M}\right]^L - 1}{LS}$ if $L \neq 0$ or $Z = \log\frac{\left[\frac{\text{measurement}}{M}\right]}{S}$ if $L=0$.

Q tests [20, 22] and inspection of worm-plots [23] were used to check the goodness of fit of selected models.

Comparison with the WHO growth standards/references and current German height-for-age reference

The third, 50th, and 97th height percentiles for ages 3–6 years of the WHO growth standards/references, German height references [21] and new Polish 2012 height references were compared graphically. The BMI z scores curves: −2; −1; 0; 1; and 2 of new Polish 2012 references were compared to the WHO growth standards/references.

Age- and sex-adjusted z-scores for height (HAZ), weight (WAZ), BMI (BMIZ), and weight-for-height z scores (WHZ) were calculated for each child in the sample relative to the WHO growth standards/references. In the case of children aged 3−5 years (exact ages, 914−1,856 days) SAS macro, software provided by the WHO, was used to calculate the indicators of the attained growth standards [10]; in the case of children aged 5−6 years (exact ages, 1,857−2,373 days) WHO SAS macro available to analyze growth data for the age group 5−19 years was used [8, 11]. Birth weight z scores (BWZ) were calculated for each child in the sample relative to the WHO growth standards according to the formula: BWZ= ((BW/M)^L−1)/L/S.

where L, M, S were derived from the WHO growth standards at age "0" [24]. Summary data were presented as means and 95 % confidence interval (CI) for the mean for the total sample and for the subsample of children exclusively breastfed for at least 4 months. Differences in the prevalence of stunting (percentage less than −2 SD of HAZ) and in the prevalence of height>+2 SD between the WHO height-for-age standards/references and new Polish 2012 height-for-age references were tested with chi-square test. Differences were considered significant when p values were less than 0.05.

Results

There were 7,545 children drawn and invited to take part in the study, of whom parents of 5,050 children (aged 2.5−6.5 years) consented and were enrolled into the study (response rate 67 %). Forty percent of study subjects were living in rural areas which reflected the national proportion. Data from 109 children were excluded from the analyses due to lack of height or weight measurement (child's refusal to cooperate during anthropometry measurement according to the protocol set requirements), or invalid data (e.g., lack of second measurement or third measurement in the case that third measurement was required), or health defined exclusion criteria. Thus, the sample comprised 2,437 healthy boys (49 %) and 2,504 healthy girls. Mean BW was 3,465 and 3,313 g, in the case of boys and girls, respectively, which reflect mean z scores, calculated relative to the WHO growth standards, of 0.18 (95 % CI, 0.13−0.22) and 0.11 (95 % CI, 0.07−0.16), boys and girls, respectively. Table 1 provides sample size by age and sex and descriptive statistics.

Polish 2012 height, weight, and BMI references

Among both boys and girls height and weight increased with age, whereas BMI declined from age 3 years reaching its lowest median value of 15.5 and 15.4 kg/m^2 in boys and girls, respectively, at the age of 5. Median BMI increased from age 5 years to age 6 years in both boys and girls.

In the construction of height-for-age and weigh-for-age reference percentiles the same edf parameters were used as in the construction of Polish 2010 height- and weight-for-age for school-aged children [15] and age was rescaled in the LMSChartMaker, as both height and weight changed with age monotonously.

The reference height percentiles for boys and girls were constructed without skewness. The Box-Cox power transformations L for height were set to 1 at all ages. In the case of weight LMS models, positive skewness was observed in all ages; smoothed L values for weight varied between −1.42 and −1.14. As in the case of weight-for-age distribution, BMI distribution was skewed to the right in all ages. The smoothed L values for the BMI varied from −2.74 to −1.86. The BMI edf parameters were: L2M5S5 and L3M5S5, boys and girls, respectively. Since BMI did not change with age monotonously, original age was used in the LMSChartMaker for fitting

Table 1 Characteristic of Polish 2012 preschool children growth references sample

Age (years)	Variable	Boys					Girls				
		N	Mean	SD	Min	Max	*N*	Mean	SD	Min	Max
3	Height (cm)	595	98.3	4.2	85.7	114.0	582	96.9	4.3	83.4	113.2
	Weight (kg)		15.5	2.3	10.4	30.4		14.9	2.1	10.6	26.5
	BMI (kg/m^2)		16.0	1.6	12.4	24.7		15.9	1.5	12.4	23.8
4	Height (cm)	666	104.9	4.7	91.4	122.9	691	103.6	4.6	87.7	119.2
	Weight (kg)		17.5	2.7	12.4	32.0		17.0	2.9	11.3	32.5
	BMI (kg/m^2)		15.8	1.7	12.2	26.7		15.8	1.8	11.6	26.6
5	Height (cm)	615	111.8	4.9	97.8	127.5	658	110.4	5.0	96.5	129.4
	Weight (kg)		19.7	3.3	13.2	35.5		19.1	3.4	12.1	38.3
	BMI (kg/m^2)		15.7	1.8	12.0	27.1		15.6	1.8	11.3	23.9
6	Height (cm)	561	118.3	5.5	106.6	136.5	573	116.9	5.5	100.7	134.1
	Weight (kg)		22.3	4.3	15.4	42.9		21.7	4.2	12.8	44.0
	BMI (kg/m^2)		15.9	2.1	11.8	25.0		15.7	2.1	9.3	27.5

BMI references. Tables 2 and 3 show height, weight, and BMI references by age in boys and girls, respectively. Table 4 shows weight-for-height references for boys and girls. The weight-for-height edf parameters were: L3M7S6 and L5M8S6, boys and girls, respectively. Since weight changed with height monotonously, we used the rescaled function in the LMSChartMaker, which improves the fit.

Table 2 Polish 2012 height-for-age (in cm), weight-for-age (in kg), and BMI-for-age (in kg/m^2) references for preschool boys

Age (years)	L	S	−2 SD	−1 SD	+1 SD	+2 SD	P3	P10	P25	P50: M (median)	P75	P90	P97
Height (cm)													
3.0	1	0.038	90.1	93.8	101.3	105.0	90.5	92.7	95.0	97.5	100.0	102.3	104.5
3.5	1	0.039	93.5	97.4	105.2	109.2	93.9	96.3	98.7	101.3	104.0	106.3	108.7
4.0	1	0.039	96.7	100.8	109.1	113.2	97.2	99.7	102.2	104.9	107.7	110.2	112.7
4.5	1	0.040	99.8	104.1	112.7	117.0	100.3	102.9	105.5	108.4	111.3	113.9	116.5
5.0	1	0.041	102.7	107.3	116.4	120.9	103.3	106.0	108.8	111.8	114.9	117.6	120.4
5.5	1	0.041	105.6	110.4	119.9	124.7	106.2	109.0	111.9	115.2	118.4	121.3	124.1
6.0	1	0.042	108.4	113.4	123.4	128.4	109.0	112.0	115.0	118.4	121.8	124.8	127.8
Weight (kg)													
3.0	−1.289	0.131	11.9	13.2	17.2	20.6	12.1	12.8	13.7	14.9	16.4	18.0	20.1
3.5	−1.350	0.131	12.8	14.2	18.5	22.1	12.9	13.8	14.7	16.0	17.6	19.4	21.6
4.0	−1.382	0.130	13.7	15.2	19.8	23.7	13.9	14.7	15.8	17.1	18.8	20.7	23.1
4.5	−1.379	0.134	14.4	16.0	21.0	25.3	14.6	15.5	16.6	18.1	20.0	22.1	24.7
5.0	−1.369	0.142	15.0	16.8	22.4	27.5	15.2	16.3	17.5	19.1	21.2	23.6	26.7
5.5	−1.384	0.152	15.7	17.7	24.0	30.1	15.9	17.1	18.4	20.3	22.6	25.4	29.2
6.0	−1.416	0.163	16.6	18.7	26.0	33.5	16.8	18.0	19.5	21.6	24.4	27.7	32.3
BMI (kg/m^2)													
3.0	−2.743	0.081	13.7	14.6	17.1	19.4	13.8	14.3	14.9	15.7	16.6	17.7	19.0
3.5	−2.696	0.085	13.6	14.4	17.2	19.6	13.7	14.2	14.8	15.6	16.6	17.8	19.2
4.0	−2.648	0.090	13.4	14.4	17.2	19.8	13.5	14.1	14.7	15.6	16.6	17.8	19.4
4.5	−2.601	0.094	13.3	14.3	17.3	20.1	13.4	14.0	14.6	15.5	16.6	18.0	19.7
5.0	−2.554	0.099	13.2	14.2	17.4	20.5	13.3	13.9	14.6	15.5	16.7	18.1	20.0
5.5	−2.507	0.104	13.1	14.2	17.5	20.9	13.3	13.9	14.6	15.5	16.8	18.3	20.4
6.0	−2.460	0.109	13.1	14.2	17.7	21.4	13.2	13.8	14.6	15.6	16.9	18.5	20.8

Table 3 Polish 2012 height-for-age (in cm), weight-for-age (in kg), and BMI-for-age (in kg/m^2) references for preschool girls

Age (years)	L	S	−2 SD	−1 SD	+1 SD	+2 SD	P3	P10	P25	P50: M (median)	P75	P90	P97
Height (cm)													
3.0	1	0.040	88.7	92.5	100.2	104.0	89.1	91.4	93.7	96.3	98.9	101.2	103.5
3.5	1	0.040	92.1	96.1	104.0	108.0	92.6	95.0	97.4	100.1	102.7	105.1	107.5
4.0	1	0.040	95.3	99.5	107.8	112.0	95.8	98.3	100.9	103.7	106.5	109.0	111.5
4.5	1	0.041	98.4	102.8	111.6	115.9	98.9	101.6	104.2	107.2	110.1	112.8	115.4
5.0	1	0.042	101.3	105.9	115.1	119.7	101.9	104.6	107.4	110.5	113.6	116.4	119.2
5.5	1	0.042	104.2	109.0	118.6	123.4	104.7	107.6	110.5	113.8	117.0	120.0	122.9
6.0	1	0.043	107.0	112.0	122.0	127.0	107.6	110.6	113.6	117.0	120.4	123.4	126.4
Weight (kg)													
3.0	−1.211	0.129	11.6	12.9	16.7	19.8	11.7	12.5	13.4	14.5	15.9	17.5	19.4
3.5	−1.202	0.135	12.3	13.7	18.0	21.6	12.4	13.3	14.3	15.5	17.1	18.9	21.1
4.0	−1.192	0.141	13.0	14.5	19.3	23.4	13.2	14.1	15.1	16.6	18.3	20.3	22.8
4.5	−1.182	0.147	13.7	15.4	20.7	25.3	13.9	14.9	16.0	17.6	19.6	21.8	24.6
5.0	−1.170	0.153	14.4	16.2	22.1	27.3	14.6	15.6	16.9	18.7	20.8	23.3	26.5
5.5	−1.157	0.158	15.1	17.1	23.5	29.3	15.3	16.5	17.9	19.8	22.2	24.9	28.5
6.0	−1.142	0.164	15.9	18.0	25.1	31.6	16.1	17.4	18.9	21.0	23.6	26.6	30.6
BMI (kg/m^2)													
3.0	−2.094	0.085	13.5	14.4	17.1	19.2	13.6	14.1	14.8	15.6	16.6	17.6	18.9
3.5	−2.054	0.090	13.3	14.3	17.2	19.5	13.4	14.0	14.7	15.5	16.6	17.7	19.1
4.0	−2.013	0.095	13.2	14.2	17.2	19.7	13.3	13.9	14.6	15.5	16.6	17.8	19.3
4.5	−1.973	0.100	13.1	14.1	17.3	20.0	13.2	13.8	14.5	15.5	16.6	17.9	19.6
5.0	−1.933	0.105	12.9	14.0	17.4	20.2	13.1	13.7	14.4	15.4	16.7	18.1	19.8
5.5	−1.894	0.110	12.9	14.0	17.5	20.6	13.0	13.6	14.4	15.5	16.7	18.2	20.1
6.0	−1.857	0.115	12.8	14.0	17.6	20.9	12.9	13.6	14.4	15.5	16.9	18.4	20.5

Table 4 Polish 2012 weight-for-height (in kg) references for preschool boys and girls

Height (cm)	L	S	−2 SD	−1 SD	+1 SD	+2 SD	P3	P10	P25	P50: M (median)	P75	P90	P97
Boys													
90	−2.591	0.073	10.9	11.6	13.4	14.9	11.0	11.4	11.8	12.4	13.0	13.8	14.7
95	−2.549	0.078	12.3	13.1	15.3	17.1	12.4	12.8	13.3	14.0	14.8	15.7	16.8
100	−2.509	0.083	13.6	14.4	17.1	19.3	13.7	14.2	14.8	15.6	16.5	17.6	19.0
105	−2.469	0.088	14.8	15.8	18.8	21.5	14.9	15.5	16.1	17.1	18.2	19.5	21.1
110	−2.428	0.093	16.0	17.1	20.7	23.8	16.1	16.8	17.6	18.6	19.9	21.4	23.3
115	−2.381	0.098	17.3	18.6	22.8	26.5	17.5	18.2	19.1	20.3	21.9	23.6	25.9
120	−2.326	0.104	18.9	20.4	25.2	29.8	19.0	19.9	20.9	22.4	24.1	26.3	29.1
125	−2.262	0.112	20.5	22.3	28.0	33.6	20.7	21.7	23.0	24.6	26.7	29.3	32.7
Girls													
90	−1.648	0.079	10.9	11.7	13.7	15.1	11.0	11.5	12.0	12.6	13.3	14.1	14.9
95	−1.674	0.084	12.0	12.9	15.3	17.0	12.1	12.6	13.2	13.9	14.8	15.7	16.7
100	−1.703	0.089	13.2	14.2	17.0	19.0	13.3	13.9	14.5	15.4	16.4	17.5	18.8
105	−1.732	0.095	14.4	15.5	18.8	21.4	14.5	15.2	16.0	17.0	18.2	19.5	21.0
110	−1.756	0.101	15.7	17.0	20.8	23.9	15.8	16.6	17.4	18.6	20.0	21.5	23.4
115	−1.773	0.107	17.0	18.4	22.9	26.5	17.1	18.0	19.0	20.3	21.9	23.8	26.0
120	−1.790	0.112	18.4	20.1	25.3	29.7	18.6	19.6	20.7	22.3	24.2	26.3	29.1
125	−1.792	0.118	20.1	22.0	28.0	33.3	20.3	21.4	22.7	24.5	26.7	29.2	32.6

Polish 2012 growth references comparison with the WHO growth standards/references and current German height references

The shape of compared height percentile curves is similar. In the case of boys, the third, 50th, and 97th height percentiles of new Polish and German references overlap almost completely, whereas the WHO growth standard/reference percentiles are systematically lower (Fig. 1). In the case of girls, comparison between the new Polish and German height references showed conformity on the third and 50th percentile, whereas body height values of the WHO standards/references are shorter. The differences among height percentiles are smaller on the 97th percentile in all three, compared references, in the age range 3−5 years (Fig. 1). The 2012 Polish boys +2 and +1 BMI *z* score was consistently higher: 1−2.8 and 0.2−1 units, respectively, compared to the WHO BMI standards/references. In the case of girls BMI references the differences yielded: 0.8−1.7 and 0.3−0.6 units, respectively, for +2 SD and +1 SD. In the case of median and −1 SD, and −2 SD, the differences between Polish and the WHO BMI references were not exceeding 0.4 unit (Fig. 2).

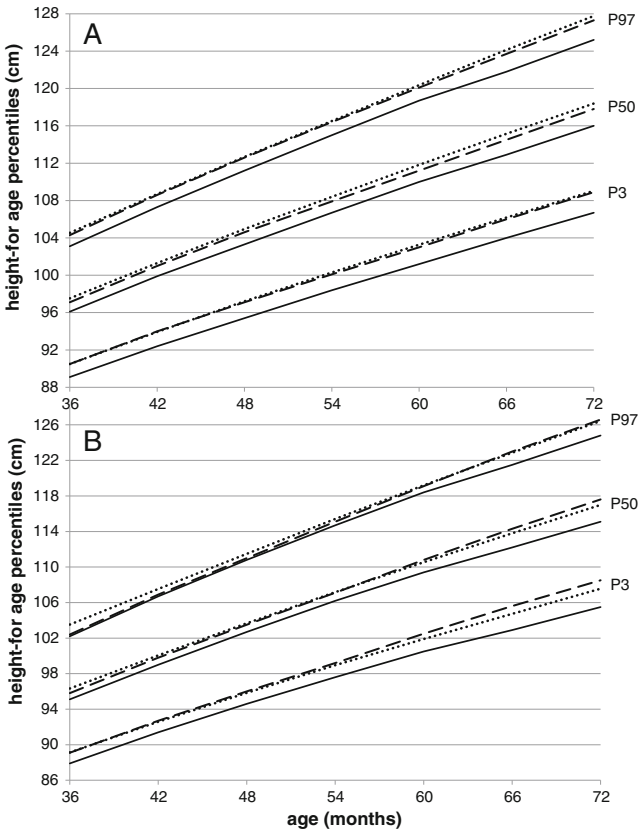

Fig. 1 Height-for-age percentiles (P3; P50; P97): Polish 2012 (*dotted line*), German (*dashed line*), and the WHO height standards/references (*solid line*) for boys (**a**) and girls (**b**)

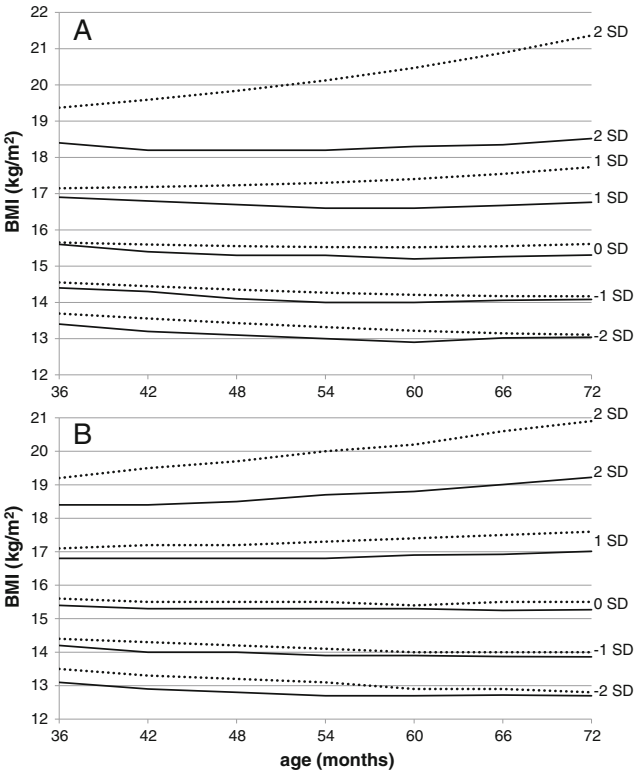

Fig. 2 BMI z-scores of Polish 2012 growth references for preschool children (*dotted line*) compared to the WHO growth standards/references (*solid line*) for boys (**a**) and girls (**b**)

Polish children aged 3−6 years from a for the nation representative sample, had significantly greater than zero mean *z* scores of height-, weight-, and BMI-for-age and weight-for-height, relative to the WHO growth standards/-references (Table 5). The proportion of children in the sample who were exclusively breastfed for at least 4 months was 41 %. In the subsample of children exclusively breastfed, mean HAZ, WAZ, WHZ, and BMIZ, calculated relative to the WHO growth standards/references, were generally greater than zero and similar to the mean *z* score in the total sample (Table 5); however, the 95 % CI included "0" in the case of WHZ in 5-year-old boys, WHZ and BMIZ in the case of 5-year-old girls and BMIZ in the case of 6-year-old girls, meaning that the difference is not statistically significant at the level of 5 %. In the OLA study sample, the prevalence of stunting according to the WHO growth standards/references was 0.45 and 0.84 %, boys and girls, respectively, whereas the prevalence of stunting according to the Polish 2012 height references was 1.97 and 1.84 %, boys and girls, respectively. The corresponding percentage of HAZ>+2 SD was 5.80 and 4.04 % compared to the 2.47 and 2.40 %, respectively. Differences in prevalence of stunting and percentage of HAZ>+2 SD between two compared references were statistically significant, both in the case of boys and girls ($p<0.001$).

Table 5 Polish preschool children mean and 95 % CIs of *z* scores of height, weight, and BMI relative to the WHO growth standards [24] and references [8]: total sample and children exclusively breastfed for 4 months

Age (years)	Variable	Total sample		Exclusive breastfeeding for 4 months		
		Mean (SD)	95 % CI	*N* (% in the sample)	Mean (SD)	95 % CI
Boys						
3	HAZ	0.40 (1.01)	0.32–0.48	233 (39.2 %)	0.36 (0.99)	0.23–0.49
	WAZ	0.44 (1.14)	0.35–0.54		0.40 (1.06)	0.26–0.53
	WHZ	0.32 (1.13)	0.22–0.41		0.27 (1.05)	0.14–0.40
	BMIZ	0.25 (1.14)	0.16–0.34		0.22 (1.05)	0.08–0.35
4	HAZ	0.39 (0.99)	0.32–0.47	273 (41.0 %)	0.37 (1.00)	0.25–0.49
	WAZ	0.45 (1.09)	0.37–0.54		0.43 (1.05)	0.31–0.56
	WHZ	0.30 (1.15)	0.21–0.39		0.29 (1.06)	0.16–0.41
	BMIZ	0.31 (1.20)	0.22–0.40		0.30 (1.11)	0.17–0.43
5	HAZ	0.41 (0.96)	0.33–0.48	268 (43.6 %)	0.41 (0.92)	0.30–0.52
	WAZ	0.43 (1.14)	0.34–0.52		0.42 (1.12)	0.28–0.55
	WHZ	0.12 (1.09)	0.00–0.23		0.13 (1.04)	−0.04–0.30
	BMIZ	0.25 (1.22)	0.15–0.35		0.22 (1.21)	0.08–0.37
6[a]	HAZ	0.48 (1.07)	0.39–0.57	232 (41.4 %)	0.48 (1.06)	0.34–0.61
	WAZ	0.49 (1.27)	0.38–0.59		0.48 (1.15)	0.33–0.63
	BMIZ	0.25 (1.30)	0.14–0.36		0.25 (1.13)	0.10–0.40
Girls						
3	HAZ	0.33 (1.01)	0.25–0.41	218 (37.5 %)	0.44 (1.00)	0.31–0.57
	WAZ	0.40 (0.99)	0.32–0.48		0.49 (0.94)	0.36–0.61
	WHZ	0.30 (0.99)	0.22–0.38		0.34 (0.94)	0.22–0.47
	BMIZ	0.28 (1.01)	0.20–0.36		0.31 (0.98)	0.18–0.44
4	HAZ	0.22 (0.95)	0.15–0.29	278 (40.2 %)	0.17 (0.91)	0.06–0.27
	WAZ	0.31 (1.07)	0.23–0.39		0.26 (0.94)	0.15–0.37
	WHZ	0.28 (1.11)	0.19–0.36		0.25 (0.91)	0.15–0.36
	BMIZ	0.27 (1.12)	0.19–0.36		0.24 (0.91)	0.13–0.35
5	HAZ	0.27 (0.98)	0.19–0.34	268 (40.7 %)	0.30 (0.97)	0.18–0.41
	WAZ	0.25 (1.07)	0.17–0.33		0.26 (1.05)	0.13–0.38
	WHZ	0.05 (0.98)	−0.04–0.15		0.00 (0.94)	−0.15–0.14
	BMIZ	0.14 (1.08)	0.05–0.22		0.11 (1.07)	−0.02–0.24
6[a]	HAZ	0.38 (1.00)	0.30–0.47	241 (42.1 %)	0.35 (0.98)	0.23–0.48
	WAZ	0.34 (1.13)	0.24–0.43		0.32 (1.13)	0.17–0.46
	BMIZ	0.15 (1.15)	0.05–0.24		0.14 (1.12)	−0.01–0.28

SD standard deviation, *CI* confidence interval of the mean

[a]For children older than 1,856 days of age WHZ is not available

Discussion

This paper provides for the first time growth references for Polish preschool children based upon a contemporary, cross-sectional, nationally representative sample. The state-of-the-art statistical methodology was employed to develop the references. Although we excluded data from children with known disorders affecting growth for growth references elaboration, the presented standard deviation scores and percentiles should be considered as a growth references (not a growth standards according to the WHO terminology [24]), because we did not identify environmental conditions "likely to favor the achievement of children's full genetic growth potential" [24].

In this paper, we present weight-for-height references, which are particularly useful in assessing a nutritional status of patients and in screening both underweight and overweight in children. The weight-for-height and BMI-for-age have similar characteristics with regard to the detection of underweight or overweight in children [17]. The advantage of using weight-for-height is that it provides quick assessment of the nutritional status without the need to perform any calculations for estimation of underweight, normal, or overweight. Therefore the weight-for-height is preferred by some practitioners.

The height, weight, and BMI of Polish children from the OLA study differ significantly from growth reference developed by the WHO. It is yet another evidence for using

local, population-specific references of anthropometric traits [2]. According to the results of the OLA study, using universal referential values may lead to missed diagnosis of delayed growth or to erroneous diagnosis of accelerated growth. The comparison of our normative data with referential values published by the WHO showed that number of children diagnosed with stunting (height-for-age below −2 SD) was significantly lower than expected and number of children with height-for-age above +2 SD was significantly higher than expected. Therefore, some of children with delayed growth could be falsely diagnosed as healthy whereas number of children with tall stature would be higher using international growth standards. Adoption of the WHO growth standards may lead to uncertainty as regard referral criteria and variations in general practitioners' referral rates. It may also influence specialized pediatric clinical care since, for example, in Poland comparison of individual child's height to the height references is required entry criterion to the treatment with growth hormone (height below third percentile for age, equivalent of −1.88 SD) [7]. Using ethnic and geographically specific growth charts in children is especially important in the era of migration and globalization. The findings of the OLA study are consistent with results of Belgian and Norwegian children analysis with regard to the age-adjusted prevalence of height below −2 SD [14] and UK data with regard to the BW, WAZ, and BMIZ comparison to the WHO growth standards [26].

The MGRS sample consisted of children exclusively breastfed for at least 4 months. In Poland breastfeeding is recommended, however less than 50 % of infants are exclusively breastfed for 4−6 months [6, 25]. In the representative sample of preschool children of the OLA study, 41 % of parents reported exclusive breastfeeding for 4 months. This subsample of children does not substantially differ with regard to the height, weight, and BMI at ages 3−6 years, compared to the total sample, consisting of majority (59 %) non-exclusively breastfed during infancy, children. The growth pattern of breastfed children in the OLA study was more alike national references than the WHO standards which is in line with findings of Belgian and Norwegian researchers [14].

Childhood overweight and obesity is a global problem reaching epidemic proportions [13]. Unlike for the adult population, there is no uniform definition for overweight and obese children. It is generally agreed that adiposity in childhood is measured as BMI [1, 12]. However, since there is no clinically defined, health-risk-related cut-off levels for increased BMI in childhood, population-based distributions of BMI are used for this purpose. The differences presented with regard to the OLA study sample and the MGRS BMI distribution indicate shift of the upper tail of BMI distribution in Polish children compared to the universal sample. However, it is worth noting that the values defined by +1 SD curve of BMI distribution of the OLA study are more close to the International Obesity Task Force (IOTF) overweight cut-off points [4], whereas corresponding values of the WHO growth standards are lower. Decision on adopting any specific BMI reference would affect rates of overweight in children: higher in the case of the WHO growth standards and lower in the case of IOTF and the OLA study reference.

Concluding, we present growth references for Polish preschool children based on analysis of data obtained from representative sample of children aged 3−6 years. We found significant differences in growth traits between country-specific and universal growth references published by the WHO. These differences should be taken into consideration when the references are applied. The OLA study growth references can be recommended as national references for preschool children.

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