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Body mass index trend as a new parameter for evaluating children's nutritional status

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ABSTRACT

Objectives: The objective was to identify a body mass index (BMI) trend as a new indicator and predictor of children's nutritional status, replacing absolute BMI, and to demonstrate that a local BMI trend is more appropriate for this purpose than a national (or international) BMI trend.
Study design: An entire school year group of primary school children were subject to a longitudinal 8-year cohort study.
Methods: BMI was measured three times during primary school education—on enrolment to primary school, then in the fifth and eighth grades. The BMI values obtained were used to create gender- and age-based percentile curves for children born in 1998/1999 (Osijek Percentile Curves (OPC) study) in the Osijek-Baranja County, Croatia. Every BMI result obtained was linked to one of the five percentile ranks (PRs) according to threshold percentiles 3, 10, 90 and 97; hence, the PRs were <3, ≥3 to <10, ≥10 to <90, ≥90 to <97 and ≥ 97. Percentiles and PRs were specified for each BMI value in a dual fashion, i.e. according to OPC and the entire Croatian territory (Croatian Percentile Curves (CROPC)-2008) cross-sectional study. After integrating the BMI values at all three time points, two BMI trends appeared—one based on the OPC criteria and one based on the CROPC-2008 criteria. Individual trends were grouped into three descriptive BMI categories: 'healthy', 'at risk' and 'unhealthy'.
Results: For the OPC and CROPC-2008, the 'healthy' trend characterised 2097 (78.72%) and 1975 (74.14%) children, respectively; the 'at risk' trend marked 434 (16.29%) and 458 (17.19%) children, respectively; and the 'unhealthy' trend was found in 133 (4.99%) and 231 (8.67%) children, respectively. The biggest difference between the OPC-based and CROPC-2008 –based results was detected in the 'unhealthy' trend. According to CROPC-2008, there were almost twice as many children in that category. For the purpose of study design and comparing results obtained based on OPC and those obtained based on CROPC-2008, the BMI of one boy was used. His BMI values on starting primary school, in the 5th and in the 8th grades were 19.05 kg/m^2, 26.11 kg/m^2 and 27.11 kg/m^2, respectively. Analysis of PRs based on OPC and CROPC-2008 reveals that the same boy was represented by different trends: '<90 <90 <97' and '<90 <97 <97', respectively. In terms of residence, girls from urban areas have higher BMI values than rural girls when starting primary school.
Conclusion: This study suggests that a BMI trend could be a better indicator and predictor of children's nutritional status than absolute BMI. In addition, a cohort study is preferential to

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a cross-sectional study as a trend in an OPC-based study can be personalised. Also, local BMI reference values defined for each generation of children are more advantageous in this context than national BMI reference values.

Introduction

Overweight and obesity, and the resulting consequences, are an increasing worldwide problem; therefore, it is important to understand the trends seen in children who demonstrate excess weight or high to normal weight status.[1,2] The risk of health deterioration due to excess weight has existed for years in developed countries, while in low- and middle-income countries, it has been present alongside the burden of underweight.[3,4] Although the respective trends are rising worldwide, in some countries, such as the USA, we are witnessing a plateau in the overall prevalence of childhood obesity, but the prevalence of severe obesity in children aged 2–19 years continues to rise rapidly.[5]

There are various factors affecting the nutritional status of children, which range from eating habits and physical activity, to genetics, epigenetics, puberty, socio-economic factors,[6] diseases and other factors.[5,7]

The most frequently used measure for assessing the weight status of children or adults is body mass index (BMI). The BMI ranges for adults are constant. An individual is considered to be underweight if the BMI ranges from 15 to 19.9 kg/m^2, normal weight if the BMI stretches from 20 to 24.9 kg/m^2, overweight if the BMI extends from 25 to 29.9 kg/m^2 and obese if the BMI is 30 kg/m^2 or greater.[1,8–10] However, assessment of the nutritional status of children is based on BMI distributions in a reference population because there are no optimal BMI levels for health, like in adulthood, and fixed thresholds could be misleading.[1,6,8,11] Also, the age and sex of a child needs to be considered because there are differences between male and female growth patterns.[1,2,6,8,11] A reference population from which thresholds are usually derived is known as a child growth reference. Recognising the need for uniform growth curves for school children, the World Health Organisation (WHO), National Centre for Health Statistics/WHO, International Obesity Task Force (IOTF) and Centre for Disease Control (CDC) and others formulate different child growth references.[8,11–14] The prevalence of overweight and obesity is usually higher when estimated by means of the WHO classification than when it is assessed using IOTF and CDC criteria.[11] These differences in prevalence result from the use of different thresholds of BMI and the difficult use of standardised BMI values (Table 1).[8,14–17]

The first cross-sectional anthropometric study of Croatian school children was conducted in 1973 and comprised children aged 7–19 years.[18] The second study of this kind was performed between 1980 and 1984 and involved children aged 6–19 years.[19] The third study resulted from the secular trend and a need for updating percentile curves and was carried out between 2006 and 2008.[12] The most recent Croatian growth charts for children aged 6.5–18.5 years were drawn up in 2012 and are still in use in Croatia today.[12]

BMI, expressed as a value on a percentile curve, is one of the measures and predictors of healthy growth. It can be obtained from cross-sectional studies, but such studies may not be convenient for assessing the nutritional status. On the positive side, BMI measurement is very practical, cheap and simple. It is also believed to be useful for younger children, as well as for estimating the degree of undernutrition or overnutrition.[19,20] However, it cannot distinguish between lean and fat mass and provides no information about body fat distribution. BMI shows poorer diagnostic performance in some minority groups, including those of South Asian, African

Table 1 – Differences in absolute body mass index (BMI) on particular percentiles between boys and girls aged 84 months, according to various BMI data sources.

Data source (reference)	Year	BMI absolute value (kg/m^2)							
		Boys percentile				Girls percentile			
		85th	90th	95th	97th	85th	90th	95th	97th
CROPC[25]	1973		18.93[a]		22.33[b]		17.79[a]		18.89[b]
NCHS[11]	1977		16.72	17.91			16.82	17.70	
CDC[9]	2000	17.40[a]	18.02[a]	19.15[b]		17.63[a]	18.35[a]	19.68[b]	
IOTF[10]	2000		17.92[a]				17.75[a]		
WHO[12]	2007	17.10[a]		18.30[a]	18.80[b]	17.40[a]		18.80[a]	19.40[b]
CROPC[7]	2008		20.17[a]		23.60[b]		19.94[a]		22.99[b]
OPC	2013	18.35	19.14[a]	20.72[a]	22.44[b]	18.45	19.30[a]	20.91[a]	22.08[b]

CDC, Centre for Disease Control, USA; CROPC, Croatian Percentile Curves; IOTF, International Obesity Task Force; NCHS, National Centre for Health Statistics; OPC, Osijek Percentile Curves; WHO, World Health Organisation.

[a] Overweight.

[b] Obese.

Table 2 – Percentile rank code, rank range and description.

Rank number	Rank code	Rank range	Rank description
1	<3	<3	Unhealthy
2	<10	≥3 to <10	At risk
3	<90	≥10 to <90	Healthy
4	<97	≥90 to <97	At risk
5	≥97	≥97	Unhealthy

or Caribbean heritage.[19,21,22] Furthermore, BMI as a fixed value on a percentile curve specified in earlier research is likely to change regarding the same percentile and the same population in future research. The bigger the time gap between two measurements, the bigger the change. Two studies conducted on the entire Croatian territory can serve as an example in this context. The first study, which was performed in 1973 (CROPC-1973),[23] showed a BMI value of 18.93 kg/m^2 on the 90th percentile for boys aged 84 months, which led to an 'overweight' classification. Within the framework of CROPC-2008,[12] the same BMI value was placed on the 86th percentile, which implied 'normal' weight, while on the 90th percentile, BMI was 20.17 kg/m^2 (Table 1). Other methods for assessment of the nutritional status of children include weight and length/height for age, weight for height, leg length, mid-upper arm circumference and head circumference.

Concerning the aforementioned flaws and advantages of absolute BMI, this study attempts to utilise the same parameter in a different way. Accordingly, the primary aim of this study was to determine the dynamics of a BMI change in the form of a BMI trend. The secondary goal is to determine differences between BMI percentile ranks (PRs) and BMI trends with respect to OPC and CROPC-2008. Finally, the study also aimed to analyse the difference in BMI trends between boys and girls.

Methods

Study design and sample

The study design refers to a retrospective cohort study carried out in the Osijek-Baranja County, Croatia. The medical teams involved were composed of employees of the Institute of Public Health (IPH), which is responsible for the health of all school children in this county. The anthropometric data were collected by routine periodic systematic examination. The IPH provided the necessary ethical approval. The study took advantage of anonymised data in compliance with the approval of the IPH Ethical Committee; therefore, there was no need for written consent from the parents of children involved.

The study was performed in 2014 and included the entire school year cohort of school children born between 1 April 1998 and 31 March 1999. Primary school in Croatia lasts 8 years. One of the criteria for enrolment in the study is that a child is born between the aforementioned dates. When the study was launched, the entire cohort of children born in 1998/1999 consisted of 2936 individuals: 272 (9.3%) pupils were excluded from the final analysis due to incomplete data. In the end, 2664 of 2936 (90.7%) school children were examined. Of 2664 children, there were 1307 (49.1%) boys and 1357 (50.9%) girls. The age of study subjects was calculated as the difference between the date of birth and the date of physical examination. With respect to school location, there were 284 (48.2%) children attending school in rural areas and 1380 (51.8%) children attending school in towns.

Anthropometric data

Anthropometric data were collected by school medical teams (physicians and nurses) and processed at three time points during the 8-year primary school education as follows:

Table 3 – Osijek percentile ranks for body mass index (kg/m^2) in school children from the Osijek-Baranja County at elementary school enrolment, 5th and 8th class.

Percentile rank	Boys			Girls		
	Enrolment	5th class	8th class	Enrolment	5th class	8th class
	Urban + rural settlements (1307 [49.1%])			Urban + rural settlements (1357 [550.9%])		
<3	<13.3	<14.42	<15.7	<12.81	<14.3	<15.88
≥3 to <10	≥13.31 to <14.06	≥14.43 to <15.43	≥15.71 to <16.87	≥12.82 to <13.69	≥14.31 to <15.37	≥15.89 to <17.33
≥10 to <90	≥14.07 to <19.13	≥15.44 to <25.29	≥16.88 to <26.91	≥13.7 to <19.42	≥15.38 to <24.6	≥17.34 to <26.12
≥90 to <97	≥19.14 to <22.43	≥25.3 to <28.2	≥26.92 to <30.55	≥19.43 to <22.07	≥24.61 to <28.14	≥26.13 to <30.14
≥97	≥22.44	≥28.21	≥30.56	≥22.08	≥28.15	≥30.15
	Urban settlements (629 [49.0%])			Urban settlements (655 [51.0%])		
<3	<13.4	<14.47	<15.69	<12.76	<14.38	<15.96
≥3 to <10	≥13.41 to <14.11	≥14.48 to <15.5	≥15.7 to <16.72	≥12.77 to <13.85	≥14.39 to <15.55	≥15.97 to <17.36
≥10 to <90	≥14.12 to <19.33	≥15.51 to <25.55	≥16.73 to <26.79	≥13.86 to <19.72	≥15.56 to <24.4	≥17.37 to <25.78
≥90 to <97	≥19.34 to <22.32	≥25.56 to <27.77	≥26.8 to <30.01	≥19.73 to <22.07	≥24.41 to <28.08	≥25.79 to <30.03
≥97	≥22.33	≥27.78	≥30.02	≥22.08	≥28.09	≥30.04
	Rural settlements (678 [49.1%])			Rural settlements (702 [50.9%])		
<3	<13.28	<14.32	<15.66	<12.83	<14.22	<15.7
≥3 to <10	≥13.29 to <13.96	≥14.33 to <15.42	≥15.67 to <16.9	≥12.84 to <13.51	≥14.23 to <15.23	≥15.71 to <17.28
≥10 to <90	≥13.97 to <19.01	≥15.43 to <24.93	≥16.91 to <26.93	≥13.52 to <19.28	≥15.24 to <24.6	≥17.29 to <26.33
≥90 to <97	≥19.02 to <22.43	≥24.94 to <28.62	≥26.94 to <30.76	≥19.29 to <21.83	≥24.61 to <27.53	≥26.34 to <30.23
≥97	≥22.44	≥28.63	≥30.77	≥21.84	≥27.54	≥30.24

Table 4 – Body mass index (BMI) percentile rank forming example.

Example	BMI percentile rank			Descriptive trend pattern	BMI trend description
	1st grade enrolment	5th grade	8th grade		
1	<90	<90	<90	<90<90<90	Maintaining normal BMI – 'healthy'
2	<3	<3	<3	<3<3<3	BMI <3 percentile – 'unhealthy'
3	<90	<10	<10	<90<10<10	Initially normal, later at risk – 'at risk'

1. When undergoing routine examinations on starting primary school (first grade), performed in March and May 2005 for the academic year 2005/2006 (4–5 months before the academic year commencement in September);
2. In the fifth grade (2009) and
3. In the eighth grade (2013).

During routine examinations, the school medical teams collected data on each subject's body weight and height. Children were measured using new and calibrated digital scales and fixed wall-mounted metres while wearing no shoes. Their BMI was calculated based on weight in kg divided by height in m^2.[14] The respective percentile and PRs were determined for each value and used to plot percentile curves. This way, a distribution curve was plotted for each gender, age and place of residence, thus shaping an OPC curve. The effective CROPC-2008 reference data[12] were also applied to the observed BMI data. The observed data were classified according to both OPC and CROPC-2008 curves and then compared.[12] Accordingly, the BMI of a same examinee can be classified in two different PRs, depending on which percentile curve was applied (i.e. OPC or CROPC-2008). For instance, a boy aged 130 months with a BMI of 14.42 kg/m^2 was classified in rank 1 (<3) in OPC categorisation, whereas in line with CROPC-2008 criteria, he was in rank 2 (≥3 to <10) [Table 2].

OPC refers to threshold percentiles for determining a PR, which are in use in Croatia: 3, 10, 90 and 97 (Tables 2 and 3). Percentiles and PRs were specified for each study subject in a dual fashion, i.e. according to OPC and CROPC-2008. Three PRs derived from each of the three measurements for each child constitute an individualised descriptive BMI trend (Tables 2 and 4). Each individualised trend, defined for project purposes, was grouped into three descriptive trends: 'healthy', 'at risk' and 'unhealthy' (Table 5) as follows:

1) 'Healthy' BMI trend—BMI of the child was most frequently in the third PR code (Table 2), between 10th and 90th percentile (≥10 to <90), in all three examinations (Table 4);
2) 'At risk' BMI trend—BMI was most frequently in the second and fourth PR code and
3) 'Unhealthy' BMI trend—BMI was most frequently in the first and fifth PR code.

In unclear cases, the decision was based solely on the third measurement of BMI, carried out in the eighth grade.

Statistical analyses

BMI data were analysed using F-test of two samples for variance and, depending on the result, *t*-test for verifying unequal variances and the coefficient of determination. The Wilcoxon signed-rank test for paired samples was used to determine differences in the number of descriptive trends between those induced based on OPC and those formulated based on CROPC-2008 percentile curves. The data were also processed using a Microsoft Excel (2015) spreadsheet.

Results

According to OPC and CROPC-2008, 75.98% (993/1307) and 72.92% (953/1307) of male children and 81.36% (1104/1357) and 75.31% (1022/1357) of female children maintained a 'healthy' BMI trend throughout the whole study period (Table 6), respectively. With respect to comparison between girls and boys, the OPC categorisation created a 5.38 percentage point difference in favour of female children and the CROPC-2008 classification generated a 2.39 percentage point difference, also in favour of girls. The 'healthy' trend group of OPC was mostly characterised by the <90 < 90<90 trend, which comprised 85.9% (853/993) of male and 78.17% (863/1104) of female children. According to OPC, the 'at risk' BMI trend was

Table 5 – Trend patterns forming the three descriptive BMI trends.

BMI trend		
'Healthy'	'At risk'	'Unhealthy'
<10<10<90	<10<10<10	<10<10<3
<10<3<90	<10<3<10	<10<3<3
<10<90<90	<10<90<10	<10<90<3
<10<97<90	<10<90<97	<3<10<3
<3<10<90	<10<97<97	<3<3<3
<3<3<90	<10≥97<97	<3<90<3
<3<90<90	<3<10<10	<90<10<3
<90<10<90	<3<3<10	<90<3<3
<90<3<90	<3<90<10	<90<90<3
<90<90<90	<3<97<90	<90<90≥97
<90<97<90	<3≥97<97	<90<97≥97
<90≥97<90	<90<10<10	<90≥97≥97
<97<90<10	<90<3<10	<97<90≥97
<97<90<90	<90<90<10	<97<97≥97
<97≥97<90	<90<90<97	<97≥97≥97
≥97<90<90	<90<97<97	≥97<10≥97
	<90≥97<97	≥97<90≥97
	<97<90<97	≥97<97≥97
	<97<97<90	≥97≥97≥97
	<97<97<97	
	<97≥97<97	
	≥97<3<90	
	≥97<3<97	
	≥97<90<97	
	≥97<97<90	
	≥97<97<97	
	≥97≥97<90	
	≥97≥97<97	

detected in 18.52% (242/1307) of boys and 14.15% (192/1357) of girls, whereas the 'unhealthy' BMI trend was found in 5.51% (72/1307) of male and 4.5% (61/1357) of female pupils.

On the occasion of routine examination for enrolment in primary school, the age of children varied more (coefficient of variation [CV] was 4.14 for boys and 4.16 for girls, Table 7) than when they underwent medical examination in the fifth grade (CV was 2.92 for boys and 2.94 for girls) and in the eighth grade (CV was 2.12 for boys and 2.12 for girls). The fact that the medical examinations were performed within just a couple of days accounts for this difference.

According to the place of residence, girls from urban areas who are starting primary school generally have a higher BMI than rural girls ($P = 0.026$), whereas rural boys have a higher BMI than urban boys (Table 9). In the fifth grade, children from towns and rural areas have similar BMI values. In the eighth grade, children from rural areas have a higher BMI than their urban peers. In regard to gender, there is no significant difference in BMI between boys and girls.

For the purpose of interpretation of BMI and BMI trends, the data relating to one boy from this study are utilised in combination with the reference values from two cross-sectional CROPC studies (i.e. CROPC-1973[25] and CROPC-2008[7]) and OPC. The BMI on the occasion of enrolment and in the fifth and eighth grades was 19.05 kg/m^2, 26.11 kg/m^2 and 27.11 kg/m^2, respectively. The boy's BMI was provided with percentiles using the BMI curves from the 1973 CROPC study (regardless of the fact that the child was not even born at that time), 2008 CROPC study and OPC (Table 8). According to CROPC-1973, the BMI values correspond to 92nd, 95th and 98th percentiles when starting primary school and in the fifth and eighth grades, respectively; together, they form a '<97 <97 ≥97' trend. The same indices are, in line with CROPC-2008, placed on 89th, 92nd and 96th percentiles; together, they provide a somewhat different trend of '<90 <97 <97'. When the same indices are subject to OPC (i.e. the population to which the boy actually belongs), a new trend of '<90 <90 <97' is generated. Consequently, the boy can be put in the 'unhealthy' BMI trend group according to CROPC-1973 criteria and in the 'at risk' BMI trend for CROPC-2008 and OPC criteria. Considering only individual indices at the moment of examination (i.e. not as a trend), the same boy can be classified as 'healthy' (<90 percentile), 'overweight' (<97 percentile) and 'obese' (≥97 percentile).

Table 7 – Child's age at the time of examination.

Examination	Age (months)					
	Mean	MIN	MAX	Median	SD	CV
Boys						
Enrolment	79.47	73.12	85.05	79.59	3.29	4.14
5th grade	134.68	125.74	143.54	134.60	3.94	2.92
8th grade	170.91	162.35	179.00	171.06	3.62	2.12
Girls						
Enrolment	79.33	73.08	85.32	79.46	3.30	4.16
5th grade	134.42	125.69	143.90	134.47	3.95	2.94
8th grade	170.75	161.42	178.98	170.78	3.62	2.12

MIN, minimum; MAX, maximum; SD, standard deviation; CV, coefficient of variation.

Discussion

It is estimated that around 20% of children in Europe are obese.[15] Different classifications of BMI (Table 1) result in its obscure interpretations as a consequence of different criteria application.[8,11,14–16] Owing to different ways of measuring and interpreting BMI,[5,8,11–17,22,24] it is important to find a unique mode of its application in order to have a realistic and precise insight into trends characterising individuals or a population. A BMI trend is definitely one of them. BMI trend classified into three groups (i.e. 'healthy', 'at risk' and 'unhealthy') can be used in a study to compare the differences in BMI trends between generations and places. A BMI trend as a descriptive value can be additionally represented, for example, in the form of the coefficient of determination with a trendline

Table 6 – Number and percentage of certain BMI descriptive trends for male and female children and for children from urban and rural settlements according to OPC and CROPC-2008.

Descriptive trend	Both genders (n [%])		Boys (n [%])		Girls (n [%])	
	OPC	CROPC	OPC	CROPC	OPC	CROPC
Urban + rural settlements						
Healthy	2097 (78.72)	1975 (74.14)	993 (75.98)	953 (72.92)	1104 (81.36)	1022 (75.31)
At risk	434 (16.29)	458 (17.19)	242 (18.52)	250 (19.13)	192 (14.15)	208 (15.33)
Unhealthy	133 (4.99)	231 (8.67)	72 (5.51)	104 (7.96)	61 (4.5)	127 (9.36)
Total	2664	2664	1307	1307	1357	1357
Urban settlements						
Healthy	1008 (78.5)	951 (74.07)	469 (74.56)	449 (71.38)	539 (82.29)	502 (76.64)
At risk	218 (16.98)	225 (17.52)	128 (20.35)	131 (20.83)	90 (13.74)	94 (14.35)
Unhealthy	58 (4.52)	108 (8.41)	32 (5.09)	49 (7.79)	26 (3.97)	59 (9.01)
Total	1284	1284	629	629	655	655
Rural settlements						
Healthy	1089 (78.91)	1024 (74.2)	524 (77.29)	504 (74.34)	565 (80.48)	520 (74.07)
At risk	216 (15.65)	233 (16.88)	114 (16.81)	119 (17.55)	102 (14.53)	114 (16.24)
Unhealthy	75 (5.43)	123 (8.91)	40 (5.9)	55 (8.11)	35 (4.99)	68 (9.69)
Total	1380	1380	678	678	702	702

BMI, body mass index OPC, Osijek Percentile Curves; CROPC, Croatian Percentile Curves.

equation. Such an equation could also be the key for comparison with other studies (see Fig. 1).

This study suggests that a BMI trend could be a more useful predictor than absolute BMI and that a cohort study is preferential to a cross-sectional study.[25,26] Individual BMI values observed over a certain period of time generate a BMI trend, regardless of study design. However, in this OPC study, a BMI trend (Table 7) as a new parameter could reveal personalised BMI dynamics of each child, which, together with other participants' trends, could present the trend of a community. This approach is different from the current practice that uses statistical comparison of absolute BMI in relation to a certain time, percentile and age. Considering BMI as a fixed number in different studies, the boy mentioned in Table 7 can belong to the group with normal BMI, the group with increased BMI and the group with high BMI (or be classified as 'healthy', 'overweight' and 'obese'). The same example discloses that the reference values of threshold percentiles for BMI in cross-sectional studies fluctuate over time (Tables 1 and 7). On the other hand, a cohort OPC study, which can also use fixed BMI values for observing BMI at a point in time, provides an individual and entire population with a personalised BMI curve on the occasion of every examination, which is in real time applied to that population. This study performed three examinations over a duration of 8 years. Such an OPC BMI curve is personalised and never outdated and can precisely assess a child's tendency with respect to BMI at a point in time. Although both CROPC studies can generate a BMI trend, such a trend cannot be personalised; however, it is better than interpretation of BMI at a certain point in time. These are crucial differences in BMI interpretation between OPC-based (cohort) and CROPC-based (cross-sectional) studies.

According to OPC criteria, females are, for the most part, characterised by a healthier trend than males, which is seen in a 5.38 percentage point difference (Table 6). According to CROPC-2008 criteria, this difference is 2.39 percentage points. In other words, according to OPC criteria, the interpretative value of the BMI trend is that 81.36% of females and 75.98% of males were in the healthy BMI limits throughout the whole study period; however, according to CROPC-2008 criteria, these figures are 75.31% and 73.92%, respectively. Therefore, the CROPC-2008 criteria seem to be more restrictive as they put more children into a lower or higher PR (<10 and >90 percentiles) than OPC criteria.

Concerning the place of residence, boys living in rural areas (77.29%) are more frequently in the healthy trend than those living in towns (74.56%) [Table 6]. Based on OPC, the difference is 2.73 percentage points, but national criteria reveal different numbers. CROPC-2008 puts 74.34% of rural boys in the healthy trend, while the percentage of urban boys comprised by that trend is 71.38% of (Table 6), which is a 2.96 percentage point difference. The same could be said for the 'at risk' and the 'unhealthy' trends. Here, the emphasis is not on the figures relating to a certain trend but on the difference arising from application of different criteria.

The OPC-based study classifies more rural girls and boys as 'unhealthy' than CROPC-2008. Also, Aberle et al.[27] who conducted a cross-sectional study, claim that there is no difference in the mean BMI between urban and rural areas in Slavonia.[27–29] On the other hand, Degač et al.[30] assert that the obesity in children is particularly evident in towns, which is confirmed by the research from Puharić et al.[28,31] The difference in the results between the aforementioned OPC-based studies (Table 6) can be interpreted as a consequence of the study design.[32,33]

Problems with comparison and interpretation of BMI values exclusively arise from the temporary nature of the reference values used in CROPC-1973, CROPC-2008 and OPC. According to CROPC-1973, CROPC-2008 and OPC,[25] the BMI value on the 90th percentile for a male aged 84 months was 18.93 kg/m^2, 20.17 kg/m^2 and 19.14 kg/m^2, respectively. Those data entail that the BMI of the children involved in both the CROPC-2008 and the OPC study reached and slightly exceeded the 90th percentile when the children were 80 months old (19.90 kg/m^2; i.e. 4 months early) and when they were 82 months old (19.14 kg/m^2; i.e. 2 months early). Therefore, it might be possible to deem different absolute BMIs on the same percentile, obtained from studies conducted at different times, as equal because they are placed on the same percentile (as a consequence of a normal distribution curve and cross-sectional study design). The real difference in the BMI values should be depicted as a trend (Fig. 1). Presented as a trend, BMI values should refer not only to an individual (fixed) value and the corresponding percentile but also to the dynamics of the BMI temporal change, thus, providing a new way of BMI interpretation with added value.

Owing to the cohort design and personalised nature, this study demonstrates that three descriptive trends of one specific child cohort could be better indicators of the nutritional status of children than absolute BMI values at a certain point in time. Thus, one could draw a conclusion for a whole cohort population and avoid the flaws of a cross-sectional study. The predictive value of a BMI trend would be more valuable if the cohort concerned continued to be tracked into adulthood. This way, an evaluation could be carried out of whether certain BMI trends could predict future positive or negative outcomes.[22,34–36]

Table 8 – Data from a study performed on an urban boy, converted into percentiles and percentile ranks and classified according to CROPC-1973, CROPC-2008 and OPC.

Examination	BMI (kg/m^2)	Cross-sectional study, Croatian national reference				Cohort study	
		CROPC-1973 year[25]		CROPC-2008 year[7]		OPC (2005–2013 year)	
		Percentile	BMI rank	Percentile	BMI rank	Percentile	BMI rank
Enrolment	19.05	92	<97	89	<90	88	<90
5th grade	26.11	95	<97	92	<97	89	<90
8th grade	27.11	98	≥97	96	<97	95	<97
BMI trend			<97<97≥97		<90<97<97		<90<90<97

BMI; body mass index OPC, Osijek Percentile Curves; CROPC, Croatian Percentile Curves.

Table 9 – Children's body mass index (kg/m^2) at primary school enrolment, 5th grade and 8th grade; OPC study.

	Urban + rural settlements					Urban settlements					Rural settlements					t-test US-RS
	Median	Mean	SD	SE	Var	CV	Median	Mean	SD	SE	Var	CV	Median	Mean	SD	SE	Var	CV	
Enrolment in elementary school 1st grade																			
Boys	15.90	16.37	2.3421	0.0648	5.4854	14.31	15.94	16.43	2.2959	0.0915	5.2714	13.97	15.88	16.31	2.3842	0.0916	5.6846	14.62	t(1305) = 0.958, P = 0,338
Girls	15.65	16.21	2.4594	0.0668	6.0487	15.17	15.88	16.36	2.5119	0.0981	6.3094	15.35	15.61	16.07	2.4023	0.0907	5.7713	14.95	t(1355) = 2.231, P = 0.026
t-test B-G	t(2662) = 1,724, P = 0,085					t(1282) = 0.527, P = 0.598						t(1378) = 1,897, P = 0.058							
5th grade																			
Boys	18.75	19.61	3.8994	0.1079	15.2056	19.88	18.86	19.69	3.9001	0.1555	15.2104	19.81	18.58	19.54	3.9003	0.1498	15.2121	19.96	t(1305) = 0,716, P = 0,474
Girls	18.60	19.38	3.7901	0.1029	14.3648	19.55	18.57	19.40	3.7397	0.1461	13.9857	19.27	18.63	19.36	3.8390	0.1449	14.7382	19.83	t(1355) = 0,198, P = 0,842
t-test B-G	t(2662) = 1,528, P = 0,126					t(1282) = 1,345, P = 0,179						t(1378) = 0,83, P = 0.406							
8th grade																			
Boys	20.01	21.04	4.0639	0.1124	16.5155	19.32	20.09	20.99	4.0532	0.1616	16.4288	19.31	19.96	21.07	4.0764	0.1566	16.6171	19.34	t(1305) = -0,36, P = 0,718
Girls	20.52	21.32	3.8568	0.1047	14.8751	18.09	20.44	21.19	3.6933	0.1443	13.6402	17.43	20.58	21.44	4.0022	0.1511	16.0177	18.67	t(1355) = -1,201, P = 0,23
t-test B-G	t(2660) = -1,837, P = 0,066					t(1280) = -0,896, P = 0,37						t(1378) = -1,676, P = 0.094							

CV, coefficient of variation; RS, rural settlements; SD, standard deviation; SE, standard error; *t*-test B-G, difference between boys and girls; *t*-test US-RS, significant difference between urban and rural boys or girls; US, urban settlements; Var, variance.

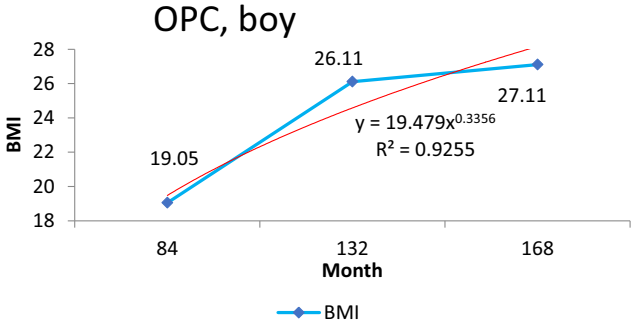

Fig. 1 – The coefficient of determination for the individual boy selected from the study. BMI, body mass index (kg/m^2); OPC, Osijek Percentile Curves Red line, trend line.

Limitations

The study elaborates BMI as one of the indicators of the nutritional status. Therefore, it considers neither the parameters having the same impact as BMI nor those directly influencing the nutritional status of children. More precise assessment of a BMI trend requires monitoring of several generations of school children. Criteria for classification of individual trends and their grouping in one of the three descriptive trends may be differently defined.

Conclusions

When it comes to assessment of the nutritional status of school children and prediction of its future development, presentation of a BMI trend (as a new and personalised parameter), cohort study design and comparison of the BMI trends of the same or different generations appear to be a better choice than absolute BMI measurements, a cross-sectional study and comparison of BMI trends with some national or international reference values. A BMI trend portrays BMI both as an absolute value and particular category (e.g. obesity) at a certain point in time. There is also a personalised BMI trend derived from a BMI change over time, and it is a better predictor in this context than absolute BMI. Using such a trend, risk groups can be precisely defined and appropriate interventions can be prepared. The study also highlights that it is better to use local BMI reference values defined for each generation of children than to apply national BMI reference values specified some years ago (which no longer show the real picture).

Author statements

Ethical approval

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Competing interests

None declared.

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