Differences in body height between the contemporary Western Balkan children and the WHO growth references core sample

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Abstract
Body height is the most commonly used anthropometric measure for the assessment and classification of somatic status and growth. The World Health Organization constructed various growth references intended for global use that are directly derived or indirectly affected by body height, but the WHO core sample is based on country-specific, relatively

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small, and temporally distant reference samples from the Health Examination Survey Cycle II (1963-65) and the Health and Nutrition Examination Survey Cycle I (1971-75). This paper aimed to assess whether the body height of the contemporary 7- to 8-year-olds from the Western Balkans is similar to the body height of their peers from the reference core sample. We utilised the 2017 data from the Western Balkans for comparison, and the analysis showed that contemporary children from this region are more than 4 cm taller from their peers from the core reference sample. The 50^{th} percentile of body height in the Western Balkan sample exceeds the 75^{th} percentile of the core reference sample, which shows that the two populations are quite distinct. The WHO references should, therefore, be used with caution for growth assessment in children from the Western Balkans.

KEYWORDS: stature, children, Balkans, growth references, misclassification

Introduction

The existing studies of body height in the Western Balkans suggest that the populations from the region are among the tallest populations in the world (Bjelica, Popović, Kezunović, Petković, Jurak & Grasgruber 2012; Popovic, Bjelica, Molnar, Jaksic & Akpinar 2013; Popovic, Bjelica, Tanase & Milasinovic 2015; Popovic 2017). Since Serbia, Montenegro, North Macedonia, Croatia, and Slovenia share common history partly from Austro-Hungarian Monarchy, partly from the Kingdom of Yugoslavia, and finally from the Socialist Federative Republic of Yugoslavia, which broke apart in 1991, these populations share a similar ethnic background and are relatively homogenous and comparable due to constant internal migrations of population within this region (Sarajlić, Resić, Gradaščević, Salihbegović, Balažic & Zupanc 2014). The adult population from the Balkans obviously differs from other European populations in body height, and the existing evidence also shows that the formulae for estimation of adult stature, which are based on American datasets, systematically underestimate stature in the Balkans (Ross & Konigsberg 2002).

There is, however, a lack of recent studies on nationally representative samples that analyse the body height of preadolescent children from the region and could provide new information regarding the changes in children's development after profound socio-economic changes, following the constitution of independent states in the post-Yugoslav period. Since body height is one of the dimensions used for the calculation of Body Mass Index (BMI), which is the most frequently used indicator of nutritional status, this study aims to establish whether the body height of contemporary preadolescent children from the Balkans differs from the body height of the core samples used in the construction of the World Health Organization's (WHO) growth references (de Onis, Onyango, Borghi, Siyam, Nishida & Siekmann 2007) as the most common globally used growth standards (De Onis, Onyango, Borghi, Siyam, Blössner & Lutter 2012).

Problems of (mis)classification

De Onis and Lobstein, as co-authors of the most commonly used BMI growth curves (de Onis, Onyango, Borghi, Siyam, Nishida & Siekmann 2007; Cole & Lobstein 2012), have already noted that the IOTF BMI-based reference for overweight and obesity is not appropriate for clinical use and should be utilised merely as epidemiological indicator (De Onis & Lobstein 2010). However, the WHO standards have been suggested to be applicable also in clinical use for assessment of an individual child's growth (de Onis, Onyango, Borghi, Siyam, Nishida & Siekmann 2007) in regard of BMI, height and weight. It is, therefore, essential that the morphological characteristics and growth patterns of the reference core sample are as universal as possible and as similar to the average child's characteristics as possible.

Any somatic development classification tool relies on three prior selections: an anthropometric indicator, a reference population with which to compare a characteristic of a child or community, and cut-off points that best identify individuals (De Onis & Lobstein 2010). In this paper, we will not problematise the anthropometric indicators, used in the WHO growth curves, but will attempt to establish whether the body height of the reference population and the derived cut-off points of these growth curves correspond to the body height of the contemporary population of children from the Balkans.

Since changes in body height are inevitably linked to changes in body weight and if the body height of certain population of children differs from body height of the WHO reference core samples, the use of the WHO growth curves (height-for-age, weight-for-age, BMI-for-age) becomes unreliable and can cause a large part of the population to be considered too tall or too heavy for their age or to have excess weight or obesity.

The problems of the unreliable performance of the existing WHO growth curves with different national populations worldwide have already been shown in the cases in which the researchers constructed national growth references of either BMI-, weight- or height-for-age curves (Ma, Wang, Song, Hu & Zhang 2010; Júlíusson, Roelants, Hoppenbrouwers, Hauspie & Bjerknes 2011; Kanwar, Sabharwal, Bhadra & Narang 2011; Schaffrath Rosario, Schienkiewitz & Neuhauser 2011; Kułaga et al. 2013; Tinggaard et al. 2014; Keke et al. 2015; Neyzi et al. 2015; Orden & Apezteguía 2016; Inokuchi, Matsuo, Takayama & Hasegawa 2018; Kim et al. 2018; Nyankovskyy et al. 2018; Smpokos, Linardakis, Taliouri & Kafatos 2019) using similar methodology as the WHO (de Onis, Onyango, Borghi, Siyam, Nishida & Siekmann 2007). However, none of the existing research studies compared the actual physical characteristics of the WHO core samples to the physical characteristics of their national samples to observe the actual extent of differences in raw body height or other somatic dimensions.

On the methods

Sample

The analysis utilises nationally representative data of 7- and 8-year-olds from Croatia (HRV), Montenegro (MNE), North Macedonia (MKD), Slovenia (SVN) and Serbia (SRB) which were sampled according to the protocol of the WHO European Childhood Obesity Surveillance Initiative (COSI)[1] in 2016/17 (Wijnhoven et al. 2014). The primary sampling

[1] The WHO COSI is a system that has been measuring trends in overweight and obesity among primary school aged children in Europe since 2007. It currently includes over 40 member states of the WHO European Region.

unit was school and the secondary was class. The analysed dataset includes children with informed consent and complete information on age, sex and height. Children were excluded from the final dataset if their age did not fall within the targeted age groups.

To compare the Western Balkan data to the WHO core sample that was used for the construction of the growth reference for school-aged children and adolescents (de Onis, Onyango, Borghi, Siyam, Nishida & Siekmann 2007), we extracted the data for 7- and 8-year-olds from the USA from the Health Examination Survey (HES II) Cycle II (1963-65)[2] and the Health and Nutrition Examination Survey (HANES I) Cycle I (1971-75)[3] datasets. The extracted data included the date of measurement (month and year of birth) expressed as mid-month date and year, sex, and height.

Chronological age in months in the Western Balkan and WHO samples was calculated using the formula: date of measurement minus date of birth expressed in months, truncated to an integer. Chronological age in years was calculated as age in month/12, truncated to an integer.

The Western Balkan sample included 16,798 boys and 16,170 girls, while the WHO samples included 1,568 boys and 1,543 girls aged between 87 to 107 months (Figures 1 and 2).

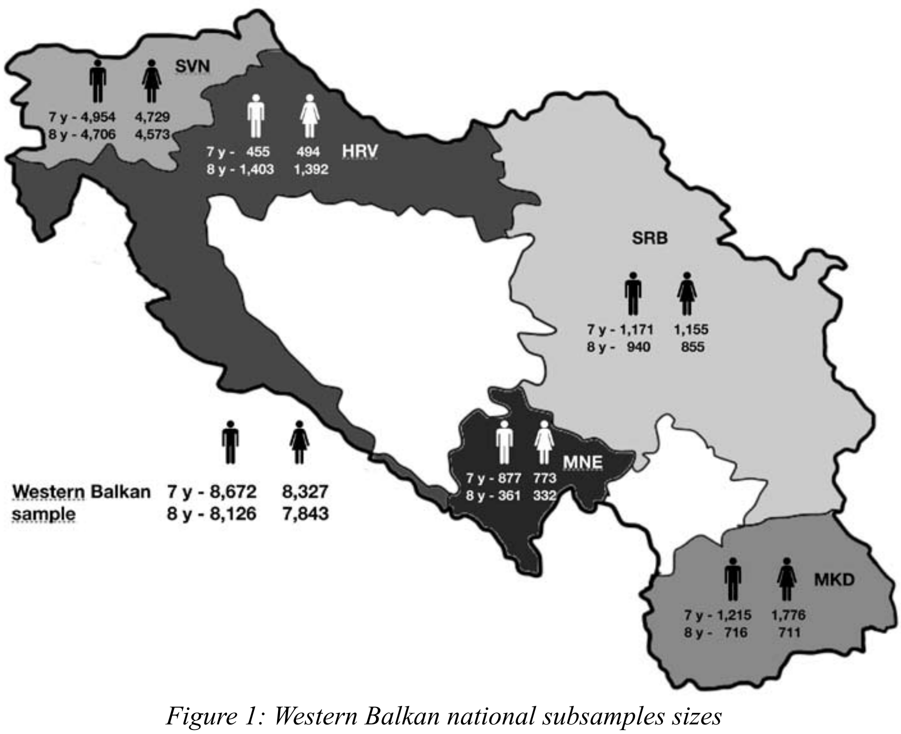

Figure 1: Western Balkan national subsamples sizes

[2] Available on-line: https://wwwn.cdc.gov/nchs/data/nhes123/DU2idt.txt

[3] Available on-line: https://wwwn.cdc.gov/nchs/data/nhanes1/DU4111.txt

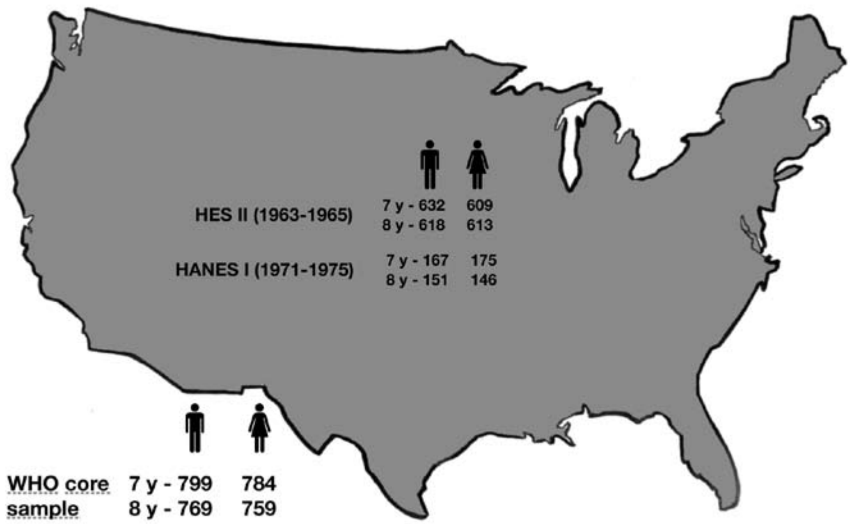

Figure 2: WHO core sample sizes

Since the Western Balkan data was gathered in different months of the year and since countries included different age-groups (HRV 8-, SVN 6-, 7-, 8- and 9-, MNE, MKD and SRB 7-year-olds) there were some differences between countries in mean age in months (Figure 3). The Croatian subsample was between 3.8 and 7 months older than the other national subsamples, and 3.9 months older than the WHO core sample, while the Montenegrin sample was between 1.6 and 7 months younger than the other national subsamples from the Western Balkans and also 3.1 months younger than the WHO core sample.

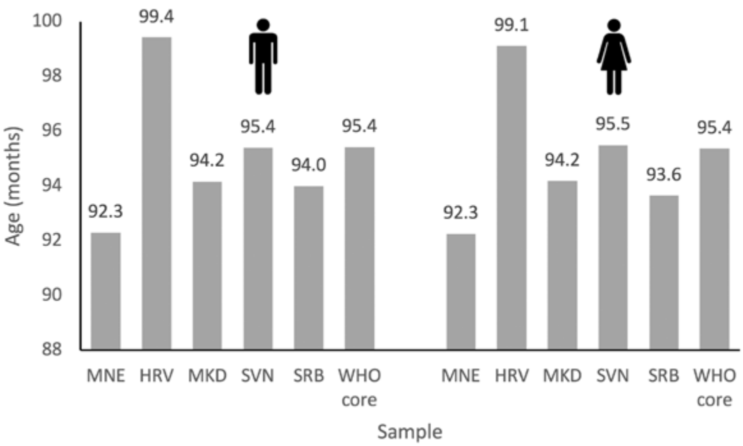

Figure 3: Mean age of the WHO core sample and the Western-Balkan national subsamples

Measurements

The children's body heights of the Western Balkan samples were measured according to the WHO standardized techniques (WHO 2014). Children were dressed lightly (t-shirt and shorts) and were asked to take off their shoes and socks. Body height was measured standing upright to the nearest 0.1 cm with portable stadiometers.

Data analysis

All statistical analyses were performed in SPSS version 26.0 (IBM, Armonk, NY, USA). A P-value of 0.05 was used to define statistical significance. There were considerable differences in sample sizes and in the distribution of age in months within age groups of the national subsamples of the Western Balkan sample and the WHO core sample. For the estimation of differences in mean height by sample and country, we used the General Linear Model analysis of covariance with body height as a dependent variable, sample and gender as fixed factors, and age in months as a covariate.

In order to better understand the extent of differences in the rank distribution of body height of the WHO core sample and the Western Balkan sample, we also calculated empirical percentile values with the Rankit proportion estimation formula for body height according to age in months and gender for both samples.

Results

There was a significant difference in estimated marginal mean body height between the samples [$F(5, 36068)=467.556$, $p<.001$, $\eta_p^2 = .061$]. Figure 4 shows the estimated means of the national subsamples of the Western Balkan sample and the WHO core sample adjusted for the effect of age differences. Post hoc tests showed there was a significant difference in body height between the WHO core sample and all national subsamples from the Western Balkans ($p<.001$). In the comparison of the estimated marginal means, the most substantial difference was observed between boys from the WHO core sample and Croatian subsample (5.9 cm), followed by the Montenegrin (5.7 cm), Serbian (4.5 cm), Slovenian (4.3 cm), and Macedonian (2.5 cm) samples. In girls, the most substantial difference was also observed between the WHO core sample and Croatian subsample (5.4 cm), followed by Montenegrin (4.8 cm), Serbian and Slovenian (4.4 cm), and Macedonian (2.4 cm) subsamples.

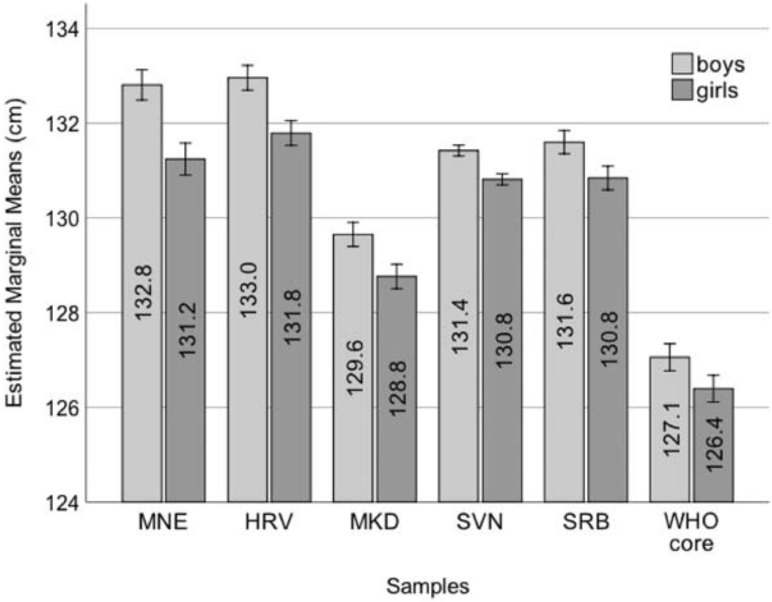

Figure 4: Estimated Marginal Means of body height of national subsamples from the Western Balkans and WHO core sample (covariates appearing in the model are evaluated at the age of 95.30 months, error bars 95% CI)

Comparison of estimated marginal means also revealed differences in body height between the national Western Balkan subsamples. The Macedonian subsample had significantly lower body height ($p<.001$) than the Croatian (3.2 cm), Montenegrin (2.8 cm), Serbian (2.0 cm) and Slovenian (2.0 cm) subsamples. The Croatian and Montenegrin subsamples did not differ in body height, but they were both significantly taller than the Serbian (1.2 and 0.8 cm) and Slovenian (1.3 cm and 0.9 cm) subsamples. No significant differences were observed between the Serbian and the Slovenian subsamples.

A significant difference in estimated marginal mean body height adjusted for age was also observed between boys and girls [$F(1, 36068)=154.679$, $p<.001$, $\eta_p^2 = .004$], which was particularly strongly expressed in the Montenegrin (2.2 cm) and also Croatian (1.6 cm) subsamples. The smallest difference in body height between boys and girls was observed in the Slovenian subsample (0.6 cm), although the difference in body height between boys and girls in all other subsamples did not exceed 1 cm.

Furthermore, the comparison of the empirical percentile distribution of body height between the Western Balkan sample and the WHO core sample (Figure 5) indicates considerable differences ranging between 3.9 and 4.9 cm for the same percentile. This means that the 25th percentile of the Western Balkan sample's body height exceeds the 50th percentile of the WHO core sample in boys and girls.

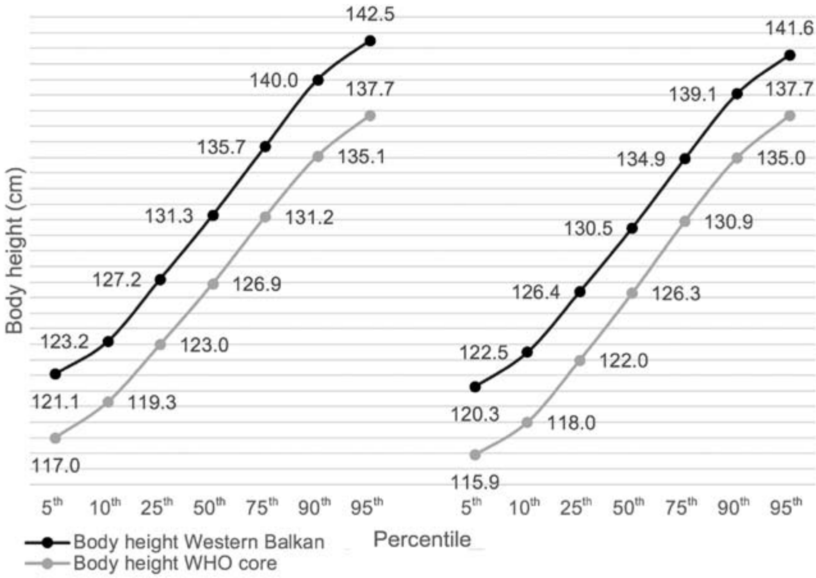

Figure 5: Percentiles of body height in the Western Balkan and the WHO core sample

Discussion

Our findings suggest that the contemporary children from the Balkan region aged between 7 and 8 years are significantly taller than their peers from the WHO core samples (HES II from 1963-1965 and HANES I from 1971-1975), which has considerable implications for the use of all WHO growth standards derived directly from body height (height-for-age, BMI-for-age) or strongly related to it (weight-for-age) for clinical or epidemiological classifications in this population.

To date, no other study has compared the national populations' raw data of body height with the WHO core sample's body height, which makes global generalisations regarding the differences in body height inconclusive but the limited data on the secular trends of body height of US children show that in the last four decades their body height increased by around 0.7 cm per decade (Freedman, Khan, Serdula, Srinivasan & Berenson 2000). The anthropometric reference data for the US children derived from the NHANES 2011-2014 study suggests for contemporary 7- to 8-year-olds from the USA to be around 2 cm taller from their peers who were included in the WHO core sample (Fryar, Gu, Ogden & Flegal 2016). This indicates that even growth classifications of contemporary US children, based on the US samples from the 1960s and 1970s should be interpreted with caution. The level of misclassifications in the contemporary Western Balkan sample based on the WHO growth standards (derived from the WHO core sample) would be even more pronounced due to larger differences in body height, although the scarce available evidence makes it difficult to assess whether the differences in body height between the 7- to 8-year-olds from the Western Balkans and the USA already existed in the

1960s and 1970s. The body height data of children from then Yugoslavia, measured in a large national study (Polič, Šepa, Stojanović, Radmili & Horvat 1964), suggests that 7- to 8-year-olds from the Western Balkans were in 1962 over 2 cm shorter than children from the HES II and HANES I study. This was true for boys (123.5 cm) and girls (122.4 cm) from Croatia, boys (123.0 cm) and girls (121.9 cm) from Montenegro, boys (118.0 cm) and girls (117.5 cm) from North Macedonia, boys (123.2 cm) and girls (122.3 cm) from Serbia, as well as for boys (126.0) and girls (124.8) from Slovenia. Another (smaller) study stratified by nationality (Žarković et al. 1975) even showed a decline in body height of 7- to 8-year-olds with boys averaging at 121.9 cm and girls at 121.5 cm in 1971.

The differences in body height between these two studies from the region and the contemporary from this region sample suggests that since the 1960s and 1970s the 7- to 8- year-olds from Western Balkans have been gaining around 1.3 cm of body height per decade. This corresponds very closely to the findings of Hauspie et al. (1997) who reviewed the secular changes of body height over the 20th century in 17 nations (including several European countries as well as Japan, Cuba, Brazil, North America, and Taiwan) and established that the average per-decade increase of body height in childhood was larger than 1.3 cm. The growing differences in body height between the WHO core sample and the population of children from the Western Balkan region seem to have occurred from the 1970s onwards and could be linked to the increased quality of the environment for growth, following the rapid economic growth of Yugoslavia in the 1970s, accompanied by another one in the post-Yugoslav period (Good & Ma 1999; Paprotny 2016). The improved economic conditions are the main drivers of body height increase in children (Bogin, Smith, Orden, Varela Silva & Loucky 2002; Mascie-Taylor & Lasker 2005; Bogin 2013) and are usually linked to improved nutrition and health care.

Although there were also significant differences in body height between the national subsamples of the Western Balkan sample, these differences were considerably smaller than the differences between these subsamples and the WHO core sample. Gender-related differences in body height in the the Western Balkan national subsamples were, nevertheless, more expressed than in the WHO core sample. This could be explained by the mechanism, observed in the second half of the 20th century, according to which boys were more strongly influenced by environmental factors than girls, both as to their rate of skeletal maturation and to their linear growth (Acheson & Fowler 1964; Bielicki & Charzewski 1977; Stinson 1985).

The main limitation of our study is its narrow age-range that does not allow generalisations regarding the differences in body height between other age groups of the contemporary population of children from the Balkan region and the WHO core sample. At the same time, the study is geographically limited only to one region, and its findings cannot be generalised to other regions. In contrast, the mai n strength of the study lies in its large, nationally representative recent samples, which depict the entire contemporary population of children from the Balkan region much better than the WHO core sample does. Although the WHO references based on the WHO core sample are used globally, the WHO core sample size is temporally quite distant, surprisingly small with less than 800 boys or girls per age group, and geographically limited exclusively to the USA.

Conclusion

In this study, we examined the differences in body height between the contemporary populations of 7- to 8-year-olds from the Western Balkan region and their peers, included in the HES II and HANES I studies from the period 1963-1975, which were used for the construction of the WHO growth standards. After examining the difference in body height between the WHO core sample and the national subsamples of the Western Balkan sample, our statistical analyses concluded that children from the latter sample are much taller than the ones form the WHO core sample and are, in this regard, incomparable to them. Since the reference population of any classification tool should be as universal as possible and as similar to contemporary children's characteristics as possible, it is justified to say that the WHO core sample no longer meets this assumption and makes the WHO references unreliable for use in the populations of contemporary children from the Western Balkan region.

Although a number of previous studies confirmed the considerable misclassifications of the WHO growth curves and recommended the use of national ones, none of them actually founded their comparisons of differences on actual physical characteristics between their samples and the WHO core sample. In this view, our study is the first to shed light on the actual difference of body height between the WHO core sample and a sample of contemporary children.

Since the WHO somatic development classification tools rely on the cut-off points, derived from the temporally distant, relatively small and country-specific reference population of the 1960s and 1970s, it would be reasonable for the WHO to rethink the use of their current tools and construct new ones, based on the more recent and universal reference populations. There are excellent examples of contemporary international research community efforts that result in massive databases of historical and contemporary data on children's morphological characteristics (Ezzati et al. 2017). These databases are one example that could be utilised to construct new somatic development classification tools, which would result in more accurate identifications of children with increased developmental risks on the clinical level, and in a more realistic assessment of obesity and stunting prevalence on the epidemiological level. In order to further explore the reliability of the existing height-dependent WHO references and plan for their updating, it would be advisable for the WHO to utilise its own data of all European COSI national samples and assess the level of misclassifications produced by their existing height-for-age, weight-for-age and BMI-for-age references in the age groups covered by COSI. If the observed significant differences in height between the Western Balkan sample and the WHO core sample also exist in other COSI member states, the existing WHO references very likely underestimate the prevalence of stunting on the one hand and overestimate the prevalence of overweight and obesity on the other. This may have considerable implications for public health and educational policies based on the estimations that are derived from the current WHO growth references and could result in the overestimation or underestimation of health risks in paediatric population globally.

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Izvleček

Telesna višina je najpogosteje uporabljena antropometrijska mera za oceno in klasifikacijo somatskega statusa in rasti. Svetovna zdravstvena organizacija je izdelala različne rastne krivulje, namenjene uporabi po vsem svetu, ki so izpeljanje neposredno iz telesne višine ali ta posredno vpliva nanje, vendar pa referenčni vzorec otrok, ki ga je Svetovna zdravstvena organizacija uporabila, temelji na nacionalno specifičnih, relativno majhnih in časovno oddaljenih referenčnih vzorcih iz raziskav Health Examination Survey Cycle II (1963-65) in Health and Nutrition Examination Survey Cycle I (1971-75). Namen prispevka je oceniti, ali je telesna višina sodobnih 7- do 8-letnikov z zahodnega Balkana podobna telesni višini njihovih vrstnikov iz referenčnega vzorca Svetovne zdravstvene organizacije. Analiza je pokazala, da so sodobni otroci iz te regije več kot 4 cm višji od vrstnikov iz referenčnega vzorca. Petdeseti centil telesne višine vzorca z zahodnega Balkana presega petinsedemdeseti centil referenčnega vzorca Svetovne zdravstvene organizacije, kar kaže, da sta obe populaciji zelo različni. Zaradi tega bi bilo treba rastne krivulje Svetovne zdravstvene organizacije pri otrocih z zahodnega Balkana uporabljati z zadržkom.

KLJUČNE BESEDE: telesna višina, otroci, Balkan, rastne krivulje, napaka razvrščanja

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