

# CHANGES IN THE MORPHOLOGICAL DEVELOPMENT OF YOUTH AGED 16–18 FROM EASTERN POLAND IN THE YEARS 2006–2016–2021

Jerzy Saczuk<sup>A, B, C, D</sup>

Department of Health Promotion, Faculty of Physical Education and Sport in Biala Podlaska, Józef Piłsudski University of Physical Education in Warsaw, Biala Podlaska, Poland  
ORCID: 0000-0001-7090-8434

Agnieszka Wasiluk<sup>A, B, C, D</sup>

Department of Health Promotion, Faculty of Physical Education and Sport in Biala Podlaska, Józef Piłsudski University of Physical Education in Warsaw, Biala Podlaska, Poland  
ORCID: 0000-0001-9781-8121 | agnieszka.wasiluk@awf.edu.pl

<sup>A</sup> Study Design; <sup>B</sup> Data Collection; <sup>C</sup> Statistical Analysis; <sup>D</sup> Manuscript Preparation

**Abstract** On the one hand, the number of individuals with excess body weight is increasing, while on the other, the issue of malnutrition among adolescents is becoming increasingly noticeable. Aim: To determine differences in the magnitude of secular trends in height and body mass, BMI, and the occurrence of underweight, normal weight-to-height proportions, overweight, and obesity in adolescents. Materials and Methods: The study was conducted from 2006 to 2021. Height and body mass were measured, and BMI was calculated. The results were statistically analyzed. Results: In the examined girls and boys in the decade from 2006 to 2016, a slowdown in height growth and slight positive changes in body mass and BMI were observed. The results from 2016 to 2021 confirmed a continued trend of increasing somatic characteristics, mainly body mass. Considering the BMI value in both observation periods, a slight decrease in the frequency of underweight and normal BMI was noted in all groups, while a significant increase in the prevalence of overweight and obesity was observed. Conclusions: The temporal trends presented in this study emphasize the need for regular monitoring of the development of adolescents in eastern Poland, as well as the implementation of proactive public health strategies.

**Key words:** physical development, BMI, adolescents, secular trend

## Introduction

Observations conducted indicate that the average Body Mass Index (BMI) and the prevalence of obesity have increased worldwide (NCD Risk Factor Collaboration, 2017). Despite the fact that the trend of rising overweight and obesity in children and adolescents has slowed down in developed countries (Wabitsch et al., 2014), it continues in developing countries (Rivera et al., 2014). As a result, we can observe a dual threat to the health of children and adolescents. On the one hand, the number of individuals with excess body weight is increasing, and on the other hand, the problem of malnutrition among young people is becoming increasingly visible. According to the analyses

conducted by Garrido-Miguel et al. (2021), the prevalence of underweight in Europe is substantial, totaling around 8-9%, with a sustained upward trend. The coexistence of malnutrition and overnutrition poses a serious problem in most countries, and it is also noticeable in the eastern regions of Poland. Sączuk's research (2018), conducted from 1986 to 2016, indicates that the highest prevalence of both underweight and excess body weight is observed in the youngest age groups, with a lower prevalence among older adolescents.

Over the past fifteen years in Poland, a period of rapid social changes and transformations related to the accession to the European Union has transpired. During this time, an exacerbation of disparities in the economic status of Polish society has been observed, along with evident differences in the nutritional status of children and adolescents, as well as other health indicators. This issue is noticeable in regions with higher economic indicators (Gomula et al., 2021) and is beginning to be recognized in areas with a slower pace of development (Wasiluk & Sączuk, 2015). Conversely, the last five years have seen, on the one hand, a change in lifestyle associated with the COVID-19 pandemic. Since 2019, there has been a restriction of physical activity for children, adolescents, and adults due to quarantine measures (Dz. U. 2021 r. poz. 2069, 2120, Dz. U. 2022 r. poz. 64, 655, 974). On the other hand, this period follows the implementation of the "Family 500+" program in the realm of social policy, aimed at supporting families in raising children through monthly childcare benefits of PLN 500 per child in the family (Dz. U. 2016 poz. 195). Therefore, the objective of this study is to determine the differences in the magnitude of secular trends in height and body mass, BMI, and the prevalence of underweight, normal weight, overweight, and obesity among adolescents residing in the eastern provinces of the country in the years 2006–2016 and 2016–2021.

## Material and Methods

The present study utilized the results of 5306 girls and 5324 boys aged 16–18 residing in the aforementioned eastern voivodeships of the country. The exact number of examined girls and boys, considering their calendar age and observation period, is presented in Table 1.

**Table 1.** Number of examined students with consideration to observation period, gender, and age

girls		age group			boys			
2006	2016	2021	Total	(years)	2006	2016	2021	Total
1053	398	380	1831	16	927	504	338	1769
948	344	430	1722	17	882	475	316	1673
1273	456	535	2264	18	1252	385	637	2274
3274	1198	1345	5817	Total	3061	1364	1291	5716

The research was conducted among children and adolescents aged 7 to 19 in the Podlaskie, Lublin and Podkarpackie voivodeships in 2021 and 2022. This study served as a continuation of observations carried out in 2005 and 2006, as well as 2015 and 2016, within the statutory research framework of the Academy of Physical Education in Warsaw (D.S. 49 and D.S. 203). For the first time in the series of studies, 90 schools were randomly selected from the list of educational institutions obtained from the Education Boards, striving to maintain equal representation in all voivodeships. All students in each school were included in the measurements. In accordance with the settlement structure of the voivodeships, efforts were made to maintain comparable populations of residents in rural and urban areas.

With the consent of the main project coordinator, the results of measurements conducted in 2021 as part of the "Active Return to School - PE with the AWF" program in the Podlaskie, Lubelskie, and Podkarpackie voivodeships were also included in this study. The results gathered from the aforementioned projects were combined for further analysis.

Measurements at three observation points were conducted while maintaining the same research methodology. The research was conducted in accordance with the principles outlined in the Declaration of Helsinki and was approved by the Senate Ethics Committee at the University of Physical Education in Warsaw. Data collected through the survey included information about the date of birth and environmental conditions in which the participants were raised.

Anthropometric measurements were carried out following the adopted anthropometric techniques (IBP, 1969), including measurements of height and body mass, from which the body mass index (BMI) was calculated, indicating body mass in kilograms per square of height in meters.

In age groups, considering gender, arithmetic means and measures of dispersion for height, body mass, and BMI were calculated. These statistics were computed using data from 2006, 2016, and 2021. Subsequently, differences in the mentioned somatic indicators were calculated between the study periods. After obtaining these statistics, arithmetic means and measures of dispersion were calculated for the analyzed features, providing an overall picture of trends in the developmental indicators.

Statistical significance of differences between the groups was verified using analysis of variance (ANOVA) and the Newman-Keuls test, at the significance level ( $p \leq 0.05$ ). From the research material, individuals with underweight and overweight, as well as those with normal weight-height proportions, were selected.

The classification into the above-mentioned groups was based on cutoff values developed by Cole et al. (2000, 2007). The obtained sample sizes allowed for the calculation of the percentages of girls and boys in I° (low underweight), II° and III° underweight, normal BMI, overweight, and obesity. Due to the small sample sizes of individuals with II° and III° underweight, these groups were combined into one category (severe underweight).

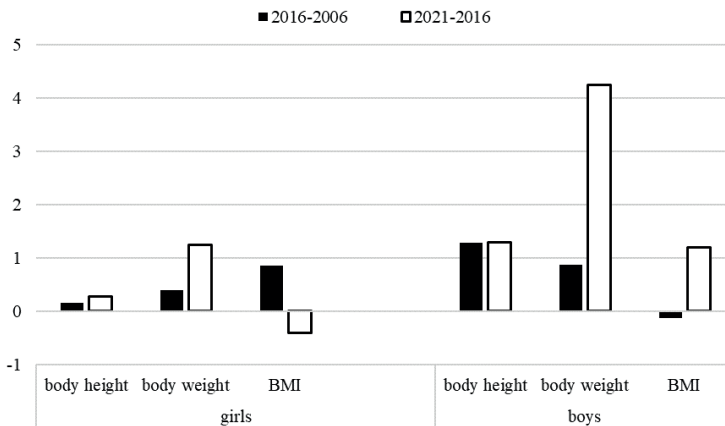
These calculations were performed at subsequent observation points. From the obtained percentages of each BMI group, differences between the years 2016 and 2006, as well as 2021 and 2016, were calculated, allowing for the determination of the magnitude and direction of changes. Statistical significance of differences in the number of individuals classified into each of the described BMI groups was determined using the  $\chi^2$  test, at the significance level ( $p \leq 0.05$ ).

## Results

From 2006 to 2016, the height of girls from the cities of eastern Poland increased on average by 0.16 cm (Figure 1, Table 2). The most significant statistically significant changes were observed in seventeen-year-olds (1.41 cm), while in other age groups, the differences between the described study periods were minor. Over the mentioned decade, larger differences in the values of this somatic characteristic were observed in boys, with an average difference calculated from all age groups being 1.28 cm. The most significant changes in height values were observed in eighteen-year-olds (1.83 cm) and sixteen-year-olds (1.79 cm), while the smallest changes were noted in seventeen-year-olds (0.1 cm).

In the years 2016–2021, the height of young females from eastern Poland increased by an average of 0.27 cm. The most significant, statistically significant differences were observed in sixteen-year-olds (1.89 cm). In the other

age groups, there were no significant differences, and they amounted to 1.10 cm at the age of 17 and 0.01 cm at the age of 18. For boys during the analyzed period, greater variations in this somatic trait were noted. The average difference in height between 2021 and 2016 was 1.29 cm. The most significant, statistically significant changes were observed in seventeen-year-olds (2.61 cm) and sixteen-year-olds (1.78 cm). In 2016 and 2021, the results obtained for eighteen-year-olds were at a similar level, with a difference of  $-0.53$  cm.



**Figure 1.** Differences in somatic indices of girls and boys

In body mass among girls between 2006 and 2016, substantial statistically significant changes were also observed in all age groups. Specifically, an increase in this somatic characteristic was noted among seventeen-year-olds by 1.58 kg and sixteen-year-olds by 0.90 kg. A regression in body mass of 1.21 kg was identified in eighteen-year-old girls. Thus, the average value of changes calculated across all age groups was 0.39 kg.

In boys, the mentioned somatic characteristic increased on average by 1.24 kg. Significant increases in body weight were observed only in eighteen-year-olds, with an average increment of 2.76 kg. In younger age groups, differences were small and statistically insignificant ( $p > 0.05$ ).

Greater values of secular trends in body mass were observed in the years 2016–2021. Among female residents of eastern Poland in 2021, a higher value of this somatic characteristic was noted, on average, by 0.87 kg compared to the results obtained in 2016. A significant acceleration was observed in eighteen-year-old females (2.74 kg). Among younger female students, the averages from both described observation periods were at a similar level. During the same time frame, among males, body mass increased on average by 4.25 kg, with statistically significant differences noted in sixteen-year-olds (8.18 kg) and seventeen-year-olds (4.25 kg).

**Table 2.** Somatic characteristics and BMI of girls and boys considering the research period

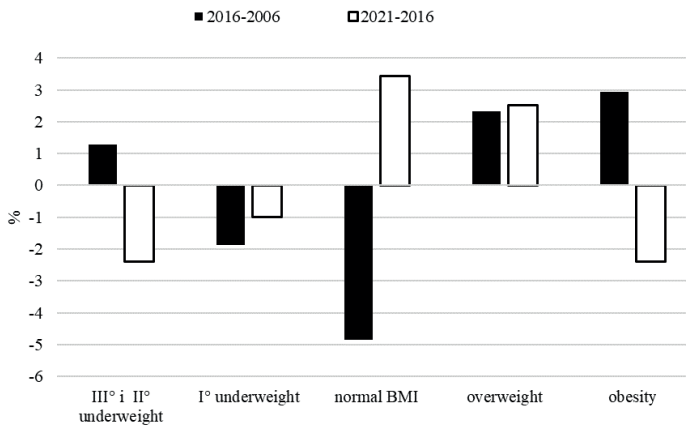
age group (years)	research term						Anova	Newman-Keuls test		
	2006		2016		2021			2006-2016	2006-2021	2016-2021
	$\bar{x}$	SD	$\bar{x}$	SD	$\bar{x}$	SD				
girls – body height										
16	165.40	5.99	164.75	5.94	166.64	5.85	10.40	2.67	4.92*	6.30*
17	166.54	6.19	167.95	5.91	166.85	6.32	6.66	5.14*	1.22	3.49*
18	166.89	6.10	166.61	5.86	166.62	7.06	0.65	1.15	1.18	0.04
girls - body weight										
16	55.24	6.68	56.14	7.60	56.87	8.34	7.28	2.98*	5.32*	1.99
17	56.51	7.24	57.99	6.92	58.21	9.01	9.40	4.34*	5.40*	0.56
18	57.16	6.97	55.95	9.43	58.71	9.63	14.30	3.83*	5.19*	7.47*
girls - BMI										
16	20.19	1.76	20.94	2.56	20.45	2.58	17.81	8.42*	2.87*	4.51*
17	20.37	1.74	21.53	1.92	20.88	2.84	39.93	12.40*	5.90*	6.05*
18	20.52	1.98	21.16	3.25	21.10	3.01	15.96	6.52*	6.26*	0.52
boys – body height										
16	173.64	8.17	175.43	8.30	177.21	7.22	26.42	5.69*	9.89*	4.46*
17	175.99	8.53	176.20	7.31	178.81	6.80	15.60	0.66	7.71*	6.44*
18	177.49	6.97	179.32	5.95	178.79	8.69	12.42	6.05*	5.15*	1.58
boys – body weight										
16	65.73	10.08	65.17	11.09	73.35	11.77	73.26	1.34	15.83*	15.36*
17	68.82	9.83	69.26	10.57	73.27	11.10	22.61	1.06	9.33*	7.59*
18	71.03	8.76	73.77	9.10	74.33	13.12	26.09	6.51*	9.39*	1.20
boys - BMI										
16	21.80	2.16	21.09	2.65	23.33	3.22	80.22	7.16*	13.43*	17.78*
17	22.30	1.90	22.24	2.63	23.33	3.22	25.50	0.61	9.39*	8.93*
18	22.55	1.73	22.92	2.40	23.15	3.36	13.90	3.73*	7.25*	2.10

\* statistically significant difference at the level of  $p \leq 0.05$

The Body Mass Index (BMI) of girls aged 16–18 years increased by an average of 0.85 kg/m<sup>2</sup> from 2006 to 2016. A statistically significant increase in BMI values was observed in participants at the age of 17 by 1.16 kg/m<sup>2</sup>, at 16 by 0.75 kg/m<sup>2</sup>, and at 18 by 0.64 kg/m<sup>2</sup>. During the same period of research, boys in all age groups experienced a decrease in BMI levels by an average of –0.40 kg/m<sup>2</sup>. The most substantial, statistically significant deceleration was observed in seventeen-year-olds (–0.65 kg/m<sup>2</sup>), followed by sixteen-year-olds (–0.49 kg/m<sup>2</sup>). Among the oldest age group, in 2006 and 2016, the results were at a similar level.

In the last five years, significantly smaller changes in the BMI of girls and larger changes in boys were observed compared to the entire preceding decade. Among girls, from 2016 to 2021, the Body Mass Index decreased on average by –0.13 kg/m<sup>2</sup>, while among their male counterparts, it increased by 1.19 kg/m<sup>2</sup>. Noteworthy reductions in the Body Mass Index were observed first among sixteen-year-old girls (–0.71 kg/m<sup>2</sup>), and increases were noted among eighteen-year-olds by 0.37 kg/m<sup>2</sup>, whereas the smallest changes were observed among seventeen-year-olds (–0.06 kg/m<sup>2</sup>). Conversely, among the surveyed boys, the most significant changes were observed at the age of 16 (2.24 kg/m<sup>2</sup>) and 17 (1.09 kg/m<sup>2</sup>). The smallest changes were observed among eighteen-year-olds (0.23 kg/m<sup>2</sup>).

The depiction of secular trends in the body mass index (BMI) presented above is somewhat flattened and illustrates the results for all examined individuals. However, it is intriguing to explore the changes in the frequency of normal weight-for-height proportions and the various degrees of underweight, overweight, and obesity among girls and boys. From the data presented in Figure 2 and Table 3, it can be observed that among girls from eastern Poland between 2006 and 2016, there was a statistically significant increase in the percentage of girls with severe underweight (III<sup>o</sup> and II<sup>o</sup> underweight) by 1.29%, as well as overweight (2.33%) and obesity (2.94%). Conversely, between 2016 and 2021, a significant reduction in the frequency of severe underweight (III<sup>o</sup> and II<sup>o</sup>) by 2.40% and obesity by 2.39% was noted among the assessed female students. Additionally, in this five-year period, an increase in the frequency of overweight by 2.52% was also observed. In other groups, the differences were small and not statistically significant.



**Figure 2.** Differences in the percentage change in BMI categories among girls in the years 2016–2006 and 2021–2016

Based on the data presented in Figure 3 and Table 3, a significant increase in the prevalence of overweight (2.31%) and obesity (2.89%) was observed among boys residing in eastern Poland between the years 2006 and 2016. Subsequently, from 2016 to 2021, a statistically significant increase in the prevalence of overweight by 6.23% and normal height-weight proportions by 7.97% was noted. No statistically significant differences were observed in the unmentioned groups. It is noteworthy that the described changes influenced the percentage of normal height-weight proportions among the examined population in eastern Poland. In the first assessed decade, there was a decrease of  $-4.84\%$  in girls, whereas in the following five years, it increased by  $3.43\%$ . Meanwhile, in boys, it decreased by  $-5.90\%$  and  $-5.84\%$ , respectively.

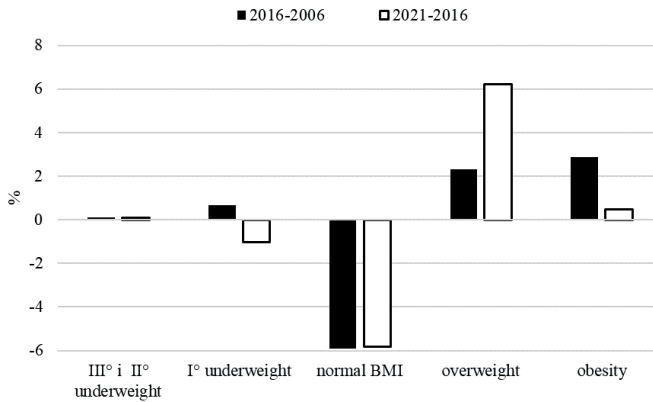


Figure 3. Differences in the percentage change in BMI categories among boys in the years 2016–2006 and 2021–2016

Table 3. Percentage of examined girls and boys in the years 2006, 2016, and 2021 in groups with underweight and overweight, normal BMI, and  $\chi^2$  test values for differences between observation periods

	research term			$\chi^2$ test values		
	2006	2016	2021	2006–2016	2006–2021	2016–2021
% girls						
III° and II° underweight	4.83	6.12	3.72	2.951	2.888	7.320*
I° underweight	13.96	12.08	11.08	2.365	6.129*	0.500
normal BMI	77.54	72.71	76.13	1.759	0.155	0.585
overweight	3.55	5.88	8.40	11.714*	44.715*	5.394*
obesity	0.12	3.06	0.67	90.305*	10.726*	21.271*
% boys						
III° and II° underweight	0.90	1.00	1.08	0.111	0.366	0.0496
I° underweight	2.59	3.27	2.25	1.774	0.504	2.5136
normal BMI	81.92	76.01	70.18	2.746	10.594*	1.8104
overweight	13.85	16.16	22.39	3.539*	38.449*	11.4477*
obesity	0.74	3.63	4.11	54.484*	64.219*	0.3792

## Discussion

The phenomenon of societal tallness, the increase in body mass relative to height, and changes in the rate and magnitude of secular trends in these traits are dependent, among other factors, on the socio-economic environment and living conditions of the population. Smaller changes were observed in girls and boys from countries with lower living standards. However, as these standards improve, these differences increase, as confirmed by research results from countries with rapid economic growth. Additionally, in highly industrialized countries, a weakening of the magnitude of height trends in the population is observed, with an accelerated increase in body mass (Fudvoye & Parent, 2017). It is essential to emphasize that significant differences in the height of youth from economically developed countries in Europe or the USA continue to be observed (Danubio & Sanna, 2008). Conversely, body mass is less genetically determined and more influenced by the environment in which boys and girls reside.

The socio-economic changes that occurred after Poland's accession to the European Union had a significant impact on the magnitude of the secular trend in somatic development. Among girls and boys in selected regions of the country observed from 1966 to 2012, a positive secular trend was noted in both height and BMI, except for the relative body mass of girls aged 14–18 (Kozieł et al., 2014). The authors observed greater changes in height between 1966–1988 compared to 1988–2012. In contrast, differences in the body mass index were more pronounced in the period 1988–2012, corresponding to the post-transitional and post-accession period to the European Union. Dobosz (2012), conducting observations on a large nationwide sample, noted a slowdown in the pace of height increase in children and adolescents from 1999–2009 compared to the 1989–1999 decade, as evidenced by the results for the oldest youth. However, in younger age groups, there was a continued acceleration of developmental processes, manifested as growth and maturation acceleration. The observed high pace of dynamic changes in body mass, especially among the youngest, was also maintained. The consequence of changes in height and body mass is a significant increase in the BMI index, especially in younger children. Similar observations were described by Saczuk (2018).

It is crucial to note that during the same period, the secular trend in somatic characteristics varied depending on the surveyed area. In children and adolescents from Krakow, between 2000–2010, the average body height slightly increased (by approximately 1.00 cm), accompanied by a greater increase in body mass and BMI (Kowal et al., 2011). Greater growth distances were observed among female students in primary and secondary schools in Lower Silesia, between 2001–2002 and 2010–2011. The average height of girls increased from 1.75 cm to 2.45 cm. Substantial increases in average body mass and BMI were also noted (Ignasiak et al., 2016). Similarly, in girls and boys from eastern regions of Poland, between 1986–2006, an increase in body height and a significant increase in body mass were observed, translating into higher values of the body mass index. It is essential to emphasize that the most significant changes were observed in the 1996–2006 decade, particularly in prepubertal and pubertal periods in girls, indicating an acceleration of maturation (Saczuk, 2018). Bartkowiak et al. (2021) also presented significant secular changes in the height and body mass of rural female students in central-western Poland from 1986–2016. Over the analyzed three decades, the authors recorded an average increase in girls' body height by 4.65 cm and body mass by 5.20 kg.

In the examined girls, between 2006 and 2016, similar to the observations of the authors cited above, a deceleration in tallness was observed, accompanied by slight positive changes in body mass and BMI. However, in the subsequent five years, there was a tendency to increase the magnitude of the discussed somatic characteristics compared to the previous decade. Nevertheless, the body mass index showed a decrease. A similar direction of changes, with higher values, was noted in boys from eastern Poland. Between 2016 and 2021, despite the shorter observation period, a significantly greater increase in the described developmental indicators was observed, especially in body mass. Alarming are the changes described in the BMI values. It can be expected that the younger generation will be characterized by excess body mass in further stages of ontogenesis. These assumptions are confirmed by the results of the frequency of underweight and overweight. In both the analyzed decade and the last five years in the studied youth, there was a slight decrease in the frequency of underweight and normal height-weight proportions in all groups, while a significant increase in the frequency of overweight and obesity was noted. It should be noted that there is currently a global trend of decreasing the number of children and adolescents with underweight and increasing the number with excess weight. This is confirmed by studies such as Ng et al. (2014) conducted from 1980–2013 in many countries worldwide. Such a trend can be observed in both developing and



economically highly developed countries. Similar conclusions, based on research on girls and boys from Brazil, China, Russia, and the USA, were presented by Wang et al. (2002), and from Australia by Hardy et al. (2017). These authors attribute the reasons for these changes to different dietary habits and a reduction in physical activity. Hardy et al. (2017) emphasize that the trend of increasing excess body weight in developed countries is slowing down.

The lack of an increase in the frequency of underweight can be considered optimistic. Underweight is a significant issue among children and adolescents, both clinically and in terms of public health. It is associated with adverse health effects at all stages of human life and may reflect poverty in access to food (Ileiri et al., 2021), unhealthy eating habits (Rawal et al., 2021), or an increased risk of developing various conditions. Children and adolescents with underweight are more susceptible to infectious diseases (Goutines et al., 2021), more likely to have impaired cognitive functions (Suryawan et al., 2022), mental disorders (Donkor et al., 2021; Zeiler et al., 2021), and a lower self-rated health status (Linardon et al., 2021).

The increase in excess body weight and the decrease in underweight among the youth assessed by us were likely influenced by the COVID-19 pandemic and the living environment. The lifestyle of young inhabitants of eastern Poland significantly differs from that of their peers in other regions, as extensively described by Saczuk (2018). Furthermore, starting from 2020, there was a reduction in physical activity among children and adolescents due to the COVID-19 pandemic. During this time, remote learning was conducted for many months, simultaneously closing sports facilities. Additionally, students, mainly staying at home, were deprived of regular, daily interactions with peers, shared play, and physical activity. Hence, the data on screen time for purposes unrelated to education are very alarming. According to the parents of the surveyed children, the number of hours spent in front of the TV, smartphone, or computer increased both during the week (43.6%) and on weekends (37.4%). Similar conclusions were presented by international research studies (Paterson et al., 2021; Stockwell et al., 2021; Manyanga et al., 2023). The introduction of the government's 500+ program in 2016, which provided a monthly allowance of PLN 500 per child, especially supported less affluent families. It is essential to emphasize that according to Eurostat's report (2018), the eastern regions of Poland are among the poorest macro-regions in the European Union, where the income per capita does not exceed 50% of the EU average income. Therefore, the temporal trends presented in this study indicate the necessity of regularly monitoring the development of young inhabitants of eastern Poland, as well as implementing proactive public health strategies.

## Conclusions

1. During the analyzed period, individuals from eastern Poland exhibited stabilization in body height, accompanied by an increase in body mass and BMI.
2. Greater variations were observed in the years 2016–2021, coinciding with the duration of the COVID-19 pandemic.
3. The aforementioned observations were further corroborated by the frequency of underweight and overweight occurrences, particularly among boys.

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