Baltic Journal
of Health and Physical Activity
e-ISSN 2080-9999

Article

Secular trends in underweight, overweight, and physical fitness of girls and boys aged 16–18 in eastern Poland from 2006 to 2016–2021

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Abstract. Introduction: Significant changes in the nutrition and physical fitness of children and adolescents have been observed in many countries around the world. The purpose of this study is to determine the changes in the prevalence of underweight, normal BMI, and overweight, as well as in the physical fitness of girls and boys from eastern Poland. Materials and methods: The study was conducted over the years 2006–2021. BMI was calculated, and physical fitness was assessed using the EUROFIT test. The results were statistically analyzed. Results: Minor changes in underweight were observed, and even a re-duction in its prevalence among girls was noted. However, a significant increase in the frequency of overweight was identified. Meanwhile, a decrease in the level of physical fitness in both girls and boys was recorded. These changes, however, were not uniform across all fitness abilities. Conclusions: The systematic decline in physical fitness among the examined girls and boys, particularly in cardiovascular-respiratory endurance, underscores the necessity for continued regular monitoring of the health of children and adolescents.

Keywords: secular trends, underweight, overweight, physical fitness, girls, boys.

Citation: Wasiluk A, Saczuk J. Secular trends in underweight, overweight, and physical fitness of girls and boys aged 16–18 in eastern Poland from 2006 to 2016–2021. Balt J Health Phys Act. 2024;16(3):Article7. https://doi.org/10.29359/BJHPA.16.3.07

Academic Editor:
Aleksandra Bojarczuk

Received: November 2023
Accepted: May 2024
Published: July–September 2024

Publisher's Note: BJHPA stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

1. Introduction

The late twentieth century and the first decade of the twenty-first century witnessed a significant increase in the percentage of boys and girls with the body mass index above the norm in many countries worldwide [1, 2]. Simultaneously, an increase in the incidence of metabolic diseases was observed [3]. Besides genetic predispositions, improper nutrition, the accelerating pace of life, the associated stress, and low physical activity were frequently identified as leading causes. The latter factor is also reflected in the declining physical fitness of girls and boys, a trend confirmed by global research [4–12]. These studies indicate a deterioration primarily in cardiorespiratory endurance, as well as in speed and strength.

While the issue of excess body weight has long been extensively discussed in scientific literature, less attention has been given to the issue of underweight. However, the occurrence of underweight in children and adolescents, especially of a significant degree, may indicate malnutrition and result in abnormalities in the functioning of the respiratory and digestive systems, as well as emotional disturbances [13, 14]. Additionally, children who experience malnutrition may be more susceptible to diabetes and cardiovascular diseases in

adulthood [15]. Therefore, from a health perspective, a broader diagnosis should be conducted among children and adolescents with a deficit of body mass, and this particular group should be under the care of specialists.

The last fifteen years in Poland have been a period of rapid social changes and transformations associated with joining the European Union. During this time, an intensification of disparities in the economic status of the Polish society, and differences in the nutritional status of children and adolescents, as well as other health indicators, have become apparent. This issue is observed both in regions with higher economic indicators [16] and is beginning to be recognized in regions with slower development [17]. In turn, the last five years represent the period after the implementation of the "Family 500+" program in the field of social policy, introducing monthly financial benefits for each child in the family amounting to 500 Polish zlotys, and the change in lifestyle associated with the Covid-19 pandemic. Therefore, it seems interesting to determine the pace and direction of changes in the physical condition of adolescents in eastern Poland from 2016 to 2021 compared to the decade of 2006–2016. Hence, the aim of this study is to determine changes in the frequency of underweight, normal weight-height proportions, and overweight, as well as in the physical fitness of girls and boys residing in the eastern provinces of the country, investigated from 2006 to 2021.

2. Materials and methods

In 2021 and 2022, research was conducted on children and adolescents aged 7 to 19 in the provinces of Podlaskie, Lubelskie, and Podkarpackie. These studies served as a continuation of observations carried out in 2005 and 2006, as well as 2015 and 2016 [18]. Measurements were taken in three observation periods, maintaining the same research methodology. For the initial survey, 90 schools were randomly selected from the list of educational institutions obtained from Educational Authorities, in line with the settlement structure of these areas. Efforts were made to ensure equal representation in all provinces. In each consenting school, all students were included in the measurements. Randomization, in accordance with the settlement structure of the provinces, aimed to maintain comparable population sizes between rural and urban areas.

For the present study, with the approval of the project's main coordinator, the results of measurements conducted in 2021 were incorporated, encompassing 1,699 girls and boys. These measurements were carried out as part of the "Active Return to School – Physical Education with the Academy of Physical Education" program in the provinces of Podlaskie, Lubelskie, and Podkarpackie. The results gathered from these projects were combined for further analysis. In total, the data from 5,306 girls and 5,324 boys, aged 16–18 and residing in the aforementioned eastern provinces, were utilized for this paper. The precise number of examined girls and boys, including their chronological age and observation period, is presented in Table 1.

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

Girls				Age Group (years)	Boys			
2006	2016	2021	Total		2006	2016	2021	Total
1053	398	369	1820	16	927	504	257	1704
948	344	337	1629	17	882	475	399	1773
1273	456	128	1857	18	1252	385	243	1898
3274	1198	834	5306	Total	3061	1364	899	5324

Data collected through surveys provided information on the participants' date of birth and the environmental conditions in which they were raised. Anthropometric measurements were performed following the established anthropometric techniques [19].

These measurements included height and body weight, from which the Body Mass Index (BMI) was calculated, representing body weight in kilograms divided by the square of height in meters.

Using the Body Mass Index values, participants were classified into groups with underweight, normal weight, and overweight, based on cutoff values developed by Cole et al. [20, 21]. The obtained sample sizes allowed for the calculation of the percentages of girls and boys with underweight (I°, II°, and III° categories of underweight), normal BMI, and overweight (overweight and obesity) in each observation period. Subsequently, differences in the BMI percentage between the years 2016 and 2006, as well as between 2021 and 2016, and across the entire analyzed period (2021–2006) were calculated within each group. This facilitated the determination of the magnitude and direction of changes. The statistical significance of differences in the number of individuals classified into each of the aforementioned groups was assessed using the χ^2 test at a significance level of ($p \leq 0.05$). This comprehensive approach aimed to provide insights into the dynamics of nutritional status changes among the studied population over the specified time intervals.

Physical fitness was assessed using the EUROFIT test [22]. The following tests were conducted:

- Trunk flexibility – sit and reach test in a seated position (SAR),
- Lower limb strength – standing broad jump (SBJ),
- Trunk strength – sit-ups in a supine position for 30 seconds (SUB),
- Functional strength – hanging on a bar with bent arms (BAH),
- Agility – 10 × 5 meters shuttle run (SHR),
- Cardiovascular and respiratory endurance – endurance shuttle run over a 20-meter distance (ESR).

Within the age and gender groups, arithmetic means and measures of dispersion were calculated for the results of the physical fitness tests. These statistics were computed for the years 2006, 2016, and 2021. To standardize units in the physical fitness tests, results for conditioning and trunk flexibility were converted into T-score points, normalizing 2016 results to 2006 and 2021 results to 2016. Subsequently, arithmetic means were calculated for each analyzed test. Despite the flattened representation, this approach globally illustrates trends in the analyzed motor abilities.

The statistical significance of differences between groups was verified through analysis of variance (ANOVA) and the Newman-Keuls test, at a significance level of $p \leq 0.05$. This statistical analysis aimed to discern meaningful variations in physical fitness across the specified observation periods, providing a comprehensive understanding of trends and potential influencing factors.

3. Results

The analysis of the results presented in this study commenced with an examination of changes in the frequency of normal weight-height proportions, as well as underweight and overweight conditions among the examined girls and boys. From the comparisons provided in Figure 1 and Table 2, it is evident that among girls from Eastern Poland in the decade spanning from 2006 to 2016, there was a significant increase only in the percentage of girls classified as overweight (5.27%). Conversely, in the period from 2016 to 2021, a noteworthy decrease in the frequency of underweight occurrences was observed (3.40%). In the remaining groups, differences were minor and statistically insignificant.

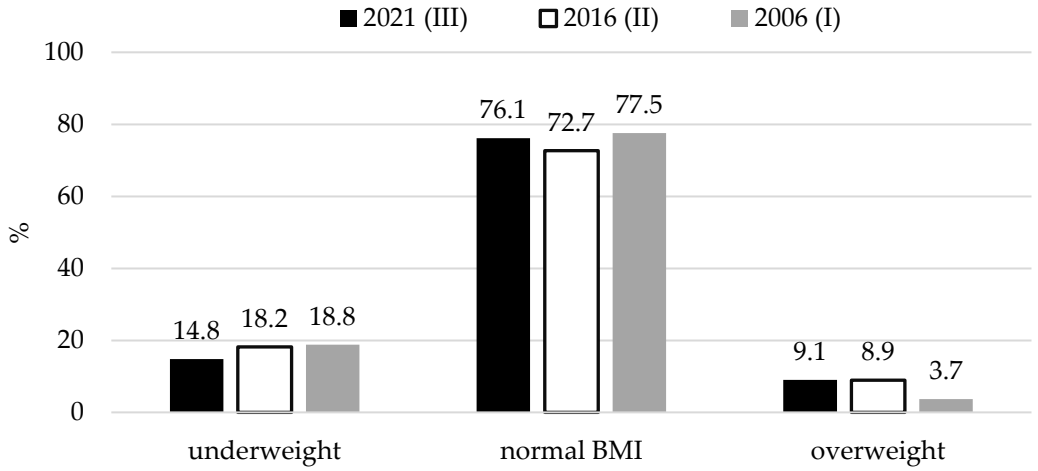

Figure 1. Differences in the percentage of the examined girls in BMI groups in the years 2016–2006 and 2021–2016.

The results for boys residing in the eastern provinces of Poland are presented in Figure 2 and Table 2. They reveal that during the decade from 2006 to 2016, there was a significant increase in the prevalence of overweight (5.20%) and a decrease in the frequency of normal BMI (5.90%). Conversely, in the period from 2016 to 2021, a statistically significant increase was observed only in the prevalence of overweight (6.70%). The remaining differences were not statistically significant.

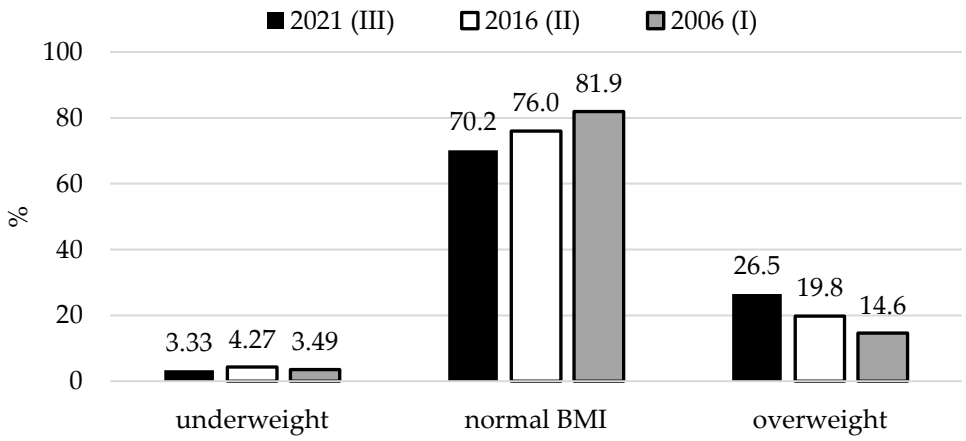

Figure 2. Differences in the percentage of examined boys in BMI groups in the years 2016–2006 and 2021–2016.

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

	Observation periods			χ^2 Test Value		
	2006	2016	2021	2006–2016	2006–2021	2016–2021
			girls			
Underweight (%)	18.80	18.20	14.80	0.160	8.449*	3.901*
Normal BMI (%)	77.50	72.70	76.10	1.759	0.155	0.585
Overweight (%)	3.70	8.90	9.10	47.260*	52.249*	0.012

	Observation periods			χ^2 Test Value		
	2006	2016	2021	2006–2016	2006–2021	2016–2021
			boys			
Underweight (%)	3.49	4.27	3.33	1.726	0.078	1.507
Normal BMI (%)	81.90	76.00	70.20	3.746*	10.594*	1.810
Overweight (%)	14.60	19.80	26.50	15.713*	66.042*	10.686*

From 2006 to 2016, significant changes in the physical fitness of girls were observed (Figure 3, Tables 3–4). During this period, a statistically significant improvement in results was noted only in trunk strength (by 4.65 points and 2.3 sit-ups). However, substantial deterioration in outcomes was observed in trunk flexibility (by 11.58 points and 8.20 cm), cardiovascular and respiratory endurance (by 10.85 points and 7.47 meters), and lower limb strength (by 3.59 points and 8.22 cm). Functional strength and agility showed similar results in both observation periods.

Between 2016 and 2021, there was no improvement in any of the assessed conditioning abilities among girls. Conversely, a decline in results was observed in cardiovascular and respiratory endurance (by 15.71 points and 7.63 meters), trunk flexibility (by 4.91 points and 3.53 cm), and trunk strength (by 2.70 points and 1.12 sit-ups). Results remained relatively consistent in lower limb strength, functional strength, and agility.

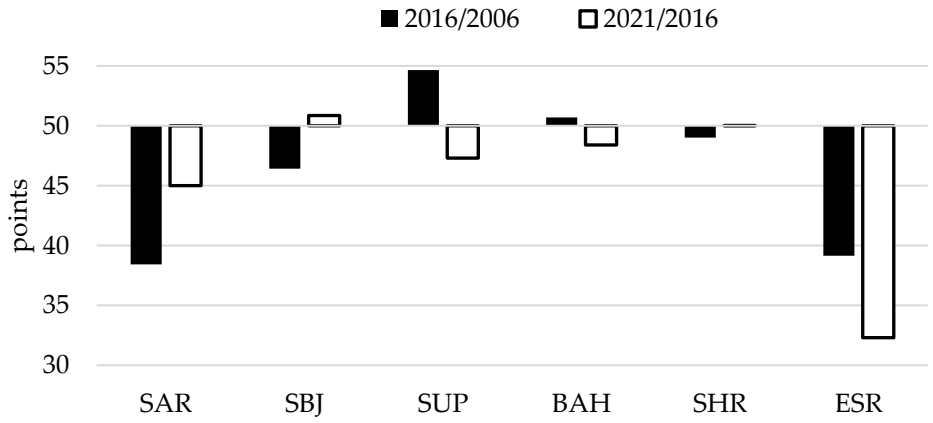

Figure 3. Results of girls from 2016 normalized on a T-score scale to 2006 results and 2021 results normalized to 2016 results *(sit and reach test in a seated position -SAR, standing broad jump - SBJ, sit-ups in a supine position for 30 seconds - SUP, hanging on a bar with bent arms - BAH, 10 x 5 meters shuttle run - SHR, endurance shuttle run over a 20-meter distance - ESR).*

Similar patterns of changes in physical fitness with notable differences were observed among boys from 2006 to 2016 (Figure 4, Tables 3–4). Over this decade, a higher level of results in the eastern provinces of Poland was only noted in trunk strength (by 2.32 points and 0.92 sit-ups), while lower levels were observed in cardiovascular and respiratory endurance (by 18.32 points and 13.55 meters), trunk flexibility (10.64 points and 8.67 cm), and lower limb strength (by 2.79 points and 7.27 cm). Similar levels of results were found in agility (1.79 points and 0.44 s) and functional strength (0.77 points and -1.33 s) in both observation periods.

From 2016 to 2021, boys showed an improvement in trunk strength (by 2.46 points and 1.32 sit-ups). Conversely, there was a decline in cardiovascular and respiratory endurance (by 8.89 points and 12.24 meters) and flexibility (2.30 points and 1.90 cm). In 2016 and 2021, residents of eastern Poland exhibited similar levels of results in agility (0.03

points and 0.41 s), lower limb strength (0.26 points and 0.58 cm), and functional strength (1.27 points and -1.98 s). Calculating overall fitness based on averages from all test trials, it was observed that girls' overall fitness decreased from 2006 to 2016 by an average of 3.61 points, while from 2016 to 2021, the decrease was 4.35 points. For boys, the differences were -3.91 points and 2.39 points, respectively.

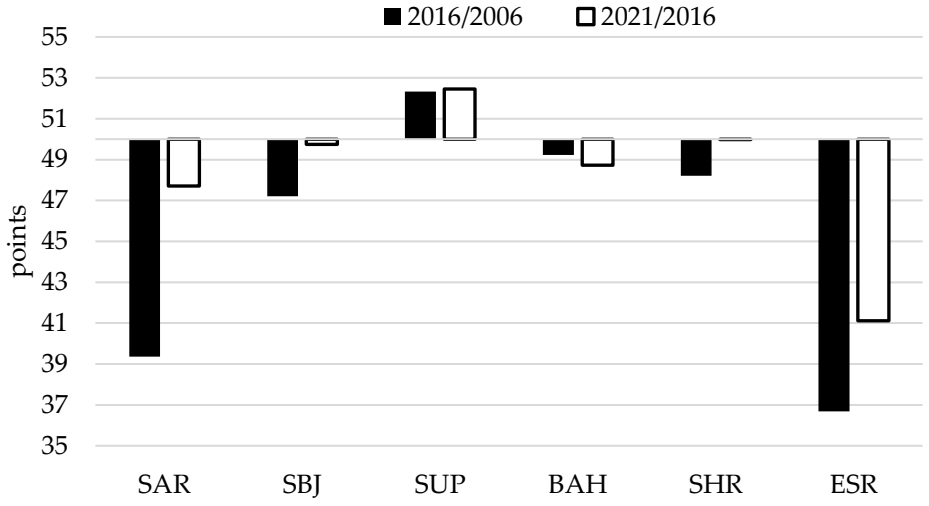

Figure 4. Results of boys from 2016 normalized on a T-score scale to 2006 results and 2021 results normalized to 2016 results (*sit and reach test in a seated position -SAR, standing broad jump - SBJ, sit-ups in a supine position for 30 seconds - SUP, hanging on a bar with bent arms - BAH, 10 x 5 meters shuttle run - SHR, endurance shuttle run over a 20-meter distance - ESR).*

Table 3. Arithmetic means ($\widetilde{x}$) and standard deviations (SD) of T-scale points of girls and boys in physical fitness tests.

	Girls				Boys			
	2016/2006		2021/2016		2016/2006		2021/2016	
	$\tilde{x}$	SD	$\tilde{x}$	SD	$\tilde{x}$	SD	$\tilde{x}$	SD
SAR	38,42	9,77	45,01	9,29	39,36	9,24	47,70	9,95
SBJ	46,41	8,53	50,86	9,50	47,21	9,00	49,74	9,73
SUP	54,65	8,44	47,30	9,90	52,32	6,58	52,46	9,97
BAH	50,69	9,31	48,40	10,92	49,23	8,33	48,73	10,02
SHR	49,02	7,64	50,02	8,13	48,22	9,18	49,97	7,92
ESR	39,15	8,84	32,29	9,05	36,68	8,26	41,11	10,00

sit and reach test in a seated position -SAR, standing broad jump - SBJ, sit-ups in a supine position for 30 seconds - SUP, hanging on a bar with bent arms - BAH, 10 x 5 meters shuttle run - SHR, endurance shuttle run over a 20-meter distance - ESR).

Table 4. ANOVA and Newman-Keuls test values calculated for mean differences in conditioning abilities between girls and boys.

Age [years]	Girls				Boys			
		test Newman-Keuls				test Newman-Keuls		
	ANOVA	2006–2016	2006–2021	2016–2021	**ANOVA**	2006–2016	2006–2021	2016–2021
Sit and reach test in a seated position (SAR)								
16	363.97	19.77*	36.27*	10.35*	163.57	15.33*	23.22*	12.96*
17	322.01	25.14*	32.14*	4.53*	220.68	29.28*	13.39*	9.68*
18	492.21	22.38*	43.27*	10.96*	499.25	34.28*	37.53*	7.38*
Standing broad jump (SBJ)								
16	11.63	6.70*	2.59	2.55	19.77	8.82*	0.69	4.67*
17	32.55	9.82*	7.75*	1.11	16.53	6.94*	5.54*	1.05
18	28.52	9.35*	7.45*	0.58	12.51	3.60*	6.54*	4.07*
Sit-ups in a supine position for 30 (SUP)								
16	16.88	6.57*	6.12*	0.93	28.40	3.25*	9.27*	10.59*
17	33.21	11.38*	4.12*	5.06*	14.84	6.59*	5.49*	0.27
18	54.73	14.67*	1.88	9.25*	50.97	11.78*	10.11*	0.98
Hanging on a bar with bent arms (BAH)								
16	2.97	3.40*	0.06	2.07	0.21	0.55	0.59	0.91
17	5.13	2.12	3.43*	4.38*	9.39	2.04	6.13*	2.76
18	2.44	1.40	2.99	1.99	10.57	3.67*	5.98*	2.33
10 x 5 meters shuttle run (SHR)								
16	14.32	2.93*	6.32*	7.54*	12.03	5.85*	5.05*	0.24
17	5.45	4.38*	0.00	3.91*	9.97	6.14*	3.56*	2.96*
18	7.13	4.39*	4.01*	1.22	3.51	1.54	2.89*	3.66*
Endurance shuttle run over a 20-meter distance (ESR)								
16	933.97	47.70*	44.39*	5.14*	855.20	32.75*	53.16*	7.04*
17	684.79	25.77*	52.44*	37.73*	869.18	19.63*	58.85*	16.30*
18	297.24	4.48*	34.46*	23.93*	932.76	33.51*	56.57*	10.43*

4. Discussion

In the perspective of numerous authors, physical fitness is considered an expression of positive health, comprising physical efficiency, physical endurance, and physical development [23,24]. However, during the diagnosis of the health status of children and adolescents, the assessment of their physical fitness is often overlooked. Przewęda [25] regards the level of physical fitness as a more accurate indicator of physical fitness, reflecting the health potential of both boys and girls, compared to mere manifestations of growth or maturation. Physical fitness undergoes a training process through regular physical activity. However, the lack of regularity, insufficient quantity, or complete cessation of physical activity can lead to a regression in physical fitness and, consequently, an increase in the likelihood of overweight and the occurrence of civilization diseases [26, 27].

Presently, a global trend is observed in the reduction of children and adolescents with underweight and an increase in those with overweight. This is confirmed by Ng et al.'s [1] research conducted between 1980 and 2013 in various countries worldwide. This trend is

noticeable both in developing countries and economically advanced nations. Similar conclusions based on the studies of girls and boys in Brazil, China, Russia, the USA [28], and Australia [29] were presented. The authors attribute these changes to different dietary habits and a reduction in physical activity. Notably, Hardy et al. [29] point out that the trend of increasing overweight in developed countries is slowing down. Considering these observations, the identified trend of not increasing the frequency of underweight in boys, and even reducing it among girls in the last five years in our study, can be considered a positive outcome.

Underweight is a significant clinical and public health problem among children and adolescents, associated with adverse health effects throughout their lives, reflecting poverty in access to food [30], unhealthy dietary habits [31], or an increased risk of various diseases. Underweight individuals are more susceptible to infectious diseases [32], often have restricted cognitive functions [33], mental disorders [34, 35], and a low self-rated health status[36].

However, the described changes in the frequency of overweight are concerning. In the first of the analyzed decades, a significant increase in the frequency of overweight was observed in girls and boys from eastern Poland, which was also evident in the subsequent five years, only among boys. It is worth emphasizing that despite the shorter time span in the analyzed five-year period, greater differences in the frequency of overweight were not-ed among students than in the entire previous decade. Such significant changes in boys may be the result of both a reduction in physical activity during the Covid-19 pandemic and improved living conditions due to the "500+" program. It may also suggest that the younger generation will exhibit a high prevalence of overweight in the future, increasing the risk of metabolic disorders mentioned in the introduction. Simultaneously, it has been proven that regular physical activity significantly reduces the risk of developing metabolic syndrome [37]. It is estimated that globally, low physical activity is responsible for 37% of mortality and 20% for cardiovascular diseases [38].

Currently, there are no uniform secular trends in physical fitness worldwide. The direction and dynamics of changes depend on the geographical latitude and economic development of countries or regions where observations were made. From the last decade of the previous century, a decrease in physical fitness among children and adolescents has been observed in Japan [39] and South Australia [40]. Adverse changes in physical fitness in the European Union countries were noted in Belgium [41], Finland [4], and Poland [42]. In Lithuania and Estonia from 1992 to 2002, researchers found a significant convergence of physical fitness in both countries, with no major differences in the level of physical fitness after the analyzed decade [43]. They simultaneously emphasized the difference in secular trends from those observed in other European countries. Venckunas et al. [44], continuing observations in Lithuania in 2012, noted adverse changes in some physical fitness. The above-mentioned reduction in physical fitness is presented as the final conclusions of the authors, despite the lack of unanimity in the results when assessing individual physical fitness.

In our conducted observations, a decrease in the level of physical fitness among girls and boys was also noted. However, these changes were not uniform across all conditioning abilities. In the first of the analyzed decades, improvement was observed only in trunk strength in both girls and boys, accompanied by a significant decrease in cardiovascular and respiratory endurance, trunk flexibility, and to a lesser extent, lower limb strength. No significant changes were observed in other conditioning abilities. From 2016 to 2021, improvement in results was noted only in trunk strength among boys. On the other hand, a substantial reduction in the performance levels of girls and boys was observed in cardiovascular and respiratory endurance, trunk flexibility, and trunk strength in girls. No major differences were found in lower limb strength, agility, and functional strength. It is noteworthy that in cardiovascular and respiratory endurance from 2016 to 2021, greater distances were observed than in the entire previous decade. Similarly, Tomkinson et al. [5,8], based on studies from 28 countries, provided evidence of a significant decrease in aerobic

endurance and physical fitness among children and adolescents in recent decades. According to these authors, the decline in cardiovascular endurance is associated with social, behavioral, physical, psychosocial, and physiological factors.

5. Conclusions

The temporal trends delineated in this study underscore the necessity for regular health monitoring of children and adolescents. Particular attention should be paid to the significant decline in conditioning abilities among the examined girls and boys, especially cardiovascular and respiratory endurance. According to the Eurostat report [45], the provinces of eastern Poland are among the poorest macroregions in the European Union, where per capita income does not exceed 50% of the EU average income. Despite the introduction of the government's "500+" program in 2016, which commenced monthly transfers of 500 PLN per child, economically supporting less affluent families, substantial environmental disparities in the nutritional status of young people persist. Furthermore, the changes observed in the prevalence of overweight and reduced physical fitness over the last five years are particularly alarming. The decline in physical activity among children and adolescents, commencing in 2020, was likely a consequence of restrictions associated with the Covid-19 pandemic. Remote learning was conducted for many months, concurrently with the closure of sports facilities. This led to a significant reduction in physical activity among children and adolescents. It may be one of the reasons for the recent increase in the frequency of overweight and the decrease in physical fitness levels evaluated in our youth study.

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Author Contributions: Study Design, AW and JS; Data Collection, AW and JS; Statistical Analysis, AW and JS; Data Interpretation, AW and JS; Manuscript Preparation, AW and JS; Literature Search, AW and JS; Funding Acquisition, AW and JS.
All authors have read and agreed to the published version of the manuscript.

Funding: The research was carried out with the financial support research of the Academy of Physical Education in Warsaw (D.S. 49 and D.S. 203) and as part of the "Active return to school – PE with AWF" program.

Institutional Review Board Statement: The research was conducted in accordance with the principles outlined in the Helsinki Declaration and was approved by the Senate Ethics Committee at the Academy of Physical Education in Warsaw.

Informed Consent Statement: n/a.

Data Availability Statement: Data available from the corresponding author on request.

Conflicts of Interest: The authors declare no conflict of interest.