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Secular changes in the height of Polish schoolboys from 1955-1988

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Abstract

Secular changes in height have been observed in many regions of Poland using cross-sectional data; however, data from four nationally representative surveys conducted from 1955 to 1988 have only been partially analyzed. Dramatic social and economic transitions during this 33 year period provide a unique opportunity to understand changes in growth within this historic context. We analyzed the changes in height of boys, aged 7 to 18 years, from surveys conducted in 1955, 1966, 1978 and 1988.

Data for height were converted to Z-scores using the LMS method and the 2000 National Center for Health Statistics reference. In each consecutive survey year, boys at all ages were significantly taller than the same aged boys from the previous survey year, with mean height increases of a 2.35 cm, 3.43 cm and 1.47 cm between 1955-1966, 1966-1978 and 1978-1988, respectively. There were significant declines with age in height Z-scores from 7 to 14 years of age, followed by improvements relative to the reference between 14 and 18 years of age. The decline in Z-scores may be partially explained by an effect of delayed maturation. However, historic context also supports that some birth cohorts likely experienced a more adverse environment during early childhood than did other birth cohorts.

Keywords

Secular changes; height; political and economic transition; Poland; children

I. Introduction

Secular changes, or changes over time, in anthropometric traits have been well established in countries around the world. The reasons for such great interest in analyzing these changes

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have also been well-recognized (Cole, 2003). Numerous publications have helped to establish the many different ways in which data on height can be used to show the long term changes and well-being in a population (Tanner, 1981; Bielicki, 1986; Fogel, 1986; van Wieringen, 1986; Komlos, 1987). Positive, negative, and oscillating trends over time have been largely associated with changes in environmental conditions that are linked to the nutrition and health status of the population (Tanner, 1990; Bodzsar and Susanne, 1998; Komlos et al., 2004; Zellner et al., 2004; Lintsi and Kaarma, 2006; Hiermeyer, 2009; Hatton and Bray, 2010). In Poland, the changing pattern of growth in conscripts was observed as early as the nineteenth century (Kopczyński, 2007). More recently, secular changes in height among Polish children have been documented in many regions of the country using cross-sectional data. The picture that emerges shows general secular changes toward an increase in average height over the past several decades in children and adolescents in selected regional groups (Milicer, 1966; Palczewska and Niedzwiecka, 2001; Krawczynski et al., 2003; Łaska Mierzejewska and Olszewska, 2007)¹.

From 1955 to 1988 there were four nationwide anthropometric surveys conducted in Poland. Parts of these surveys were previously analyzed and described in other publications (Bielicki et al., 1981; Hulanicka et al., 1990). However, data for girls in 1955 and 1966 are not yet available in electronic form and large parts of the data related to boys examined in 1955 and 1966 were only recently computerized. Therefore, an analysis across a wide range of ages and all four nationwide surveys has not been presented. Thus, the aim of this analysis is to describe the changes in height in Polish boys born from 1937 to 1981. These years encompass World War II, followed by a period in which Poland had obtained formal independence, yet, up until 1989, was still living under the political and economic control of the Soviet Union. It is important to understand changes in anthropometric measurements in this turbulent period of Polish history and make inferences as to how such significant changes in the social, political and economic environment may have affected the growth of children during this period.

2. Methods

2.1 Survey Methods and study subjects

Survey data included boys and girls aged 7 to 18 years, and were collected consecutively in 1955, 1966, 1978 and 1988 from selected regions in Poland². However, because data for girls in earlier survey years is not yet computerized, the present analysis includes data for boys only (N=39,656). All surveys were completed under the auspices of a special Anthropometric Commission of the Polish Academy of Science and included professors of anthropology, mathematicians and medical doctors. Consent of the local district school administration was required in order for the school to participate (Polish Anthropological Survey. Warsaw-Wrocław, 1955-1959). During this time period, education in primary schools for children ages 7 to 14 years was obligatory, and thus, those who did not participate were likely those children that were randomly absent on the days when data

¹Additional references available in Polish

²Data are available from the archives of the Institute of Anthropology of the Polish Academy of Science in Wrocław, Poland. Data from 1966 were computerized by EB and several student assistants at this location.

collection occurred. Children ages 15 to 18 years that attended secondary schools were likely those with better school performance, or those whose parents had higher expectations for educational attainment. Thus, the sample of secondary school children measured in these surveys may represent a group of children from more affluent families in this population, as suggested by a reduced sample size in 18 year old boys.

In the 1955 and 1966 surveys, children were chosen with a multi-stage sampling procedure in proportion to the population density by the National Bureau of Statistics (GUS). In the first stage of sampling, the regions of the country were selected, followed by locations within the regions. Next, the schools within the locations, and finally the required number of children were randomly chosen from each grade of each school. The surveys in 1978 and 1988 were organized using a somewhat different design than the previous two, insofar as children were examined only in three large cities, (Warsaw, Łódź, and Wrocław), four small towns and in the villages that were within the county districts of these towns (Hulanicka et al., 1990). Due to the high costs of conducting the surveys in 1955 and 1966, the surveys in 1978 and 1988 were reduced to include these smaller but presumably demographically representative areas of the country. In the urban locations, schools were randomly selected, while the sample in the small towns and villages included the entire population of school boys living within these selected areas. As expected, the overall number of boys examined increased in consecutive surveys, consistent with the increasing population density in Poland. However, within each survey year, the age distribution of sample sizes remained similar. All regions included in the 1978 and 1988 surveys were represented in the 1955 and in 1966 surveys.

2.2. Measurements

All surveys included data for multiple anthropometric characteristics. Additional information on demographic and social characteristics was collected from three sources: an interview with the examined child, information from parents and teachers, and school reports. Height (cm) was measured using a Harpenden anthropometer to the nearest 1.0 mm. In all four surveys, children were measured in light clothing without shoes by trained biology and medical students who were supervised by professional anthropologists during all examinations (Polish Anthropological Survey, 1955-1959)³. Each child's age was rounded to the nearest whole year, so that for example, the group of 9 year old boys contains all boys from 8.50 to 9.49 years with their ages coded as 9.0 years.

2.3. Statistical analyses

The individual values for height were converted to Z-scores using the LMS method and the published L, M and S parameters from the 2000 National Center for Health Statistics (NCHS) reference population for the United States using the following equation, in which X represents the individual data point for height: $Z = [(X/M)^L - 1]/LS$. The LMS method summarizes the data in terms of three smoothed, age specific curves. The M and S parameters correspond, respectively, to the median and coefficient of variation of height at

³References available in Polish from the Polish Academy of Science, Institute of Anthropology

each age. The L parameter allows for age dependent skewness in the height distribution (Cole et al., 2000).

The NCHS reference population was chosen due to the public availability of the age specific L, M and S parameters for height, and because the population used to create this reference is well-described (Kuczmarski et al., 2000). Subjects with missing data for height were excluded from the analysis (n=55). A fixed exclusion range defined as height Z-score < -5.0 or > 3.0 was used to classify outliers as recommended by The World Health Organization (World Health Organization, 1995). Subjects that fit this criteria were also excluded from the analysis (n=34), making the final sample size used in the present analysis 39,567 boys. The mean Z-score values for height within and between survey years were tested using one-way ANOVA with a Bonferroni correction and an alpha level of 0.05. All analyses were performed using SPSS version 15.0 (SPSS Inc.).

3. Results

Among Polish boys aged 7 to 18 years, there was a significant positive secular change in height; specifically, in each consecutive survey year, from 1955 to 1988, boys at all ages were on average significantly taller than the same aged children from the previous survey year (Table 1). The largest coefficient of variation in height within each survey year occurred between the ages of 13 and 15 years. The difference in mean height was generally the largest between 1966 and 1978 and the smallest between 1978 and 1988 (Figure 1). Within all four survey years, mean height Z-scores traced a U-shaped curve, reaching a nadir at approximately 14 years of age, and then rising relative to the reference until 18 years of age (Figure 2).

By 14 years of age Polish boys had height Z-scores that were significantly lower relative to the NCHS reference than those of 7 year olds within the same survey year ($p < 0.001$). These declines with age were of greater magnitude in 1955 and 1966 than in 1978 and 1988. Following these declines, there were significant increases with age in mean height Z-score between 14 and 18 years of age in 1955 and 1966 ($p < 0.001$), and non-significant increases in 1978 and 1988 ($p = 0.095$ and 0.106 , respectively) (Table 2). By 18 years of age, mean height Z-scores were not significantly different from those of 7 year olds within the same survey year ($p=1.00$, 1.00 , 0.298 , and 1.00 , respectively). By 1988, 18 year old Polish boys had largely caught up with their American counterparts (Figure 2).

18 year old Polish boys measured in 1966 were from the same birth cohort as 7 year old boys measured in 1955. These 18 year old boys had a significantly higher mean height Z-score, relative to the reference, than the group of 7 year olds boys measured in 1955 ($p < 0.001$). Likewise, the 18 year olds measured in 1978 had a significantly higher mean height Z-score relative to the reference than 7 year olds measured in 1966 ($p < 0.001$). 18 year olds measured in 1988 had a significantly higher mean height Z-score relative to the reference than 8 year olds measured in 1978 ($p < 0.001$) (Table 2).

4. Discussion and conclusions

Findings from the present analysis demonstrate that a positive secular change in height occurred between 1955 and 1988, with the greatest increase between 1966 and 1978. Among 18 year old boys, there was a 2.35 cm increase between 1955 and 1966, followed by a 3.43 cm increase between 1966 and 1978, and a 1.47 cm increase between 1978 and 1988, consistent with the findings of Bielicki and Szklarska (1999) in their analysis of cross-sectional data for 19 year old military conscripts in Poland. Krawczynski et al., (2003) showed similar patterns in height for children and adolescents in their cross-sectional analysis in Poznań, Poland from 1880-2000.

Results from Poland were also compared at both 8 and 18 years of age to boys from several European free market affluent countries, and to several countries that were also under communist rule (Figure 3). Comparisons were made to countries in which surveys were well described, and conducted in either one or two decades between 1960 and 1989. In the 1960's, Polish boys measured at both 8 and 18 years were the smallest, by approximately 3-6 cm, compared to boys from other countries. In the 1980's, Polish boys largely caught up to the average heights attained by boys at both age 8 and 18 years in other European populations (Twisselmann, 1969; Vercauteren, 1969; Brundtland et al., 1980; Flügel et al., 1983; van Wieringen, 1986; Lindgren and Hauspie, 1989; Eveleth and Tanner, 1990; Tutkuvienė, 1995; Bodzsar and Susanne, 1998; Vercauteren and Susanne, 1998; Jaeger, 1998; Vignerova et al., 2006).

In the 1960's, boys from Lithuania, a country, that was occupied by the Soviet Union during this time period, had attained heights at 8 and 18 years that were close to the average heights observed in many western European populations. However, by the 1980's, Lithuanian boys had experienced a positive secular change in growth, albeit a more modest change than that observed in Polish boys during this period. By the 1980's Lithuanians ranked amongst the tallest boys in Europe, while the height of Polish boys remained comparable to the heights of their other eastern European counterparts. Despite possible genetic differences between the Polish and Lithuanian populations (Kasperavicius et al., 2004), it is likely that growth in both countries was somewhat constrained by environmental factors that improved during the period of observation. In the 1960's Belgian boys at both ages were quite tall compared to Polish boys, a difference that largely disappeared by the 1980's, despite a more favorable environment in Belgium than in Poland during this time period. However, it is possible that comparisons to data from other European countries could be biased by differences in genetic background, different methods of sampling, and variation in age classifications.

Several potential explanations exist for the observed secular changes in height in Poland. The following discussion will consider both methodological and historic factors, including an assessment of how political, social and economic circumstances may have affected growth in early life. According to Tanner (1990) and Frongillo and Hanson (1995), an unstable political situation could have important influences on the growth of children. During this time period, Poland had a very small fraction of ethnic and religious minorities, almost no external migration, and a population with negligible regional genetic variation (Gronkiewicz, 2001). Therefore, in such a population, changing environmental influences

may provide important insights into the observed secular changes. Figure 3 outlines the historic context for the period of interest. For this analysis, we largely rely on general social, political and economic events because, until recently, specific statistics were either not available or likely contained inaccuracies. From the mid 1950's to the late 1980's, post-neonatal mortality fell from approximately 45 per 1000 live births to 4.5 per 1000 live births. Over time, there were also improvements in the general level of education and medical services. At the same time, there was an intensive rural to urban migration that began in 1955 and peaked between 1960 and 1970. This migration resulted in substantially improved living conditions for the migrants, increased the number of families with fewer children and increased the number of parents with secondary education (Central Statistical Office GUS). These trends may be indicative of an overall improvement in the health and well-being of the population over this 33 year period. Bielicki and Szklarska (1999) noted that the absence of any reversals in the secular change in Polish conscripts was surprising given the turbulent times. However, the continuous increases in the secular changes are supported by these improved post-neonatal mortality data, which correlate positively with adult height insofar as improvements in the medical system improved the biological standard of living (Schmidt et al., 1995).

Despite overall improvements in height over this time period, there were clearly periods of increased and decreased tempo. There may be several reasons for the observed trend. The decrease in tempo in the later cohorts could indicate a ceiling effect, such that the later cohorts more closely approached their genetic potential for attained height. Alternatively, an increase in favorable environmental factors for growth may have been more marked between earlier, rather than later survey years (Figure 3) (Hulanicka et al. 1990). Lastly, these data may indicate that some catch-up growth may have influenced the observed changes and patterns over this time period.

Catch-up growth refers to the ability of a child to return to their normal growth trajectory once an environmental insult is corrected (Tanner, 1981). Although these cross-sectional data cannot provide a conclusive assessment of catch up growth, a comparison of mean Z-scores of the youngest and oldest children between survey years indicates that 18 year olds were taller relative to the reference than they were at age 7 years, and thus caught up to their American counterparts (Table 2). However, as previously discussed, the group of 18 year old boys, particularly in 1955 and 1966, may possibly represent a group of children from more affluent families.

Shifting to a discussion of secular changes within, rather than between survey years, this analysis showed that there were significant declines with age in height Z-scores relative to the NCHS reference during the pubertal years, with greater declines occurring in 1955 and 1966 (Figure 2). The apparent differences in birth cohorts observed in this analysis lead to two possible interpretations; the age by cohort confounds were an artifact of the chosen reference population, specifically, the Polish boys had different timing of biological maturation at puberty compared to the boys from the NCHS reference (Haas and Campirano, 2006), and second, varying environmental circumstances in Poland may have uniquely affected the early life of different birth cohorts. Secular changes in the maturation of girls (e.g. age of menarche) have been widely reported in Poland (Hulanicka and

Waliszko, 1991; Łaska Mierzejewska et al., 2007). However, the data on the maturation of boys, measured by peak height velocity (PHV), are very limited, with no nationally representative data available that clearly establishes secular changes in boys. However, it is well documented that the largest variation in height occurs during puberty (Tanner, 1978). In the NCHS reference the largest coefficient of variation occurs at approximately 13 years of age (MacMahon, 1973), while in the Polish boys, the largest coefficient of variation is shifted to approximately 14 years of age. One longitudinal study (n=177) in boys born in 1953 from Wrocław, Poland likewise showed that mean age at PHV occurred at approximately 14.0 ± 1.2 years (Bielicki et al., 1984).

Despite these observations, it seems unlikely that delayed maturation can entirely explain the age by cohort confounds in the present study, and in addition, delayed maturation itself may be influenced by changing environmental conditions. The patterns observed suggest that the birth cohorts of younger children within each survey year experienced a more adverse environment during the first few years of life than did the birth cohorts of the older children. Differences in early life experiences are particularly important to consider in 1955 and 1966 when the declines in height Z-scores during puberty were of the greatest magnitude. Younger cohorts in 1955 and 1966 may have been exposed to poor conditions during their preschool years in a cyclical fashion, reflecting rapidly changing conditions in Poland at the time. This in turn could have negatively affected growth, reflected in the decline with age in height Z-scores observed in the present cross-sectional data (Figure 2).

The economic situation in Poland prior to World War II produced a relatively more favorable environment for the older group of children measured in 1955, compared to the younger children, who spent their earliest years during the peak destruction of the war and early years of communist rule (Figure 4) (Korbo ski, 1992). The war itself may have also exerted a selective pressure in favor of the survival of stronger, healthier children. In the 1966 survey, the older children that were measured were born during a period that, by most standards, was still a very oppressive time in Poland. However, after 1956, there may have been a slightly more favorable environment for growth than during the massive political and economic circumstances of the early Stalinist times in the 1950's. These economic crises led to decreased access to food, and a likely decline in the nutritional situation of the younger children.

A few aspects of this study must be considered when interpreting the results. The first limitation is the cross-sectional design; longitudinal data would better enable the monitoring of growth over time. The second limitation is the potential influence of differences in survey methods, particularly between 1966 and 1978 when there were slight differences in the sampling methods. The Central Statistical Office (GUS) in Poland reported that large population growth between the late 1950's and 1988 occurred almost exclusively in urban areas, and that the number of inhabitants in rural areas, despite their high reproductive rates, remained almost unchanged, indicating a large rural to urban migration (GUS Central Statistical Office, Statistical Yearbooks of the Republic of Poland 1955 GUS Central Statistical Office, Statistical Yearbooks of the Republic of Poland 1966 GUS Central Statistical Office, Statistical Yearbooks of the Republic of Poland 1978 GUS Central Statistical Office, Statistical Yearbooks of the Republic of Poland 1988). From 1955 to

1978, the number of inhabitants in rural areas decreased from 15,483,000 to 14,698,000, while the number of inhabitants in urban areas increased from 12,067,000 to 23,187,000 (GUS Central Statistical Office Warsaw, 2010).

Bielicki (1986) and Hulanicka et al., (1990) reported marked social, urban-rural and educational differences in the magnitude of secular changes in boys after World War II. However, since the samples were not weighted to reflect changes in the urban and rural populations, it is difficult to know if, and how much bias in secular changes was introduced due to rapid changes in demographic parameters over time. What is known is that the number of schools chosen was explicitly based on the number of children located in a particular area. Due to the fact that the largest changes in height were observed between the 1966 and 1978 surveys when large migrations occurred, one might suspect that there were a greater number of children from more affluent families in the latter two survey years, leading to potential inflation of the changes in height between survey years. However, the magnitude of these changes is plausible and also consistent with the magnitude of secular changes in other countries (Figure 3). In addition, marked secular changes still occurred between both 1955 and 1966, and between 1978 and 1988, when the sampling methods were the same. These observations lend support to the assumption that the differences in sampling methods between 1966 and 1978 made relatively little difference in the findings of secular changes in the present analysis.

This paper presents for the first time the most complete analysis of the secular changes in height that occurred in Polish boys from nationally representative data between 1955 and 1988, and introduces a historical framework for understanding how environmental influences in early life may help to explain the secular changes and age by cohort confounds observed in these cross sectional data. In the present analysis, the population of Polish boys by 1988 appears to have attained heights that are comparable to the NCHS reference values, which is impressive given the large difference in income between the two countries. Analysis of nationally representative data from more recent years is needed to establish if the secular changes have come to a halt in the Polish population in both urban and rural areas.

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Highlight

- > We analyze secular changes in height of Polish schoolboys aged 7-18 years from four cross-sectional anthropometric surveys between 1955 and 1988.
- > We examine secular changes from both a methodological and historic perspective.
- > From 1955 to 1988 there was a clear positive secular change in height in Polish boys.
- > Delayed maturation of schoolboys and environmental influences in early life may help explain observed age by cohort confounds from these data.

Figure 1. Difference in mean height (cm) between survey years at each age

Figure 2. Mean height Z-scores of Polish boys relative to the NCHS Z-score reference (zero line is the NCHS reference)

Figure 3. Mean height (cm) of boys at age 8 and 18 years, measured in the 1960's and the 1980's in different European countries

Figure 4. Historical framework for the growth of Polish school boys from the mid 1930s until the late 1980's

Table 1
Mean height (cm) and standard deviation (SD) of Polish boys by age and survey year

Survey Years																	
1955 (n=8070)				1966 (n=9193)				1978 (n=9867)				1988 (n=12,437)			Between Survey Increases		
Age	n	Mean	SD	n	Mean	SD	n	Mean	SD	n	Mean	SD	1955/1966	1966/1978	1978/1988		
7	706	117.39	4.82	458	119.71	5.55	821	121.73	5.54	1041	122.15	5.30	2.32**	2.02**	0.42*		
8	910	121.78	5.41	572	124.21	5.90	881	126.98	5.64	1133	128.06	5.80	2.43**	2.77**	1.08**		
9	874	127.25	6.04	675	128.81	6.10	885	131.92	6.16	1179	133.01	5.76	1.56**	3.11**	1.09**		
10	673	131.33	5.65	672	133.77	6.10	844	137.10	6.03	1131	138.30	6.28	2.44**	3.33**	1.20**		
11	619	135.65	5.74	830	137.63	6.32	828	141.76	6.27	1044	142.81	6.41	1.98**	4.13**	1.05*		
12	561	139.49	6.32	776	142.40	6.58	847	147.27	7.44	1062	148.79	7.20	2.91**	4.87**	1.52**		
13	613	145.26	7.58	877	148.33	7.92	840	152.91	8.38	1025	154.72	8.51	3.07**	4.58**	1.81**		
14	827	151.92	7.94	819	153.74	8.72	816	160.87	9.23	946	162.36	8.50	1.82**	7.13**	1.49**		
15	868	158.48	8.85	1150	162.20	8.96	854	166.63	8.69	1184	168.80	7.84	3.72**	4.43**	2.17**		
16	755	163.70	7.63	1093	167.77	7.91	837	171.37	7.08	1105	172.71	7.08	4.07**	3.60**	1.34**		
17	459	166.86	7.35	874	170.98	6.75	764	172.98	6.85	949	175.08	6.55	4.12**	2.00**	2.10**		
18	205	169.10	6.68	397	171.45	6.34	650	174.88	6.26	638	176.35	6.22	2.35**	3.43**	1.47**		

* p < 0.05;

** p < 0.001;

Significance based on differences in mean height Z-scores

Table 2

Mean height Z-score by age, survey year and date of birth

Survey Year	Age (years)	7	8	9	10	11	12	13	14	15	16	17	18
1955	Birth Year	1948	1947	1946	1945	1944	1943	1942	1941	1940	1939	1938	1937
	Z-score	-0.94 ⁺	-1.04	-1.02	-1.08	-1.12	-1.28	-1.37	-1.41 [*]	-1.34	-1.21	-1.10	-0.96 [†]
1966	Birth Year	1959	1958	1957	1956	1955	1954	1953	1952	1951	1950	1949	1948
	Z-score	-0.49 ⁺	-0.58	-0.75	-0.71	-0.84	-0.89	-0.97	-1.16 [*]	-0.91	-0.70	-0.56	-0.62 [†]
1978	Birth Year	1971	1970	1969	1968	1967	1966	1965	1964	1963	1962	1961	1960
	Z-score	-0.02	-0.11 ⁺	-0.23	-0.19	-0.24	-0.24	-0.36	-0.32 [*]	-0.35	-0.23	-0.28	-0.16
1988	Birth Year	1981	1980	1979	1978	1977	1976	1975	1974	1973	1972	1971	1970
	Z-score	0.10	0.06	-0.04	-0.03	-0.09	-0.02	-0.14	-0.11 [*]	-0.09	-0.05	0.00	0.05

* Significantly different from mean height Z score at 7 years of age within the same survey year, p 0.001;

[†] Significantly different from mean height Z score at 14 years of age within the same survey year, p 0.001;

⁺ Significantly different from mean height Z score at 18 years of age in the following survey year.