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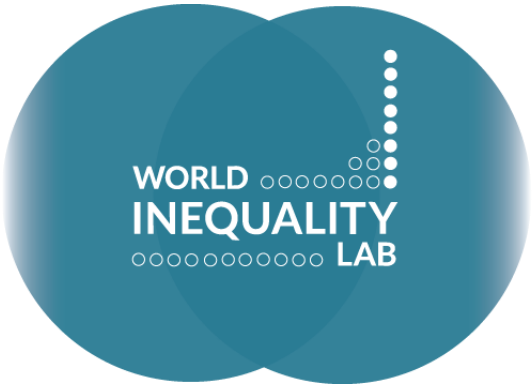

The full distribution of adult height in Poland: cohorts born between 1920 and 1996. The biological cost of the economic transition.[1]

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Abstract: Body height often serves as a proxy for economic progress. In this paper, we investigate the evolution of average height and height dispersion in Poland based on full administrative data on body height (n=36,393,246). In the cohorts born between 1920 and 1996, the average height of men increased by 10.15 cm, while the average height of women rose by 8.18 cm. Height increase was fastest in the years 1940 – 1980. After the economic transition, body height stagnated. Post-transition unemployment had negative effects on body height. Height declined in municipalities where there were State Agricultural Farms. Height dispersion decreased in the first decades under investigation and increased after the economic transition.

JEL classification: N14, P20, Z13

Keywords: height, secular trend, inequality, Poland

1. Introduction

Variation in height has two components: genetic and environmental. Genetic and paragenetic factors explain 70% of the variation in height (Byard et al., 1993). The rest of the variation is driven by living conditions. Body height is a cumulative measure reflecting nutrition and health in the first twenty years of life (Kopczyński & Rodak, 2021). It is widely accepted that human height may serve as a proxy for public health and material well-being (e.g Tanner, 1982; Komlos & Baten, 2004; Deaton & Arrora, 2009; Baten & Blum, 2012; Cameron & Schell, 2021). Height is also an important determinant of the quality of life. The positive effects of height on earnings have been demonstrated in many diverse countries, for example, the United States (Case & Paxon, 2008), Germany (Rietveld et al., 2015), Pakistan (Bossavie et al., 2021), and Taiwan (Tao, 2014). The earnings height premium reflects higher cognitive and social skills and better physical capacity. However, a significant height premium is identified even after correcting for these factors. It arises because of the sorting of short people into low-paid occupations, which may reflect discrimination by stature (Lundborg et al., 2014). The

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height premium is not limited to labor market participation. Taller people tend to evaluate their lives more favorably, more often report positive emotions, and are less likely to report negative experiences (Deaton & Arora, 2009).

In this paper, we provide the first estimates of the height trends in Poland based on the administrative dataset covering the whole population. In the years 2001 – 2015, information on body height was given on all identity cards issued in Poland. Because identity cards in Poland are valid for only ten years, our data source (n=36,393,426) covers the entire adult population of Poland. Based on this data source, which was not used by the researchers previously, we investigate the evolution of adult height in the cohorts born in 1920 – 1996. We measure the secular trend, assess height dispersion, investigate regional gaps, and estimate the econometric model to measure the impact of the economic transition on height.

1.1. Historical context

In 1918, Poland regained independence after over a century, during which Polish lands were partitioned between Prussia, Austria, and Russia. Initially, the country was democratic, and many progressive public policies (e.g. progressive income taxation, wealth tax, health insurance, unemployment insurance) were introduced. In the late 1920s, an authoritarian regime was established and survived until the Second World War. Since the beginning, Poland has been plagued by economic problems. During the First World War, war destruction in Poland was probably the highest among the participating countries. It is doubtful whether the country's GDP in 1938 was significantly higher than in 1913 (see the discussion in Kopczyński & Rodak, 2021). The Polish economy was highly impacted by the Great Depression. Based on the contemporary evidence it has been estimated that in the years 1929 – 1935, the national income declined by half. Regional inequalities in economic development were high, and huge ethnic inequality could be observed. The First World War reduced income inequality, however, it continued to increase during the interwar period (Bukowski & Novokmet, 2021). Data from wealth taxation clearly show that the middle class in interwar Poland was weak. The share of the top decile in national wealth was among the lowest in interwar Europe. However, the very top wealth shares were very high. The top 0.01% (approx. 900 richest families) controlled close to 15% of national wealth.

The anthropometric research shows that despite the poor economic performance, the biological standard of living increased. The nutritional stress caused by the war was quickly eliminated. Advances in body height in Poland were related not only to economic growth but

also reflected the spread of public hygiene, medical knowledge, and education. In the interwar period, Poland doubled its medical personnel, introduced compulsory prevention vaccines against smallpox, expanded the waterworks and sewage systems, and introduced compulsory education. In the interwar period, the rise in biological well-being exceeded the change in monetary measures (Kopczyński & Rodak, 2021).

During the Second World War, Poland experienced vast war destruction. After the war, the country changed its borders and social system. Land reform and nationalization of industry and trade destroyed the economic foundations of the pre-war elite. Intensive industrialization, urbanization, and an education boom changed the social structure of the country. Although economic inequality was significantly reduced (Bukowski & Novokmet, 2021), some privileged groups still may be identified. While before the war, the wealth elite consisted mainly of business owners (Wroński, 2023a), wealth tax data from the 1970s show that the wealth elite in socialist Warsaw consisted primarily of intellectuals, people employed in academia, and the cultural sector. Interestingly, both party elites and workers were nearly absent among top wealth holders, at least according to the wealth tax data (Wroński, 2023b). In the 1980s, income inequality in Poland was relatively high. The value of the Gini index was the highest among communist countries in Central and Eastern Europe, and higher than in capitalist Sweden (Atkinson & Micklewright, 1992; Wroński, 2023b). The change of the social system increased intergenerational mobility, but while the new system stabilized it decreased again. Intergenerational mobility experienced a significant decrease in the late 1980s and after the transition to a market economy in 1989 (Wroński, 2023c).

While the late 1940s and the early 1950s were a period of rapid economic and social change, the late 1950s and the 1960s were a time of so-called "low stabilization". Political liberties and cultural freedoms were extended, and more educated workers entered the labor force. State investments shifted from heavy industry to consumer goods. The urban population was for the first time in Polish history larger than the rural population. In the 1970s, countries partially opened to the West, and economic cooperation with market economies increased. Foreign credits allowed for higher investment and led to an economic boom. The prosperity ended when the interest rate increased due to the oil crises. The 1980s were a period of Martial law (1981-1983), and economic crisis. While food rationing was introduced, those receiving a higher income (especially foreign currency income) and who had connections could purchase additional rations (Zawistowski, 2017).

In 1989, after the agreement between the communist party and political opposition, Poland transitioned to democracy and a market economy and joined the European Union in 2004. Although the transition to a market economy led to an impressive increase in the GDP, income gains were mostly captured by top income groups, and mass unemployment was an important problem of the 1990s and early 2000s (Kowalik, 2012; Piątkowski, 2018; Bukowski & Novokmet, 2021; Ghodsee & Orenstein, 2021, Brzeziński et al., 2020; Brzeziński et al. 2021, Wroński, 2021; Wroński 2023c).

1.2. Anthropometric research in Poland

The historical context discussed above makes Poland a good laboratory for scholars interested in the link between economic conditions, social stratification, and human biology, especially human height. Poland is genetically highly homogenous, which makes the investigation of the impact of social factors on human height easier (Gronkiewicz, 2001; Plonskie et al., 2002; Kozieł, 2021).

Kozieł (2021) reviews the literature on human height in Poland in recent decades. Six nationally representative surveys of military conscripts were conducted in the years 1965 – 2015. These systematic surveys are internationally acknowledged for their completeness and quality (Fudvoye & Parent, 2017). Anthropometric research indicates a positive correlation between a mother's education and the increase in the importance of this factor after the economic transition. The urbanization level of place of residence is another important factor impacting the height of conscripts. In the years 1965 – 2009, the height of inhabitants of villages and small towns increased faster than the height of inhabitants of large cities (8.2 cm vs 6.9 cm). Research based on surveys of schoolchildren conducted in 1966, 1978, 1988, and 2012 finds a positive correlation between socio-economic status (SES) and height (Gomula et al., 2021). Data from military conscription was used also to study the secular trend in height in earlier periods (Kopczyński, 2006, 2011, 2019, 2020, Ogórek, 2020; Sobechowicz, 2020; Kopczyński & Rodak, 2021). Ogórek (2019) documents the height-school premium in Poland during the interwar period.

Kołodziej et al. (2015) measure the secular trend in body height based on six surveys of military conscripts from the years 1965 – 2010. Over 45 years, the average height increased by 7.8 cm (from 170.5 cm in 1965 to 178.3 cm in 2010). The decennial stature gain declined from 2.4 cm in the 1960s to 0.8 cm in the 1990s, and 1 cm in the first decade of this century. Lopuszanska-Dawid et al. (2020) investigate social class-specific secular trends in height in the

years 1965 – 2009. The authors demonstrate that social distance in body height decreased, but the social gradient was constant. In the investigated period, sons of farmers experienced the highest height increase (7.77 cm), while the lowest increase was observed among sons of specialists (5.45 cm). Based on a survey of 6,028 women from large Polish cities, Łopuszańska-Dawid & Szklarska (2020) measure the secular trend in height in women. In the years 1931 – 2001, the average height of women in large Polish cities increased by 9.63 cm. The height increase was highest in the 1960s (3.53 cm) and the 1970s (2.38 cm), while it was the slowest in the 1990s (0.08 cm). This is a notable exception in Polish height research, which is predominately focused on men due to the availability of data from military conscription. On the other hand, however, the study did not cover women living outside large cities, and even in the case of large cities, its representativeness may be open to debate.

Anthropometric research identifies the biological consequences of the economic transition in 1989. Lipowicz et al. (2016) find higher loads of stress in Poland during the transition. After adjustment for socioeconomic variables, men examined in 1991 had a 31% greater risk of higher Allostatic Load compared with men examined in 1985. In 1992, the risk was 50% higher, and in 1993 it was 66% higher. Kozieł et al. (2004) investigate the effects of economic transition on BMI. The mean BMI of young men did not change in the years 1986 – 1995, but increased slightly (from 22.0 to 22.3) between 1995 and 2001. The variation in BMI increased in all social strata in the entire period. Authors attribute this trend to economic modernization, which increased the diversity of lifestyles.

Based on the Life in Transition Survey (administered by the EBRD and World Bank) conducted in 29 post-communist economies, Adserà et al. (2021) find that cohorts born during the transition (in the year of transition or one/two years before) are 1 cm shorter than their peers. Batinti & Costa-Fonta (2022) document that being born in a democracy increases average male stature by 1.3 - 2.4 cm, and decreases height dispersion. Our research will verify these findings in the Polish context.

1.3. Contribution

Our research complements earlier anthropometric research based on surveys of military conscripts and school children. While surveys by definition only cover a sample of the population, our data source includes every adult citizen of Poland. In Poland, only men were subject to military conscription, and therefore women are nearly absent from research on height in Poland. The representative data for female height do not exist. Our research covers both

genders and therefore limits gender bias existing in literature. Moreover, our research also covers people above the age of military conscription, which is rare in the existing literature on height in Poland. Modern surveys of military conscripts start with the birth year 1946. Using a novel, administrative data source we may extend our research back to 1920. We also provide empirical evidence on the impact of economic transition on human height.

The most important goal of this paper is to measure the secular trend in height based on a new data source covering the whole adult population. Moreover, we are interested in height inequality and the link between growing economic inequality after 1989 and height inequality. Earlier research mostly focuses on height inequality between social strata, while we investigate height dispersion itself. More unequal economic conditions should increase inequality of height. Moreover, due to the positive impact of height on income and life satisfaction, higher height inequality may increase economic inequality. Boix & Rosenbluth (2014) document that the distribution of economic resources and political institutions shape the distribution of height, and impact height inequality. Rogin et al. (2017) demonstrate that a more equal distribution of income is correlated with higher average height. Income inequality is a more important predictor of average height than GDP per capita. Bird et al. (2019) demonstrate that children are taller in countries with lower income inequality. Height dispersion can be used as a measure of economic inequality (Van Zanden et al., 2014).

We find that the average height increased by 10.15 cm in the case of men (1.28 cm per decade), and 8.18 cm in the case of women (1.04 cm per decade). The decennial height increase was highest in the first decades after the Second World War and slowed significantly in the 1980s. After the economic transition, the mean height of men stagnated, while the mean height of women even declined. In the cohort born in 1996, the mean height of men was only 0.03 cm higher than in the cohort born in 1990, while in the case of women mean height was 0.2 cm lower. Height dispersion decreased in the first decades under the investigation and significantly increased after the economic transition. Contrary to the results of Batinti & Costa-Font (2022), the transition to democracy cannot be linked to stature gain in Poland. Moreover, it did not decrease height dispersion. On the contrary – it increased it. This outcome is probably driven by the high social cost of the economic transition.

To estimate the impact of the economic transition on height, we use the regional dimension of our data. The estimated econometric model shows that post-transition unemployment and liquidation of State Agricultural Farms (SAFs) had a negative effect on body height. After the transition, people living in municipalities (the lowest level of local

government) with higher unemployment are shorter than people born in municipalities where unemployment was lower. This effect varies across cohorts between 0.4 – 0.9 cm and is highly statistically significant. In municipalities where SAFs existed, height decreased by 0.1 – 0.2 cm.

The transition to a market economy resulted in strong growth of national income, but it was accompanied by an explosion in economic inequality (Brzezinski et al., 2020; Brzezinski et al., 2022). Our research provides evidence of the high biological cost of the transition. It complements earlier research identifying lower stature of cohorts born at the time of the transition in post-communist economies (Adserà et al., 2021), higher loads of stress in Poland during the transition (Lipowicze et al., 2016), and higher dispersion of BMI in Poland after the transition (Kozieł et al. 2004).

2. Data and method

In the years 2001 – 2015, information on body height was given on all identity cards issued in Poland. We obtained a full anonymized dataset with information on body height from the Polish Ministry of Interior and Administration, which is responsible for population registers. In Poland, identity cards are issued when reaching adulthood (18 years) and are valid only for ten years. Because identity cards are reissued every ten years, and our dataset covers fourteen years, our data source includes all adult citizens of Poland, including those who do not reside in Poland but have a Polish identity card. In some cases, identity cards may be also issued for children under eighteen years old, but we discard these observations.

After removing duplicates resulting from the re-issuance of identity cards. Our dataset includes 36,393,246 individual records. The oldest person recorded in the data source was born in 1892. However, to analyze only large cohorts, our investigation started with the cohort born in 1920 (n=70,195) and ended with the cohort born in 1996 (n=406,641). The dataset includes information on height, year of birth, year of issuance, gender, place of birth, place of issuance of identity card (current place of residence), and an anonymous identifier of each person.

In Table 1, we compare the average height reported based on surveys of military conscripts and identity cards issued in 2014. According to identity card data, mean height tends to be higher than based on surveys of military conscripts (Kozieł, 2020). For the 1946 cohort, the difference is 2.3 cm and decreases to 1.6 cm for the 1991 cohort. There are several potential explanations for this. Surveys of military conscripts may not be fully representative of society. Height may increase also after conscription. Taller people may live longer, which increases the

average height of the cohort as the cohort ages. People may measure their height in different ways than anthropologists. Usually, some small positive bias is found in the self-assessment of height (Olbrich et al., 2022). Finally, although a clear link between age and height exists, people may not regularly update their height when applying for compulsory re-issuance of an identity card every ten years.

Please insert Table 1 here

To estimate the height trend, we calculate the mean height of men and women in each year of birth. Then, we calculate the decennial height increases. We use the coefficient of Variation as the measure of height dispersion. Our approach is standard in literature on height trends. We investigate the change in body height not only at a national level but also at a regional level. We compare the decennial height increases in large cities, the rest of the country, and across NUTS-2 regions. To better assess the effects of the economic transition on body height, we employ statistical tests for the structural breaks in time series data, and estimate the econometric model. This model is discussed in a separate subsection.

We decided not to censor the height distribution. The shortest adult people in our dataset are 50 cm tall, and the 1st percentile height is 160 cm in the case of men and 150 cm in the case of women. The highest people are close to 250cm, and 0.04% of men are highest than 200 cm. The 99th percentile of the height distribution is 193 cm in the case of men, and 178 cm in the case of women. We removed two erroneous observations with heights equal to 1550 cm, and 1760 cm.

The most important limitation of our dataset is the fact that height is provided for people of different ages. Identity cards issued in 2014 are an example. A person born in 1930 was 84 years old in 2014, a person born in 1950 was 64 years old, and a person born in 1990 was 24 years old. People shrink as they age, and shrinking usually begins after 40. Shrinking also varies with socio-economic status (Huang et al., 2013).

Initially, we wanted to use surveys of military conscripts to correct identity card data to account for shrinking. Because the height of older cohorts is higher – not lower than the height of the same cohorts during conscription, we cannot correct our data this way. As far as we know, no representative estimates of shrinking exist for Poland. Ideally, such estimates should be corrected for SES. Therefore, we decided not to correct the data for shrinking. In our opinion, the benefits of such correction are smaller than its risks. On the one hand, our estimates should be therefore interpreted with caution. However, despite differences in height, trends are nearly

the same as in the case of surveys of military conscripts. We further discuss the issue of shrinking and present the set of estimates corrected for shrinking in Appendix 1.

3. Results

3.1. Height trend at a national level

Information on the long-term evolution of the height of men born between 1920 and 1996 is provided in Figure 1. Figure 2 provides the same information for women. Decennial height increases for both genders are reported in Table 2. Information on average height and height dispersion in each cohort is provided in Appendix Table A.2.

Please insert Figure 1 here

Please insert Figure 2 here

Please insert Table 2 here

In the years 1920 – 1996, average male height increased from 169.44 cm to 179.60 cm, by 1.28 cm per decade. The growth rate of male height in Poland was not constant during the investigated period. Before the Second World War, the decennial growth increase was significantly slower than in the decades after the Second World War. In the 1920s, the average height increased only by 0.89 cm, while in the 1930s height increase was 1.10 cm. The growth rate was highest in the 1950s, when the average height increased by 2.26 cm. Average male height increased significantly also in the 1940s (1.88 cm), 1960s (1.79cm), and 1970s (1.7 cm). Male height increased only by 0.48 cm in the 1980s and stagnated in the years 1990 – 1996, when average height increased by only 0.03 cm. The lower height increase in the 1980s (0.48 cm) may reflect difficult economic conditions and food rationing. The stagnation of height after the economic transition reflects the huge social costs of the transition.

In the investigated period, the average female height increased from 158.02 cm to 166.20 cm, by 1.04 cm per decade. Unlike in the case of men, female height increased significantly in the 1920s (1.42 cm) and 1930s (1.23 cm), while the increase in the 1940s (1.02cm) was relatively slow. Interestingly, Polish women gained the right to vote and the right to be treated equally after the First World War. However, it is too early to discuss whether the stature increase in the interwar period may be linked to new political rights. In the 1950s, the height increase was again faster (1.38 cm). The decennial female height increase was highest in the 1960s (1.52 cm) and the 1970s (1.49cm). Similarly, as in the case of men, female height

has stagnated in the last two decades. In the 1980s, it increased only by 0.35 cm, while in the years 1990 – 1997 it declined by 0.20 cm.

Our results complement earlier research on the evolution of adult height in Poland based on surveys of military conscripts (Kołodziej et al., 2015). According to this literature, the mean height of men aged nineteen years increased by 7.8 cm in the years 1946 – 1991. In our data source, there was an increase of 6.8 cm. The 1 cm gap may be the result of self-assessment, catch-up growth after conscription, height change, and mortality bias. Like the surveys of military conscripts, our estimates also show that the 1960s and the 1970s were a period of rapid height increase. However, by using novel data sources, we can extend our research back in time, and show that the decennial height increase was even higher in the 1940s and 1950s.

Based on surveys of women living in large cities, Łopuszańska-Dawid & Szklarska (2020) identify higher stature growth. According to their results, female mean height increased by 9.63 cm in the years 1931 – 2001. In our data, the increase in the years 1931 – 1996 was 6.52 cm in the general population, and 6.97 cm in the large cities. On the one hand, our results cover the whole population, while the survey data used by the authors are not representative. On the other hand, however, our height trends may be to a larger extent biased by shrinking. However, shrinking to some extent is also a problem in the survey data used by Łopuszańska-Dawid & Szklarska). In the first cohorts, the surveyed women are 40 – 50 years old, and in the last cohorts only 18-19 years old.

Kopczynski (2019) investigates the evolution of male height between the Great War and the Great Depression based on measurement cards of military conscripts. He estimates that between two World Wars, the mean male height increased by at least 0.7 cm per decade. In the Second Polish Republic slowly rising monetary measures were surpassed by the rise in biological well-being (Kopczyński & Rodak, 2021). According to our results, the mean male height increased by 0.9 cm in the 1920s and 1.1 cm in the 1930s. Although our results for older cohorts may be biased by the mortality bias (to be included in our sample people born in 1920 had to live at least 81 years to obtain an identity card in 2001), the secular trend is similar to estimates by Kopczynski.

To better assess height trends in Poland, we compare the evolution of body height in Poland with two other countries of the region (the Czech Republic and Russia), four advanced economies (Germany, France, the United Kingdom, and the United States), and two south European peripheral economies, Portugal and Greece. The source of data for other countries is

an international database compiled by Baten & Blum (2015). The information on mean male height in 1920, 1940, and 1980, and decennial height increases is provided in Table 3.

Please insert Table 3 here

In 1920, the average male height in Poland was significantly lower than in Germany, the United Kingdom, and the United States. It was similar to Greece and France, and higher than in Russia and Portugal. In the years 1920-1940, the decennial height increase in Poland was the same as in Russia, and slightly higher than in Germany (1 cm vs. 0.95 cm). The secular trend in Poland was significantly weaker than in the Czech Republic, France, the United Kingdom, and the United States (1 cm vs. 1.5-1.9 cm). In the years 1940-1980, decennial height increases in Poland were significantly higher than in the previous period (1.9 cm vs 1.0 cm). Only in Greece, where the height increase in the interwar period was close to zero, and in Russia, was the secular trend stronger than in Poland (2.0 cm vs 1.9 cm). Interestingly, decennial height increases in Poland were three times higher than in the Czech Republic, where data ends in the 1970s (1.9 cm vs 0.6 cm). However, according to this data source, the Czech Republic experienced a particularly strong height increase in the interwar period.

International comparison shows that in the years 1920-1980, height in Poland to a large extent caught up with advanced economies. This fact may however partially be driven by cross-country differences in migration. While the United Kingdom and the United States experienced significant migration from countries where people are on average shorter, migration to Poland was close to zero. At the beginning of the investigated period, mean male height in Poland was medium in comparison with investigated countries. In 1980, only Germans were significantly taller than Poles (180.5 cm vs 179.1 cm). In the interwar period (1920-1940), the height increase in Poland was medium in comparison with other countries, and after the Second World War there was a significantly higher rate of increase. International comparisons discussed here should however be considered circumspectly because data sources differ across countries.

Figures 3 and 4 report height inequality measured using the coefficient of variation (CoV) for both genders. In the first decades of the investigated period, height inequality declined significantly. Strong growth in average height was accompanied by the compression of height distribution. Shorter people were catching up with the top of the distribution. In the cohorts born after the Second World War, the evolution of height dispersion is different among men and women.

Please insert Figure 3 here

Please insert Figure 4 here

For men, the CoV decreased from 0.0390 for the cohort born in 1920 to 0.0340 for the cohort born in 1945 (a relative decline of 12.8%). The interquartile range (the gap between the 25th percentile of the height distribution and the 75th percentile) declined from 10 cm in the 1920s to 6 cm in the late 1940s. The height gap between the 90th percentile of height distribution dropped from 21cm to 17 cm. The equalization of height probably reflects more equal distribution of income, wealth, and consumption, which resulted from social reforms introduced after the war.

In the cohorts born after the Second World War, we observe a slow increase of the CoV to 0.0357 in 1963 (an increase of 4.9%). At the same time, average height increased significantly, Poland's economy became industrialized and urbanized. The regional evidence discussed below shows that decennial height increases were in these years significantly higher in large cities than in the rest of the country. Therefore, a rise in height dispersion on a national level may reflect a greater rate of increase in the biological standard of living in large cities than in other areas. In the cohorts born in the years 1963 – 1978, the CoV stagnated at 0.357 – 0.360. In the cohorts born after 1978, we observe a strong increase in the height variation, with the CoV growing to 0.0385 in 1996. The increase in height dispersion in the 1980s may reflect food rationing and the fact that those with higher incomes, occupational privileges, and connections were able to acquire more food than the rest of the population. The increase in height dispersion was particularly strong after the economic transition. At the same time, income inequality, especially measured by the top income shares, exploded (Brzeziński et al. 2021, Bukowski & Novokmet, 2021). Between 1990 and 1996, the CoV increased from 0.371 to 0.385. The interquartile range increased from 7 cm in the cohort born in 1975 to 9 cm in the cohort born in 1996. In the same period, the height gap between the 10th percentile and the 99th percentile of the height distribution changed only slightly, increasing from 20 cm to 21 cm.

For women, the CoV dropped from 0.0387 in 1920 to 0.0326 in 1945. Subsequently, it stagnated at 0.326 – 0.330 until 1966 (0.319 in the cohort born in 1964 is a notable exception). The interquartile range decreased from 8 cm in the cohort born in 1920 to 6 cm in the cohort born in 1960. In the same period, the gap between the 10th percentile and the 99th percentile of height distribution decreased from 18 cm to 16 cm. After 1966, we observe a significant increase in height dispersion. This increase, absent in the case of men, may reflect strong economic growth in the 1970s. The CoV increased from 0.0330 in 1966 to 0.0348 in 1974 (a relative increase of 5.4%). From that time, the CoV stagnated at 0.347 – 0.350 until 1990.

Interestingly, in contrast with men, in the case of women, we do not see an increase in height dispersion in the cohorts born in the 1980s. However, similarly as in the case of men after the economic transition, we observe a rapid dispersion of height distribution. The CoV increased from 0.0347 for the cohort born in 1990 to 0.0364 for the cohort born in 1996 (a relative increase of 4.90%). The interquartile range of height increased from 7cm in the cohort born in 1990 to 8 cm in the cohort born in 1996, while the gap between the 10^{th} percentile and the 99^{th} percentile of female height distribution increased from 17 cm to 18 cm.

To further investigate the impact of the economic transition on body height, we employ the Wald test for the structural break. We separately estimate the test statistics for men and women. The Wald test rejects the null hypothesis of no structural breaks in the height trend in the years 1920 - 1996 ($p=0.000$), and rejects the hypothesis of no structural break in the height trend in 1989 ($p=0.000$). The structural break in the height trend in 1989 is confirmed for both men and women.

Our data show that height stagnated during the 1980s and the economic transition. In the case of women, the mean height even declined after 1990. Height dispersion increased after the economic transition for both genders. In the case of men, height dispersion increased also in the cohorts born in the 1980s. The stagnation of average height, both in the case of men and women, may reflect the difficult economic conditions of the last decade of the centrally planned economy, and painful economic transition, during which strong GDP growth coexisted with mass unemployment and growing economic inequality. Below we provide empirical evidence on the negative impact of post-transition unemployment on height. Although the transition to a free market economy increased national income, this increase was accompanied by an increase in socioeconomic inequality. Brzezinski et al. (2020) find that despite only 25 years of free wealth accumulation, wealth inequality levels in Central and Eastern Europe caught up with the Western European wealth inequality levels. Brzezinski et al. (2022) report that in the years 1994 – 2015, income inequality in Poland exploded. Despite relatively low inequality (in comparison with most capitalist economies) at the beginning of the transition, by 2015 income inequality in Poland was among the highest in Europe. Our research shows that the increase in economic inequality caused by the transition was accompanied by high biological costs.

3.2. Height trend at a regional level

Our data source reports the place of birth of each individual. We use this information to compare height trends in large cities (defined as cities with over 500 000 residents in 2021:

Warsaw, Kraków, Wrocław, Łódź) and the rest of the country. The mean height in large cities and the rest of the country, as well as the height gap, are reported in Table 4. The decennial height increase is reported in Table 5. We report outcomes for men and women separately.

Please insert Table 4 here

Please insert Table 5 here

Since 1920, men born in large cities have been taller than men born in the rest of the country. The height gap increased from 1.00 cm in the cohort born in 1920 to 1.93 cm in the cohort born in 1960. After that time, the height gap decreased, dropping to 0.79 cm in 1990. In 1996, the height gap stood at 0.77 cm. Until 1960, decennial height increases were higher in large cities, while from that time the rest of the country started to catch up. The rest of the country ceased catching up with large cities after the economic transition. After 1990, mean height stagnated both in large cities and the rest of the country (it increased by 0.00 cm for large cities and 0.02 cm for the rest of the country, much less than before).

Interestingly, women born in large cities were not always taller than those born in the rest of the country. Until 1950, the height gap was negative – women born outside large cities were slightly (by 0.3 cm in 1920) taller than women born in the large cities. However, from the beginning, decennial height increases were higher in the large cities than in the rest of the country. In the 1960s, the height increase was the same in both areas. In the 1970s, there was a reversal in this trend. Height increases were greater in the rest of the country than in large cities. After 1990, mean height dropped both in the case of women born in and outside large cities (by 0.53 cm and 0.20 cm respectively).

The evolution of height trends in large cities and the rest of the country show that in the interwar period and during the first phase of industrialization and urbanization, the biological standard of living increased faster in large cities than in the rest of the country, while subsequently the rest of the country started to catch up. Interestingly, the negative effects of the economic transition on the biological standard of living seem to be greater in large cities than in the rest of the country. This may be due to the closing of large plants and reductions in employment after the transition (Łódź was especially hit by the transition, but even in Warsaw some districts experienced significant social and economic problems), difficult housing conditions (construction of new housing nearly stopped in the 1990s), and lack of own food production. In the case of men, the increase in height dispersion (as measured by the coefficient of variation) in the cohorts born after 1980 was significantly higher in large cities than in the

rest of the country. This probably reflects the period of food rationing, during which rural areas still profited from their own food production. Interestingly, in the case of women, the opposite is true. Height dispersion increased at a higher rate in the rest of the country than in the large cities.

In Table 6 and Table 7 we report the height trend at the NUTS-2 level. We observe significant regional variation in decennial height increase in the years 1920 – 1950 across the NUTS-2 level. However, this variation is hard to interpret because the country's border changed in 1945. The vast majority of those living in Western Poland (Dolnośląskie, Lubuskie, Zachodniopomorskie) migrated to this region after the Second World War. In the years 1950 – 1980, the decennial height increase was nearly the same across the regions of the country. In the case of men, it varied between 1.77 cm per decade in Podkarpackie and 2.05 cm in Podlaskie. The gap between the regions growing fastest and regions with the slowest growth was only 15%. In the case of women, the dispersion was higher, but still relatively low. The decennial height increase varied between 1.22 cm in Podkarpackie and 1.68 cm in Dolnośląskie. Here the gap between the region growing fastest, and the region with the slowest growth was 33%. It seems that during the socialist era height trends were similar across the country. While regional economic convergence in the socialist era was limited (Zimon, 1979; Koryś and Tymiński, 2022), the increase in biological well-being was relatively equally distributed across the regions of the country.

Please insert Table 6 here

Please insert Table 7 here

In the years 1980 – 1996, the dispersion of regional height trends increased significantly. In the case of men, body height stagnated. However, in some regions, it continued to slowly increase, while in others it began to slowly decline. While in Dolnośląskie mean height continued to increase by 0.22 cm per decade, in Lubuskie it declined by 0.15 cm per decade. The mean height of women declined in all regions. However, in Lubuskie the decline was close to zero (only 0.01 cm per decade) and in Świętokrzyskie the decline was 0.23 cm per decade. Interestingly, the trends in male and female height do not match. For example, in the case of men, Dolnośląskie experienced the greatest increase in height, while in the case of women, the same region recorded one of the greatest declines. The economic recession of the 1980s, and the experience of the economic transition, may explain the divergence of regional height trends in comparison with the previous period.

3.3. The impact of economic transition on height: quantitative evidence

Above, we have described the evolution of height during the economic transition and present the statistical evidence for the structural break in the height trend in 1989. Height increase stagnated in the case of men, while in the case of women mean height decreased slightly. Height dispersion increased in the case of both genders. In this subsection, to better assess the impact of economic transition on height, we estimate the econometric model.

We use the regional dimension of our data. For each record, we observe the municipality (pl. *gmina*), where the identity card was issued. A municipality is the lowest level of local government, and there are currently 2477 municipalities in Poland. For the birth cohorts 1983 – 1996, we observe height at the age of 18, when most of them apply for the identity card for the first time. We estimate OLS regression taking into account the following explanatory variables: gender, being born in a large city (over 500 000 inhabitants), medium cities (cities of county status not classified as large cities), the unemployment rate in the municipality in 2001 (first estimates of the unemployment rate at the local level come from the census, earlier data is not available), a variable indicating whether a State Agricultural Farm existed in the municipality, and a variable controlling the type of the municipality (urban, rural, mixed). In the early 2000s, post-transition unemployment was at its peak. By including the unemployment rate, we incorporate the social cost of the transition, which varied across the country. State Agricultural Farms (pl. *Państwowe Gospodarstwa Rolne*) were liquidated in 1992 and 1993. To identify the municipalities in which there were SAFs we use an official government list. However, some large cities are also included on this list. This may be a consequence of the extension of city borders, or the existence of small SAFs in the city peripheries. We omit all municipalities with a population of more than 50 000 from the list of SAF municipalities. The economic transition was a disaster for the majority of previous workers of SAFs. Post-SAF areas were symbols of the social costs of the transition, mass unemployment, deprivation, and lack of economic opportunities. In Table 8 we present the descriptive statistics. The outcomes of the regression, estimated separately for each birth cohort, are presented in Table 9.

Please insert Table 8 here

Please insert Table 9 here

In all birth cohorts, men are taller than women. The estimated male height premium increases during the investigated period. People born in cities with over 500 000 inhabitants are taller. The estimated large city height premium decreased in the 1980s, increased sharply in

1989, and continued decreasing from that time. The medium city height premium is also statistically significant, but only about half of the large city height premium.

In the cohorts born in the years 1983-1986, the impact of the unemployment rate in 2001 is not statistically significant. This outcome confirms that our variable indeed measures the social cost of the transition, and is not affected by some pre-existing trends. Post-transition unemployment starts to have a negative and statistically significant effect on body height in 1987. However in 1988, 1990, and 1991, the effects are not statistically different from 0. Starting from 1992, we observe robust negative effects of unemployment on height. The estimated parameters vary between 0.5 – 0.9 cm. The fact that the robust negative effects started only in 1992 is not surprising – the initial rise in unemployment after the economic transition was limited. The unemployment rate surpassed ten percent in 1992.

Kopczyński (2016) discusses the biological well-being of employees of SAFs. There is some evidence for a higher biological standard of living of SAF employees than of individual farmers. The positive impact of SAFs on height may reflect easier access to food, access to a SAF's "social policy" (SAFs organized common kitchens, vacation, health, etc.), and relatively equal distribution of income in the municipality. However, according to our estimates, in the early 1980s the effects of SAFs on height are not statistically significant. Since 1987, the estimated effects of SAFs on height have been negative and statistically different from zero. The estimated parameters vary between 0.1 – 0.2 cm. Thus, residents of municipalities in which there were SAFs suffered high costs during the transition.

The estimated model provides evidence of the high biological cost of the transition. In areas where social costs were higher there was shrinkage in relation to other areas of the country. Higher unemployment in the 2000s had negative effects on height. Height declined in municipalities in which there were SAFs. The male height premium increased. The large city height premium, which had been decreasing in the 1980s, rose again.

4. Conclusion

In the years 2001 – 2015, information on body height was given on identity cards in Poland. In this paper, based on administrative data (n=36,393,246), we evaluate the evolution of mean height and height dispersion in Poland. We also compare height trends in large cities and the rest of the country and provide evidence of height change on the NUTS-2 level. Our data source covers the full adult population of Poland. Unlike the research based on military conscripts, we cover both men and women.

We find that the mean height of men born in 1996 was 10.15 cm higher than the mean height of men born in 1920. In the case of women, the height difference was 8.18 cm. Decennial height increases were highest in the years 1940 – 1980. After the economic transition, height increase stagnated in the case of men, and in the case of female height trends reversed – the mean height declined after the transition. Height dispersion decreased in the first decades under investigation and increased significantly after the economic transition. The estimated econometric model shows that people living in municipalities with higher post-transition unemployment are shorter. Municipalities with State Agricultural Farms recorded height declines.

Our research provides evidence of the significant biological costs of transition from a centrally planned to a market economy. The transition resulted in a strong increase in national income, but it was accompanied by exploding inequality and mass unemployment. Our results may be seen as an important argument for fully considering the social costs in the design of economic policies. Administrative data on the height of the population offers many new possibilities including closer investigation of the economic determinants of body height, comparison of the body height of migrants and the rest of the population, the measurement of height trends on the local level, and the impact of body height on mortality. We hope to address these issues in further research.

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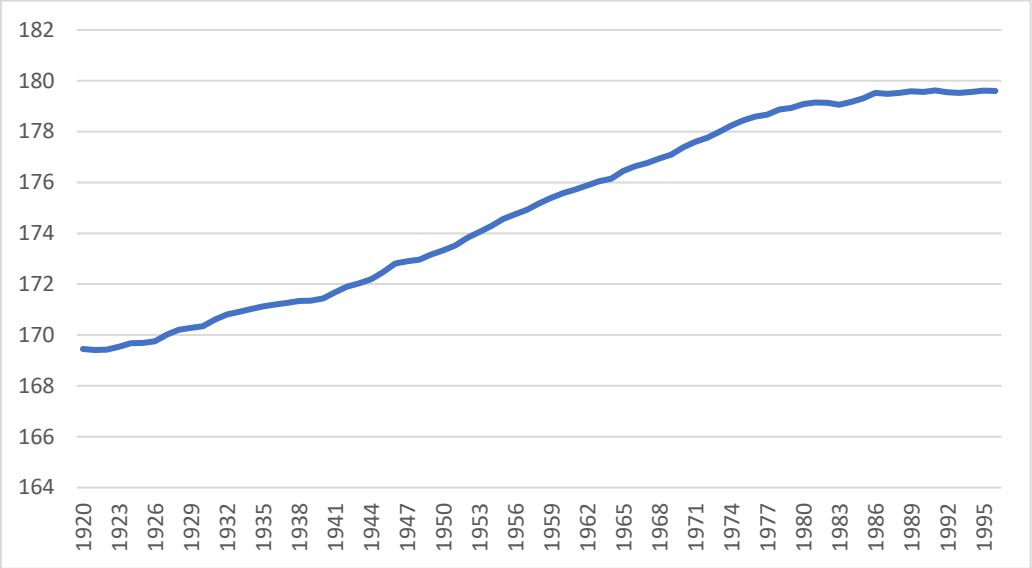
Table 1. Average height: surveys of military conscripts vs. administrative data (identity cards)

Year of birth	Average height (men, cm)		Difference (cm)
	Military conscripts	Identity cards (2014)	
1946	170.5	172.8	2.3
1957	173.2	175.0	1.8
1967	175.3	176.9	1.6
1976	176.9	178.8	1.9
1982	177.4	179.2	1.8
1991	178.3	179.9	1.6

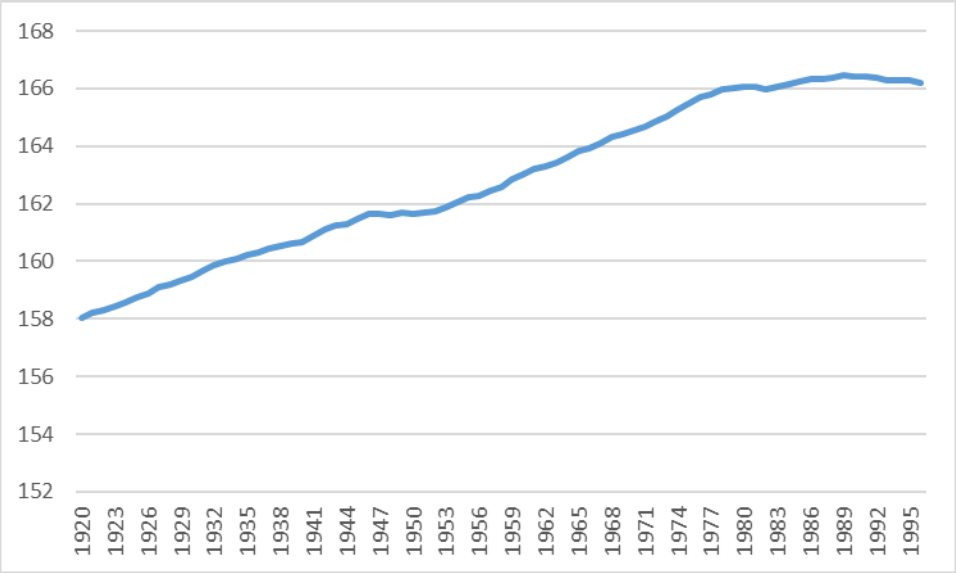
Source: own based on Kozieł (2020) and administrative data on adult height.

Figure 1. The evolution of average male height, years of birth 1920 – 1996.



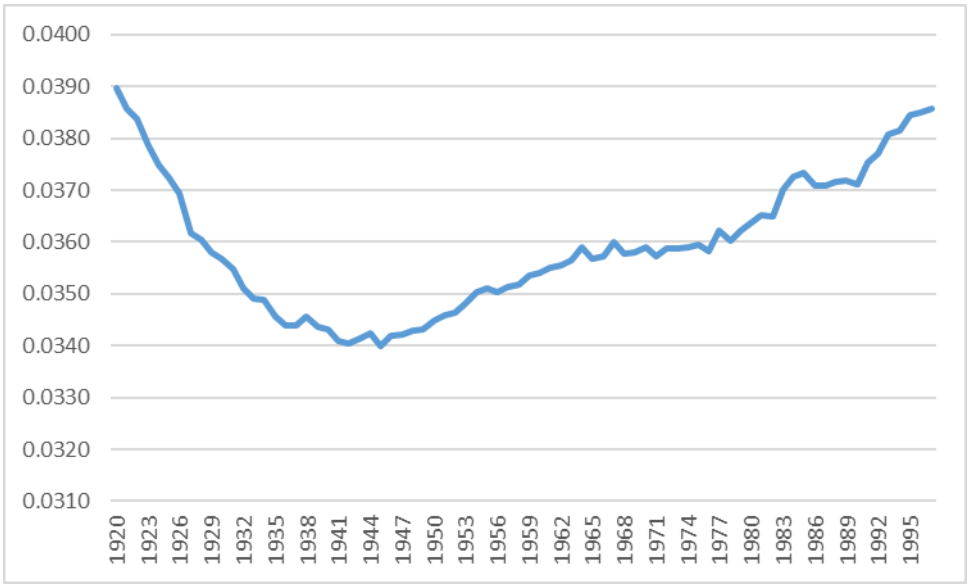
Source: own estimation based on the administrative data on adult height.

Figure 2. The evolution of average female height, years of birth 1920 – 1996.



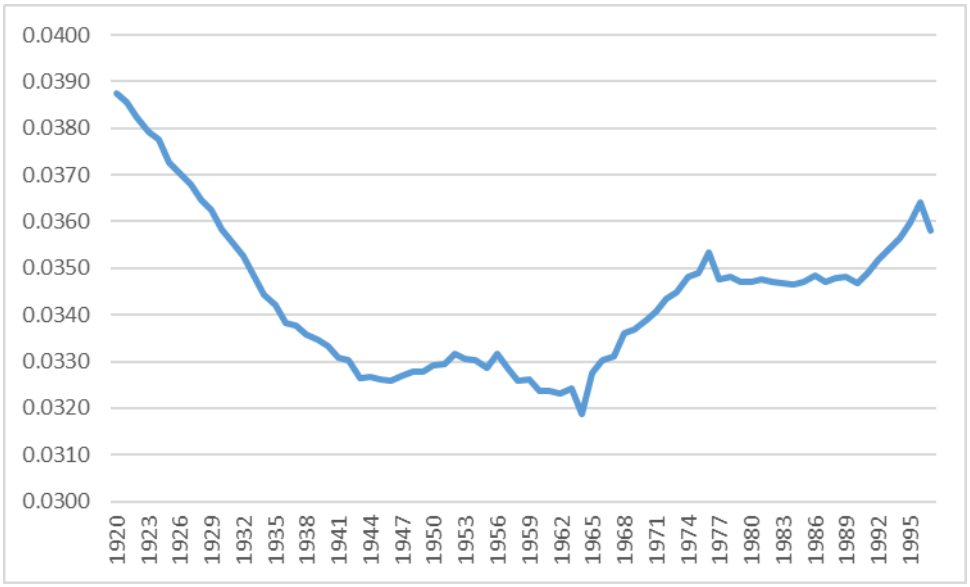
Source: own estimation based on the administrative data on adult height.

Figure 3. The evolution height dispersion measured by the Coefficient of Variation. Men, years of birth 1920 – 1996.



Source: own estimation based on the administrative data on adult height.

Figure 4. The evolution height dispersion measured by the Coefficient of Variation. Women: years of birth 1920 – 1996.



Source: own estimation based on the administrative data on adult height.

Table 2. Decennial height increase (cm).

Decennial increase	Men	Women
1920 - 1930	0.89	1.42
1930 – 1940	1.10	1.23
1940 - 1950	1.88	1.03
1950 - 1960	2.26	1.38
1960 - 1970	1.79	1.52
1970 - 1980	1.70	1.49
1980 - 1990	0.48	0.35
1990 - 1996	0.04	-0.20
Average	1.28	1.04

Source: own estimation based on administrative data on adult height.

Table 3. Male height in the international comparison

	Mean height			Decennial height increase		
Decennial increase	**1920**	**1940**	**1980**	**1920-80**	**1920-40**	**1940-80**
Czech Republic	173.30	176.80	178.70	1.08	1.75	0.63
France	168.50	171.70	176.50	1.33	1.60	1.20
Germany	173.30	175.20	180.50	1.20	0.95	1.33
Greece	168.40	169.20	177.30	1.48	0.40	2.03
Poland	169.44	171.44	179.08	1.61	1.00	1.91
Portugal	164.88	166.39	172.13	1.21	0.75	1.44
Russia	167.00	169.00	177.00	1.67	1.00	2.00
United Kingdom	171.00	174.90	176.83	0.97	1.95	0.48
United States	173.10	176.10	179.00	0.98	1.50	0.73

Notes: data for the Czech Republic end in 1970.

Source: for Poland own estimation based on administrative data on adult height, for other countries the international database compiled by Baten & Blum (2015).

Table 4. Mean height (cm) in large cities (500k +) and the rest of the country, height gap.

Year	Men			Women		
	Large cities	Rest	Gap	Large cities	Rest	Gap
1920	170.40	169.40	1.00	157.69	158.04	-0.35
1930	171.60	170.28	1.33	159.28	159.45	-0.18
1940	172.83	171.37	1.46	160.54	160.68	-0.14
1950	174.85	173.20	1.65	161.69	161.66	-0.03
1960	177.37	175.44	1.93	163.64	162.99	0.64
1970	178.72	177.25	1.47	165.14	164.51	0.64
1980	179.98	178.98	1.00	166.55	166.00	0.55
1990	180.28	179.49	0.79	166.81	166.50	0.45
1996	180.28	179.51	0.77	166.50	166.16	0.34

Source: own estimation based on administrative data on adult height.

Table 5. Decennial height increase (cm): large cities (500k+) vs. the rest of the country.

Decennial increase	Men		Women	
	Large cities	Rest	Large cities	Rest
1920 - 1930	1.20	0.87	1.58	1.41
1930 – 1940	1.22	1.09	1.26	1.22
1940 - 1950	2.03	1.83	1.15	0.98
1950 - 1960	2.52	2.24	1.94	1.33
1960 - 1970	1.35	1.81	1.51	1.51
1970 - 1980	1.27	1.73	1.40	1.49
1980 - 1990	0.29	0.51	0.26	0.36
1990 - 1996	0.00	0.02	-0.53	-0.20

Source: own estimation.

Table 6. Regional height trends: men.

Region	Mean height 1920	Dec. Inc. 1920 - 1950	Dec. Inc. 1950 -1980	Dec. Inc. 1980 - 1996	Mean height 1996
Dolnośląskie	169.42	1.35	1.92	0.22	179.57
Kujawsko-Pomorskie	169.77	1.19	2.02	0.04	180.00
Lubelskie	169.36	1.25	1.85	0.02	179.42
Lubuskie	169.57	1.16	1.97	-0.15	179.24
Mazowieckie	169.80	1.35	1.90	0.11	180.26
Małopolskie	169.59	1.22	1.79	-0.03	178.89
Opolskie	170.42	0.89	1.91	-0.13	179.05
Podkarpackie	169.53	1.10	1.77	0.12	178.85
Podlaskie	169.32	1.31	2.05	0.11	180.24
Pomorskie	170.15	1.19	1.96	0.01	179.79
Warmińsko-Mazurskie	169.23	1.22	2.04	-0.04	179.61
Wielkopolskie	169.35	1.40	1.96	0.06	179.87
Zachodnipomorskie	169.72	1.16	2.01	-0.12	179.50
Łódzkie	168.87	1.50	2.01	0.06	179.99
Śląskie	168.96	1.40	1.89	-0.08	179.31
Świętorzyskie	168.65	1.30	1.95	0.07	179.17

Source: own estimation.

Table 7. Regional height trends: women.

Region	Mean height 1920	Dec. Inc. 1920 - 1950	Dec. Inc. 1950 - 1980	Dec. Inc. 1980 - 1996	Mean height 1996
Dolnośląskie	157.88	1.17	1.58	-0.17	166.14
Kujawsko-Pomorskie	158.47	1.13	1.52	-0.08	166.44
Lubelskie	158.31	1.25	1.25	-0.11	166.18
Lubuskie	158.11	1.06	1.53	-0.01	166.31
Mazowieckie	157.90	1.30	1.50	-0.09	166.68
Małopolskie	158.22	1.21	1.28	-0.22	165.68
Opolskie	158.31	1.08	1.41	-0.20	165.92
Podkarpackie	158.32	1.16	1.22	-0.11	165.59
Podlaskie	157.19	1.51	1.50	-0.07	166.75
Pomorskie	158.34	1.17	1.59	-0.14	166.58
Warmińsko-Mazurskie	157.55	1.25	1.53	-0.15	166.22
Wielkopolskie	158.32	1.19	1.53	-0.12	166.43
Zachodnipomorskie	157.78	1.18	1.63	-0.17	166.17
Łódzkie	157.57	1.31	1.52	-0.09	166.45
Śląskie	157.86	1.18	1.46	-0.14	165.80
Świętorzyskie	157.96	1.24	1.35	-0.23	165.86

Source: own estimation.

Table 8. Descriptive statistics.

Variable	Mean	Standard deviation
Gender (0 = women, 1 = men)	0.5153	Binary variable
Large city (Large city = 1, other = 0)	0.0099	Binary variable
Medium city (Medium city = 1, other=0)	0.2127	Binary variable
Unemployment rate in 2001	0.2169	0.0626
State agricultural farm	0.5007	Binary variable

Note: each individual is a separate observation. The explanatory variables are determined on the municipality (pl. gmina) level.

Source: own estimation

Table 9. The biological cost of the economic transition. poprawione

Birth year	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996
men	12.74*** (0.0189)	12.77*** (0.0202)	12.89*** (0.0206)	13.03 *** (0.0195)	13.05*** (0.0194)	13.06*** (0.0195)	13.02*** (0.0199)	13.04*** (0.0198)	13.06*** (0.0204)	13.09*** (0.0210)	13.16*** (0.0221)	13.24*** (0.0226)	13.29*** (0.0242)	13.37*** (0.0252)
large city	0.92*** (0.0391)	0.85*** (0.0414)	0.86*** (0.0390)	0.72*** (0.0368)	0.65*** (0.0372)	0.65*** (0.0372)	0.83*** (0.0459)	0.77*** (0.0466)	0.73*** (0.0470)	0.67*** (0.0480)	0.60*** (0.0492)	0.72*** (0.0489)	0.67*** (0.0515)	0.63*** (0.0535)
medium city	0.54*** (0.0298)	0.52*** (0.0317)	0.54*** (0.0331)	0.43*** (0.0314)	0.33*** (0.0315)	0.29*** (0.0317)	0.37*** (0.0316)	0.34*** (0.0313)	0.33*** (0.0324)	0.22*** (0.0332)	0.30*** (0.0351)	0.34*** (0.0355)	0.32*** (0.0382)	0.28*** (0.0398)
unemployment (2001)	0.16 (0.1604)	0.23 (0.1684)	-0.21 (0.1712)	-0.25 (0.1634)	-0.42*** (0.1617)	0.03 (0.1612)	-0.33** (0.1627)	-0.00 (0.1611)	-0.19 (0.1656)	-0.53*** (0.1706)	-0.45** (0.1797)	-0.41** (0.1833)	-0.93*** (0.1972)	-0.73*** (0.2063)
state agricultural farm	-0.03 (0.0258))	-0.07** (0.0277)	0.00 (0.0282)	-0.04 (0.0266)	-0.06** (0.0262)	-0.06** (0.0261)	-0.13*** (0.0246)	-0.20*** (0.0244)	-0.17*** (0.0251)	-0.21*** (0.0259)	-0.19*** (0.0273)	-0.12*** (0.0278)	-0.06* (0.0299)	-0.11*** (0.0312)
Constant	153.5*** (0.0558)	153.5*** (0.0585)	153.6*** (0.0596)	153.7*** (0.0579)	153.7*** (0.0567)	153.6*** (0.0563)	153.5*** (0.0545)	153.4*** (0.0540)	1535*** (0.0553)	153.5*** (0.0581)	153.2*** (0.0601)	153.1*** (0.0614)	153.2*** (0.0657)	153.0*** (0.0685)
N	428,353	384,348	372,709	407,923	405,467	405,158	388,974	392,498	377,094	361,910	331,053	286,491	285,161	266,713
R^2	0.5109	0.5104	0.5121	0.5195	0.5230	0.5234	0.5209	0.5245	0.5213	0.5179	0.5158	0.5176	0.5123	0.5123

*Note: the model includes also a control variable indicating the type of municipality (urban, rural, mixed). Standard errors (robust) are reported in parantheses. Asterisks indicate the level of statistical significance (*p<0.1; **p<0.05; ***p<0.01).*

Source: own estimation based on administrative data on adult height .

Appendix 1. Shrinking and the long-term trends in body height in Poland.

Our dataset is based on identity cards issued in Poland in the years 2001 – 2015. On the one hand, the administrative data covers the entire population. On the other hand, however, in our data, height is (self-)measured for people of different ages. For example, a person who obtained an identity card in 2001 and was born in 1920 was 81 years old, while a person who obtained an identity card in 2001 and was born in 1950 was only 51 years old. We know that people shrink as thye age. Sorkin et al. (1999) estimate that in the United States, cumulative height loss between 30 and 80 averages 5 cm for men, and 8 cm for women.

Ideally, the estimates of body height in our dataset should be corrected for shrinking. However, no estimates of shrinking are available for Poland. Moreover, literature demonstrates that shrinking varies by socio-economic status (Huang et al., 2013). Literature on the impact of body height on mortality is not conclusive. The impact of body height on all-cause mortality is probably different than its impact on specific-cause mortality (see for example Samaras et al., 2003; Özaltin, 2012; Emerging Risks Factor Collaboration, 2012, Sohn, 2016). Thus, the body height recorded in our dataset may be biased not only because of shrinking but also due to the impact of body height on mortality. Chmielewski et al. (2023) investigate the association between body height and longevity in Poland. They find that in the years 2004 – 2008, no statistically significant effects of body height on longevity can be identified. The estimates of shrinking based on the Baltimore Longitudinal Study of Ageing (Sorkin et al., 1999) are most often used in literature to correct for shrinking (Nienweg et al., 2003; Haghdoost et al., 2008). We use the following formulas proposed by Sorkin et al. (1999).

Men: Cumulative height change = 0.0435 * Ag e– 0.00009 * Age^2 – 0.000015 *Age^3

Women: Cumulative height change = 0.0714 * Age – 0.00075Age^2 – 0.000016 *Age^3.

Then we add the estimated cumulative height change to the current height to obtain the estimate of the maximum height. The observed height and estimated maximum height are presented in Figures A.1 and A.2. The decennial height increases are presented in Appendix Table A.1. According to the results of the estimation, the mean estimated maximum height of women declined up until 1950, while the mean estimated maximum height of men declined up until 1940. The significant decennial increases in body height have only been observed since 1950 in the case of men, and 1960 in the case of women. Therefore, the average decennial height increase dropped from 1.28 cm (men) and 1.04 cm (women) to 0.58 cm (men), and -0.04 cm (women).

The estimated decline in body height in the cohorts born in the interwar period contradicts the direct evidence from the surveys of military conscripts conducted in the interwar period (Kopczyński & Rodak, 2021). Estimates for the late 1940s and the 1960s contradict the results of surveys of military conscripts in the post-war period discussed in the paper. Therefore, we do not treat our estimates as reliable and decided to keep them only in the Appendix.

Probably, the shrinkage of body height in Poland is different than in the USA. We also have to keep in mind that estimates of shrinkage by Sorkin et al. (1999) are based on a relatively small sample of less than 2,000 people with less than 200 older than 80 years old. The alternative formulas presented by Nienweg et al. (2003) produce an even larger decline in height in the interwar period. The other explanation for the discrepancy between direct evidence on height in the interwar period and estimated maximum height may be the selective mortality. We have to keep in mind that the impact of the Second World War on the demography of Poland was much greater than in the case of the US or the Netherlands. Nearly six million Polish citizens (over 15% of the country's population in 1938) lost their lives. It is possible that taller and healthier people had a higher probability of survival, and this biases our estimate of the body height in the interwar period. The vast majority of Polish Jews perished in the Holocaust. Kopczyński (2011) demonstrates that Jews born in the second half of the 19th century were 2.5 – 4.0 cm shorter than Christians. Probably, the negative impact of body height on mortality during the Second World War is simply due to the fact that more Jews than Christians lost their lives in the years 1939 – 1945. Unfortunately, there is no direct, empirical evidence of selective mortality during the war in Poland. We have some estimates showing that the general mortality rate in the first post-war years was lower than in the last pre-war years. According to ex-post estimates by Statistics Poland, this rate declined from 14.1 per mille in the late 1930s to 10.2 per mille in 1946, and then gradually increased to 11.5 per mille in 1950. However, these estimates should be treated circumspectly, because fully credible and complete registration of deaths in Poland did not start until 1950 (Gawryszewski, 2005). Sagi-Scwartz et al. (2013) find that survivors of the Holocaust seem to have been at significantly lower risk of dying younger than persons without a Holocaust background.

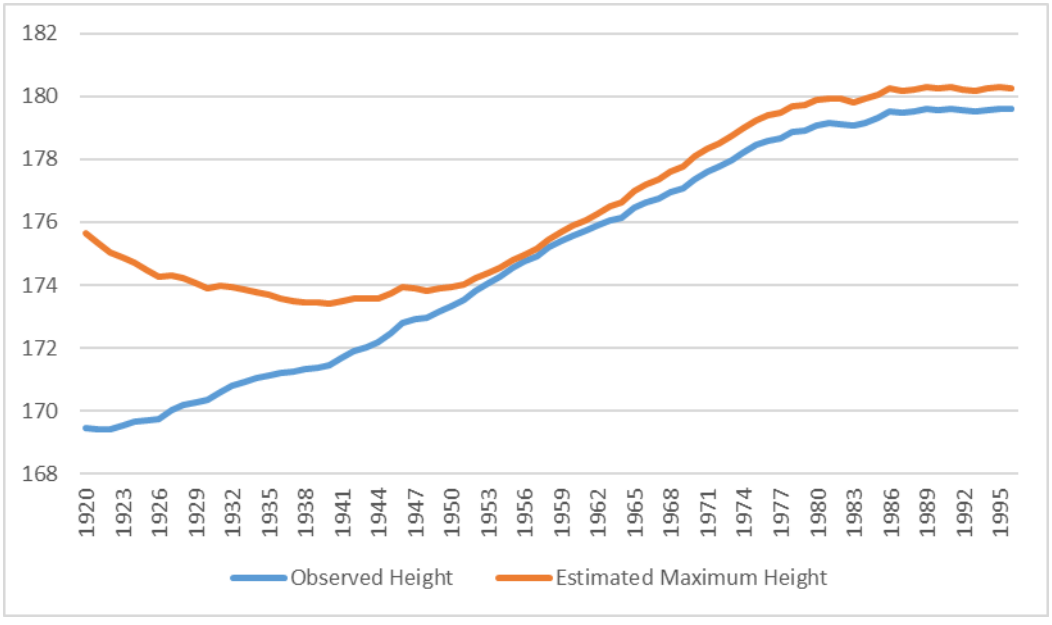
Alternatively, estimates of the cumulative height change based on the formula proposed by Sorkin et al. (1999) may be overestimated because Americans are on average higher than Poles. Men born in 1940 in Poland were 2.5% shorter than men born in the U.S (see Table 3 in the main text of the article). We reduce the estimated height change by 2.5% to check whether this removes the contradictory results on shrinking the body height in the interwar period.

However, after implementing this correction, according to our results, the maximum body height is also declining during the interwar period.

The correction for shrinking does not change our conclusions on the evolution of body height after 1950. Height increased significantly in the years 1950 – 1980, while the height increase slowed after 1980. After 1990, the height of men stagnated, while the height of women declined.

According to the estimates of maximum height, in the years 1920 – 1996, the height of men increased only by 4.2 cm (0.58 cm per decade), while the height of women declined by 0.3 cm (0.4 cm per decade). As discussed, we do not treat these estimates as reliable, because they directly contradict earlier anthropological research. However, if we limit our focus to the years 1950 – 1996, the height increase of men is nearly the same as in the raw data. Based on the estimates of maximum height, the height of men increased by 6.32 cm (1.37 cm per decade), while based on the raw data the increase was 6.27 cm (1.36 cm per decade). However, in the case of women, a significant gap remains. According to estimates of the maximum height, the increase in the years 1950 – 1996 was only 3.3 cm (0.72 cm per decade), while according to raw data, the increase was 5.0 cm (1.09 cm per decade).

Figure A.1. Observed height vs. estimated maximum height: men



Source: own estimation

Figure A.2. Observed height vs. estimated maximum height: women

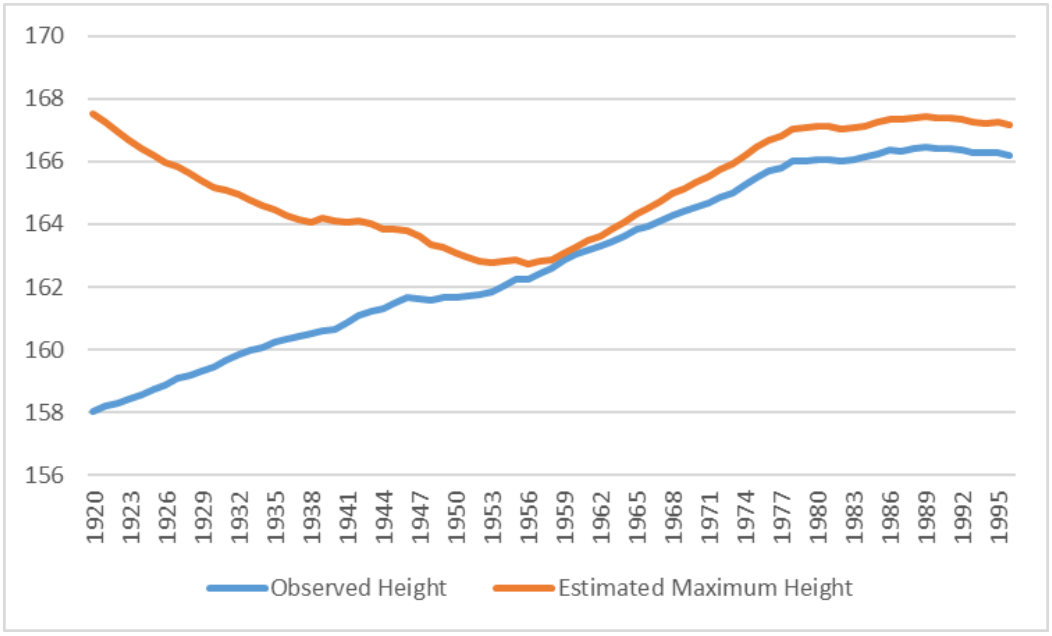


Table A.1. Decennial height increase: data corrected for shrinking (cm).

Decennial increase	Men	Women
1920 – 1930	- 1.74	-2.16
1930 – 1940	-0.50	-1.01
1940 – 1950	0.53	-1.24
1950 – 1960	1.96	0.53
1960 – 1970	2.18	2.05
1970 – 1980	1.80	1.58
1980 – 1990	0.37	0.30
1990 – 1996	0.01	-0.20

Source: own estimation based on administrative data on adult height.

Appendix Table A.2. The long-term evolution of average height and height dispersion (coefficient of variation).

	Men		Women	
Year of birth	**Mean height**	**CoV**	**Mean height**	**CoV**
1920	169.44	0.0390	158.02	0.0387
1921	169.41	0.0386	158.19	0.0386
1922	169.42	0.0384	158.29	0.0382
1923	169.54	0.0378	158.44	0.0379
1924	169.67	0.0375	158.56	0.0378
1925	169.69	0.0372	158.73	0.0373
1926	169.75	0.0369	158.87	0.0370
1927	170.02	0.0362	159.09	0.0368
1928	170.20	0.0361	159.21	0.0365
1929	170.28	0.0358	159.34	0.0362
1930	170.34	0.0357	159.44	0.0358
1931	170.60	0.0355	159.68	0.0355
1932	170.81	0.0351	159.84	0.0353
1933	170.91	0.0349	159.98	0.0348
1934	171.02	0.0349	160.09	0.0344
1935	171.12	0.0346	160.24	0.0342
1936	171.21	0.0344	160.33	0.0338
1937	171.26	0.0344	160.45	0.0338
1938	171.33	0.0346	160.52	0.0336
1939	171.36	0.0344	160.61	0.0335
1940	171.44	0.0343	160.67	0.0333
1941	171.68	0.0341	160.87	0.0331
1942	171.90	0.0340	161.11	0.0330
1943	172.03	0.0341	161.25	0.0327
1944	172.19	0.0342	161.30	0.0327
1945	172.47	0.0340	161.49	0.0326
1946	172.81	0.0342	161.65	0.0326
1947	172.90	0.0342	161.64	0.0327
1948	172.97	0.0343	161.58	0.0328
1949	173.16	0.0343	161.67	0.0328

1950	173.32	0.0345	161.66	0.0329
1951	173.52	0.0346	161.70	0.0329
1952	173.81	0.0346	161.76	0.0332
1953	174.05	0.0348	161.87	0.0331
1954	174.28	0.0350	162.04	0.0330
1955	174.56	0.0351	162.24	0.0329
1956	174.75	0.0350	162.25	0.0332
1957	174.93	0.0351	162.43	0.0329
1958	175.18	0.0352	162.58	0.0326
1959	175.40	0.0354	162.86	0.0326
1960	175.58	0.0354	163.04	0.0324
1961	175.71	0.0355	163.19	0.0324
1962	175.88	0.0355	163.31	0.0323
1963	176.05	0.0357	163.44	0.0324
1964	176.15	0.0359	163.60	0.0319
1965	176.45	0.0357	163.83	0.0327
1966	176.64	0.0357	163.93	0.0330
1967	176.76	0.0360	164.10	0.0331
1968	176.94	0.0358	164.30	0.0336
1969	177.09	0.0358	164.41	0.0337
1970	177.38	0.0359	164.56	0.0339
1971	177.59	0.0357	164.69	0.0341
1972	177.76	0.0359	164.86	0.0343
1973	177.98	0.0359	165.02	0.0345
1974	178.23	0.0359	165.27	0.0348
1975	178.45	0.0359	165.48	0.0349
1976	178.59	0.0358	165.70	0.0353
1977	178.67	0.0362	165.79	0.0348
1978	178.87	0.0360	165.99	0.0348
1979	178.93	0.0362	166.02	0.0347
1980	179.08	0.0364	166.06	0.0347
1981	179.15	0.0365	166.05	0.0348
1982	179.13	0.0365	165.99	0.0347
1983	179.06	0.0370	166.05	0.0347
1984	179.17	0.0373	166.13	0.0347
1985	179.31	0.0373	166.23	0.0347
1986	179.52	0.0371	166.35	0.0349

1987	179.48	0.0371	166.34	0.0347
1988	179.52	0.0372	166.39	0.0348
1989	179.58	0.0372	166.46	0.0348
1990	179.56	0.0371	166.41	0.0347
1991	179.62	0.0375	166.43	0.0349
1992	179.55	0.0377	166.37	0.0352
1993	179.52	0.0381	166.29	0.0354
1994	179.57	0.0381	166.27	0.0356
1995	179.61	0.0385	166.30	0.0360
1996	179.60	0.0385	166.20	0.0364

Source: own estimation based on the administrative data on adult height.

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