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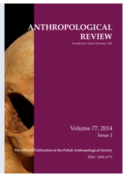

The association between social factors and body length proportions in Polish schoolchildren from Lower Silesia

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Abstract: Many studies worldwide have shown that social factors are significantly associated with growth in childhood. However, very few researchers studied influence of social factors on body length proportions. The aim of the present study was the assessment how urbanization level, sibship size and parental education may affect body length proportions in schoolchildren. 325 boys and 335 girls aged 7–18 years were measured in schools in Wrocław, two small towns and villages around these towns. Height, sitting height, leg length , and lower leg length were measured in all children, then relative lengths (in relation to height) were calculated: leg, femur, lower leg, estimated leg and lower leg length to leg length ratio. Height was standardized on age using LMS parameters for CDC 2002 year cohort. Other indices were standardized on age by using residuals variance derived from linear regressions. Four-way analysis of variance was used for height and each index, where independent variables were four social factors. Except for father's education in boys, no other social factor was significant associated with height. Urbanization level significantly differed almost all indices, whereas father's education level was significantly associated with relative leg length in girls and estimated leg length in both sexes. Our study has shown that the segments of lower limb seems to be more sensitive than height to the effect of social factors. In Lower Silesia, the level of urbanization is still related to differences in environmental conditions, enough to significantly affect growth of children, especially within the segments of lower limbs.

Key words: body proportion, social status, height, tibia, children

Introduction

For decades, a stature has been utilized by many anthropologists as an indicator of economic well-being of individuals and populations. Tanner (1990) made a remark that data on growth provide a meaningful measure of social inequality in living standard. Although physical growth is highly determined by genetic factor (Jelenkovic et al. 2011), it is also sensitive to adequacy of nutrition and level of health care (Ulijaszek 1995; Bielicki 1999), especially during infancy and puberty which are considered as the most sensitive periods.

Many studies have shown that in Poland social factors significantly affected

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the growth of children in height (Jedlinska and Lebioda 1981; Waliszko et al. 1985, Jedlinska et al. 1988; Hulanicka et al. 1990), resulting in social variation in adult height of population (Bielicki 1986; Bielicki et al. 1993; 2003). In Poland many previous studies, particularly conducted during communism and political transformation, reported vast socioeconomic influence on human height. One of the most extensive study of this issue, has demonstrated astonishingly constant social gradients in adult height of conscripts from 1965 to 2001 (Bielicki et al. 2003). Similarly, the study of 7–18 years old boys and girls between 1966 and 2012 have shown the same pattern of social variation in standardized height, however in 2012 survey in both boys and girls differences in height substantially decreased between analyzed categories of social factors (Nowak-Szczepanska and Gomula 2014; Kozieł 2014).

Meadows and Jantz (1995) were one of the first who have pointed out that lower leg's long bones were positive allometric with stature. In other words, length of lower limbs became proportionally longer in comparison to the other body segments, when the stature increased. Other findings confirmed that total lower limb length was more plastic than head-trunk height, usually measured as a sitting height (Gunnell et al. 1998; Wadsworth et al. 2002; Bogin and Rios 2003; Pomeroy et al. 2012). Some studies suggested that lower leg length (tibia) seems to be more sensitive than analogue distal parts of upper limb (ulna/radius). It was also demonstrated that distal parts of limbs (ulna/radius and tibia/fibula) are more variable than proximal parts (humerus and femur), and within them tibia is more sensitive than radius (Holiday and Ruff 2001; Auerbach and Sylvester 2011). Other researchers confirmed that total lower limb length may be more sensitive than total upper limb length (Lampl et al. 2003). A comparison of growth in limb segments in two populations of Peruvian children, living in contrasting stressful environments, showed that highland children, exposed to the greater stress, have significantly shorter ulna and tibia than their lowland peers (Pomeroy et al. 2012).

There are some evidences that lower social position, measured by education level, income or level of urbanization, increases exposure to stressful events in individual's life. Additionally, fewer social and material resources do not buffer, but even enhance arisen stressful events (Baum et al. 1999). Dowd et al. (2009) reviewed the findings on association between low SES and high level of cortisol, clearly showing a reasonable relationship. For example, in a sample of 217 school children aged 6–10 years in Canada it was found that lower family income was associated with higher level of cortisol measured in the morning (Lupien et al. 2000). From the other hand, chronically elevated levels of cortisol have been linked to a variety of pathogenic processes (Young et al. 2004).

Therefore, it could be also expected that low socioeconomic position, except of its stressful action, determines, *inter alia*, the type of food resources, dietary habits and the level of health care during development. They all may inhibit the growth of long bones, resulting in lower height and/or body disproportions. Both human height as well as body proportions (particularly relative leg length) may be affected by the influence of socioeconomic factors during growth. Therefore, the aim of the present study was an assessment of the association between urbanization level, family size and parental education and body length proportions in Polish schoolchildren.

Material and Methods

325 boys and 335 girls aged 7–18 years were examined in Lower Silesia as a part of the V Polish Anthropological Survey conducted in 2012 year. Children were inhabitants of city of Wroclaw and two small towns below 50 000 inhabitants (Bystrzyca Kłodzka i Polanica Zdrój), and villages surrounding the towns. Children included in the survey were measured in randomly selected all types of schools in Wroclaw, and in schools in two towns as well as villages. This subgroup of children was randomly selected in age classes and underwent an extended set of measurements. Among other height, leg length (B-tro)*, lower leg length (B-ti), sitting height were measured by trained staff according to general principle described by Martin and Seller (1959). Then 5 indices of body length proportion were calculated: relative leg length (LL) [(B-tro)/(B-v)*100]; relative femur length (FL) [(B-tro)-(B-ti)/(B-v)]; relative lower leg length (LLL) [(B-ti)/(B-v)]; relative lower leg length to leg length (LLL-to-LL) [(B-ti)/(B-tro)]; relative estimated leg length (ELL) [(B-v)-(BS-v)/(B-v)].

Before analysis the height was standardized to the reference population using the LMS parameters from CDC 2002 database, separately for boys and girls. All other indices were standardized by using linear regression where age was dependent variable and standardized residuals variance derived from regression were further analyzed. Four social factors were scored as follows: urbanization level (city/town/village), family size (1/2/3 or more children), father's and mother's education (vocational/college/university). Then four-way analysis of variance was applied where social factors were independent variables and standardized height and indices were dependent variables. The analysis included 304 boys and 306 girls with completed measurements and information of social factors. All calculations were done using Statistica 12.5 (StatSoft 2014).

*Acronyms: B – Basion, tro – trochanterion, ti – tibia, v – vertex, BS – sitting height

Results

Descriptive statistics of height and five body proportions indices by age and sex are presented in Table 1, whereas Table 2 shows the numbers of boys and girls in each of scores of all social factors. Table 3 shows the results of the analysis of variance where independent variables were four social factors and standardized height and five indices were dependent variables. Nearly all social factors were not significantly associated with height in children from Lower Silesia, except for father's education in boys, where boys having father with vocational education were shorter than in groups with father's college & university education ($p<0.05$) (Figure 1). Among social factors, the level of urbanization seems to be the most meaningful factor which was significantly associated with: relative leg length (LL), relative femur length (FL), and relative lower leg length (LLL) and lower leg length to leg length (LLL-to-LL) in boys, as well as relative leg length (LL), relative lower leg length (LLL) and estimated leg length (EL) in girls. Father's education significantly differentiated height in boys, relative leg length (LL) in girls and estimated leg length

Table 1. Descriptive statistics of height, relative leg length (LL), relative lower leg length (LLL), relative lower leg length to leg length (LLLtoLL), relative femur length (FL) and relative estimated leg length (ELL) in Boys and Girls by age.

		Height		LL		LLL		LLL-to-LL		FL		ELL	
Age [years]	N	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
BOYS													
7	23	126.23	4.80	49.23	2.63	27.64	1.39	56.35	4.90	21.59	3.32	46.63	1.99
8	26	130.43	5.89	50.67	4.06	27.74	1.92	55.07	5.89	22.94	4.50	46.07	1.81
9	31	134.62	5.90	51.19	3.24	27.83	1.26	54.53	3.81	23.36	3.18	46.71	1.51
10	29	142.21	5.22	51.62	3.37	28.08	1.45	54.54	3.62	23.55	3.09	47.60	1.33
11	28	146.79	6.30	51.71	4.04	28.60	1.84	55.55	4.81	23.11	4.10	48.32	1.29
12	23	148.72	5.63	53.12	3.82	28.59	2.00	54.03	4.94	24.53	4.07	48.55	1.33
13	28	161.37	7.02	52.97	3.97	28.80	1.30	54.74	5.65	24.17	4.59	48.81	1.68
14	19	168.83	8.74	55.18	3.77	28.42	1.33	51.74	4.28	26.75	3.95	49.36	1.15
15	25	173.18	7.34	54.78	3.04	28.29	1.01	51.78	3.01	26.49	3.02	48.78	1.86
16	26	174.74	5.37	52.93	4.57	28.11	1.38	53.55	5.94	24.82	5.02	48.33	1.09
17	31	181.92	7.27	53.66	4.68	28.73	1.56	53.90	5.21	24.93	4.81	48.79	1.38
18	28	178.04	5.32	53.13	5.55	28.94	1.73	54.96	5.83	24.19	5.43	48.40	1.77
GIRLS													
7	25	123.81	6.48	50.83	3.56	27.26	1.66	53.96	5.92	23.57	4.39	46.03	1.28
8	27	128.81	5.78	50.58	2.59	27.96	1.60	55.41	4.22	22.62	3.00	46.34	1.41
9	25	135.20	7.70	52.25	2.02	28.05	1.68	53.73	3.22	24.19	2.16	47.16	1.19
10	26	140.62	6.68	51.79	3.44	28.65	2.01	55.56	5.70	23.15	4.06	47.60	2.02
11	32	143.47	7.05	51.90	2.42	28.81	1.72	55.64	4.39	23.09	3.06	48.32	1.84
12	22	151.39	6.54	52.84	3.01	27.96	1.43	53.06	3.90	24.89	3.27	47.90	1.40
13	27	158.02	6.84	51.54	3.44	28.84	1.85	56.14	4.50	22.70	3.43	48.54	1.92
14	28	161.96	7.28	53.46	3.36	28.56	1.75	53.60	4.32	24.90	3.41	48.30	1.85
15	28	164.00	4.36	53.03	3.41	28.24	1.68	53.41	3.80	24.79	3.09	47.88	1.61
16	37	163.97	6.60	52.87	4.28	28.62	1.58	54.45	5.05	24.25	4.18	47.85	1.74
17	28	167.23	6.63	51.09	4.12	29.30	1.41	57.67	4.96	21.79	4.02	47.66	1.50
18	20	166.07	5.69	51.42	3.73	29.19	1.92	57.00	5.15	22.23	3.75	48.05	1.50

Table 2. Numbers of boys and girls in each categories of social factors.

Social factors	Boys	Girls
Urbanization		
Wrocław	63	67
Town	52	51
Village	189	188
Family size		
One children	62	83
Two children	164	152
Three and more children	78	71
Father's education level		
Vocational	108	93
College	91	105
University	105	108
Mother's education level		
Vocational	57	62
College	111	112
University	136	132
Total	304	306

(EL) in both sexes. Mean partial eta square, as a measure of size effect, for height for all social factors accounted for 0.005 and 0.012, for boys and girls, respectively, whereas for body length segments varied from 0.011 for ELL to 0.021 for LLL-to-LL in boys, and from 0.009 for LLL-to-LL to 0.028 for ELL in girls. Thus, the results showed that the body length segments are more frequently sensitive to social environment than body height.

Association between urbanization level and body length segments in boys is shown on Figure 1. There is no marked differences between boys from city and villages. The standardized indices of body length proportions remained mainly the same. However, the boys from towns showed relatively longer lower leg length and relative lower leg length to leg length. It means that town environment, allowing for other social fac-

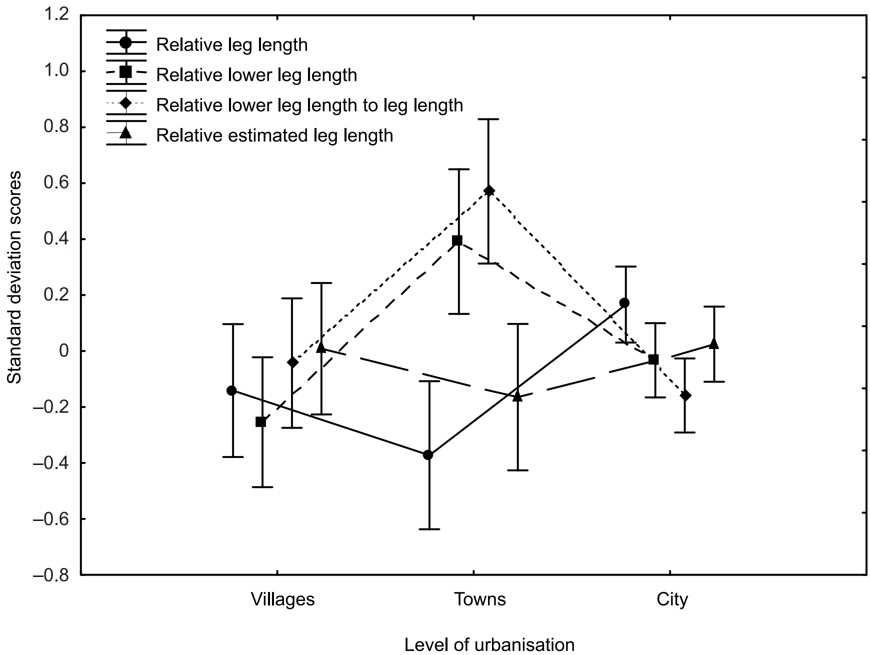

Fig. 1. Means (±95%CI) of standardized values of relative length of leg length, lower leg length, lower leg length to leg length and estimated leg length in boys by urbanization level

Table 3. Results of the four-way analysis of variance where four social factors were independent variables and standardized height and five indices of body proportions dependent variables in boys and girls.

	Height		LL		LLL		LLL-to-LL		FL		ELL	
	F	p	F	p	F	p	F	p	F	p	F	p
							BOYS					
Urbanization	0.21	NS	6.52	<0.01	5.14	<0.01	9.20	<0.001	7.94	<0.001	0.74	NS
Sibship size	0.82	NS	0.88	NS	2.02	NS	0.15	NS	0.23	NS	0.76	NS
Father's education	3.99	<0.05	0.37	NS	0.75	NS	0.85	NS	0.82	NS	3.14	<0.05
Mother's education	0.27	NS	0.76	NS	0.54	NS	0.76	NS	0.76	NS	0.99	NS
							GIRLS					
Urbanization	1.22	NS	4.04	<0.05	4.68	<0.01	1.01	NS	1.27	NS	10.33	<0.001
Sibship size	1.69	NS	0.56	NS	0.12	NS	0.18	NS	0.35	NS	2.71	NS
Father's education	0.29	NS	3.04	<0.05	1.92	NS	0.29	NS	1.12	NS	3.23	<0.05
Mother's education	0.34	NS	2.16	NS	1.34	NS	1.56	NS	1.98	NS	0.49	NS

NS – statistically not significant.

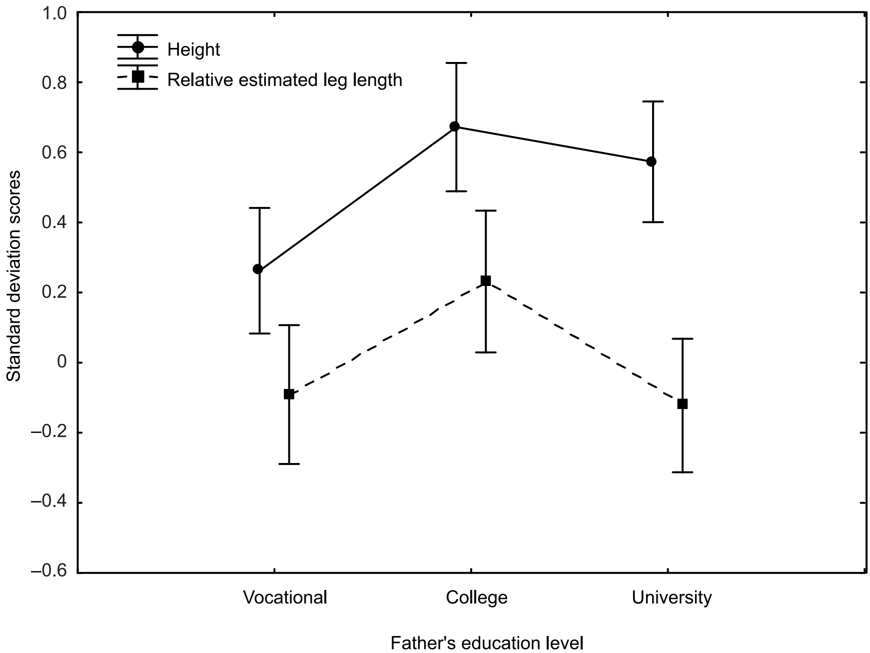

Fig. 2. Means (±95%CI) of standardized values of height and relative estimated leg length in boys by father's education level

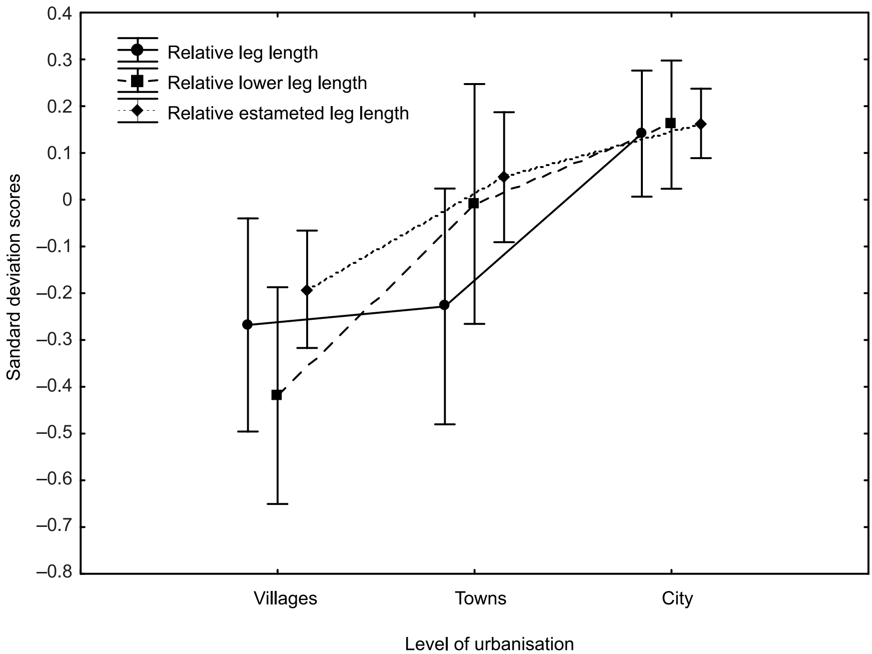

Fig. 3. Means (±95%CI) of standardized values of relative length of leg length, lower leg length and estimated leg length in girls by urbanization level

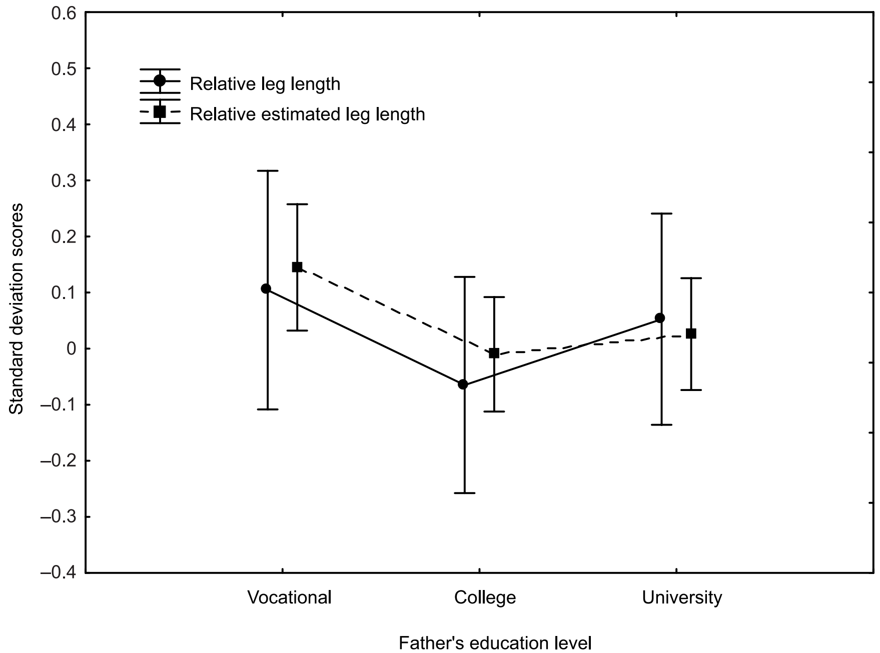

Fig. 4. Means (±95%CI) of standardized values of relative leg length and estimated leg length girls by father's education level

tors, somehow promoted the growth of lower leg length, i.e. distal part of lower limb as tibia length. Association between f father's education and height and relative estimated leg length is shown on Figure 2. The shortest boys had fathers with vocational education. There were no differences in relative leg length between sons of fathers with different level of education, whereas in terms of relative estimated leg length this association was significant: boys with fathers of college education have the highest values of this index.

In girls, association between urbanization level and body length proportions showed more regular patterns (Fig. 3). Standardized values of relative leg length, lower leg length and estimated leg length systematically increased with shifting from villages to city. Also the father's education level was associated with relative leg length and estimated leg length. Daughters of fathers with vocational education had relatively the longest lower limb length, whereas this features did not markedly differ between daughters of fathers with college and university education level (Fig. 4).

Discussion

Social variation in growth and development of children is a permanent phenomenon observed in developing and most of developed countries, constituting a serious challenge to social policy and health services. In Poland, all anthropological studies have shown social gradients in height of children and adults (Waliszko et al. 1985; Hulanicka et al. 1990; Bielicki et al. 1993, 2002). However, so far there was no study considering the social variation on body length proportions. In the present analysis we have shown that body length segments, especially lower limb segments, are much more frequently sensitive to social environment than total body height. Both in boys and girls, lower limb segments showed the greatest variations between levels of urbanization.

Variation in lower extremity length, especially lower leg length, is considered as a biomarker of nutritional and health status during early life. Advantaged conditions in childhood, related to better nutrition and health, contributes to the more rapid growth of the lower extremities (Bogin and Varela-Silva 2010). As was mentioned before, researchers pointed at the lower leg lengths appeared as the most sensitive one to environmental conditions. For example, Pomeroy et al. (2012) revealed that highland children, exposed to greater stress (related to socioeconomic position, poorer nutrition, access to education and healthcare, compared to lowland population) had significantly shorter limbs and zeugopod elements as well as these last were relatively shorter among highland children compared to autopod elements. Similar results were obtained in the research on hypoxia and body proportions, where relative tibia length was significantly reduced in children with lower blood oxygen saturation (Bailey et al. 2007). These differences in tibial length are also visible during prenatal development under the circumstances of chronic hypoxia associated with maternal smoking (Lampl et al. 2003). Results presented in this study, similarly to those obtained by previous research, suggest existence of a mechanism which protects certain anatomical regions over others and contribute to the thrifty phenotype hypothesis extended to limb proportions, which would suggest that zeugopod elements may be sacrificed under adverse conditions to buffer more functional traits, such as head-trunk height (Pomeroy et al. 2012).

Urbanization level seems to be an important factor in the course of children's development, significantly affecting body proportions. What is interesting, its impact is different depending on sex. Longer lower legs and legs among girls living in cities compared to the villages may suggest still present social discrepancies between Polish rural and metropolitan areas. Although Poland has undergone political transformation over a quarter of a century ago, and joined the European Union more than 10 years ago, differences in living conditions between cities and villages are still visible in the biological features, such as body height, weight or age at menarche (Kozieł et al. 2014). Previously, the differences were caused by the general poor economic situation, sanitation, access to health care, as well as nutrition and physical workload in the Polish villages (Wronka and Pawlińska-Chmara 2005; Wronka 2010), nowadays, however, socio-economic status of the rural families has radically changed. In many developed countries these biological differences in the urbanization level diminished or became at least considerably smaller (e.g. Marrod et al. 2000; Padez and Rocha 2003). Therefore, observed differences between different urbanization levels reflected in biological traits seem to be even more disturbing.

What is interesting, for boys situation in Polish towns seems to be more favorable, compared to cities and villages. These sex-dependent differences in the reflection of urbanization level in lower limb length may result from different response of boys and girls to environmental conditions. Probably for girls higher level of overall life conditions in cities significantly stimulates growth of the long bones in lower limbs, whereas boys may be more vulnerable not only for the socioeconomic level, but also to such environmental conditions as pollutions, that may be observed in city, but not in examined towns, as some of these were spa & health resorts at the ecologically clean mountain region.

It is also important to mention that Polish society is highly ethnically homogeneous. Serological, and genetic research conducted among men from different regions of Poland revealed no differences of social change and intergenerational geographical differences in terms of both genetic markers and polygenic traits with strong genetic determination. These differences in tibial length between children from different social strata cannot result from genetic variation since Polish population is highly genetically homogeneous (Gronkiewicz and Gronkiewicz 1995; Gronkiewicz 2001; Ploski et al. 2002).

The importance of studies on the diversity of plasticity of different body segments results not only from the significance of research on its social stratification and, consequently, control the quality of life of the populations, but also from its relation to health outcomes: including higher risk of many chronic diseases, such as cardiovascular ones, diabetes, hypertension, obesity or liver dysfunction and dementia, as these illnesses are related to shorter statures and/or shorter legs, especially to lower leg length, as early growth environment could affect not only body proportions, but also metabolic characteristics which subsequently would lead to these diseases. In this term, tibia could serve not only as a sensitive environmental marker, but also as a predictor of future illnesses.

In conclusion, it seems that the segments of lower limb are more sensitive than height to the effect of social factors. In Lower Silesia, the level of urbanization is still related to differences in environmental conditions, enough to significantly affect growth of children, especially within the segments of lower limbs.

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Authors' contributions

SK drafted manuscript and provided critical comments; AG collected the data and drafted the manuscript; NNSz collected and analysed the data.

Conflict of interest

The Authors declare that there is no conflict of interests.

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