Secular trends in body height in Balkan populations from 1945 to 1995

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Abstract

The aim of this study was to look for any secular trend in the stature of Balkan populations from the time of World War II (1939–1945) to the Balkans War (1991–1995). The research was based on the examination of exhumed skeletons of 202 men killed in World War II in the area of the Republic of Slovenia, and 243 men killed in the Bosnian War in Bosnia and Herzegovina. The length measurements of the right and left humerus, femur, tibia and fibula were taken. Since the results revealed no significant differences and the left-sided bones were more complete and recurrent in the sample, the bones of the left side were used in the analysis. Since the increase in height depends mostly on the increase in length of the long bones, with an average absolute change of about 0.28 cm for humerus, 0.55 cm for femur, 0.49 cm for tibia and 0.20 cm for fibula per decade in our case, these results suggest a significant increase of the height of the Balkans population. The difference of the sum of the average femur and tibia length for the study period was 4.13 cm. Recalculated average length increase of the sum length of femur and tibia per decade was 0.88 cm for the left side. Our study revealed that there was a trend towards increased long bone lengths, at least in the male population analyzed.

KEY WORDS: Skeletonized remains, long bone lengths, mass grave, secular trend, Balkan populations

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INTRODUCTION

The key objective in physical anthropology is to document the vast range of human variability of past and present populations, and to investigate the evolutionary and environmental forces responsible for that variation [1]. Stature estimation is a constant challenge for forensic anthropologists because of secular trend in stature, allometric changes in long bones, and migrations of world populations [2].

Secular trend means that the general population is changing over time and that, not only can be noticed, but it can be measured as well. Traditionally, secular changes of growth, and maturation were explained by improvements in socio-economic and environmental conditions in which children are growing up [3-6]. Body height and skeletal development are directly influenced by industrialization and consecutive better socio-economic status with better nutrition and improved healthcare. These qualities allow measurable differences to be established between populations, groups and individuals in the dimension of bones, specific for different geographic areas [7, 8].

Cole (2000) believes that an increase in adult height can be related to an increase in the height of children over the age of two years, especially related to the growth of long bones and feet [9]. It has been shown that these factors of growth changed for white Americans from those from Terry's collections (people born in the 1880s and 1890s), compared to those who died in World War II (1940s)(WWII), and the Korean War (1950s), all the way to the present generation [10].

Ross (2004) in her work showed differences in the craniofacial variation between the Balkan population, and we thought that the same could apply to the growth of long bones [1].

Throughout history, Bosnia and Herzegovina (B&H), Croatia and Slovenia were part of the same country: firstly, Austro-Hungarian Monarchy, then the Kingdom of Yugoslavia, and finally the Socialist Federative Republic of Yugoslavia. These populations have similar ethnical background (South-Slavic nations), and because of constant internal migrations of population in this region, populations can be regarded as relatively homogenous and comparable.

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The aim of this study was to look for any secular trend in the height of Balkan populations from the time of WWII in the 1940s to the Balkans Wars (BWs) of the 1990s. Ross and Konigsberg (2002) used the data on the Bosnians and Croats exhumed from the BWs of the 1990s, and for reference sample they used data from the literature [11]. Our current study should provide credible representation of different anthropometric dimensions in different populations living in a rather small geographic region based on comparison of bone measurements of Balkan populations from the 1940s to the 1990s and demonstrate that improvements in living and economic circumstances over five decades had an impact on the height of Balkan populations.

MATERIALS AND METHODS

Population selection

The retrospective study was carried out on exhumed and identified skeletal remains of 243 deceased from the territory of B&H, who had disappeared between 1992 and 1993, and 202 exhumed skeletal remains of deceased from the territory of the Republic of Slovenia, who were killed at the end of WWII. The deceased from B&H teritory were not exhumed from a single mass grave, but from about 50 single graves and mass graves, from 1998 till 2000, and the deceased from WWII sample were exhumed from two locations – Zgornja Bistrica (2002) and Laško (2009). In the B&H sample all the deceased were Bosnian males, and sex was determined by DNA analysis. In WWII sample the deceased were males of Slovenian and Croatian nationality [12], and sex was determined by standard method of examination of the pelvis, and by measuring the diameter of the heads of the humerus and femur [13-15].

Measurements

The maximum lengths of four long bones from collected skeletons: humerus, femur, tibia and fibula, were measured using osteometric board to the nearest 0.1 cm according to the standards presented by Moore-Jansen ***et al.*** [16], and were analyzed by means of descriptive statistics. Osteometric measurements were performed by one author on each side to minimize interpersonal errors. The sample from B&H consisted of the following: 242 left humeri (LH), 198 right humeri (RH), 242 left femurs (LF), 176 right femurs (RF), 241 left tibias (LT), 176 right tibias (RT), 241 left fibulas (LF), 184 right fibulas (RF). The sample from Slovenia consisted of: 31 LH, 24 RH, 190 LF, 190 RF, 190 LT, 190 RT, 7 LF and 13 RF. Because of the eventual difference in bone lengths between the two sides of the skeleton, the bones were measured on both sides when available.

Statistical methods

All numerical variables were tested for normal distribution as criteria for further use of parametric methods. Kolmongorov-Smirnov (KS) test was used on all the analyzed variables, lengths of long bones of the humerus, femur, tibia and fibula of the right or the left side of skeleton, and revealed p value less than 0.05, which indicates that the assumption of "normality" is not satisfied and that non-parametric tests should be used for the comparison of samples. Since all the data had shown a nonparametric distribution, Mann-Whitney U test for independent samples was used in subsequent statistical analysis. A p value of 0.05 was considered to be significant and 0.01 to be highly significant. As a statistical software, we used IBM SPSS v. 17.0 (International Business Machines Corporation Statistical Package for the Social Sciences, Chicago, IL, USA) and Microsoft Excel.

RESULTS

The results of the statistical comparison between lengths of long bones of the left and right side of the body in the tested samples showed that there were no statistically significant differences between separate bones from both sides of the body (for Bosnian war (BW) sample: humerus (p=0.318); femur (p=0.310); tibia (p=0.667); fibula (p=0.311) and for WWII sample humerus (p=0.739); femur (p=0.890); tibia (p=0.983); fibula (p=0.689).

Since there were no statistically significant differences (p>0.05) between the lengths of left and right bones in both samples, we decided to compare only bones of the left side, because there were more complete and recurrent in the samples (B&H and WWII). Table 1 presents the results of descriptive statistics parameters for analyzed variables of the left side of the body of observed samples and the results of the comparison of the left side bone lengths between these two samples. The majority of analyzed bones – humerus, tibia and femur - except fibula (p=0.366), had statistically significant differences in bone length, over the analyzed period. The increase in length for each bone per decade was 0.28 cm for humerus, 0.55 cm for femur, 0.49 cm for tibia, and 0.20 cm for fibula (Figure 1). Overall, the results indicate a significant increase in bone length of humerus (p<0.001), femur (p<0.001) and tibia (p<0.001) between Bosnian, Croatian and Slovenian males over a period of 40 years, which could influence the increase in body height.

Taking into account that the length of leg long bones gives the most accurate results for evaluation of stature [17], adding the length of the femur and tibia (F+T) together for each period, and their comparison gives the closest results of the secular growth trend in height over the studied period. In

Table 2 the differences of the sum of the average F+T length between the samples for the studied period are presented. There are significant differences (p<0.01) in the sum of bone lengths (F+T) between the deceased in B&H and in WWII sample. The sample from Bosnia revealed a higher average sum (F+T = 4.13 cm) and if calculated per decade being 0.88 cm for the left side.

DISCUSSION

The Bosnian war in the former Yugoslavia fought from 1991–1995 led to a large number of missing persons, and thus the need for anthropological examination of the exhumed remains. Several studies from these examinations have dealt with the estimation of living stature from the length of long bones [18-21], and while they demonstrated some variation between different parts of the Balkans population, in this study we regarded our two observed populations similar, given that historically they had been part of the same country (or countries), and that there had been much mixing and migrations among them. Therefore, although the observed differences in long bone lengths in different, but yet close Balkan populations in two different time periods, can be in part attributed to population-specific differences, they certainly can indicate the existence of a significant secular trend in height among Balkan populations in forty years period [17]. Namely, most of the people from the WWII sample, killed in WWII, were born in the first three decades of the 20th century, while the majority of those from the B&H sample, killed between 1992 and 1993, were born in 1960s and 1970s.

The present study revealed the existence of a secular trend in the bone length that certainly correlates with height changes of Balkan populations from WWII to the BW. The length of long bones from the left side of the body increased in four decades by approximately 1.12 cm for humerus, 2.19 cm for femur, 1.96 cm for tibia and 0.78 cm for fibula, or per decade 0.28 cm for humerus, 0.55 cm for femur, 0.49 cm for tibia and 0.20 cm for fibula. Besides, it was shown that the average sum of the length of F+T is higher in the sample from Bosnia (dating from the 90's) than in the WWII sample (dating from the 40's). Due to known correlation between the height of a population and the growth of long bones, the observed increase in bone length most probably led to an increase in stature. This emphasizes the need for continuous update of formulas for estimating the height of more recent populations [22]. However, these are different for populations living in different geographical and socio-economic conditions [10], as noted also by Trotter and Gleser (1951) who warned of the danger of using formulas derived from one population on another, without taking into consideration the needful secular trend in the development of a specific population [23].

Similar studies on stature estimation determined from limb bone length have been conducted in other parts of the world in recent years although most have shown an increase in population height over time, the rate of increase varying from study to study [6, 24, 25]. Adult height has been increasing over centuries and decades in line with improvements in healthier childhoods, less illness, and longer life spans [26], with a clear increase in length of long bones over decades [25-30]. In Thai

TABLE 1. Descriptive statistics and comparison differences between lengths of the bones on left side of the body for two population samples.

	Period	N*	Minimum	Maximum	Average	SD (±)**	p value
Left humerus	BW	242	30.0	39.0	33.76	1.62	0.000
	WWII	31	30.0	37.0	32.65	1.47	
Left femur	BW	242	42.0	53.0	47.40	2.22	0.000
	WWII	190	37.0	52.0	45.21	2.43	
Left tibia	BW	242	33.0	45.0	38.71	2.16	0.000
	WWII	190	30.0	42.0	36.75	2.43	
Left fibula	BW	241	33.0	44.0	38.35	1.99	0.366
	WWII	7	34.0	41.0	37.57	2.37	

The majority of analyzed bones, except fibula, had statistically significant differences (p<0.001) in bone length, over the analyzed period. *N, number of samples; **SD (±), standard deviation; BW, Bosnian war (1992-1995); WWII, World War II; All values are presented in centimeters (cm).

TABLE 2. The differences of the sum of the average femur and tibia length for the left side of the body.

Period	Left side	Min	Max	Mean	SD (±)	p value
BW	F+T	75.00	98.00	86.09	4.19	<0.01
WWII	F+T	67.00	94.00	81.96	4.39	

Differences in the sum of the left leg long bone lengths between the deceased in B&H and in WWII sample were found to be significant (p<0.01). BW, Bosnian war (1992-1995); WWII, World War II; F+T, sum of length of femur and tibia; Min, minimum; Max, maximum; SD (±), standard deviation.

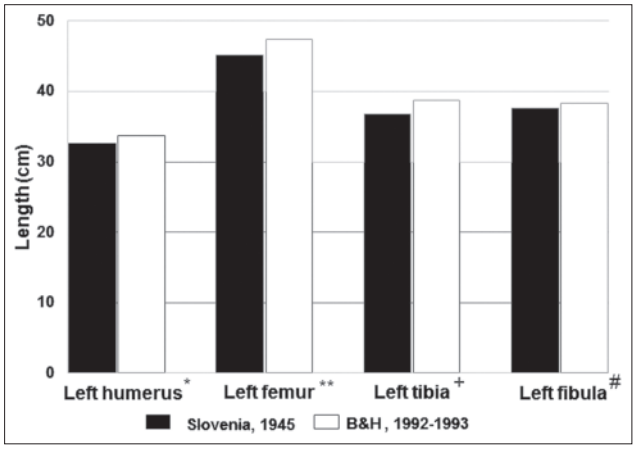

FIGURE 1. Increase in length for each bone on the left side of the body. *Left humerus length increased for 1.12 cm or 0.28 cm per decade; **Left femur length increased for 2.19 cm or 0.55 cm per decade; +Left tibia length increased for 1.96 cm or 0.49 cm per decade; #Left fibula length increased for 0.78 cm or 0.19 cm per decade.

population the change in bone size was observed, with a clear increase in length of long bones over a period of a few decades. The lowest increase was for left fibula (0.78 cm) and the largest for right femur (2.41 cm)[25], which is in concordance with our results. With the length of the leg bones being the best indicator of a person's height [25], the increase in the length of femur and tibia allowed the estimation of the increase in height and secular trend for the investigated period. Namely, statistical analysis showed a significant increase in growth of French children (0.8 cm per decade in stature), characterized by increased length of the lower limbs [27]. An overall positive secular trend in height was recorded in urban China between 1985 and 2010, with the average rate being 2.4 cm and 1.7 cm per decade for boys and girls, respectively. Cities with different socio-economic levels had different trends, with the increase in mean stature in large cities being greater than that in moderate size and small cities. The boys and girls in moderate size and small cities showed greater potential for growth in stature [28]. In Italy there was an average increase in height of about 0.97 cm per decade [29]. Similar figure (0.96 cm per decade) was determined for Turkish males from the period of 1884 to 2006 [30].

Depending on their socio-economic, bio-cultural status [29-31], and impact of war [32], population groups throughout the world have shown different secular trends in stature over the past century [29-32]. Steckel (2004) reported that the average stature in certain developed countries such as the UK, USA, Sweden, France, and Australia began to increase with the industrialization of the 19th century, with or without transient decreases beforehand, whereas the stature of the German population remained the same, with minor fluctuations, until the beginning of the 20th century [33]. De Beer (2004) reported a sharp increase in the height of the Dutch population over the second half of the 19th century, with further progress continuing into the second half of the 20th century [34]. On the other hand, in Portugal, the mean stature began to increase relatively late, in the middle of the 20th century [35].

It is assumed that socio-economic and bio-cultural factors play an important role in the increase in height of the general population. This could equally explain the results of the present study. Most of people exhumed from B&H were born in the 1960s and 1970s, which coincides with probably the most successful time period in the former Yugoslavia, in terms of social, economic, educational and cultural achievement. This brought a significant improvement in quality of life compared to previous (and unfortunately future) generations, which, amongst other things, could have produced an increase in body height.

Further research is needed to determine the situation in female population, and bring a conclusion which could be applied to the entire population.

CONCLUSIONS

This is the first survey of this kind related to the Balkans region, and besides simply demonstrating the increasing height of the population, it also highlights a trend of long bones length increase among males in the region. Such an overall positive secular growth trend could be related to industrialization and socio-economic progress.

DECLARATION OF INTERESTS

The authors declare no conflict of interests.

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