

SHORT REPORT



Use of joinpoint regressions to evaluate changes over time in conscript height

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Abstract

Objectives: Cohort variation in adult height expresses both the impact of socio-economic change on human biology in a wide temporal perspective and social inequalities within populations. We aimed to test the use of joinpoint regressions to identify periods in which changes in height trends were statistically significant.

Methods: Data correspond to the height recorded in Madrid City (Spain) for 65 313 conscripts between 1936 and 1974 (cohorts from 1915 to 1953), a period of social and political turmoil. Secular trends in height were analyzed in eight districts with contrasting socio-economic conditions, grouped in two categories, lower-class and middle- and upper-class. Trends in height were evaluated by quadratic regressions and by joinpoint regressions to identify the cut-off years when trends changed significantly.

Results: Height increased in both socio-economic categories of districts, more among conscripts from the lower-class ones. However, results clearly show differences in trends according to district of residence. Whereas the increase in height in conscripts from the middle- and upper-class districts was steady, it was slower in those from the lower classes, with declines in height during the Civil War and first years of the Franco dictatorship.

Conclusions: Joinpoint analysis reveals the association between urban living conditions and adult height, and that the disparities intensified during critical historical periods of Spain.

1 | INTRODUCTION

The prenatal stage, infancy and adolescence are periods of the human life cycle of rapid growth velocity, in such a way that a negative energetic balance over these critical periods affects growth irreversibly and determines health and illness patterns in the adult stage (Bogin et al., 2018). The study of differences in adult height thus allows both for an evaluation of inequalities in terms of access to resources and living conditions within populations (Blum, 2016) as well as of the impact of socio-economic

transformation on the biology of human populations from a wide time perspective, that is, secular trends. Secular trends and population differences in adult height are often ascribed to living conditions during infancy (Cole, 2000), although there is increasing evidence of the influence of environmental conditions also during later childhood and adolescence (Bogin, 2021).

Data from conscripts confirms a sustained increase (over 1 cm per decade) in male height in industrialized countries throughout the 19th and 20th centuries associated with the increase of household resource allocation

and the improvement in global living standards (Hatton & Bray, 2010). In a long-term perspective, height increased smoothly in Europe throughout the 20th century despite the many socio-economic transformations—including revolutions, two World Wars and the Great Depression—(Hermanussen, 2013), which suggest that the increase in height was determined by deep social and demographic trends that transcended, in general, periodic economic and political crisis (Hatton & Bray, 2010). However, there is also clear evidence of the reversal of this positive secular trend determined by the impact of severe food restrictions during growth, as was the case of the Dutch famine during World War II (Burgmeijer & Wieringen, 1998; Portrait et al., 2017), and of Spain during the Civil War (1936–1939) and the first decade of General Franco's dictatorship (Cámara et al., 2019), among others. Therefore, an evaluation of trends in height based on the initial and end values of a temporal series, or even on regression models for a complete, long-term period, or for predefined periods may overlook the complexity of the patterns. Even in the presence of a generally positive or negative long-term trend in adult height, it is often not apparent when exactly the trend begins, changes in direction, or ends. We propose the use of joinpoint regressions as a statistical method to identify periods in which the changes in height trends were statistically significant.

2 | MATERIAL AND METHODS

Data correspond to the height recorded in Madrid (Spain) for 21-year-old men called up between 1936 and 1974 (birth cohorts from 1915 to 1953). Analyzed data correspond to 65 313 conscripts, a random sample of 30–40% of the male census population of that age, including those finally assessed not fit for military service. Compared with other European big cities, Madrid delayed its definitive economic and demographic expansion until the first third of the 20th century. This was a process characterized by a rigid spatial segregation between social classes associated with severe socio-economic and living conditions inequalities (Juliá et al., 2008). Lower-class districts were initially slum areas on the northern and south periphery of the city, improvised conurbations of unhealthy and overcrowded housing receiving the flood of migrants during the first two decades of the 20th century. By contrast, middle- and upper-class districts included the historic center of the city, modernized, and expanded at the turn of the century. Both categories of districts maintained—albeit reduced—a clear, significant gap in adult male height throughout the period analyzed (Varea et al., 2019).

According with these considerations, eight districts of the city, well-defined administratively and with contrasting socio-economic conditions, have been grouped in

two socioeconomic categories, lower-class ($n = 35\,198$) and middle- and upper-class ($n = 30\,115$). We used quadratic regressions to evaluate the change in height in both categories of districts during the whole period. Secondly, trends in height by district of residence were evaluated by Poisson joinpoint regression analysis to identify the cut-off years when the trend changed significantly. Joinpoint regression uses permutation analyses to fit a series of straight lines to estimate annual per cent change ($APC \pm 95\% \text{ CI}$) and if the change in the trend of height for each identified period is significant statistically or not (Kim et al., 2000; Terán et al., 2020). Analyzed data adjust better to a joinpoint model (regression function continuous) than to a breakpoint model (regression function discontinuous).

3 | RESULTS

Height increased significantly in both socio-economic categories of districts, more among conscripts from the lower-class districts (6.39 cm, from 165.10 to 171.49, $R^2 = 90.77$) than in those from middle- and upper-class ones (5.50 cm, from 166.87 to 172.37, $R^2 = 95.04$).

Models obtained by joinpoint regression include three specific joinpoints and four periods for each socio-economic grouping of districts (Figure 1 and Table 1) (see Tables S1 and S2 from the Supporting Information). According to year of conscription, height decreased significantly in the period from 1936 to 1948 among lower-class conscripts, while it remained without significant change for the middle- and upper-class ones during 1936–1944. Thereafter, height increased significantly in both groups although with different patterns. Among conscripts from middle- and upper-class districts, height started to increase in 1944, 2 years before doing so among lower-class conscripts, maintaining a steady, significant rise during the periods 1944–1961 and 1961–1966, while during the last period (from 1966 to 1974) there was not a significant change in height. Among conscripts from lower-class districts height increased sharply between 1948 and 1954, slowed down in 1954–1967, and again increased sharply in the last period, 1967–1974, being all APC significant.

4 | DISCUSSION

Joinpoint regression analysis allowed us to establish and to evaluate statistically different patterns of change in height during the first half of the 20th century according to socio-economic status of conscripts. As far as we know, this short report presents for the first time the application of this epidemiological methodology to the evaluation of secular trends in anthropometric data.

FIGURE 1 Secular trends in height for conscripts from upper- and middle-class districts (white dots and black solid line derived from joinpoint regression) and for lower-class districts (gray dots and black dashed line derived from joinpoint regression) by year of birth and conscription (21-years-old) (Madrid, Spain). Gray dashed lines represent the 2 year moving average for each analyzed group

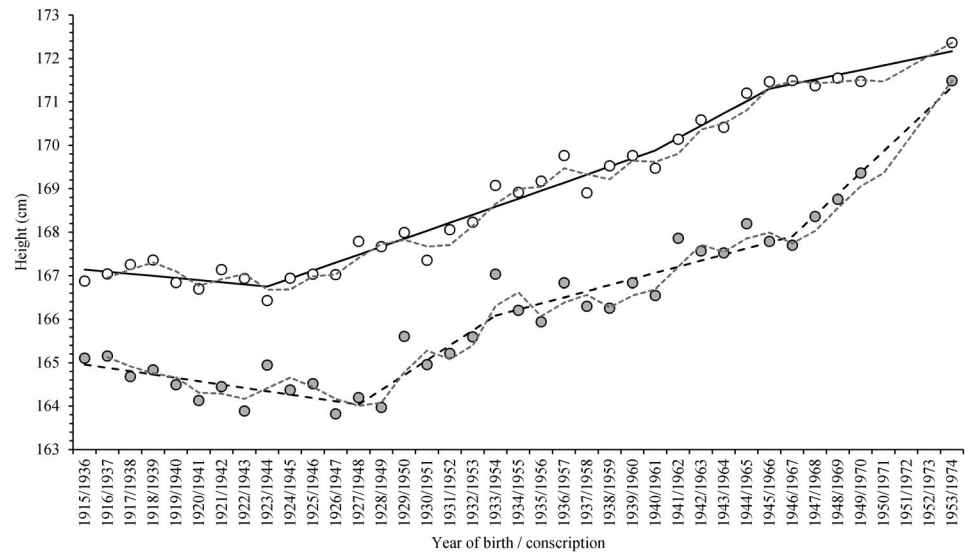


TABLE 1 Periods (year of birth), annual percent change (APC), and confidence interval for APC obtained by joinpoint regressions (Madrid, Spain)

	APC	Lower CI	Upper CI	t test
<i>Middle- and upper-class districts</i>				
Period 1936–1944 (1915–1923)	-0.029	-0.083	0.025	1.117
Period 1944–1961 (1923–1940)	0.110***	0.092	0.127	12.885
Period 1961–1966 (1940–1945)	0.167*	0.014	0.320	2.243
Period 1966–1974 (1945–1953)	0.063	-0.022	0.148	1.518
<i>Lower-class districts</i>				
Period 1936–1948 (1915–1927)	-0.047*	-0.090	-0.003	2.194
Period 1948–1954 (1927–1933)	0.207**	0.061	0.354	2.911
Period 1954–1967 (1933–1946)	0.084***	0.048	0.120	4.808
Period 1967–1974 (1946–1953)	0.290**	0.134	0.447	3.832

*<0.05;
 **<0.01;
 ***<0.001.

The period under study corresponds to decades of profound socio-economic change and of social and political turmoil in the country—including a rapid process of industrialization and urbanization, the Spanish Civil War, and the instauration of General Franco's dictatorship (1939–1975). Despite the global, positive secular trend in height, results show clear differences in both adult heights attained and in trends over time according to social class as proxied by district of residence. Whereas the increase in height in conscripts from the middle- and upper-class districts was steady, it was slower and fluctuating in those from the lower classes. Heights of the social classes finally converged as the consequence of the intense, although delayed, improvements in living conditions and social opportunities among conscripts from the lower-class districts born the late 1940s and early 1950s, following the national trend (María-Dolores & Martínez-Carrión, 2011).

Living conditions influencing human growth and final height need to be understood from a comprehensive life cycle perspective (Bogin et al., 2018). Results confirm the differential impact of environmental conditions during the more sensitive stages of growth—infancy and adolescence—among members of the same cohorts but different social classes. Urban disparities were responsible for social inequalities and, finally, for adult height differences by district of residence, both intensified during critical periods. The decrease in height among low-class conscripts born between mid-1910 and mid-1920 (1.47 cm) expresses the double burden of an infancy spent in the slums around Madrid and of the impact of the lengthy period of famine suffered over their late childhood and adolescence during the Civil War and the first decade of dictatorship. Height increased among cohorts born and raised during periods of social reforms and economic growth, more intensely among those living

in the low-class areas who suffered more in the previous period and, thus, benefited more when there was a relative improvement in their situation. This was the case of those born during the final years of the 1920s and the first years of the failed Second Spanish Republic (1931–1939), a period of economic stabilization and improvements in sanitation and socio-economic conditions. Relative improvement in living and emotional conditions was evident from the late 1940s onwards and more evident in the 1960s, in a new context of international recognition and of economic liberalization of Franco's regime.

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AUTHOR CONTRIBUTIONS

José Manuel Terán: Conceptualization; formal analysis; methodology; writing-original draft; writing-review and editing. **Elena Sánchez-García:** Formal analysis; writing-review and editing. **José Miguel Martínez-Carrión:** Conceptualization; writing-review and editing. **Barry Bogin:** Writing-original draft; writing-review and editing. **Carlos Varea:** Conceptualization; writing-original draft; writing-review and editing.

CONFLICT OF INTEREST

The authors declare no conflict of interest with regards this study.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of this article.

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