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ESCUELA INTERNACIONAL DE DOCTORADO

Essays on biological living standard, inequality and poverty in Spain: A long-term view

Ensayos sobre nivel de vida biológico, desigualdad y pobreza en España: Una visión a largo plazo

Dª. Begoña Candela Martínez

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Dª Begoña Candela Martínez

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Fue más tarde en julio de 2018 cuando mi vinculación con el proyecto de I+D+i *Desigualdad y pobreza en España en el muy largo plazo. Nuevas aproximaciones desde los niveles de vida biológico*s financiado por el Ministerio de Ciencia, Innovación y Universidades. Agencia Estatal de Investigación y el Fondo Europeo de Desarrollo Regional y con referencia HAR2016-76814-C2-2-P (MINECO/AEI/FEDER/UE - Gobierno de España) se formalizó con el inicio de mi contrato predoctoral asociado a este proyecto de investigación. Un contrato para la formación de personal investigador (FPI) que ha supuesto poder desarrollar esta tesis doctoral con financiación a cargo de los fondos mencionados anteriormente. Además de mi vinculación con este proyecto liderado por mis directores de tesis entre 2018 y 2021, mi formación también ha estado ligada al proyecto *Malnutrición, niveles de vida biológicos y desigualdad en poblaciones contemporáneas. Estudios comparativos en el largo plazo*, financiado por el Ministerio de Ciencia e Innovación. Programa Estatal de Generación de Conocimiento y Fortalecimiento Científico y Tecnológico del Sistema de I+D+i y de I+D+i Orientado a los Retos de la Sociedad, Plan Estatal de Investigación Científica y Técnica y de Innovación 2017-2020 y la Agencia Estatal de Investigación, con referencia PID2020-113793GB-I00 (MICIU/AEI/FEDER/UE - Gobierno de España). Este último proyecto comenzó en septiembre 2021 y estará vigente hasta finales de 2024. Los dos proyectos forman parte de la Red Temática PHA-HIS. RED2018-102413-T *Niveles de vida, Salud, Nutrición y Desigualdad. Siglos XVIII-XXI* (NISALDes). Los dos proyectos de investigación están liderados por mis directores de tesis a los cuales agradezco enormemente el haberme incluido en ellos y hacerme partícipe de sus investigaciones, además de financiar asistencias a congresos y otras actividades de investigación. Esta financiación junto con su asesoramiento y acompañamiento ha sido fundamental para desarrollar esta tesis doctoral.

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Resumen

El objetivo general de la tesis es estudiar el impacto de los procesos socioeconómicos y de las distintas coyunturas económicas en los niveles de vida biológicos a través de distintos contextos ambientales y grupos socioeconómicos. Una vez ya conocidas las tendencias y los ciclos de las estaturas gracias a estudios previos, en esta tesis se profundiza en los diferentes contextos ambientales y las diversas coyunturas económicas. Se pretende verificar si un aumento de la desigualdad va asociado a contextos de menor crecimiento de la altura. La investigación ahonda en las relaciones entre la desigualdad y los diversos aspectos microeconómicos, tales como el capital humano. Asimismo, se abordan las relaciones dinámicas del ambiente geográfico influido por las variables climáticas con la evolución de la talla humana. En esta dirección, trata de averiguar el impacto de la variabilidad del clima en la talla según la estacionalidad de los nacidos. Es una investigación que profundiza en el análisis de la evolución y la desigualdad de las estaturas de la población española durante las transiciones demográfica, epidemiológica y alimentaria, y su relación con otras variables del bienestar humano.

La tesis se divide en cuatro capítulos donde se realizan estudios de caso usando como herramientas de análisis tanto métodos estadísticos como modelos econométricos básicos. En el primer capítulo se emplea un modelo de regresión lineal donde la variable dependiente es la altura. Los modelos incluyen variables de control contextuales. En el segundo capítulo se utiliza una regresión armónica y un modelo predictivo de la altura siguiendo el algoritmo de random forest de manera que se pueden capturar no linealidades entre variables. En el tercer y cuarto capítulo se usan medidas de dispersión tales como el coeficiente de variación y los percentiles para explorar la desigualdad y también se emplean las puntuaciones Z (Z-score) con el fin de obtener resultados nutricionales que informen sobre el grado de malnutrición en relación a estándares nacionales e internacionales. En los párrafos siguientes se detallan los materiales, métodos, resultados y conclusiones de cada uno de los capítulos que forman la tesis doctoral.

Las desigualdades socioeconómicas y su evolución en los diferentes contextos históricos se han estudiado ampliamente. Sin embargo, algunas de sus dimensiones se

mantienen relativamente sin explorar. Una de ellas es el papel que el estatus socioeconómico supone en la trayectoria de los niveles de vida biológicos, especialmente sobre el estado nutricional neto. El principal objetivo del primer capítulo de esta tesis es analizar si el poder del estatus socioeconómico a la hora de explicar diferencias en las dimensiones biológicas del bienestar humando –en este caso, la altura adulta, una medida fiable de la salud y el estado nutricional- ha aumentado o disminuido a lo largo del tiempo. Para ello se usan los logros educativos y la clase social como dos medidas diferentes del estatus socioeconómico entre mujeres y hombres españoles nacidos entre 1940 y 1904. Este período temporal permite cubrir un periodo histórico en España caracterizado por un sobresaliente desarrollo socioeconómico y un marcado aumento de la altura medida. La base de datos procede de nueve oleadas de la Encuesta Nacional de Salud y dos oleadas de la Encuesta Europea de Entrevistas de Salud para los años entre 1987 y 2017. La totalidad de la muestra está formada por 73.699 observaciones de hombres y mujeres con edades comprendidas entre los 23 y 47 años. Este estudio representa una contribución novedosa a la literatura ya que nos permite incorporar alturas tanto de hombres como de mujeres, lo que supone una diferencia respecto a la mayoría de estudios previos donde las alturas son masculinas ya que se obtienen principalmente a través de los registros procedentes de los alistamientos militares. Estas encuestas nos han permitido reconstruir la estructura familiar para una gran cantidad de hogares españoles. Usando un análisis de regresión lineal multivariable, los resultados muestran que los diferenciales de alturas por nivel educativo se han reducido a lo largo del tiempo, mientras que las diferencias por clase sociales se mantienen. Estos resultados indican la necesidad de una mayor precisión a la hora de describir el proceso de convergencia en los indicadores de bienestar biológico entre los grupos sociales. Por ejemplo, el progresivo aumento de una mayor proporción de la población que se inscribe en mayores niveles educativos puede distorsionar el análisis o llevarnos a subestimar las diferencias reales entre grupos socioeconómicos, mientras que otras medidas del estatus socioeconómico aún apuntan en gran medida a la persistencia de tales diferencias. Por último, aunque no era el objetivo principal del estudio, los resultados nos han ofrecido un hallazgo relevante puesto que se observa un estancamiento en el crecimiento de la altura a partir de los años 70, aunque éste no se ha visto acompañado por un incremento en la desigualdad.

La estacionalidad de nacimiento se correlaciona con una gran cantidad de condiciones de salud a lo largo de la vida medidas por la antropometría. En el segundo capítulo de la tesis exploramos si el mes de nacimiento y el clima durante el período de gestación influyen en la altura masculina adulta, con datos basados en un municipio de la España rural antes del final del proceso de modernización. La base de datos de alturas está formada por 16.266 registros militares de reclutas que alcanzaron la edad de 21 años entre 1908 y 1985 (cohortes de nacimiento de 1886 a 1965). La muestra de la población se ha obtenido del municipio de Hellín que se sitúa en la España interior en la región de Castilla la Mancha, principalmente, una zona agraria, con pocos recursos e ingresos bajos hasta las décadas de 1970/1980. En primer lugar, usamos una regresión lineal con covariables sinusoidales para comprobar que la variable mes de nacimiento es significativa para describir la altura, siguiendo una metodología basada en una regresión armónica de altura con año y mes de nacimiento. Usando esta metodología, observamos que el mes de otoño es favorable para la altura. Una vez se resuelve que es una variable con influencia, dado que los coeficientes de la regresión no indican la importancia de dicha variable en la variable dependiente, se realiza otro modelo predictivo de la altura con el algoritmo random forest. Se elige esta técnica (más robusta que un árbol de decisión y más precisa que mínimos cuadrados ordinarios) porque permite analizar la importancia de las variables para realizar la predicción, de manera que, si resulta una buena predicción, se puede analizar para determinar la influencia de una variable. Además, permite capturar no linealidades entre variables. Para ello, en este caso se realiza el modelo con todas las variables disponibles en la base de datos. En concreto, se observa una influencia considerable de la variable mes en la altura, siendo junto al año de nacimiento, la variable principal en la base de datos para realizar la predicción de la altura. La predicción sin esta variable empeora significativamente y observamos que hay una relación positiva entre el mes de nacimiento y la salud de los individuos, usando la altura como proxy. Por un lado, los resultados muestran que nacer al final del verano y durante el otoño es favorable para la altura. El mes de nacimiento con alturas más altas se obtiene para febrero, con alturas 0,5 cm por encima de la media anual y 0,9 cm por encima de febrero, mes de nacimiento con las medias de alturas más bajas. Estos resultados estarían en línea con la hipótesis que sostiene que se derivan efectos positivos de climas con temperaturas suaves y épocas de recolección de frutos y en consecuencia precios más bajos y mayores ganancias económicas. Por otro lado, se observa que las lluvias y la temperatura durante el período de gestación tienen poca influencia adicional debido al efecto sustitución con la variable mes de nacimiento. En conclusión, los resultados sugieren que los efectos estacionales sobre la altura pueden ser significativos y pueden verse afectados parcialmente por factores ambientales durante los primeros años de vida. Estos hallazgos pueden ser de interés para poblaciones de bajos ingresos y sociedades rurales en desarrollo, aunque consideramos que más investigaciones sobre este ámbito son necesarias ya que a pesar de la menor dependencia climática de las cosechas por las innovaciones tecnológicas, el cambio climático puede suponer efectos devastadores en los tiempos venideros.

En las últimas décadas se han desarrollado multitud de estudios sobre historia antropométrica en la Península Ibérica. Sin embargo, en el caso de las poblaciones insulares como es el caso de la Islas Canarias, los estudios que analizan la evolución del crecimiento de niños y adultos durante la transición nutricional son menos abundantes. En el tercer capítulo de la tesis se estudian las alturas, peso e índice de masa corporal de reclutamientos militares que tuvieron lugar en un municipio rural de las Canarias Orientales durante el proceso de modernización económica a lo largo del siglo XX. En particular, se cuenta con 1.921 observaciones pertenecientes a reclutamientos militares entre 1907 y 2001 (cohortes de nacimiento de 1886 a 1982) en el municipio de San Bartolomé (Lanzarote). El análisis antropométrico en el largo plazo se lleva a cabo usando dos enfoques. En primer lugar, se analiza desde el enfoque de la malnutrición y el retraso en el crecimiento y en segundo lugar se explora desde la perspectiva de la desigualdad. Para el primer enfoque, se usa la metodología que recomienda la Organización Mundial de la Salud (OMS) que se basa en el cálculo de puntuaciones z con el fin de obtener resultados nutricionales que informen sobre el grado de malnutrición. En nuestro caso se han calculados las puntuaciones z tanto en relación a estándares internacionales como a estándares nacionales. En el segundo enfoque, se estudian diferentes medidas de desigualdad tales como el coeficiente de variación, los percentiles y un análisis sobre la evolución de la altura y el índice de masa corporal según cinco categorías socioeconómicas. Por un lado, los resultados confirman las evidencias previas que establecen que las medias de estaturas de los habitantes de las Islas Canarias son más altas que las medias de la población española en los siglos XIX y XX. Los datos sugieren que las mejoras en los niveles de vida biológicos se debieron a los avances de la nutrición desde la década de 1960. La nutrición infantil está sensiblemente asociada al crecimiento económico y al cambio demográfico y epidemiológico. Por otro lado, el análisis de desigualdad muestra que la tendencia de las alturas no fue lineal para todos los grupos sociales y la desigualdad todavía es persistente hasta finales del siglo XX en el municipio de San Bartolomé (Lanzarote).

En el último capítulo se usan datos de reemplazos militares de mozos llamados a filas entre 1876 y 1969 en seis municipios del País Vasco. La muestra contiene información de mozos de tres municipios que se sitúan en áreas rurales y tres municipios de naturaleza urbana. En total se dispone de 17.298 registros. La metodología empleada se basa al igual que en el capítulo anterior en un estudio de la malnutrición utilizando las puntuaciones z y los percentiles y un análisis de la desigualdad por nivel educativo y categoría profesional. Los resultados muestran que la ventaja del mundo rural en términos de niveles de vida biológicos en el País Vasco se mantiene con la industrialización y el desarrollo económico. Las estimaciones de las puntuaciones z revelan que la prevalencia de malnutrición se reduce en el tiempo tanto para las zonas rurales como las urbanas. Los análisis por educación y diferenciación social muestran mejoras significativas para las clases populares. Los impulsos de una nueva oleada de la industrialización en las décadas de 1950 y 60 prosiguieron con las mejoras en los niveles de vida biológicos, aunque persistió todavía una desigualdad por grupos sociales. Las diferencias de alturas fueron de tres cm en las cohortes de las décadas de 1930 y 1940, que vivieron su adolescencia final en las décadas de 1950 y 1960. Y no encontramos evidencia de convergencia en las tendencias de alturas para ambos mundos, de hecho, la brecha rural-urbana aumenta en las décadas de 1930 y 1940.

Introduction

Economists and economic historians have long shown an interest in and concern about wellbeing, inequality and living standards. The recent worldwide covid-19 pandemic has, once again, emphasized the importance of national health systems, both as health administrators and as a prevention mechanism. This crisis, like all previous ones, has revealed differences between countries with greater inequality and widening disparities.

Anthropometric history research in recent decades has provided evidence of secular trends in adult height, territorial (rural/urban) and regional differences, and social inequalities in the nutritional status between the 1840 and 1950 cohorts. However, we know very little about the scope of malnutrition and its differential impact on child growth patterns of both sexes. Malnutrition by default (growth retardation), prevalent in the nineteenth century with industrialization and urbanization, and malnutrition by excess (overweight and obesity), on the rise with new lifestyles and food consumption habits due to globalization, are objects of new research from a historical perspective. This research seeks to generate knowledge of both sexes, suing anthropometric indicators that evaluate the differential impact of malnutrition in the past and the way in which populations have escaped from it. In addition, it is important to analyze excess weight and obesity from the developmentalism of the 1960s. The study seeks to address the cycles of malnutrition and inequality in biological living standards in Spain from the mid-nineteenth century to the beginning of the twenty-first century. The approach should focus on vulnerable populations and environments of poverty, marginalization and inequality coexisting in the different trajectories of malnutrition. In their analyses, economic historians and physical anthropologists use data on heights and weights at specific ages, body mass indexes and robustness, and other anthropometric measures, such as low birth weight and anemia among the infant and maternal population.

Among the main specific objectives in the literature, the following stand out: a) to rebuild child and maternal malnutrition indicators and promote new methods of analysis of nutritional status from a long-term perspective b) to measure the extent of delayed biological maturation between social groups and explore the environmental conditions that perpetuated the intergenerational cycle of poverty and malnutrition and c) to explore the determinants of malnutrition and how it was escaped (diets, disease, government programs, sanitation, education, and income). National health surveys of past decades allow us to analyze growth patterns from a gender perspective by addressing the impact of malnutrition in girls and boys from the end of the nineteenth century in men and women. As indicated by the World Health Organization (WHO, hereafter), in addition to the first 1000 days of life, adolescence is also a critical stage of growth that is sensitive to malnutrition and that affects adult health.

While some economic historians use chrematistic indicators such as income per capita, Gross Domestic Product (GDP, hereafter) or real wages as measures of wellbeing and living standards (Feinstein, 1998, Clark, 2005, Allen, 2009), there is a growing trend in economics and economic history research that criticizes the use of GDP as a measure of wellbeing (Murphy, 2006, Prados de la Escosura, 2015, Gallardo-Albarrán, 2019) because it fails to incorporate factors that contribute meaningfully to the quality of life, such as leisure activities, non-market activity and changes in the quality of life (Stiglitz, Sen, & Fitoussi, 2009). There is abundant literature that proposes alternative measures, typically related to access to sanitary services, mortality, life expectancy, educational attainment (Steckel, 2009, Inwood & Roberts, 2010) and, in particular, average human stature (Floud, Wachter & Gregory, 1990, Engerman, 1997, Crafts, 2007, Galofré-Vilà, 2018). Height can be defined as a measure of physical welfare or what is sometimes called the biological standard of living.

Over the last few centuries, anthropometric history has studied the evolution of statures and body mass index (BMI, hereafter) as indicators of living standards. According to studies of twins, height is 80% dependent on genetic factors (Bogin, 1999 Jelenkovic et al., 2011, Lango Allen et al., 2010) and the remaining 20% can be related to specific environmental factors such as the nutritional intake and the energy cost of physical activity, disease and daily survival (Steckel, 1986, 1995, 2008, Fogel, 1994, Akachi and Canning, 2007, Baten 2014, Bogin, 2013). Adverse childhood conditions can limit the growth of children and young adolescents. There is evidence that socioeconomic circumstances, overcrowding and childhood illnesses (Kuk, 1989, Bailey, Hatton & Inwood, 2016), poor childhood nutrition (Silventoinen, Lahelma, Lundberg & Rahkonen, 2001), maternal smoking during pregnancy (Bernstein, et al., 2005, Leary, Davey & Ness, 2006), the father's social class (Mazzoni, Breschi, Manfredini, Pozzi & Ruiu, 2017, Quanjer & Kok, 2019), and the number of siblings (Stradford, van Poppel & Lumey, 2017, Lawson & Mace, 2008) are conditions that can limit infant and childhood growth, and hence adult height (Subramanian, Ackerson , Davey Smith & John, 2011, Subramanian, Özaltin & Finlay, 2009, Bhalotra and Rawlings, 2013).

The vast majority of studies focus on the anthropometric variable of height, although some have also investigated the changes in weight and the BMI (Harris, 2014, Komlos, 1987, Cole, 2000). The main sources of anthropometric data are enlistment and military recruitment or prisoner records together with skeletons deposited in cemeteries and archeological deposits. In particular, the size of the femur, sheds light on human sizes and the nutritional changes taking place in recent millennia (Steckel & Rose, 2002, Steckel, 2009). Height records have an important advantage with respect to weight data given that height reflects the accumulated nutritional health and the environmental context of the individuals, while weight is a measure in a specific moment in time.

Human growth is the result of a positive difference between the nutrients ingested and the energy consumed through maintaining the basic vital functions, the disease burden and physical activity. If we want to understand the history of living conditions, we can do so by studying the human height evolution. We can also study the biological living standards of different populations. Furthermore, height data are available for periods and places for which it is very difficult to find data on wages or mortality. For example the availability of skeleton registers allows us to make anthropometric measurements of populations from the very distant past (Galofre-Vilà, Hinde & Guntpalli, 2018, Steckel, Larsen, Roberts & Baten, 2019).

Also, stature can be used to compare living standards between modern populations in different countries (Pak, 2004, Komlos & Kriwy, 2003, Komlos, 2001) or within countries over time (Steckel & Floud, 1997, Komlos, 1993, Lopez-Alonso & Condey, 2003). Height is also used as an inequality indicator among population subgroups within the same country (Moradi & Baten, 2005, Deaton, 2008, Margo & Steckel, 1982). For example, differences in height by social class that surpassed 10 cm in eighteenth-century England (Floud & Wachter 1982). Most governments wish to reduce income inequality and it has been proven that the European welfare state has contributed to providing a more egalitarian socio-economic environment that can convert material welfare into biological well-being. There is an abundance of literature that considers that height is a determinant of socioeconomic inequality. Height has been found to increase with social status (Steckel, 1983, Komlos, 1994, Baten, 2000) and there is a significant correlation (negative) between the average height of the population and certain indicators of economic inequality, such as the Gini index in former societies (Boix & Rosenbluth 2014).

Human capital has also emerged as an important factor to explain economic growth. The physical growth and the health of children not only affect their current capacities, but also their future development in terms of general health and productivity. It has been hypothesized that stature is highly influenced or is associated with social and family background factors. Previous studies show that body stature is highly influenced by socioeconomic factors such as education and income level (Baynouna et al., 2009, Silventoinen, 2003, Arcaleni, 2006). Furthermore, height is also positively associated with employment, earnings, and occupational attainment, both directly and indirectly through education (Case & Paxson 2010, 2011). There is growing concern among economists regarding the effects of environmental conditions on the health and growth of children. There is also widespread interest in educational interventions that might be helpful if they are made before family background or genetic factors play an irreversible role in generating intergenerational inequality.

Previous studies show a high correlation between height and cognitive and non-cognitive skills. This relationship remains robust when educational measures are included (Guven & Lee, 2013, Schick & Steckel, 2010, 2015, Barker, Eriksson, Forsén, Osmond, 2005). Taller people have, on average, better physical and mental health (Case & Paxson, 2008), a higher height can explain better educational results and being employed in occupations of higher social status (Persico, Postlewaite & Silverman, 2004, Chen and Zhou, 2007), and finally, there is also a wage-height premium (Case & Paxson, 2008, Heineck, 2005, 2008).

Many studies reveal an unprecedented body height increase from the mid-nineteenth century, showing the improvements in nutrition and in combatting diseases. Some studies indicate a growth of around 12 cm as a direct result of economic progress (Fogel, 2004, Hatton, 2014, Komlos & Kelly, 2016, Perkins, Subramanian, Özaltin, 2016). Although this increase has occurred in almost all countries in the world in the last 100 years, there are differences between countries. The height increase in the developed world has been related to the positive effect of the Industrial Revolution. Some authors have sought to identify the main environmental factors contributing to this huge increase in stature. Besides GDP per capita, the main factors found are infant mortality, the quality of the health systems, education, social equality, urbanization and nutrition (Komlos & Baur, 2004, Baten, 2006, Bozzoli et al., 2007, Hatton, 2013, Currie, 2009, etc.). Furthermore, it has been found that better living conditions can increase a population's anthropometric dimensions, such as height (Fredriks et al., 2000, Silventoinen, 2003, Matton et al., 2007, Schwekendiek & Jun, 2010, Tomkinson, Daniell, Fulton & Furnell, 2017).

Human height has steadily increased over the past two centuries across the globe. This trend can be related to the general improvements in health and nutrition that occurred during this period. After the 1880s, Western Europe, Eastern Europe and Central Asia experienced a substantial upward trend. In contrast, Latin American and Middle Eastern populations were relatively tall during the nineteenth century, but fell behind in relative terms in the twentieth century (Salvatore, 2004a). Sub-Saharan Africa is the only world region to experience a decline in average heights in absolute terms (Moradi, 2005).

Some countries have recorded much larger increases in average human height than others. In these regional trends, we can observe that the largest increases occurred in Europe and Central Asia. On average, the shortest men can be found in South Asia, where the average height is 165 cm, while the tallest are from Europe and Central Asia, at 177 cm. The Dutch grew to be the tallest population in the world as a result of the remarkable secular growth trend that started in the mid-nineteenth century (Hatton & Brey 2010). In 1858, conscripts had an average height of 163 cm (Fredriks 2000, Drukker & Tassenar, 1997). Later studies, based on four large cross-sectional nationwide surveys, showed that young Dutch adults are among the tallest people in the world, with women measuring almost 171 cm on average and men 184 cm on average in 1997 (Wieringen, 1988). These results reflect a height increase of 21 cm over a period of 140 years. However, for the giants of the world and also in most European countries, heights have been stagnating and the cause is unclear (Fredriks, 2000, Gohlke, 2009). It may be the case that there is a maximum height beyond which we will not grow or perhaps some environmental factors are preventing the population from attaining its full growth potential.

Nowadays, one the most significant challenges that some societies face is to achieve a balance between calories consumed and those spent (Leonard, 2003, Popkin, 2011). Over the last decade, large demographic, socioeconomic and epidemiologic changes have occurred on a global level. Human diets have seen an increase in simple sugar consumption (sodas, industrial food, etc.) and lower consumption of foods rich in complex carbohydrates (tubers, bread, cereals) and fiber (Popkin, 2006). These nutritional changes have been accompanied with a reduction in daily physical activity and hence, a reduction in energy expenditure.

For the Spanish case, data drawn from military recruitment records is one of the main sources of anthropometric measures. The main advantage of this source is its universality, given that it provides information on the whole male population at the age of 21 years old, an age when biological growth has stopped. The main problem is that the female population is generally excluded from anthropometric studies. Fortunately, the Encuesta Nacional de Salud de España (ENSE-Spanish National Health Survey) that has been carried out since 1987 (the last conducted in 2017), surveys a large pool of individuals, both male and female, belonging to a wide range of the twentieth century birth cohorts. This survey can be used to study the population's health and its main determinants from a longitudinal perspective and also yields information about self-reported heights.

In Spain, anthropometric research has revealed the principal trends in male height since the end of the eighteenth century and their probable socio-economic determinants. Anthropometric results show that in the twentieth century, significant improvements were made in human well-being and in biological standards of living. At the end of the twentieth century, Spanish heights converged with those of other Southern European countries, notably Italy and France, in a process similar to that observed in per capita income. Studies have shown that improvements in the public policies related to income, food consumption, health and well-being have been decisive for the significant increase in Spaniards' heights. The nutritional, demographic and epidemiological transitions conditioned the changing dynamics of height and the secular trend. One feature of the modern nutrition transition was the growing consumption of animal proteins. Particularly noteworthy is the contribution of foodstuffs such as meat and milk.

Previous studies have compared the trend in Spanish male heights with the evolution of GDP per capita for the cohorts born between 1840 and 1980. These investigations show that those generations who were children and adolescents in the 1930s and 1940s were the shortest in the century. This deterioration can be related to the effects of the Great Depression in the 1930s, the Civil War (1936-1939) and, especially, Franco's autarchic policies. In this period, there was a loss of economic well-being. Specifically, there was a significant decline in private consumption, which dropped sharply between 1935 and 1950. The twentieth century was characterized by an evolution of economic growth until the oil crisis, which was only interrupted by the Civil War and the post-war period (Carreras & Tafunell, 2010, Prados de la Escosura, 2003, 2007). Spanish height increased, on average, by approximately 12 centimeters during the twentieth century, growing from 163 cm in 1900 of those recruits aged 20 years old, to 175 cm at the end of 1990 (Martínez-Carrión, 1994, 2005, 2007, Quiroga, 2001). This increase was only interrupted in 1915-1944, when a decline and stagnation took place.

Anthropometric research also shows the perverse influence of the Civil War (1936-39) and the postwar and "years of hunger" that coincided with the consolidation of the Francoist regime (Martínez-Carrión & Salvatore) in the twentieth century. These factors had a perverse influence on growth and human wellbeing. The cohorts born between 1915 and 1930 experienced the main decline and stagnation. Those social strata with less economic and educational resources were the most affected by the disastrous well-being policies that were designed during the autarchic period, mainly affecting nutritional status and health (Barciela, 2003, Cussó, 2005, Bernabeu et al., 2006). In short, the social gap, considering differences in terms of residence, education and occupation for those that were born during the decade of the 1940s, increased during Franco's autarchy.

However, in half a century, Spain evolved from underdevelopment and authoritarianism to prosperity and democracy. Research suggests that in comparison to other European countries, the increase in height recorded for Spanish cohorts from the end of the nineteenth century was dramatic. The Spanish population grew at a higher rate than those of Northern Europe (Hatton & Bray, 2010, Martínez-Carrión, 2012). The impact of the Welfare State in Spain came later than in other European countries due to the country's economic and democratic backwardness. However, some institutions formed in the decades preceding 1930 were influential in the improvement of nutritional health, such as the Gotas de Leche (Drops of Milk) campaign or the lactation consultancies, as were a series of actions carried out in the fields of healthcare and public hygiene by national, local, and provincial governments.

There is a growing number of studies that analyze Spanish height differentials from different perspectives: territorial differences, fundamentally during the twentieth century, rural–urban differences, those between diverse rural contexts, intra-urban differences, differences in household composition (Ramon-Muñoz & Ramon-Muñoz, 2017) and social class or educational differences. According to the available evidence on the main Spanish industrial regions, the average height of workers decreased during the Industrial Revolution (Martinez-Carrión et al., 2012) and important rural-urban differences have been found, together with social, economic, professional and environmental inequalities.

In the following chapters we will offer new approaches to analyzing biological living standards, inequality and poverty for the Spanish case over the last few centuries. It is well-known that Spanish heights have increased in recent centuries. However, has this growth occurred equally in terms of socioeconomic status? This is one of the main questions in the Spanish anthropometric literature that requires a study of the role played by socioeconomic status in the trajectory of biological standards of living, especially net nutritional status. Also, among the determinants of infant and adult height, one aspect has been little explored, namely the effects of month of birth on height. Economic development and globalization have contributed to making societies less dependent on food resources that are conditioned by climate conditions. However, at the same time, climate change is a global concern that can have devastating effects in the future. On the other hand, in Spain, most of the literature refers to peninsular areas but it is interesting to study the behavior of insular Spanish population groups and infant and adult growth during the nutritional transition. Furthermore, although previous research has studied the rural-gap height differences, we also wish to determine whether the rural advantage of the Basque environment was maintained with respect to the urban areas in the Basque Country.

These questions are investigated and evidence is presented in the following chapters. In the first chapter we study the evolution of height differentials by socioeconomic status (SES, hereafter) in Spain in the second half of the twentieth century, using education and social class as two different proxies of SES. In the second chapter, we explore whether the month of birth and climate during gestation influence male adult height, based on Spain's rural population before the end of the modernization process. In chapter 3 we explore the final phase of the nutritional transition based on anthropometrics after the 1950s cohorts on whom less research has been conducted. In this research, we analyze the height, weight and BMI of military recruits (conscripts) in a rural municipality from the eastern Canaries during the economic modernization process throughout the twentieth century. In the last chapter, we study the dimension of the rural-urban gap in the Basque Country in the light of its economic growth and the subsequent industrialization. And finally, section five summarizes the main conclusions of this thesis.

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CHAPTER 1

Growing taller unequally? Adult height and socioeconomic status in Spain (1940-2017)

1.1. Introduction and objectives

In the study of the biological dimensions of well-being, anthropometric parameters – and human stature in particular – have accrued unquestionable relevance in recent decades (Blum, 2013, Galofré-Vilà, 2018, Thompson, Quanjer & Murkens, 2020). Since Tanner's groundbreaking work in auxology, human physical growth has come to be regarded as a 'mirror of health'(Tanner, 1986) and, as a result, adult height is widely accepted as a final output indicator of several determinants of health related to living conditions through pre-adult life. The height reached by an individual in adulthood is considered a reasonable measure for the influence of environmental factors (i.e. physical, epidemiological and socioeconomic -Akachi & Canning, 2015, Bozzoli, Deaton & Quintana-Domeque, 2009, Steckel, 2012) on maximum genetic growth potential[1]. Basically, these factors interact in determining the balance between energy intakes (e.g. quantity and quality of food - Morgan, 2000, Puentes et al, 2016) and energy expenditures (e.g. burden of exposure to illness and infectious diseases and its interplay with malnutrition - Crimmins & Finch, 2006, Perkins, Subramanian, Smith & Özaltin, 2016)[2].

Over the course of the 20th century, average adult height increased dramatically in most populations around the world with few exceptions, due to general improvements in living standards, nutrition and health (Cole, 2000, Grasgruber, Sebera, Hrazdíra, Cacek & Kalina, 2016, NCD Risk Factor Collaboration, 2016). Developed Western societies are a good illustration of this process from the end of the 19th century onwards (Deaton, 2013, Floud, Fogel, Harris & Chul Hong 2011, Hatton & Bray, 2010). In light of the

[1] The effects of environment on height and health susceptibility in adulthood can be traced right back to the gestational period (Roseboom, de Rooij & Painter, 2006) and the predictive value of height in early childhood has been extensively demonstrated (Chen & Zhou, 2007).

[2] Child labor is considered another major source of energy expenditure and its deleterious effect on growth and development have been demonstrated in some studies (Ambadekar, Wahab & Khandait, 1999). Its negative effects on health are also well known. However, its impact on adult height is still a matter of some controversy (Cortez, et al., 2007). work during childhood, particularly in the case of females, increases the risk of illness, thus potentially interfering with the abovementioned balance between energy intake and energy expenditure (O'Donnell, Rosati & van Doorslaer, 2005)

evidence, it is assumed that among different birth cohorts, environmental conditions will dictate the development of adult height and its trends within genetically similar populations. In the long run, therefore, we may expect increases in human height to mirror the general improvement in living conditions, which is in line with the evolution of other health and well-being indicators (Bogin, Varea, Hermanussen & Scheffler, 2018, Fogel & Costa, 1997, Fogel, 2004, Grasgruber, Cacek, Kalina & Seberal, 2014).

That said, progress in environmental conditions is not necessarily linear and, moreover, their impact varies considerably across different segments of the population. There is extensive literature documenting drop cycles as well as periods of stagnation of inter-generational growth, correlating with diverse socioeconomic, political and epidemiological scenarios (e.g. Baten & Wagner, 2003, Cox, 2019, Komlos & A'Hearn, 2019). Furthermore, it is widely accepted that environmental factors are mediated by the socioeconomic status of individuals in that both energy intake and energy expenditure are often socially determined, which drives us to consider height differentials across diverse social groups as potential indicators of inequalities in the biological dimensions of well-being (Blum, 2013, Carson, 2009, Gomula, Nowak-Szczepanska & Koziel, 2021, Lopuszanska-Dawid, et al., 2020, Jaadla, Shaw-Taylor & Davenport, 2021)[3].

This paper aims to examine the evolution of height differentials by socioeconomic status (SES, hereafter) in Spain over a period of steep improvement in living conditions: the second half of the 20th century. To this aim, we analyze the role of individual and household-level factors. In practice, this involves analyzing the variation in level of impact on height of such factors across different socioeconomic and political scenarios. Spain is a particularly interesting case in this regard due to the accelerated pace and intensity of its transition towards high levels of development and standards of well-being (Prados de la Escosura, 2021, Carreras & Tafunell, 2021), which resulted in highly marked contrasts in living conditions over the time span (i.e. among the birth cohorts) analyzed in this study. For instance, life expectancy increased from 50 years (decade of 1930-39) to 66 years (decade of 1950-59) (Human Mortality Database, online). Prior to

[3] Spain serves to illustrate this. Since the mid-18th century, height differentials across socioeconomic groups (i.e. according to occupation, educational attainment, etc.) have been clearly documented by elite groups recording “modern” heights (averages of more than 1.70 meters in the case of men), Cámara & García Román (2010); Fuster, (2017); Cañabate& Martínez-Carrión (2018); García-Montero, (2018).

the COVID-19 pandemic, this indicator in Spain ranked among the highest in the world (82.7 years in the period 2010-18, Human Mortality Database, online). As for adult height, this country recorded one of the highest rates of inter-generational increase over the second half of the 20th century (Hatton & Bray, 2010). The involvement of various different factors in this trend has been broadly discussed at the macro level, e.g. the positive evolution of economic indicators (Prados de la Escosura, 2008, María-Dolores & Martínez-Carrión, 2011), the nutrition transition (Cañabate & Martínez-Carrión, 2017), the dramatic drop in the prevalence of infectious diseases and infant mortality (Galofré-Vilà & Harris, 2020, Quintana-Domeque, Bozzoli & Bosch, 2011) and, lastly, the implementation of social provisions that reduced the inequality by socioeconomic status and enabled regional convergence (Cámara, Martínez-Carrión, Puche & Ramon-Muñoz, 2019, Martínez-Carrión & Maria-Dolores, 2017). Nonetheless, relatively little is known about the effect of these socioeconomic processes on specific segments of the population, or in other words, about the ways in which individual and household-level determinants operate on the trajectory of biological well-being.

Two specific research questions form the focus of this paper. The first is whether the rapid increase in cohort average height observed since the 1940s was evenly spread across different social groups in Spain. In this regard, we aim to determine the degree of social convergence for biological living standards. The second question addresses the capacity of SES to explain height differentials across different socioeconomic contexts. Men and women are dealt with separately in the analysis of these two questions, which a view to finding out – as a matter of additional interest – whether the key determinants operate similarly on both sexes over time.

The main hypothesis driving our research is that historical contexts of high environmental stress contributed to an increase in anthropometric inequality in the absence of significant institutionalized social provisions. In such contexts, socioeconomic status (SES) would condition access to an adequate diet in both quantitative and qualitative terms, as would the burden of disease and physical labor in pre-adult ages. SES would gradually lose its ability to explain height differentials over time (i.e. across successive groups of cohorts) as welfare state provisions were more effectively implemented. Thus the effects of SES on height would diminish for younger cohorts of Spaniards as a result of the general improvements in nutrition and sanitation, as well as increased access to health services and a broader range of facilities. For older cohorts, however, SES was expected to determine biological well-being to a greater extent due to the way it mediates access to basic resources and a healthier domestic environment.

Accordingly, height trends by social group should tend to converge among younger cohorts of Spaniards who underwent their physical growth cycle in the context of both 1) the framework of a highly developed society and 2) widespread welfare provisions. Conversely, we expected to observe higher social differentials and a greater influence of SES on height within historical contexts associated with high environmental stress and/or low level of social provisions.

Our study covers Spanish cohorts born from the 1940s to the 1990s. These cohorts were grouped into 10yr groups for analysis, except for one 5yr group (1990-94). Clearly, the length of the growth cycle of any given cohort will exceed the decade in which they were grouped. This is a limitation of our study that we have opted to accept in the interests of parsimony in both our analysis and the interpretation of results. As a rule, all cohort groups are made up of single cohorts who went through their growth cycle in progressively improving environmental conditions.

1.2. Data and methods

The analyses use microdata from the adult samples of two health interview surveys: la Encuesta Nacional de Salud/ The Spanish National Health Survey – conducted in 1987, 1993, 1995, 1997, 2001, 2003, 2006, 2011 and 2017 – and the Spanish sample from the European Health Interview Survey (ENSE, hereafter) conducted in 2009 and 2014[4]. Both are cross-sectional surveys (there is no follow-up of individuals) and used multi-stage stratified sampling techniques with proportionality criteria based on sex, age and place of residence.

We proceeded by firstly, harmonizing the variables involved in the analyses across the waves of these surveys and, secondly, by aggregating these data thus obtaining one large database. The harmonization and aggregation of this large body of data allows us to construct long-term series of cohort height and also provides the statistical

[4] For detailed information about criterial and general methodological aspects see Ministerio de Sanidad Online and Instituto Nacional de Estadística (INE, hereafter) Online.

consistency required to produce cross-tabulations of height as well as a number of key explanatory variables. To homogenize the respondent type, only direct informants were selected. Data provided by proxies were used in the ENSE of 2003 and 2006 but these were discarded for the analysis. Furthermore, only individuals with Spanish citizenship were selected[5]. Age and/or year of birth were used to sort individuals into the above-mentioned cohort groups that formed the basis of our approach.

The age of the respondents selected for analysis was restricted according to two criteria: they had to be over 20 in order to have completed their physical growth process and they had to be under 50 in order to avoid distortion of the data due to age-related shrinkage[6]. After the selection and grouping of birth cohorts, the age range of the respondents included in our dataset was 23-47 at the time of interview. The aggregation of the microdata from different waves of ENSE allows to obtain a good representativeness of cohorts born throughout the 20th century. Also this permits to observe the evolution of the key variables of the study for each group of cohorts in time. To this respect, it is important to note that previous studies based on the ENSE have shown that the mean height of a group of cohorts remains very stable once adulthood is reached. Table 1.1. shows the number of valid cases according to each variable of analysis.

[5] Immigration flows and the immigrant stock in this country prior to the decade of 2000-2010 were low. According to the 1991 population census, a mere 0.9% of the population was foreign-born, increasing to 1.4% in 1996 and 1.5% in 1998 (INE, online a,b). ENSE 2003 asked for citizenship but not for country of birth. For this reason, and given that the date (age) of arrival in Spain was not provided in any survey, we opted to use the variable citizenship. It should be noted that, within the age range of respondents used in this research, the proportion of foreign-born Spanish citizens sampled in the surveys was negligible in the cross-tabulations of cohort groups by the key variables of analysis: 3.3% in 2009 and below 0.5% in the rest of the surveys.

[6] Shrinkage may occur gradually from age 40 onwards, but especially after 50 (Birrell, Pearce, Francis & Parker, 2005; de Groot, Perdigao & Deurenbert, 1996; Dey. Rothberg, Sundh, Bosaeus & Steen, 1999).

Table 1.1. Sample size of valid cases by variable of interest[7]

Variable of interest	Valid cases
Height	73,699
Educational attainment	72,905
Educational attainment (household head) [8]	34,844
Social class (household head)	32,551
Region of residence	73,741
Age	73,741
Population size (municipality of residence)	73,741
Sex	73,738
Marital status	73,665

Source: Own elaboration from the abovementioned sources.

Height without shoes is self-reported in centimeters and the wording of this item is uniform across surveys ("Approximately, what is your height without shoes?"). It is well known that people tend to overestimate their height, which might be problematic for the use of this indicator in clinical practice at the individual level. However, at a population level, self-reported height has displayed very high correlations with measured height (Rowland, 1990) and it has been used as a valid measure in studies that investigate associations between anthropometric parameters, health predictors and health outcomes (Lipsky, et al., 2019). In the case of Spain, the validity of self-reported height to depict general trends over time and socioeconomic differentials has been previously demonstrated (e.g. Spijker, Pérez & Cámara, 2008, Cámara, 2015). In previous works the high coherence of responses regarding cohort adult height among different waves of the ENSE has been assessed (Spijker, et al., 2008) showing that cohort height remains relatively constant once adulthood is reached. Although the ENSE is a cross-sectional survey where no follow-up is done, that coherence allows to aggregate microdata from all these surveys by birth cohorts thus improving consistency and representativeness. For the case at hand, it can be seen that the resulting height distributions from our sample roughly follow a normal distribution curve. While 0 and 5-digit preference in self-reports generally results in heaping, it takes place at both tails of the distribution, which tends to remain symmetric for the most part. Moreover, the standard deviations are very constant

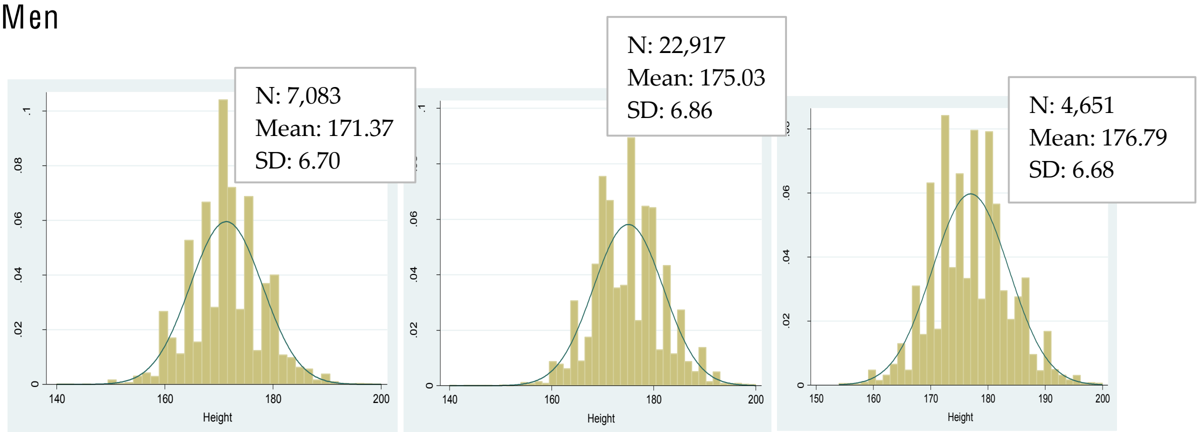
[7] Sex and age of the household head are not included in the analysis because these variables only offer information for a limited number of observations. Furthermore, 93% of household heads were male and only 7% female.

[8] Respondents who headed households came to a total of 35,178 whereas those who did not totaled 38,563.

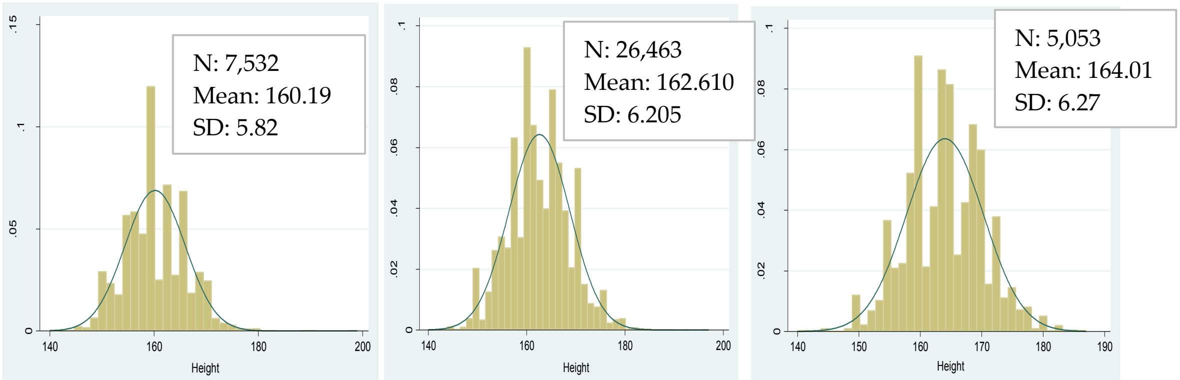
across cohort groups and subgroups and are very close to those found in normal distributions of measured heights (Cole, 2000). (Figure 1.1.).

Figure 1.1. Histograms. Height distributions by 20-year birth cohort [9]

Men



Women



Source: Own elaboration on the abovementioned data sources.

Missing values for height (5% of the whole sample) were not randomly distributed across the control variables used in our analyses. For instance, missing heights are more frequent for older cohorts, less educated individuals and women. For these reasons, we proceeded to impute any missing values and contrast the results of our analyses with and without imputed heights (not shown, available upon request). As the differences were negligible in terms of height trends and regression coefficients, we opted to keep the

[9]Given that our surveys were carried out between 1987 and 2017 and the selected individuals are aged 23 to 47, there are more observations for the 1960-1979 birth cohort group.

imputed heights in order to achieve statistical consistency for the diverse cross-tabulations implemented in the descriptive analyses. Table 1.2. displays the valid cases in the final sample by cohort group and sex.

Table 1.2. Final sample, by 10-year birth cohort and sex

Cohort	Men	Women	Total
1940-1949	2,214	2,376	4,590
1950-1959	4,869	5,156	10,025
1960-1969	11,131	13,170	24,301
1970-1979	11,786	13,293	25,079
1980-1989	4,153	4,506	8,659
1990-1994	498	547	1,045
Total	34,651	39,048	73,699

Source: Own elaboration on the abovementioned data sources.

Data on educational level and occupation were not uniformly coded over the waves of the ENSE. Thus these variables have been re-coded as follows.

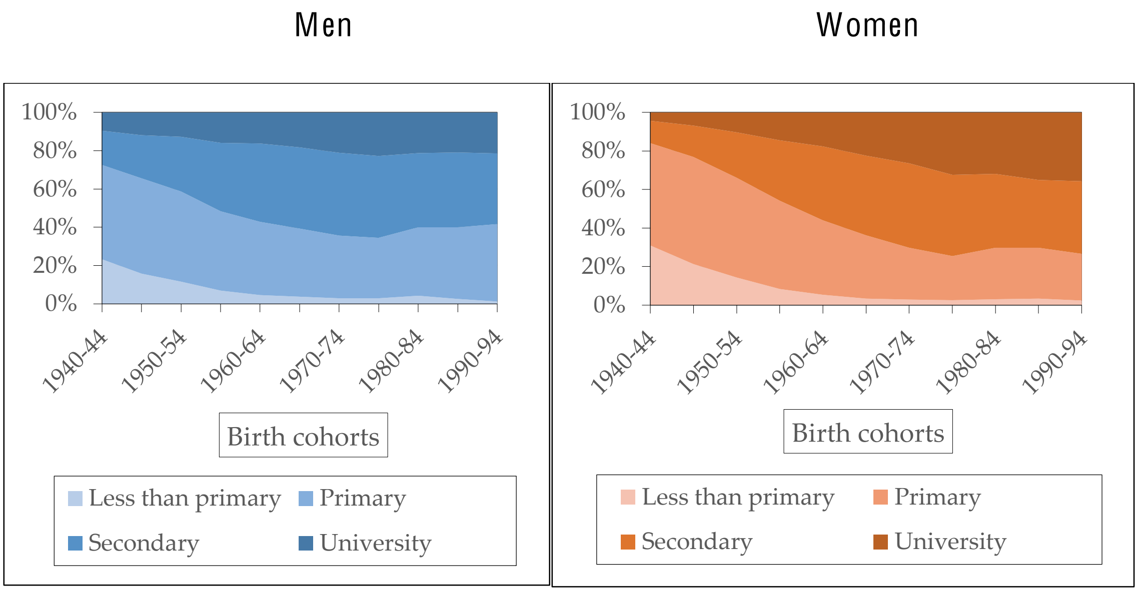
Socioeconomic status: We use educational attainment and social class as proxies for socioeconomic status (SES)[10]. This information was collected for both interviewees and the head of the household. To our knowledge, previous anthropometric studies in Spain only tested the effect of SES as approximated by occupation and/or education level of the respondents. Although we may assume that the respondent's SES is related to parental SES to a certain extent, both the respondent's age and the process of social mobility could distort the interpretation of height differentials according to SES on the sole basis of the former. In other words, it is important to relate height reached in adulthood to the prevailing household socioeconomic conditions during the physical growth cycle. This can only be approximated through information on the SES of the household head.

Educational attainment had to be harmonized across surveys, as sometimes the person interviewed was asked for the number of years of education and other times for the highest level of education attained. Furthermore, the educational levels are not uniform in the response set due to changes made in the educational system over the last five decades in Spain. We used the abridged ISCED classification to harmonize this variable into four categories (the results are shown in Figure 1.2.):

[10] Income was ruled out in this study due to the large proportion of missing cases across surveys.

1. *Less than primary*: individuals who did not complete the first level at school, which implies less than six years of schooling.
2. *Primary*: individuals who did complete the first level at school, thus receiving at least six years of schooling.
3. *Secondary*: individuals who completed the second level at school (old system), secondary school (under the new system), or obtained a professional training qualification (under the new system, equivalent to secondary school in total years of schooling).
4. *University*: individuals who obtained a university degree, PhD, or any equivalent under the old system.

Figure 1.2. Educational attainment by birth cohort for individuals aged 25 or more years' old[11]



Source: own elaboration from the abovementioned data.

We supplemented the first analysis based on educational attainment with a second one based on social class. The latter variable is based on occupation data. Occupation was

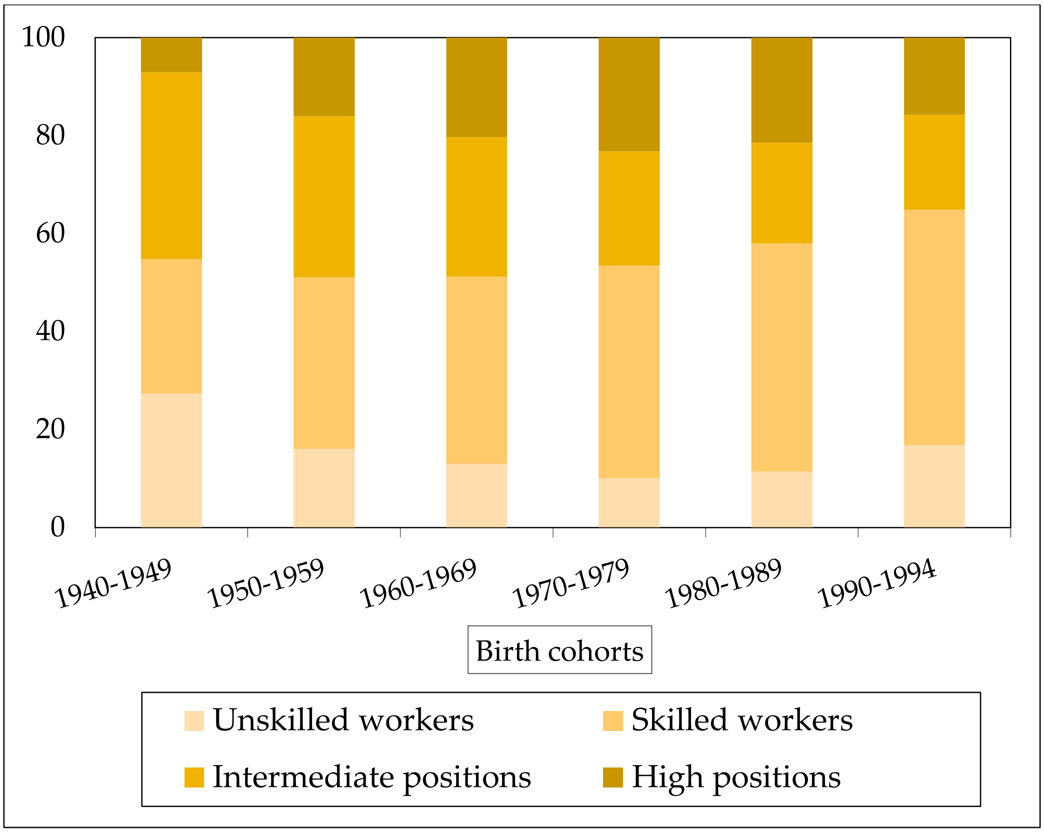
[11] We have compared the result of this harmonization of the educational attainment across surveys with the distribution resulting from the 2011 Spanish census. Upper levels of education range similarly across cohort groups between the two sources whereas the percentage of those with no studies is significantly lower in the surveys with respect to the census among the oldest cohorts. We tend to believe that this is due to the differences in the codification of the original categories of education between both sources. Both the evolution of the distribution of educational categories over time and gender-related differentials displayed a very similar and coherent pattern between these two sources.

harmonized following the simplest codification used for the different ENSE waves. The more recent waves of the ENSE provide much more detailed data on occupation (through the four-digit codes of the National Classification of Occupations: CNO79 in 2001, CNO94 in 2003 and 2006, and CNO11 in 2011, 2014 and 2017), whereas the early waves only included occupation in broad categories (i.e. skilled workers, non-skilled workers, etc.). Given that the more recent waves also included a variable referred to as CLASS, obtained by classifying the occupations into seven broad categories that are roughly equivalent to the former response sets, we were able to harmonize this variable into the following four categories:

- *Class 1*: Unskilled workers.
- *Class 2*: Skilled workers.
- *Class 3*: Intermediate positions in public administration, freelancers and white-collar workers.
- *Class 4*: High positions in public administration, businessmen, CEOs and liberal professions.

For the survey that did not include the variable social class, we were able to infer it using occupation at time of interview (or most recent occupation in the case of the unemployed or retired) of either the respondent or head of household, mirroring the correspondence between occupation and social class established in the surveys for which both variables were available. Figure 1.3. shows the resulting distribution of occupation according to the four categories described above.

Figure 1.3. Distribution of occupation (%) by birth cohort



Source: own elaboration from the abovementioned data.

Analyses: cohort series and regression model specifications. Height series are depicted for men and women separately using birth cohort as a time scale. For this purpose, birth cohorts were all grouped into decades except for the youngest group, which covers a five-year period.

Height differentials by SES over time are examined through three descriptive analyses, according to 1) educational attainment of the respondents, 2) educational attainment of the household head (among respondents who were not the household head), and 3) social class of household head (for those respondents who were not the household head). In the results section, we present the analyses based on two categories (of education and social class) created by combining the two lower and upper categories respectively.

Occasionally, we refer to the results obtained when analyzing the four original categories established for these variables (not shown but available upon request).

Each descriptive analysis is supplemented by the corresponding multivariate linear regression model, which serves two main purposes: 1) to control for additional variables which might influence the trends and/or height differentials found and 2) to assess whether the trends and differentials obtained are statistically significant. All the covariates listed below are included in the models following the usual norms and protocols. Categorical variables are introduced by means of dummy variables whereby one category/variable is excluded, thus serving as the reference category when interpreting the regression coefficients. The models include the following control variables:

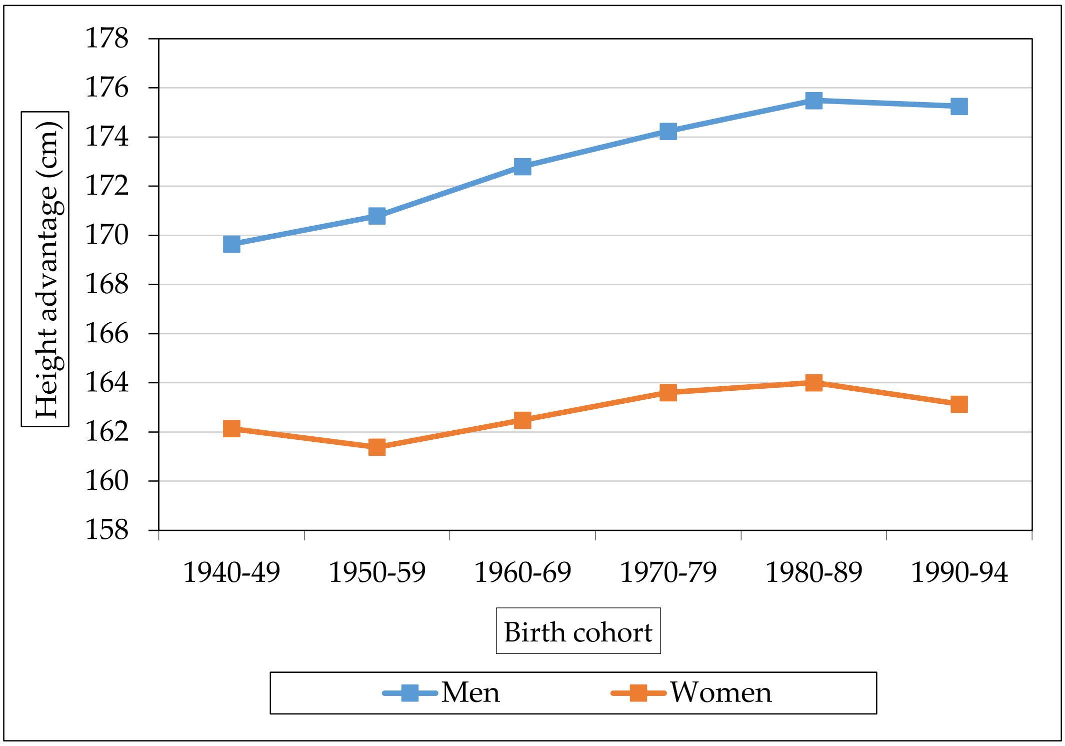
- Age (which technically produces the effect of including a time-trend, thus helping to illustrate the improvement of environmental conditions across single cohorts included in a given cohort group).
- Region of residence (in total, there are 18 regions, the 17 Spanish Autonomous Communities and the two cities of Ceuta and Melilla that are considered as a solely region).
- Population size of place of residence (up to 10,000 inhabitants, from 10,001 to 50,000, from 50,001 to 100,000, more than 100,000).
- Marital status of the respondent. The latter, together with age, are instrumental variables which serve to indirectly control for the actual role of the respondent within the household. Ideally, the influence of the household head's SES on biological well-being should be tested on their descendants' height. In practice, however, such an approach is not possible as kinship within households is not provided in the surveys, but we can at least distinguish between the head and non-heads of any given household.

Finally, for the models based on the household head's SES, cohort groups 1980-89 and 1990-94 were merged for the purposes of statistical consistency. The results section presents several graphs summarizing the main regression results, we only graphically represent those coefficients that are statistically significant. The complete regressions results can be found in detail in the Appendix.

1.3. Results

Figure 1.4. (Table 1.3. in the Appendix) displays the trend in mean cohort height aged between 23 and 47 years old (in this analysis we use all heights available independently if the individual is household head or not). We have included exclusively control variables that are contextual and personal referred to the respondents (and not the household heads). The control variables included are: age, educational level of the individual, region of residence, population size of region of residence and marital status (i.e. the mean height for each birth cohort group is computed by means of the constant and the beta coefficients from the multivariate linear regression model which takes the group 1940-49 as the reference category). Average stature shows a marked upward trend for birth cohorts born from the 40s to the 80s in the case of men, for women this upward trend is interrupted by a decrease in average height from the 40s to the 50s. In the case of men, there is evidence of a considerable increase in mean height of more than 5 cm among those birth cohorts. Among women the upward trend is less pronounced but still significant for all birth cohorts, representing an increase of around 2 cm in 40 years. For both sexes, the upward trend stopped from the 1980s birth cohorts onwards.

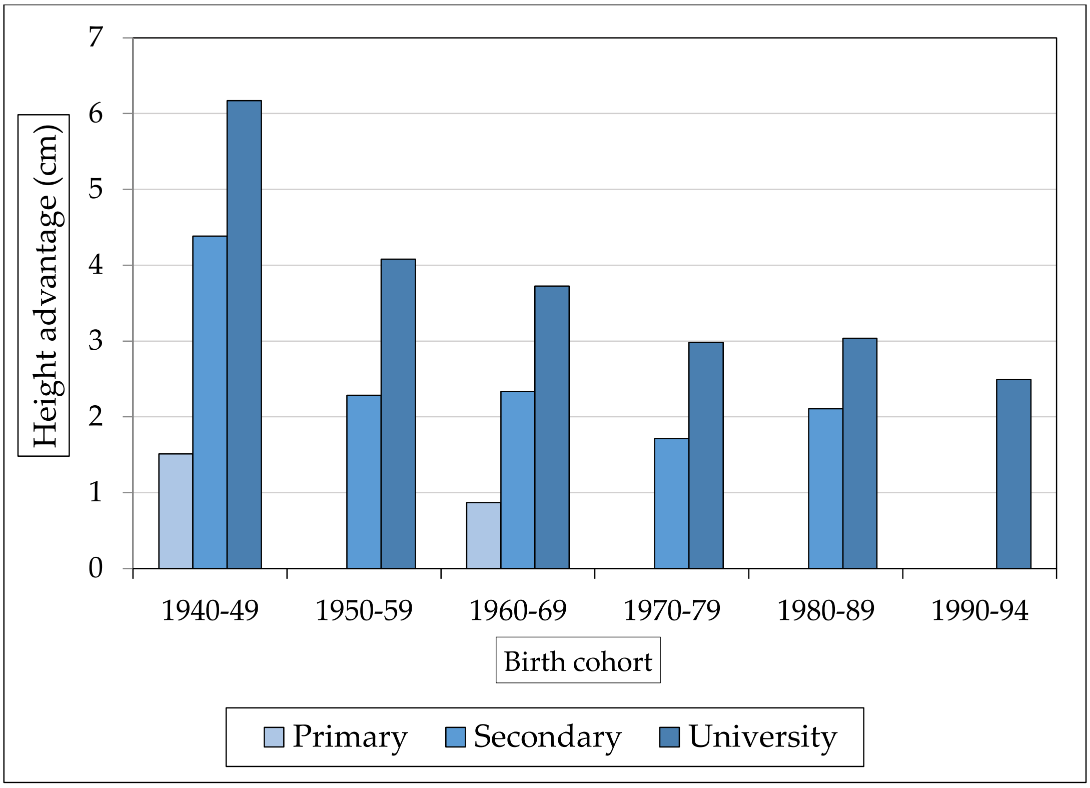
Figure 1.4. Regression results of average height (cm) by birth cohort (1940-1994)



Source: own elaboration from the abovementioned data.

In the next figures, we summarize regression results of height advantages by educational level and social class groups as two alternative approximations to socioeconomic status. Figures 1.5. and 1.6. (Table 1.4. in Appendix) show height differentials according to educational attainment, using no studies completed as the reference category. As before we use heights that can be from household heads or non-household heads when we make the analysis using the educational level of the individual and we restrict only to heights from non-household heads when we include in the analysis the educational level of the household head. Among men, we observe that for those born in the 1940s, having a university degree implied a significant height advantage of 6 cm with respect to those with no finished studies. For those born in the 80s, this significant difference drops to 3 cm, and among the youngest cohorts to less than 3 cm. The height advantage among those who completed secondary studies was of more than 4 cm for men born in the 40s, falling to less than 2 cm among cohorts born in the 70s. Finally, the height advantage associated with completing primary studies was smaller and only significant among those born in the 40s and in the 60s.

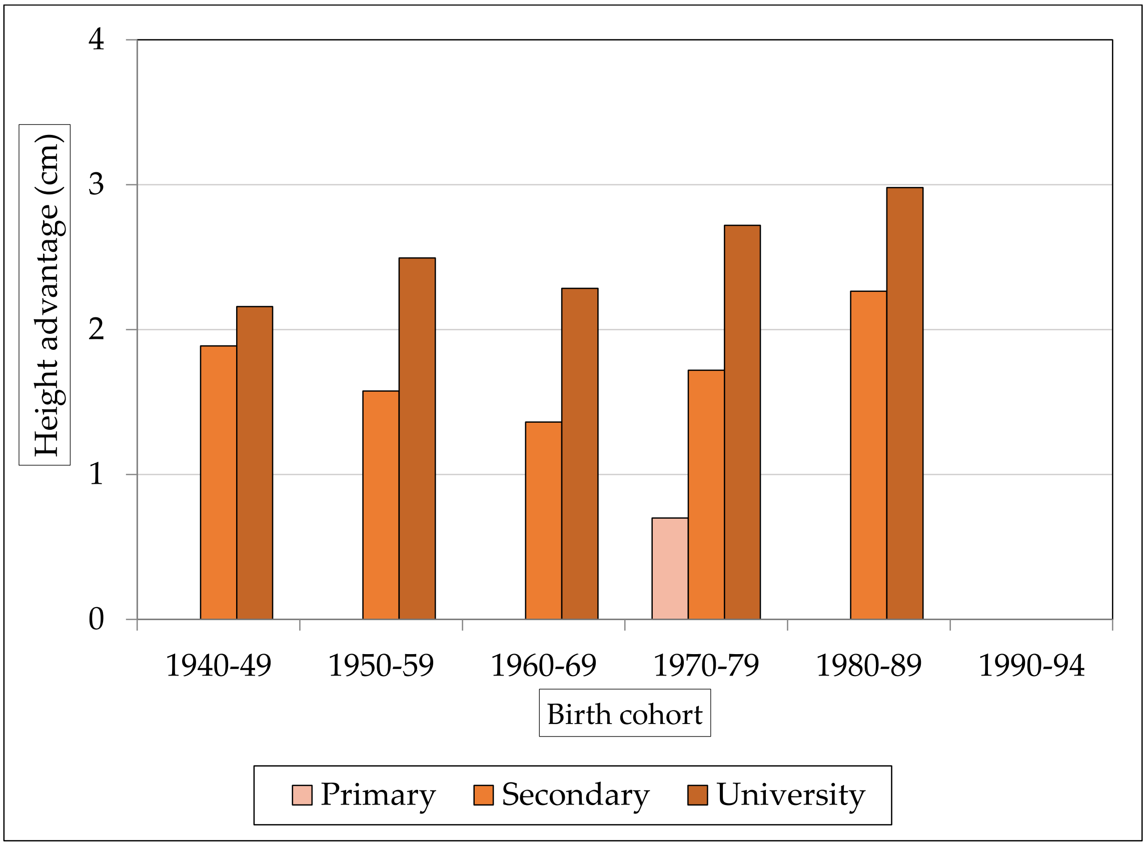
Figure 1.5. Regression results of height advantage (cm), by educational group and birth cohort (males). Reference: no studies completed



Source: own elaboration from the abovementioned data.

The above analysis is replicated for women in Figure 1.6. We found that differentials in height between the educational categories are noticeably smaller than among men and, moreover, they remain more constant over time. Having university studies implies a significant height advantage around 2 to 3 cm with respect to any studies completed for all birth cohorts except for the most younger one. In the case of secondary studies this height advantage reduces to less than 2 cm for the cohorts born from the 40s to the 70s, and for those born in the 80s represents a bit more than 2 cm. Having primary studies only represents a significant height advantage with respect to no studies completed for those born in the 70s.

Figure 1.6. Regression results of height advantage (cm), by educational group and birth cohort (females). Reference: no studies completed

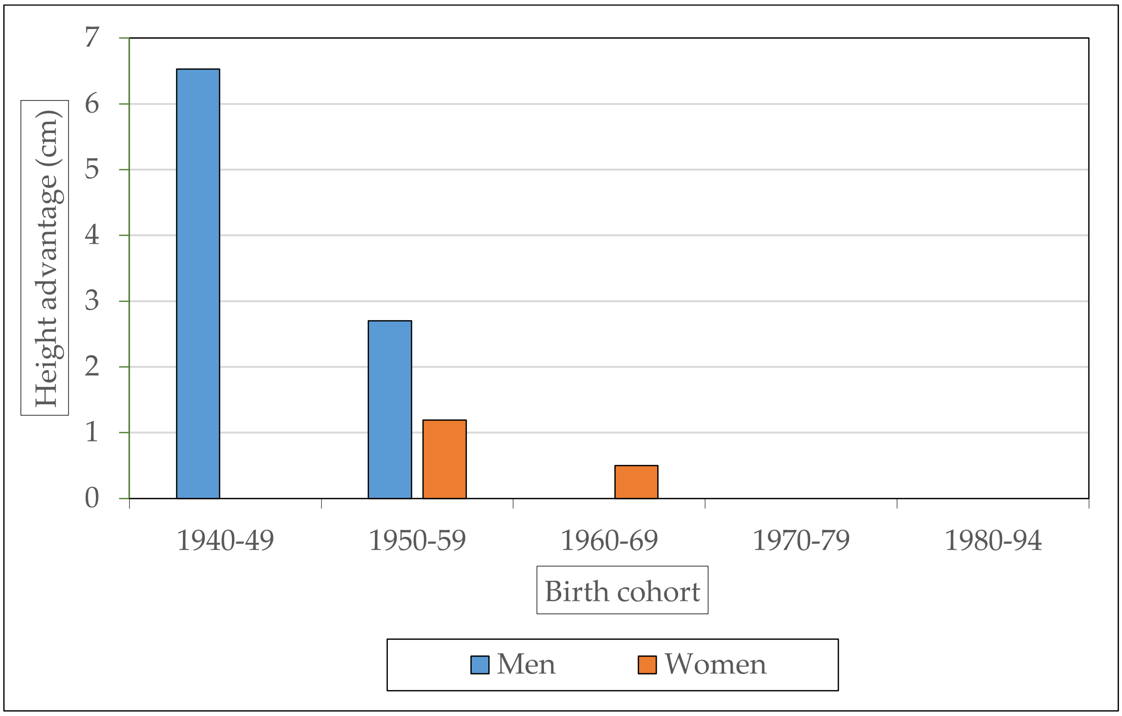


Source: own elaboration from the abovementioned data.

Figure 1.7. (Table 1.5. in Appendix) shows the relation between household heads' education level and respondents' height, considering only heights for those who are not household head. In this case, we have grouped the four educational categories into two levels: lower (no studies or primary) and higher (secondary or university). Living in

a household where the household head has a high educational attainment implies only a significant height advantage for the male non-household heads that were born in the 40s and for those that were born in the 50s. In the case for those that were born in the 40s the height advantage is of more than 6 cm but for the those that were born in the 50s this height differential reduces to less than 3 cm. In the case of women that are not household heads, this height advantage is only significant for those women that were born in the 50s being over 1 cm and for those born in the 60s which is less than 1 cm.

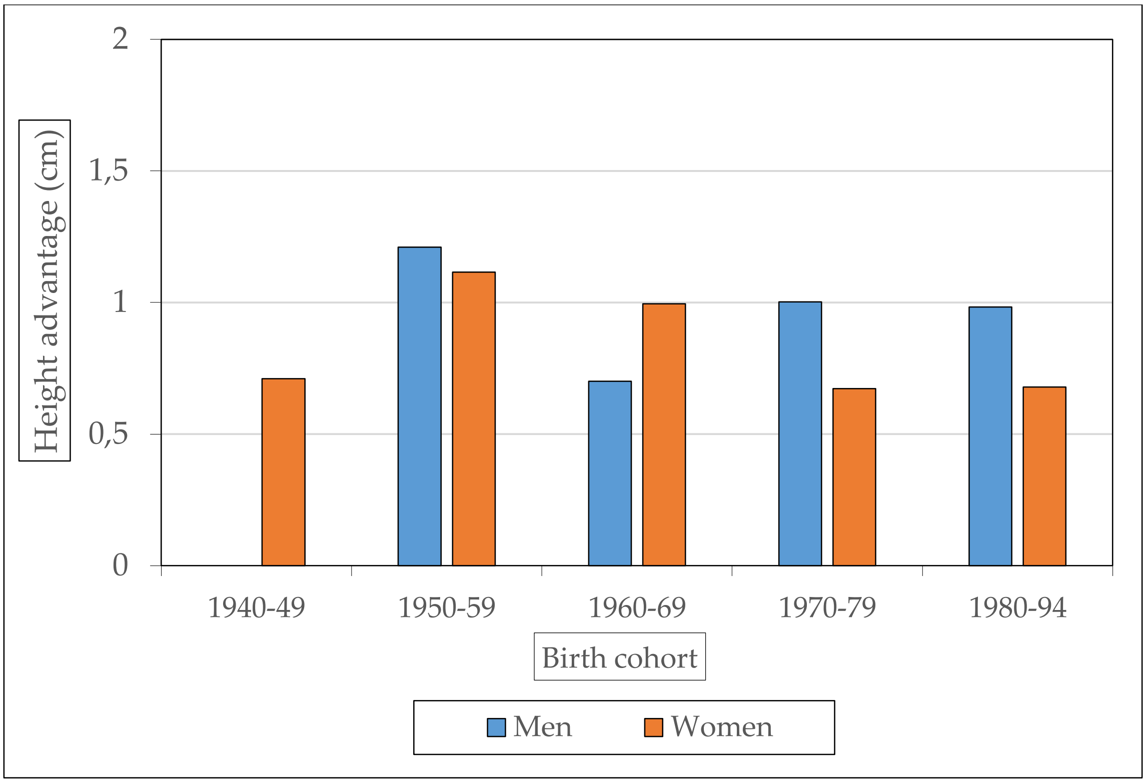
Figure 1.7. Regression results of height advantage (cm) of non-household heads associated with high educational attainment of the household head. Reference: low educational attainment of household head



Source: own elaboration from the abovementioned data.

Our final step was to replicate the above set of analyses using the social class of the household head as the key explanatory variable and the height of non-household's heads as the dependent variable (Figure 1.8., Table 1.5. Appendix). Interestingly, we observed that the effect (i.e. advantage) of living in an upper class household remains significant and quite stable for almost all the birth cohorts included in our analysis. It is also worth noting that this advantage is quite similar for both sexes. Another vivid contrast to our findings on educational attainment is that the breadwinner's social class does not show a significant effect among men born in the 1940s. Although SES-related height advantage decreases moderately for cohorts that were born after the 50s, it remained close to 1 cm for both sexes.

Figure 1.8. Regression results of height advantage (cm) of non-household heads associated with high social class of the household head. Reference: low social class of household head



Source: own elaboration from the abovementioned data.

1.4. Discussion

The dynamics of inequalities in biological well-being during periods of intense progress in living standards, particularly post-World War II, have already received ample attention in previous studies (e.g. Cavelaars, et. al, 2000, Silventoinen, 2001, Deaton, 2008, Bann, Johnson, Li, Kuh & Hardy, 2018). Average height has increased dramatically during the second half of the 20th century in many populations across the world with some notable exceptions (Morgan, 2000, Cole, 2003, Moradi, 2010, Schwekendiek & Baten, 2019). In Europe, this improvement in living standards and biological well-being was tied to rapid and steady economic growth, alongside advances in health care and sanitation as reflected by the fall in infant mortality and the fabulous increase in life expectancy. Improvements in health care are difficult to identify but the effects of welfare state spending do not appear to have been modest (Hatton, 2014). Accordingly, both energy inputs related to nutrition and energy outputs related to the burden of infectious diseases improved noticeably (Crimmins & Finch, 2006b, Perkins, et al., 2016, Vallin, 2003). In Spain, research shows a strong increase in adult height during the 20th century, which was dramatic between 1950-55 and 1976-80 (Hatton & Bray, 2010, María-Dolores & Martínez-Carrión, 2011, Spijker, Cámara & Blanes, 2012, Cámara & Román, 2015, Cámara et al., 2019). The data suggest that the Spaniards recorded the largest increase in height observed in Europe after World War II, after having suffered a famine triggered during the postwar period (1939-1947) that mainly affected the adult height of the cohorts born in the 1920s (Cámara, Puche & Martínez-Carrión, 2021). The life courses of birth cohorts born from 1940 to 1994 have featured profound economic, social, and political transformations, yet little is known so far about how such changes have shaped SES-related differentials in health. This paper contributes to filling this knowledge gap by using height data to explore this question.

Results show that, on average, male height increased 5 cm among the cohorts analyzed. This upward trend is less marked among women (2 cm). The largest increases in height are observed between the 1950s and 1980s. These results are consistent with the European Community Panel height-for-age data from 1994-2001 (García-Domeque, 2007). The data show a strong growth in height that was common for most of southern Europe and made it possible to converge with the adult height of northern Europe (Hatton & Bray, 2010, Martínez-Carrión, 2012). Results also reveal that the upward trend in intergenerational growth shows signs of having come to an end, at least temporarily, as the youngest cohorts analyzed are on a height plateau. Research from different European countries with data from conscripts and national health surveys suggests that growth has virtually stopped in northern Europe and may have started to slow in southern Europe. It is important to highlight that with the data available for Spain there is no evidence that this stagnation is due to an increase in height differences between social groups. It stands to assume that there might be an upper limit to average heights, especially in countries where living standards are already very high, such as Spain and a number of other European societies. Early studies of populations in Finland and Sweden showed a slowdown in heights in the 1990s (Silventoinen, Lahelma, Lundberg & Rahkonen, 2001).

Using data from military recruitment, some studies assessed whether the secular trend in growth continued after 1990. The findings showed that some European countries reached a height plateau including Italy (Larnkjær, Schrøder, Schmidt, Jørgensen & Michaelsen, 2006, Gohlke & Woelfle, 2009), but not Greece, whose recruits continued to grow (Papadimitriou et al 2008). A study carried out in the Netherlands, the tallest population in the world, found that the long secular trend of increase in height in the Netherlands has slowed down in recent decades (Schönbeck, et al., 2013). Similar results have also been found in other European countries and in the United States (Komlos, 2007, Kues, 2010, Vinci, et al., 2019).

After decades of intense growth, and like the Dutch and other European and North American populations, the Spanish population may have reached the optimum height distribution in the 1990 cohorts. It is difficult to know whether the environmental factors that promote growth may have stabilized in the last decade. Given that the last generation, those born in the 1990s, have lived through childhood and adolescence in extreme situations, with strong economic growth and the impact of the Great Recession of 2007, it is problematic to recognize whether populations have reached their full potential of growth as they suggest is happening with the populations of northern Europe or with the 'giants' of Europe. The differences between the average heights of northern and southern Europeans remain significant and sometimes reaching up to 5 cm.

As for socioeconomic-related differentials in height, for the most part, the convergence of trends in adult height by educational attainment has been proven in Spain over the second half of the 20th century. This convergence may be partly related to the spread of access to lower levels of education for the bulk of the Spanish population. That said, the gap in height between the higher and lower educated has clearly shrunk. This finding is in line with previous research conducted in European countries that revealed a decrease in height differentials between social classes (Bann, et al., 2018). In Greece has been found that mean height increased from 175.7 cm to 178.06 cm from 1990 until 2006 and that the socioeconomic status and place of residence have a significant influence on body height (Papadimitriou, et al., 2008). This convergence is likely related to economic progress and the expansion of the welfare state in the final decades of the 20th century (Bodzsar, Zsakai & Mascie-Taylor, 2015, Hauspie, Vercauteren & Susanne, 1996). Nevertheless, considerable inequalities in nutritional status are still present even in the most advanced industrialized societies, and to a greater extent in developing countries

(Bredenkamp, Buisman, Van de Poel, 2014, Komlos & Baur, 2004). In Poland, although there has been an improvement in living conditions across nearly 50 years as it is reflected in the secular trend in children's height, there are still to some extent differences in height due the biological effects of social inequalities (Gomula, et al., 2021). Furthermore, the above evidence on the convergence of height trends by educational attainment is not conclusive. Studies with English children (Galobardes, et al., 2012) found that differences in height persisted, although they were small. In France, height inequalities associated with education remained virtually unchanged between 1970 and 2003: around 4.5-5 cm among men and around 2.5-3 cm among women (Singh-Manoux, et al., 2011).

As regards these puzzling findings, this study demonstrates that the way SES is operationalized matters in itself. Our results indicate that height differentials according to household head social class (i.e. SES-related occupation categories), though noticeably lower than those depicted by the educational attainment data, persist over most of the period analyzed. In previous investigations about Spain, specifically a field of study such as the East – well characterized that represents the Spanish average- shows that the cohorts since the beginning of the 20th century until 1960 maintained significant differences in heights, reaching up to 4 cm, and the gap increased during the last period, the cohorts from 1940-1967 (Ayuda & Puche, 2014). They show that the gap between middle-skilled non-manual workers and agricultural workers and between these two groups and that of manual workers widened, a reflection of the general increase in inequality between socioeconomic classes. It is very likely that this increase in inequalities in the stage of greatest economic growth, reflects the fact that from mid-1950s the income of the agricultural classes decreased, the decline of agriculture, compared to the gains of the stockings from industrialization and services. This research is an antecedent that shows inequalities by social class before our period of analysis, but also in the economic growth period that experimented the population that lived their childhood in the years 50s, 60s and 70s. Our work shows the persistence in the decades of the Spanish's society modernization and during the globalization. Another study made for Spanish cohorts born between 1840 and 1964 that investigated height differentials associated with the socioeconomic status approached by educational attainment revealed that nutritional inequalities augmented during the autarchic years, specially affecting the lowest social classes (Cámara, et al., 2019).

This socioeconomic inequalities remaining persistent are also found in low- to middle-income countries, particularly in Africa (Subramanian, Özaltin & Finlay, 2011). These and other evidences from previous research throws into question whether general improvements in living standards in Western European welfare economies always lead to convergence in terms of adult stature (Silventoinen, 2003, Singh-Manoux, et al., 2011). A paper that analyzes the trends in physical stature of the Swiss population born between 1955 and 1985 concludes that the quality of the health care systems and equal access to it seem to have a greater impact than other redistributive aspects of the welfare state (Kues, 2010). There exist some other research papers that question about how state policies and practices may affect population health (McDonough, Worts & Sacker, 2010, Bird, et al., 2019, Bhatta, 2021) and there exists some examples of the critical effect that public policies that promote income redistribution and universal access to education, health and sanitation services may have on nutrition and living conditions (Núñez & Pérez, 2015, Monteiro, et al., 2010).

At this point, it is also worth commenting on the differences found between men and women. Our results indicate that education appears to be more discriminatory for the oldest birth cohorts in our study, but it loses discriminatory power for the younger ones. Although this is true for both sexes, the effect described is much stronger in the case of men, which could be related to both a higher ecosensitivity among men (Cámara, 2015) and to the fact that access to higher education for older female cohorts was very limited in Spain. We are inclined to believe that the role of ecosensitivity is more influential in this regard, given that the results provided by the analysis based on educational attainment of the household head (these were mostly men) painted the same picture.

Finally, we consider that future studies could expand the sample and also more research could be done in order to relate the stagnation of stature with obesity such as previous papers have already suggested (Bann, et al., 2018).

1.5. Conclusions

Overall, the results obtained in this work lead us to conclude that inequalities in the biological dimensions of well-being have tended to diminish over time among Spaniards born since the 1940s. Yet the variety of approaches used to address this issue also prompt us to further qualify this apparent convergence. While differences in stature by educational level reduce dramatically over time, differences by social class (household heads) largely persist. Results using the educational level of either the respondent or the household head are quite similar, and show that height differentials decreased among younger cohorts of Spaniards This is particularly true in the case of men, for whom the education-related height advantage with respect to the lowest educated was 6 cm (university studies), 4 cm (secondary) and more than 1 cm (primary) in the 1940s. Among women, these differentials were smaller and remained more constant over time. These results should be interpreted taking two facts into consideration: the later access of women to education and the likely greater ecosensitivity of men (i.e. susceptibility to environmental conditions and changes in these over time).

As for SES approached through social class data (of household heads), our results reveal that height differentials remain highly constant over time (i.e. across successive groups of cohorts). For men, these differentials remain significant from the 1950s to the 1990s birth cohorts, while for women they remain significant for the whole birth cohorts included in the analysis.

In sum, we find that the effect of social class on height differentials is much less than that of educational attainment, but it is also much more persistent over time. This implies that education may play a more complex and diverse role in determining biological well-being, over and above acting as a sole proxy of SES. But also, and most importantly, it indicates that height differentials by educational attainment may mask actual socioeconomic differences in biological well-being. This could be due to the extension of education to lower classes in societies with high levels of welfare provision. Alternative approaches and indicators should therefore be contrasted with these results. In light of this evidence, the hypothesis that social provisions have led to a reduction in inequality does not hold entirely. Instead, our results support the idea that, regardless of the level of social provisions, the household environment still appears to be a relatively significant mediator in access to certain basic resources and factors related to health and nutrition. Of course, the nature of such a mediation, as well as the specific factors involved, are yet to be determined, given the limitations of the (mostly) contextual approximation we have performed through cohort groups.

It is clear that our results add nuance to any conclusions on the evolution of inequalities in biological well-being that can be reached on the sole basis of educational attainment. We have certainly been able to verify that in Spain, the differentials in adult height according to education level have shrunk and almost vanished over time. However, in light of the contrasts revealed with the approach based on social class, we are inclined to believe that education is a better proxy of SES in contexts where access to education is highly determined by economic factors. Conversely, its utility in the analysis of height differentials decreases as education democratizes. This is not surprising since, for the most part, the opening of access to the lower classes of higher educational levels coincided, in Spain at least, with the implementation of a number of social provisions including access to health care and improved sanitation.

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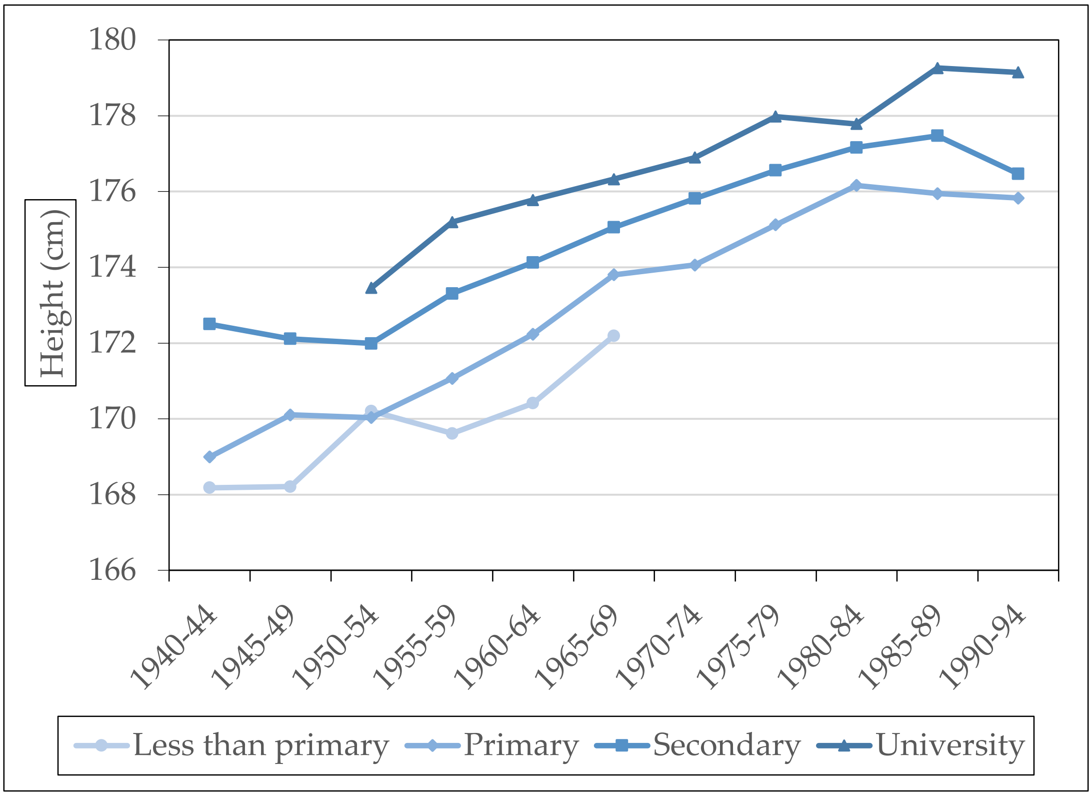
1.7. Appendix

Figures 1.9. Mean height series, by educational groups*

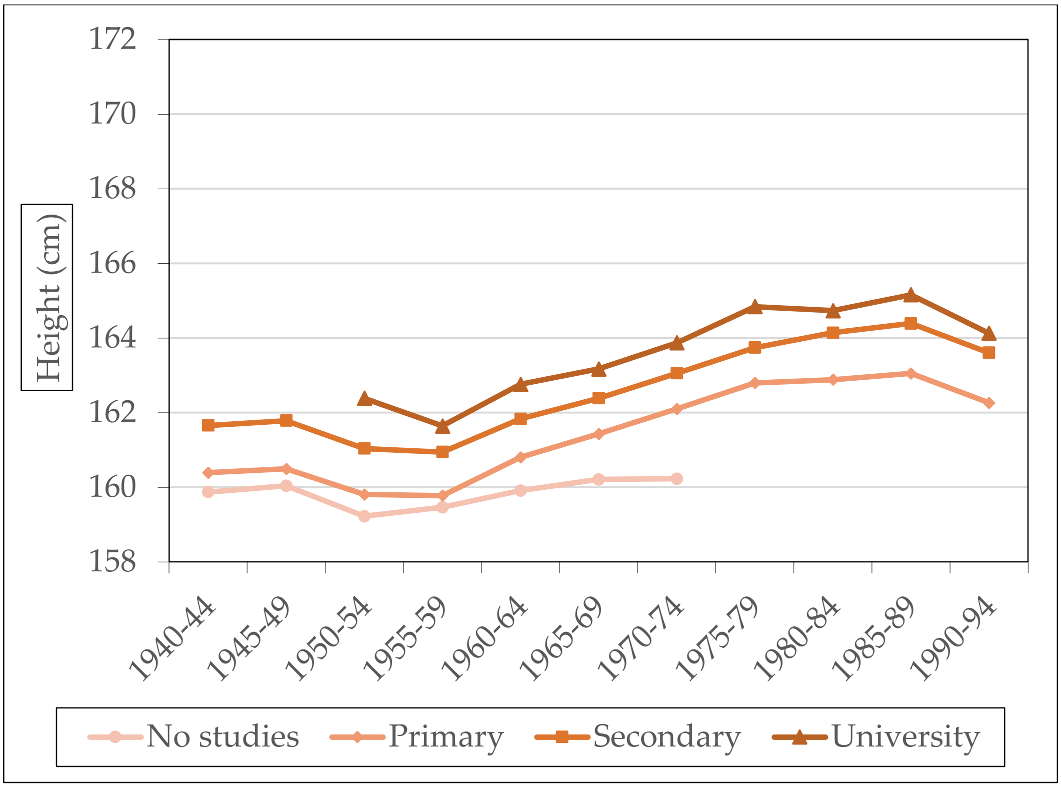
* The following Figures represent the results from the combinations that are over 90 observations

Men



Source: own elaboration from the abovementioned data.

Women

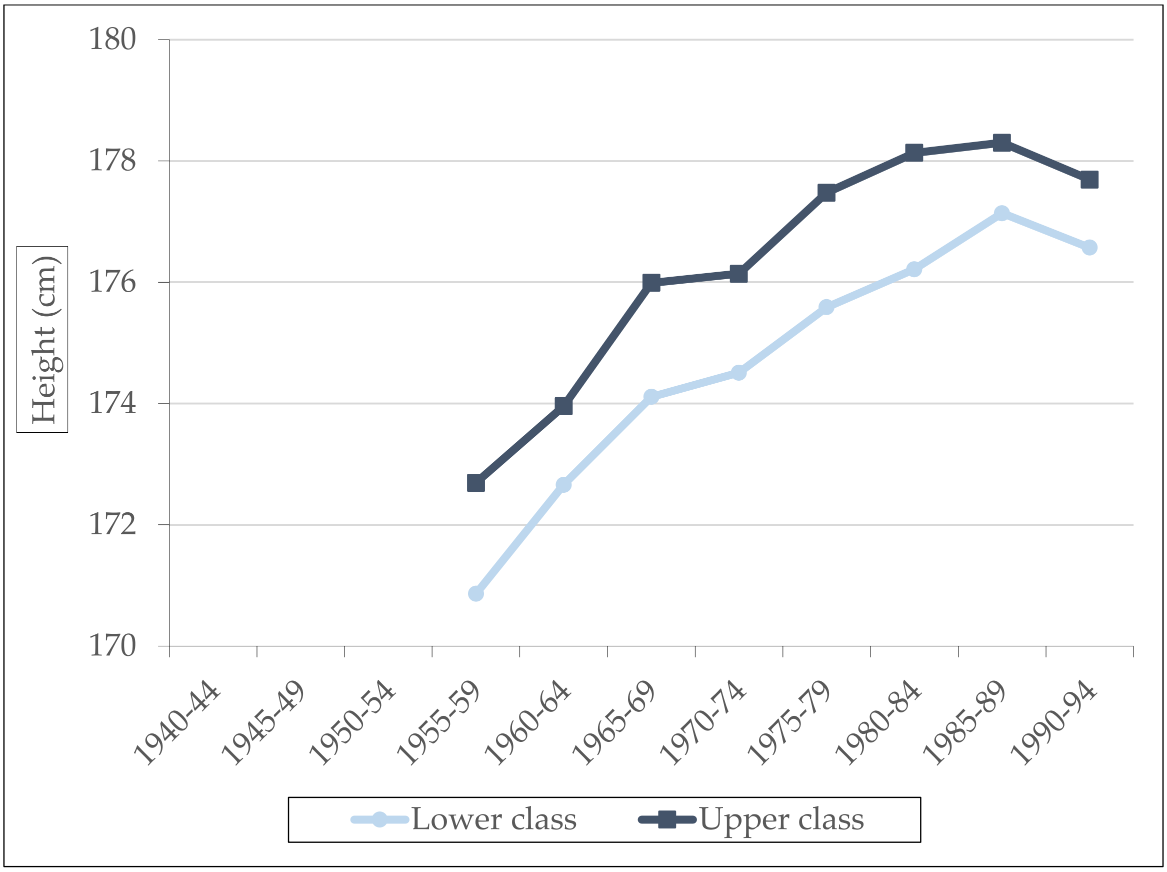


Source: own elaboration from the abovementioned data.

Figures 1.10. Mean height series, by social class of household head *

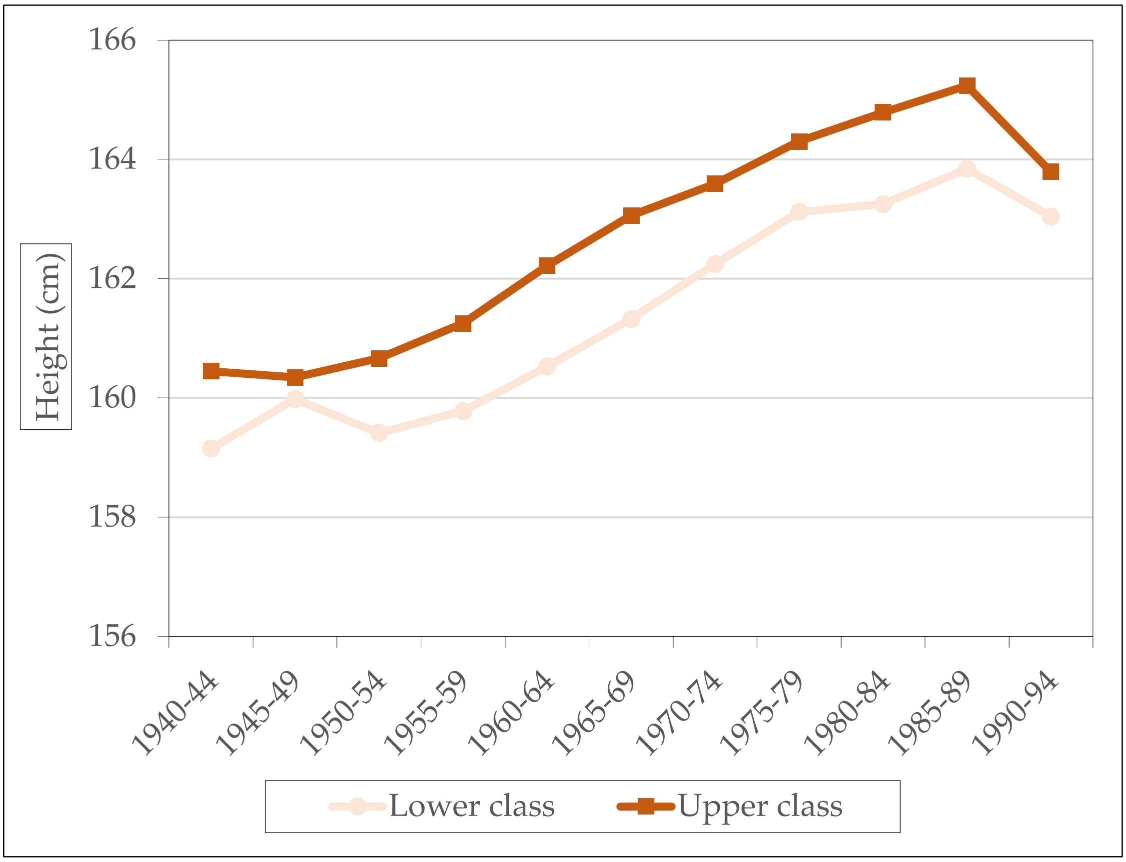
* The following Figures represent the results from the combinations that are over 100 observations

Men



Source: own elaboration from the abovementioned data.

Women



Source: own elaboration from the abovementioned data

Table 1.3. Regression results by sex using height as dependent variable*

	Men			Women		
	Coefficient	Standard error	Significance	Coefficient	Standard error	Significance
Constant	169,641	0,367	0,000	162,137	0,327	0,000
Birth cohort 1950-59	1,151	0,186	0,000	-0,755	0,179	0,097
Birth cohort 1960-69	3,162	0,175	0,000	0,344	0,168	0,041
Birth cohort 1970-79	4,598	0,179	0,000	1,465	0,175	0,000
Birth cohort 1980-89	5,845	0,212	0,000	1,872	0,202	0,000
Birth cohort 1990-94	5,613	0,365	0,000	0,999	0,330	0,002

*Control variables included: age, educational level, region of residence, population size of place of residence and marital status.
Source: own elaboration from the abovementioned data.

Table 1.4. Regression results by birth cohort using height as dependent variable*

Birth Cohort	1940-49		1950-59		1960-69		1970-1979		1980-89		1990-94	
	M	W	M	W	M	W	M	W	M	W	M	W
Constant	171,939*** (2,315)	160,250*** (2.302)	169,791*** (0,855)	161,575*** (0,779)	172,567*** (0,550)	162,108*** (0,473)	176,881*** (0,521)	164,221*** (0,445)	176,353*** (1,177)	164,481*** (1,058)	179,647*** (5,571)	175,204*** (5,622)
No studies completed	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Primary Education	1,511*** (0,367)	0,589 (0,336)	0,220 (0,375)	0,311 (0,304)	0,869** (0,331)	0,385 (0,268)	0,312 (0,359)	0,700* (0,307)	0.896 (0,684)	0,903 (0,660)	-0.816 (0,710)	-0,646 (2,708)
Secondary Education	4,383*** (0,425)	1,889*** (0,446)	2,286*** (0,380)	1,577*** (0,319)	2,337*** (0,328)	1,363*** (0,264)	1,715*** (0,357)	1,720*** (0,301)	2,109** (0,682)	2,266** (0,652)		0,605 (2,711)
University Education	6,171*** (0,592)	2,159** (0,827)	4,081*** (0,448)	2,494*** (0,408)	3,724*** (0,353)	2,286*** (0,283)	2,980*** (0,367)	2,720*** (0,305)	3,037*** (0,702)	2,981*** (0,657)	2,491** (0,855)	0,904 (2,737)

*Control variables included: age, region of residence, population size of place of residence and marital status. SE errors in parentheses. *p<0.05, **p<0.01, ***p<0.001
Source: own elaboration from the abovementioned data.

Table 1.5. Regression results using height of non-household heads as dependent variable *

	1940-49		1950-59		1960-69		1970-79		1980-94	
	M	W	M	W	M	W	M	W	M	W
Constant	191,712*** (9,834)	159,817*** (2,403)	173,459*** (2,109)	161,777*** (0,860)	171,442*** (0,988)	161,429*** (0,545)	175,580*** (1,044)	163,441*** (0,633)	177,149*** (1,657)	163,338*** (1,238)
Low education (household head)	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
High education (household head)	6,529* (2,882)	0,770 (0,427)	2,700*** (0,747)	1,194*** (0,237)	0,390 (0,322)	0,500** (0,146)	0,506 (0,311)	0,073 (0,174)	0,298 (0,561)	0,239 (0,441)
Constant	185,943*** (9,752)	159,840*** (2,402)	171,918*** (2,129)	161,551*** (0,860)	171,192*** (0,993)	161,156*** (0,545)	175,643*** (1,024)	163,397*** (0,613)	177,408*** (1,641)	163,514*** (1,223)
Low social class (household head)	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
High social class (household head)	-0,918 (1,442)	0,711*** (0,320)	1,211* (0,559)	1,115*** (0,209)	0,701** (0,269)	0,995*** (0,141)	1,003*** (0,242)	0,673*** (0,148)	0,983** (0,317)	0,679** (0,249)

*Control variables included: age, educational level, region of residence, population size of place of residence and marital status. SE errors in parentheses. *p<0.05, **p<0.01, ***p<0.001

Source: own elaboration from the abovementioned data.

CHAPTER 2
Month of birth and height. A case study in modern rural Spain

2.1. Introduction

In recent years, there has been a growing amount of research based on historical data examining the influence of climate on nutrition and children's health through stunting, given the fact that agriculture and food security are more affected by the climate crisis. In the agrarian societies of the past, in addition to the nutritional environment and infections, the variability of the climate was one of the main determinants of the health of newborns and adult height, mainly among populations characterized by low income and scarce resources (Baten, 2002, Carson, 2009, Moradi, 2012, Bruckner, Modin & Vågerö, 2014, Galofré-Vilà, Guntupalli, Harris & Hinde, 2018, Galofré, Martínez-Carrión & Puche, 2018, Ogasawara & Yumitori, 2019, Bassino, Lagoarde-Segot & Woitek, 2022). Investigations show that season and month of birth are a reliable indicator of the nutritional and epidemiological circumstances at the end of the uterine life and in the first years of life, also influencing the results of adult height. However, there is little historical research about the effects of month of birth on adult height (Cvrcek 2006, Lehmann, Scheffler & Hermanussen, 2010: Koepke & Baten, 2005). The evidence of seasonality on height in historical populations of rural Spain could enable us to gain a clearer picture and open a line of research for modern populations with medium or low income.

The climate variability observed in the fluctuations of temperatures and rainfall and the phenomenon of climate change, which also influence diet and diseases, are a real challenge for children and adolescents, mainly in agricultural-dependent societies with a low level of technological development (Grace, Davenport, Funk & Lerner, 2012, Groppo & Kraehnert, 2016, Bauer & Mburu, 2017, Davenport, Grace, Funk & Shukla, 2017, Wineman, Mason & Ochieng, 2017). Nutrient consumption, income, the distribution of income and wealth, the prevalence of environmental diseases and the impact of infections can be affected by climate variability. The shocks derived from climate change and the amplitude of seasonal fluctuations influence the endowment and availability of resources, subsistence and the increase in the vulnerability of the child population, which can also be affected by malnutrition, anemia, low weight and growth retardation (Puch, Krenz-Niedbała & Chrzanowska, 2008, Arndt, Hussain, Salvucci & Østerdal, 2016, Vaivada, et al., 2020, Molina & Saldarriaga, 2017).

Since seasonal patterns were identified in infant and adolescent growth parameters some decades ago (Tanner, 1962, Marshall, 1971, Bogin, 1978), the impact of climate variability on seasonality and the month of birth on adult height remain a controversial topic in the literature (Strand, Barnett & Tong, 2011, Sohn, 2015, Douros, Fytanidis & Papadimitriou, 2019). Although nobody contradicts the evidence of seasonality variations in growth observed in children and youngsters of all ages, the results are not always consistent and show diverse patterns of height depending on the season of birth in both hemispheres (Schwekendiek, Pak & Kim, 2009, Zhang 2011, Pomeroy, et al., 2014, Day, Forouhi, Ong & Perrya, 2015, Dalskov, et al., 2016, Fangliang, et al., 2017, Lei, et al., 2017). The patterns of seasonal variability of weight at birth and BMI during the nutritional transition process have also been particularly variable (Jensen, et al., 2015, Rosset, Żądzińska, Strapagiel, Grzelak & Henneberg, 2017, Bollen & Hujoel, 2020, Hemati, et al., 2020).

Previous studies examining the seasonal impact on height show that those born in spring or autumn reach the highest average heights. The European studies on male adults reveal that the tallest Austrian recruits were born between February and July (Weber, Prossinger & Seidler, 1998). A study of a sample of young Swedish men finds that those born between March and May had higher heights than those born in November and December (Kihlbom & Johnason, 2004). Meanwhile, a study of Spanish males between 35 and 64 years old shows that the tallest were born in June and July (Banegas, Rodríguez-Artalejo, Graciani, De La Cruz & Gutierrez-Fisac, 2001). Although the vast majority of studies indicate that those born in the cold season (winter months) were shorter than those born in other seasons, other studies produce divergent results. Research on children up to 20 years of age in rural villages in Poland shows that those born from October to March proved to be significantly taller and heavier than those born from April to September (Kościński, Krenz-Niedbała & Kozłowska-Rajewicz, 2004). The anthropometric Danish birth data show complex and variable seasonal patterns (McGrath, Barnett & Eyles, 2007).

The effect of the month of birth is more heterogeneous among developing countries. In the case of India, Lokshin & Radyakin (2012) find that children born during the monsoon months had lower anthropometrics scores compared to children born during the autumn-winter months. However, recent systematic reviews suggest that there is no clear pattern between the month of birth and height, or even between weight at birth and the season/month of birth, with the findings showing that a low birth weight is more frequent in babies born in summer (Rosset, et al., 2017, Hemati, et al., 2021). Other research suggests focusing on identifying the impact of confounding factors, for example, the vitamin D status. The importance of solar radiation, the availability of ultraviolet light and the synthesis of vitamin D as factors that contribute to the early postnatal growth have been explanatory reasons since the earliest studies (Bogin, 1978).

In this chapter, we examine the relationship between climate and children's health through height reached at the end of adolescence, given that the link between the seasonal variability and the month of birth has received less attention. We explore whether being born at a certain moment of the year could have an effect on growth retardation, using adult stature with information about the date of birth of the conscripts that were enlisted in military recruitment in the Spain in the twentieth century, a period characterized by the modernization process, the demographic transition and the boost to modern economic growth. From the beginning of the twentieth century, the environmental and socioeconomic changes were dramatic and eroded the traits of a traditional agrarian society. The increase in height was significant in both the rural and urban contexts, at least in the 1950s, due to the general improvements in income, education and living standards (García & Quintana-Domeque, 2007, Martínez-Carrión, 2016, Cañabate & Martínez-Carrión, 2017, Cámara, Martínez-Carrión, Puche & Ramon-Muñoz, 2019). However, we do not know the relationship between the seasonal climate variability and height according to month of birth. Furthermore, we test the influence of rainfall and temperature on height during the gestational period. Using harmonic regression and random forest algorithm we can conclude that they do, in fact, have an influence, although the month of birth already captures the effects of the climatological variables.

This chapter is organized into the following sections. The first part describes the database and the methodology implemented. The second section presents the results of the different analytical methods. Finally, the third section draws some conclusions and discusses the results obtained.

2.2. Materials and methods

The data have been obtained from enlistment records and declarations of military draftees and the conscript classification records (Cañabate & Martínez-Carrión, 2017). In this research, we use height data of recruits aged 21 years, who were born between 1886 and 1965. These recruits were from an interior town in southeast Spain: Hellín, located in the south of the province of Albacete, bordering with the province of Murcia. This municipality was an agrarian zone with a significant percentage of rural population even during the modernization of the country in the 1960s-1970s, when the most important economic, social and demographic transformations occurred.

In Hellín, the climate is considered to be local steppe. The average annual temperature is 15.2 ° C and the average rainfall is 365 mm per year. The driest month is July, with 7 mm of rain. In April, the precipitation reaches its peak, with an average of 49 mm. July is the warmest month of the year with an average of 24.5ºC, while January is the coldest month of the year. There is a difference of 42 mm of precipitation between the driest and the wettest months. The variation in annual temperature is around 17.4 ºC.

In this study, we first analyze whether the month of birth is a variable that might influenced the height of the conscripts, following Douros, et al. (2019). Based on their methodology, we have used a linear regression with sinusoidal covariables. After confirming that it is an influential variable, and given the fact that the regression coefficients do not inform about the importance of this variable on the dependent variable, we complemented the analysis using another predictive model of height, the random forest algorithm (Breiman, 2001). We selected this technique (more robust than a decision tree and more precise than ordinary least squares) because it allows us to investigate the importance of the variables in order to make the prediction. If the prediction is correct, it can be used as an indirect way to determine the influence of a variable in the prediction variable. Furthermore, it captures non-linearities between variables. For this method, we need to use all the variables available in the dataset so that the model selects the variables most frequently used in the prediction.

Second, we have investigated whether temperature and accumulated rainfall can also have an influence in the gestational period. In this case, the database is limited to the period between 1933 and 1965 due to the availability of meteorological data from the Agencia Estatal de Meteorología de España (AEMET, hereafter).

2.3. Results

First, we ran a harmonic regression in order to prove the significance of the variable of month on height. In this regression, we have included the variable year of birth. The final sample is composed of 16,266 observations from the initial 20,017 that included missing values that had to be removed. Table 2.1. shows the sample size by month of birth and mean height for each month.

Table 2.1. Sample size and mean height by month of birth

Month of birth	Sample size	Mean height
January	1,564	164.33
February	1,592	164.16
March	1,531	164.70
April	1,403	164.19
May	1,435	164.18
June	1,365	164.50
July	1,247	164.57
August	1,149	164.64
September	1,293	165.01
October	1,280	164.67
November	1,153	164.74
December	1,254	164.69

Source: Actas de Clasificación y Declaración de Soldados y Suplentes.

A sinusoidal transformation of the variable month needs to be performed in order to obtain the variables sin and cos. We ran the regression of both variables with the year of birth and height and the estimation results can be found in the table below (Table 2.2.).

Table 2.2. Estimation results with standard errors and T-values

	Estimate	Standard Error	T value
Intercept	-17.713***	4.300	-4.120
sin(2*π*month/T)	-0.201**	0.069	-2.925
cos(2*π*month/T)	0.124	0.069	1.782
Year born	0.095***	0.002	42.389

Root MSE equals to 62.15 * p<0.05, **p<0.01, *** p<0.001
Notes: Best OLS regression estimation with sinusoidal transformation of the variable month (sin and cos).

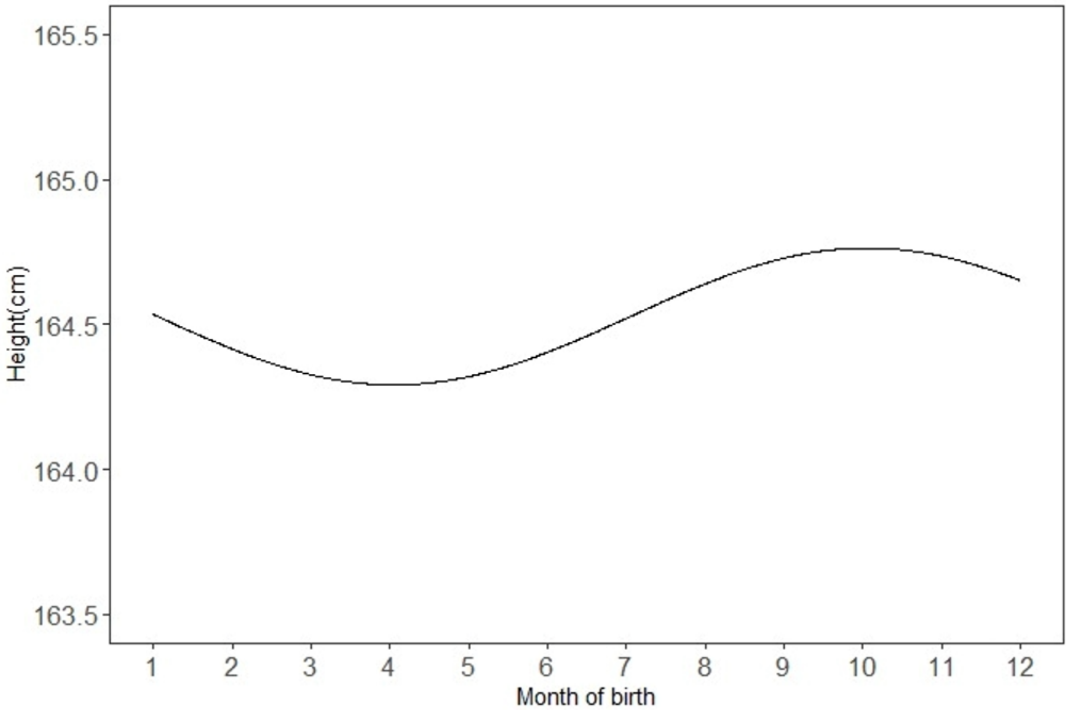
Both parameters of the model are significant at a confidence interval of 90% level of significance (β_1=-0.20, p=0.0034 y β_2=0.12, p=0.0748). The amplitude is 0.236 and the cyclical variation (defined as the difference between the highest and the smallest point) is 0.472 cm. The value of t_m is -1.95 and given that $\beta_1<0$, the minimum is 4.05 at the end of April and the maximum is 10.05 at the end of October. The coefficient of variation indicates that the ratio between the deviation and the mean is 3.8% and the whole coefficient of cyclical variation is -1.3% with an interval between -2.3 and -3.3 at the 95% confidence level. Furthermore, the model is able to explain at 10% the height's variance (R^2=10.0020).

In order to be more rigorous, we analyzed the residuals of the regression, which proves that we cannot reject the null hypothesis that states that the errors are not correlated, using the DW test (DW=1.9 y p-value=1.92e-10) and also the residuals do not follow a normal distribution using the Jarque-Bera test (X-squared=99,44 y p-value 2.2e-16), even though the errors show normality in a graphical visualization. Therefore, we proceeded to run the harmonic regression with HAC errors in order to solve the problems assessed and other inconveniences such as heteroscedasticity. The resulting estimators are identical until the fourth decimal digit, so we can consider that the results are robust. In fact, with the Box-Cox transformation the tests hypothesis could be rejected.[12]

In Figure 2.1., we can observe the correlation between height and month of birth according to the model prediction that autumn birth months generate higher heights.

[12] These results were proved using both Stata and R.

Figure 2.1. Month of birth and height correlation



Source: Actas de Clasificación y Declaración de Soldados y Suplentes.

In this sense, the procedure of the first regression is correct for testing whether the influence of month of birth was significant for height. In fact, a certain influence of this positive effect of autumn months has already been observed in the data (Figure 2.1.).

We have also investigated differences in height between rural and urban areas. The variable urban-rural explains height, and in general, like the variable year, its influence is very large. In fact, we can observe the importance of the urban-rural variable by just looking at average heights for each area. Average height for those living in an urban area was 163.92 cm while for those living in a rural area was 162.7 cm. Furthermore, this difference in averages is statistically significant (unlike the age averages). Next, we performed the Welch or Wilcoxon test. In order to know which, one to use, we first had to confirm that the variances are not homogenous with the F- Fisher test, obtaining a p-value=0.0003<0.05, we checked whether they were normal or not. Given that we have a large sample we were able to use the Anderson-Darling test instead of Shapiro, obtaining p-values of 1.2e-07 and 0.03 for the urban and rural data, respectively. Therefore, we can reject that they are normal. In this case, instead of using the Welch t-test, we had to use the Wilcoxon-rank test (for unpaired samples in our case), obtaining a p-value =2.2e-16 < 0.05. Thus, the average heights are statistically different (the difference in both samples was p-value=0.22 >0.05, then the difference in height is not due to differences in the years for the samples but to rural-urban differences).

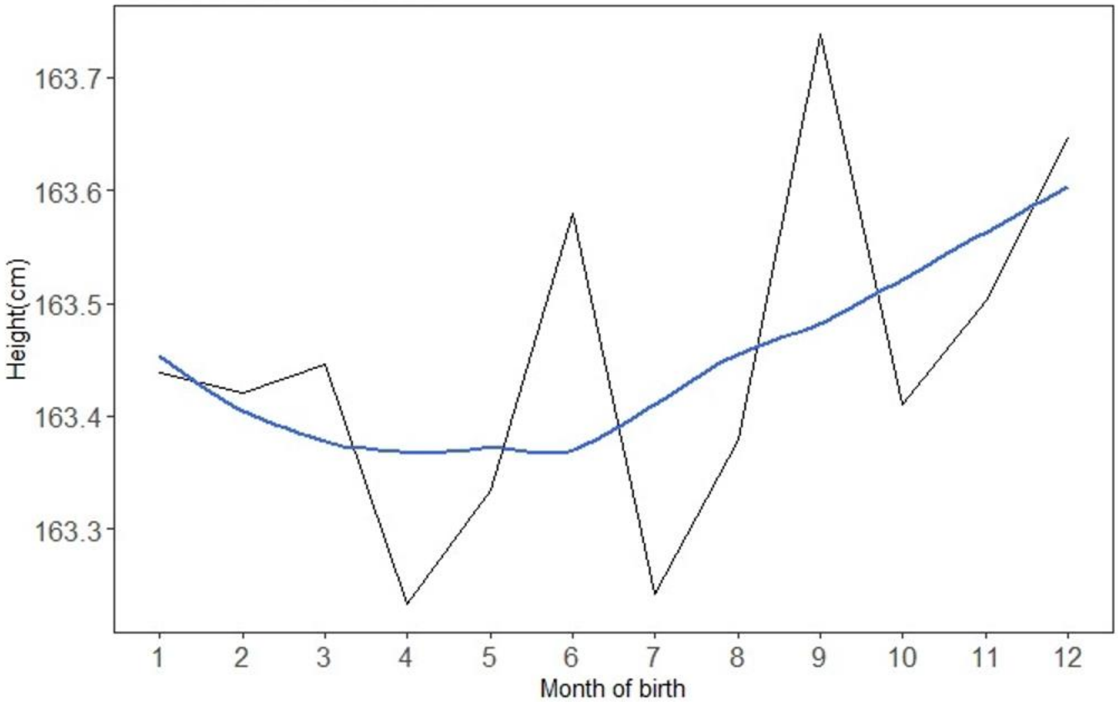
If we are interested in knowing the influence of the month of birth in the rural and urban areas separately, we can perform a normal harmonic regression for each sample and we can observe that the influence is higher for the rural area, but is not statistically significant for either of them. We also look at HAC standard errors as in the general case, in order to check whether the errors satisfy the regressions' assumption, obtaining similar results as in the normal regression. In short, we can say that the birth month has an effect but is not statistically significant, contrary to the case when we do not distinguish between rural and urban. This may be due to the fact that when we divide the sample, it is no longer large enough to ensure significance.

Second, after determining the month of birth significance and taking advantage of a larger database, we adjusted a random forest model (decision tree with a selective bagging algorithm) that indicates which of our variables from the database are relatively important when we predict height. If our model can predict height well and for these predictions the variable of month is frequently used, it could be interpreted that, in a qualitative way, this variable is important to predict and describe height and the results will be more robust. Furthermore, this model enables us to identify which variables are the most important to predict height and if this prediction is good, we will be able to consider the relative importance of the other variables in our problem.

Considering a scale of 0 to 100, when constructing the predictions, the model gives a weight of 43% to the variable year of birth that can be explained by the fact that more recent cohorts have benefited from better sanitary conditions, a healthier work environment and income gains. The variable month of birth has a weight of 33%, being a qualified worker has a weight of 9% when constructing the prediction and the rural or urban variable 5%. The other variables are barely used to construct height predictions. Next, our model, seeking to correctly predict the height of individuals according to the remaining data, constructs these predictions, particularly considering the variable month of birth.

Furthermore, this methodology allows us to create partial dependence graphs that analyze the influence of a unique variable with respect to the predicted variable of interest, in our case, height. In Figure 2.2., we can observe a dependence partial plot of month of birth with predicted height and we can see that autumn months have a higher probability of a taller height.

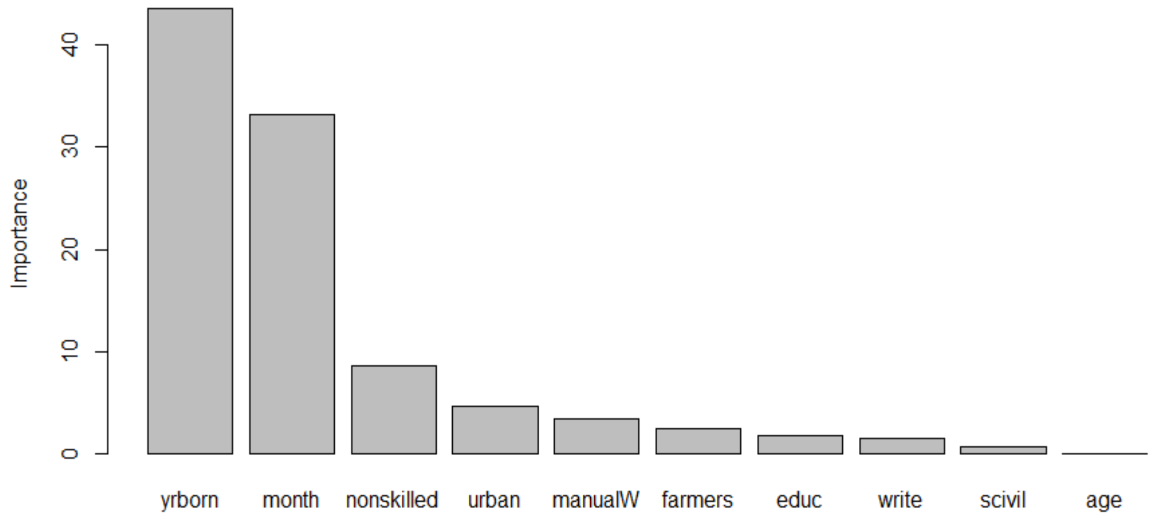
Figure 2.2. Partial dependence between month of birth and height



Notes: Partial dependence between month of birth and height. The blue line represents a moving average fit.

Furthermore, as coefficients do not give us information about the importance of the variables, we can study the importance in our database, as previously mentioned. We have implemented a random forest (RF, hereafter) model with all the data and we can observe that it gains predictive power when including the month. This confirms the previous hypothesis and we can see that it is a very important variable when we make the prediction with our database. These results are summarized in Figure 2.3., showing the importance of each variable in the model.

Figure 2.3. Relative importance in the RF prediction



Notes: Yrborn is the year of birth, month is the month of birth, nonskilled is the kind of job, urban refers to the place of living (city or not), manualW refers to the manual workers, educ to literate, write refers if they know how to write, scivil refers to single or married person.

The error in the prediction using OLS is higher than the prediction using RF (mean squared error (MSE, hereafter) OLS is 3509.961 and MSE with RF equals 2732.694). Therefore, using this model in order to study the importance of the variables seems to be a good option.

We will now present evidence of the analysis including month of birth, temperature and accumulated rainfall during pregnancy using a linear regression. We also investigate whether accumulated temperature and accumulated precipitations during pregnancy are useful in the prediction, given that the months with shorter heights are the ones in which the summer was not part of the pregnancy. For this analysis we have used the small sample available (1933-1965) due to the lack of climate data prior to 1933. The regression results show that it is barely significant, and month of birth loses significance, probably because they contain similar information. These results are presented in the following tables (Table 2.3.).

Table 2.3. Estimation results with standard errors and T-values (1933-1965)

A) Same regression as before but with subsample 1933-1965

	Coefficient	Standard Error	T-value
Intercept	-237.7***	15.19	-15.649
sin(2*π*month/T)	-0.181	0.105	-1.724
cos(2*π*month/T)	0.106	0.106	0.998
Year birth	0.208***	0.008	26.622

Root MSE 3910.586 * p<0.05, **p<0.01, *** p<0.001
Notes: OLS regression estimation.

B) Including temperature

	Coefficient	Standard Error	T-value
Intercept	-2283***	167.9	-13.597
sin(2*π*month/T)	-2.144	1.095	-1.958
cos(2*π*month/T)	0.935	1.077	0.869
dftemp	0.024	0.016	1.469
Year birth	0.208***	0.008	26.622

Root MSE 3909.36 * p<0.05, **p<0.01, *** p<0.001
Notes: Best OLS regression estimation with accumulated temperature during gestation (dftemp) included with no sinusoidal transformation.

C) Including precipitation sinusoidal

	Coefficient	Standard Error	T-value
Intercept	-2345***	155.5	-15.079
sin(2*π*month/T)	0.681	1.094	0.623
cos(2*π*month/T)	-1.771	1.066	-1.661
sin2	-1.838	1.064	-1.727
cos2	0.8215	1.082	0.759
Year birth	2.058***	0.080	25.801

Root MSE 3909.35 * p<0.05, **p<0.01, *** p<0.001
Notes: Best OLS regression estimation with accumulated precipitation during gestation with a sinusoidal transformation (sin2 and cos2).

The results with temperature, month of birth and rainfall exhibit the worst performance and lowest significance. Those including only temperature or only precipitation also perform worse.

When temperature is introduced in the prediction model with random forest, we can observe that the gain is very small, just 1.5%, and the importance achieved by the variable is due to the month, given that the variable month already contains this information. The model without the month performs much worse, so we can conclude that the variable month is important and contains all the information about accumulated temperature and precipitation, which barely adds any information to that already provided by the month. We can observe this reasoning in Table 2.4. that summarizes the MSE of each model.

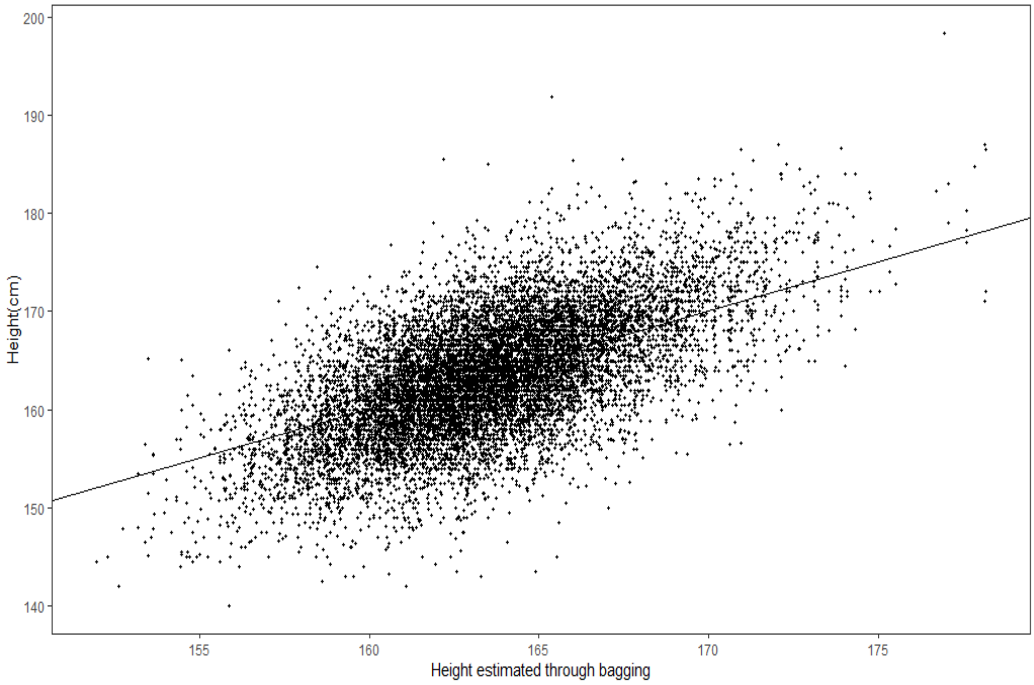
Table 2.4. Mean standard error by model

Model	MSE
OLS month and precipitation	3470.194
RF without month, nor temperature nor precipitation	3227.525
RF without month and with temperature	2415.133
RF without month and with precipitation	2423.562
RF without month with temperature and precipitation	2423.434
RF with month	2269.330
RF with month and temperature	2302.934
RF with month and precipitation	2265.169

Notes: Accuracy of the different Random Forest models.

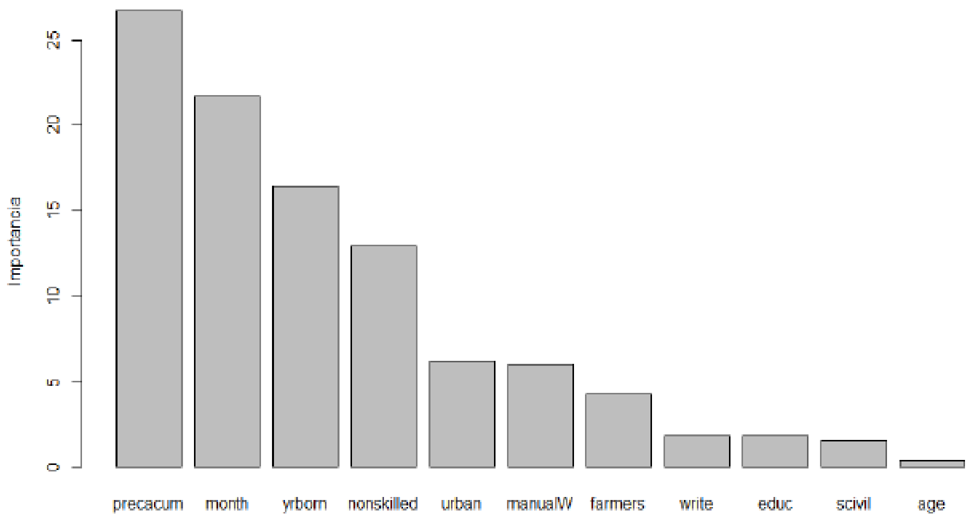
We can observe how the introduction of the variables of month, temperature or precipitation does not improve the model with respect to the model without them. The comparison between the models with these variables shows that, as previously mentioned, the effect of these variables is mainly substitutive. The model that generates a better performance is the one that includes the variable month and the variable precipitation with all the remaining variables in the database, showing concentration when pairing data and prediction (Figure 2.4.).

Figure 2.4. Random Forest Prediction and real values



On the other hand, the importance of the variables in this latter extended model, are presented in Figure 2.5.

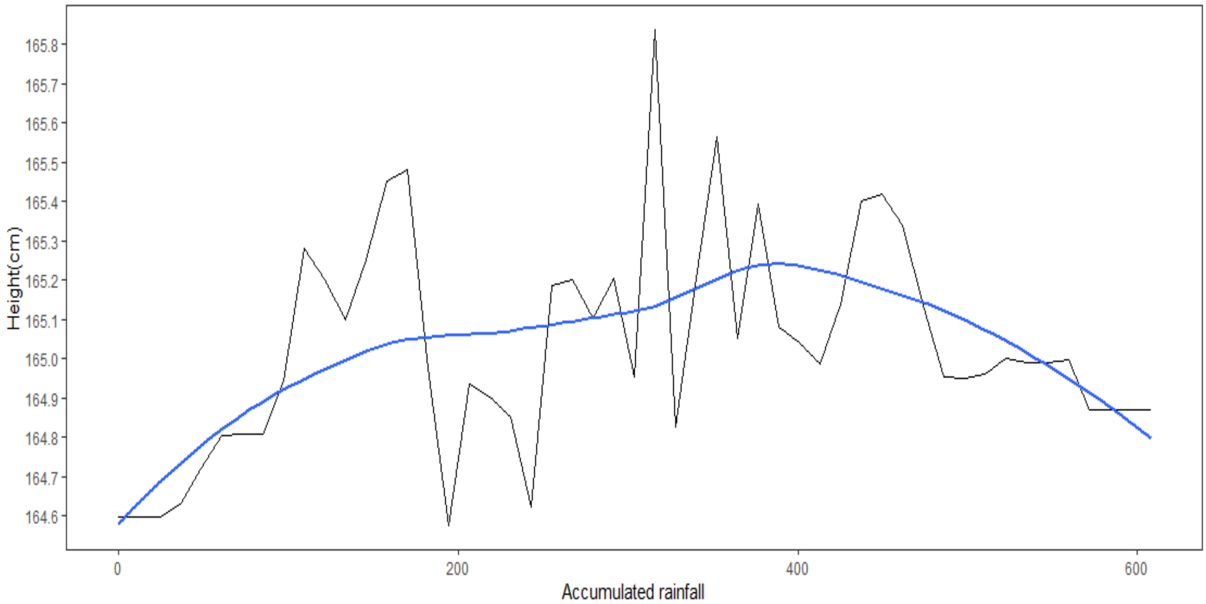
Figure 2.5. Relative importance of each variable in the prediction



Source: Spanish Meteorology Agency –AEMET, Hellín Observatory (1968-83, 1987. CLIMATE-DATA.ORG (Hellín, 1982-2012). https://es.climate-data.org/info/sources/Notes: Relative importance in the RF prediction. Yrborn is the year of birth, month is the month of birth, nonskilled is the kind of job, urban refers to the place of living (city or not), manualW refers to the manual workers, educ to a higher education, write refers if they know how to write, scivil refers to single or married person. Finally, age refers to the age of the individuals.

In comparison with the figure that does not include the variable precipitation (Figure 2.3.), the importance of the variable precipitation resides in removing it from the variable month because of the mentioned substitutive effect. Furthermore, for this latter model, the partial dependence graph (Figure 2.6.) generated by RF shows that between the range from 300 to 400 mm accumulated in the nine months of pregnancy, height is taller, but this effect is basically zero compared to the influence of the birth month variable, as shown in the analysis.

Figure 2.6. Partial dependence of height and accumulated rainfall during gestation



Source: own elaboration.

In the future, it would be interesting to study the changes in the period, establishing well-defined sub periods and the sensitivity to climate change, testing whether height is less sensitive to climate as technology becomes more available and productivity improves, breaking the dependent cycle of food resources with climate. Also, it would be appropriate to check if z-scores were higher in the summer and autumn months or lower in winter (Tanaka, et al., 2007).

2.4. Discussion and conclusions

The literature on human stature differentiated by season and month of birth has been an important issue for child nutrition for several decades (Weber et al., 1998, Bassino, et al., 2022). However, the results have not always been consistent and are frequently contradictory (Strand, 2011, Pomeroy, 2014, Sohn, 2015, Kramer, 2016, Rosset, et al., 2017, Hemati, et al., 2020, Bollen & Hujoel, 2020). The influence of climate on physiological characteristics through its impact on nutrition is also a proven fact based on historical height data, at least since the eighteenth century (Baten, 2002, Carson, 2009, Galofré-Vila, et al., 2018, Ogasawara, 2018). However, the direct effect of the seasonal climate changes on health in the past has not been studied.

The population used in this study can be considered to be fairly representative of the young adult population of rural interior Spain, given that we have used height data from a period when national military service was compulsory for all men. The anthropometric history and the extensive physical anthropology literature shows that recruits are considered an appropriate population for studying height. It is important to point out that we have used data of heights at the age of 21 years, when physical growth has stopped. In general, the population can be considered relatively homogenous.

Our results suggest that the birth months of September to December are the most favorable for adult height. The month that registers the highest statures is September, with 0.5 cm above the annual average and 0.9 cm above February, which registers the lowest height. In contrast, those born in winter months (January-February) show differences in opposite directions. The findings are consistent with results from previous studies of middle-aged Spaniards, in which male adults who were born in the summer appear to be taller than their counterparts who were born in winter (Banegas, 2001). They are also similar to the study of Austrian recruits from the 1966-75 cohorts (Weber, 1998).

Using a harmonic regression and random forest, our findings show that the month is a variable with a certain influence on height. With the former model, we also find that the month of birth already captures the effect that temperature and rainfall have during gestation on height. Furthermore, these variables seemed to have a greater influence than those related to initial education and the level of qualification of the youngsters, characteristics that are more related to income level. Our case study suggests that an autumn birth month seems to be favorable to height. This is consistent with previous studies that highlight that fruit harvests and husbandry yields and thus food prices and income gains (Koepke, 2016), in addition to more solar radiation in the corresponding seasons, had effects on the nutritional health of children. The season of birth, an indicator of vitamin D exposure in the uterus, has been associated with a wide number of health outcomes. Our results are consistent with some previous studies about historical populations. At the end of the eighteenth century, the German children from the internee Carlsschule in Stuttgart reached high growth rates in summer and autumn (Lehmann, et al 2010). Our results are also in line with other studies, such as Lei, et al. (2017), that show that for counties with low income in western China, the children who were born in the months of summer and autumn, were less likely to present growth retardation than the children who were born in the winter. Several previous studies have also revealed a link between the month of birth and adult stature, but with contrasting patterns between the different populations (Day, et al., 2015, Doblhammer & Vaupel, 2001, Fangliang, et al., 2017, Zhang, 2011). Probably, the effect of the month of birth diminishes with age and is more pronounced in men, further evidencing the higher sensitivity of male height to environmental changes.

The research suggests that differences between individuals who are born in the summer and winter months could be due to the amount of solar light that the mother receives during pregnancy, given that this determines to some extent the exposure to vitamin D. There is a vast literature on vitamin D exposure and sun radiation, which is worth referring to (Bogin, 1978). Vitamin D represents an important contribution to early postnatal growth, as some authors have suggested (Roth, Perumal, Al Mahmud & Baqui 2013, Ma, Wei, Bi, Weiler & Wen, 2021), although both parameters are independently affected by the same condition, that is, solar radiation. Some studies show that perinatal sunlight is the main factor underlying the relationship between stature and the month of birth, although the mechanisms implied are still an issue of debate. The findings also confirm that prenatal sunlight is an important determinant of height (Waldie, Poulton, Kirk & Silva, 2000, Siniarska & Koziel, 2010, Botyar & Khoramroudi, 2018). The exposure of women to UV radiation had beneficial effects on fetal growth and arterial pressure during the period of pregnancy. However, given that this topic has not been widely studied in the past, the previous results must be generalized with great care and caution. Therefore, it is suggested that more studies could be made in this field.

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CHAPTER 3
Biological well-being and inequality in Canary Islands: Lanzarote (1886-2001)

3.1. Introduction

There exists a vast literature on historical populations that uses anthropometric measures to evaluate the net nutritional status and explore inequality (Floud, Fogel, Harris & Hong, 2011, Schoch, Staub & Pfister, 2012, Blum & McLaughlin, 2019, Cavelaars, et al., 2000, Meisel-Roca, Ramírez-Giraldo & Santos-Cárdenas, 2019). Since the Industrial Revolution, economic historians study the relationship between human stature and body mass index (BMI) and the diverse socioeconomic contexts. Previous research has explored the changes in living standards and the impact of modernization processes and economic growth on nutritional health, human well-being and inequality (Martínez-Carrión & Salvatore, 2019, Carson, 2013, Craig, 2016, Lehman, Floris, Woitek, Rühli & Staub, 2017, Komlos, 2019, Llorca-Jaña, 2019).

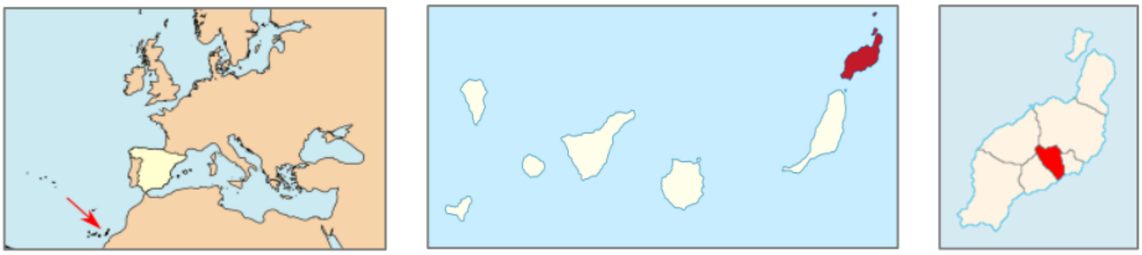
There are two key anthropometric measures of malnutrition: height for age and weight for age. While low height for age indicates "stunting"—a retardation of normal growth— weight for age can be an indicator for under- and over-nutrition (Bredenkamp, Buisman, Van de Poel, 2014, Mahmudiono, Segalita, Rosenkranz, 2019, Komlos & Brabec, 2011). Both indicators are associated with insufficient nutrition, infectious diseases, environmental aggression and excessive labor exertion. Stunting is related to health and nutrition during infancy, can become permanent and have an impact on mid-life health, increasing the risk of chronic diseases and mortality. In the case of weight, there exists a complex problem called the double burden of malnutrition (DBM, hereafter) that occurs when one part of the population faces undernutrition while another suffers from over-nutrition (Finucane, et al., 2011).

Anthropometric data represent human body influences over time and may provide insights into health inequalities that are not discernible by other indicators (Batty, et al

2009, Steckel, 2009, Inwood & Roberts, 2010, Whitlock, 2010, Bann, Johnson, Li, Kuh & Hardy, 2018, Mansukoski, et al., 2020). For past populations, anthropometric data are a valuable source of information about living standards and health inequalities. The absence of data to study the evolution of well-being reaches a major dimension mainly in rural and peasant townships. In many places around the world, until the mid-20th century, the peasantry remained outside the market economy and was located in informal economic scenarios where salaries were barely spread or the salaried workers were not the majority. As a consequence, the economic well-being indicators in historical periods are scarce or non-existent. Thus, anthropometric data from military recruitments from the past are appreciated by historians, development specialists and physical anthropologists.

Military sources have informed about the socioeconomic conditions of male heights since the 19th century and allow the construction of alternative and/or complementary indicators, such as per capita rent and income or real salaries, that are indicators commonly used to measure economic well-being (Linares-Luján & Parejo-Moruno, 2019, Franken, 2021, Llorca-Jaña, Rivas, Clarke & Traverso, 2020, Jun, Lewis, Schwekendiek, 2017). In addition, weight and body mass index data that are incorporated throughout the 20th century, together with height, allow the exploration of changes in nutrition in the long run and health in rural societies, including small peasant communities (Mansukoski et al 2020, Pérez-Rodrigo, et al., 2017, Cranfield, Inwood, Oxley & Roberts, 2017, Marco-Gracia & Puche, 2021). In this case, we are studying the easternmost Canary Island. We analyze the historical anthropometrics of the rural population of San Bartolomé (SB, hereafter), a municipality located at the center of the island of Lanzarote (Figure 3.1.), in the province of Las Palmas of Great Canary. The municipality was composed mainly of a peasant population 77 miles from the African coast.

Figure 3.1. (Left). Location of the Canary Islands, a region of Spain. (Center): Canary Islands and Lanzarote in red. (Right): Lanzarote and SB town in red



In past decades, anthropometric historical developments in peninsular Spain have been relevant. Studies arising from the biological anthropology and the economic history have revealed the variability in Spanish height, according to environmental and socioeconomic contexts throughout the last 150 years. Climate and ecological conditions, the diet and food consumption habits, socioeconomic, family and cultural environments, apart from genetics, form the determinants of nutritional status and biological well-being. This will explain the significant differences observed among average heights in Spain, a country remarkably characterized by interregional environmental contrasts. Spaniards' height trends are well known in the long term at a national level, by autonomous community, region and province and also the rural–urban gap and socioeconomic differences (Quiroga, 2001, Martínez-Carrión, 1994, María-Dolores & Martínez-Carrión, 2011, Cámara & García-Roman, 2014, Martínez-Carrión, Cámara & Ramon-Muñoz, 2018)

Recently, more research into the individual inequality field has been developed. These investigations have been carried out through the use of coefficients of variation (CVs, hereafter), between classes and social groups, through the HISCO and HISCLASS methodologies of socio professional classification, and through the analysis of social differentiation processes by residential areas inside the towns. All this research has created a wide knowledge about trends and the magnitude of nutritional inequality since the end of the 18th century until the decade of 1980 (Martínez-Carrión, et al., 2018, García Montero, 2018, Ayuda & Puche, 2017, Terán & Sánchez García, 2021). Furthermore, worldwide concern about the rapid increase in corporal height in many societies is boosting the number of studies about the origins and trends of obesity in Spain (de Ruiter, Olmedo-Requena, Sánchez-Cruz & Jiménez-Moleón, 2017, Hernáez, et al., 2019, Aranceta Bartrina, 2013, Sánchez-García, Martínez-Carrión, Terán & Varea, 2020, Carson, 2020).

Despite the anthropometrical research achievements in Spain, we barely know about the anthropometrical behavior of Spanish insular population groups and about infant and adult growth during the nutritional transition. We know even less about the anthropometric history of populations from the Canary archipelago during the economic and demographic modernization. The available data of average heights by region or autonomous communities show that inhabitants of the Canary Islands were historically tall, although this geographical area had a relatively low GDP (Martínez-Carrión & María Dolores, 2017).

3.2. The historical context and economic cycles in Lanzarote

The Canary Islands were one of the less-developed regions during the first stage of the modern process of urbanization. However, men from the Canary Islands were relatively taller than Spaniards in the peninsula, leading us to think about something other than just environmental conditions, in explaining their above-average height (e.g., ethnic origins). Some authors state that genetic factors and ethnical peculiarities, coming from ancient and primitive inhabitants of these islands (*guanches*, of Berber origin) could explain the superior stature of Canary men versus Spaniards. This popular and widely extended belief is based on ancient stories from chroniclers that are collected by Bethencourt, that designate the first nations of Canary islanders as “tall men, robust, strong, with beautiful features”. The heights of those primitive populations, according to archeological studies, normally reach heights above 170 cm (Bethencourt Alfonso & Fariña González, 2016, García-Talavera, 2016). However, infant mortality in the Canary Islands was among the highest in Spain, and therefore height cannot be easily related to a low morbidity exposure (Cámara & García-Román, 2014).

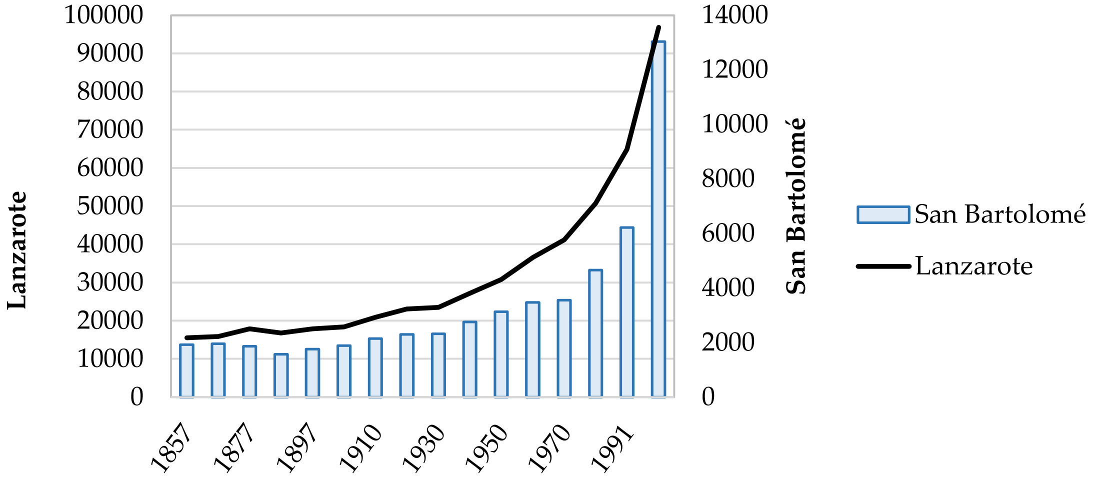
Previous anthropometric historical studies have shown that the inhabitants of the archipelago presented better physical well-being standards than the average in Spain during the 19th century. This primacy remained until the end of the 20th century (Martínez-Carrión, Román-Cervantes & Candela-Martínez, 2018, Román-Cervantes, 2013). Environmental factors, such as the benignity of the climate without cold winters and with mild temperatures, allowed a more stable agricultural production over the years.

A food singularity in the islands, in particular of Lanzarote, is the production and consumption of *gofio*, composed of a non-sifted flour from toasted cereals, usually wheat and corn. This flour was used in different meal preparations. Lanzarote also had a strong presence in the fishing industry that was developed during the 19th century and at the beginning of the 20th. This allowed a richer nutrition that might explain the improvements in biological well-being.

Lanzarote's economy received an impulse from the middle of the 19th century. The port infrastructure improved with the change of the new capital from Teguise to Arrecife in 1847, the main urban nucleus, and its inclusion among the duty-free and customs-free ports with the Free Ports Law in 1852 (Macías Hernández, 2001). The instauration of free trade increased the exports of cereals, mainly of cochineal (*grana*) to the most important European industries, mostly to Great Britain. The cochineal, used as a purple-colored dye in the textile industries of Europe, was one of the drivers for the economic growth of Lanzarote from 1850 until the 1880s. After the cochineal and cereal crisis, the diffusion of new substitutive cultivations, such as chickpeas, onion, tomato, pumpkin, corn or millet (*millo*) and vines took place, that consolidated in the first half of the 20th century, including the potato (Lemus, 2001, Ulises, 1995).

The diffusion of the potato occurred very early, from the middle of the 18th century, and especially from the end of the 19th century, like that of corn or millet (González, Hernández, Miguel & Cabrera, 2007). The fishing exploitation and the fish canning industry gave an impulse to the local salt industry. However, Lanzarote did not participate in the expansion of the banana economic cycle that was mainly carried out on the two big islands of the archipelago, Tenerife and Las Palmas of Gran Canaria. Lanzarote's economy was not so dynamic and this explains the importance of emigration to America in the first decades of the 20th century, first to the main island of the Canary Islands and Cuba and afterwards to Venezuela, Uruguay and Brazil. The clandestine emigration lasted until the decade of the 1940s (Macías Hernández, 1992, Hernández Delgado, 2010, Martón Ruiz,1985). Figure 3.2. shows the demographic crisis in the 1880s and the scarce dynamism of the island's population and in the city of SB until 1930.

Figure 3.2. Evolution of the population in the municipality of SB and Lanzarote, 1857–2020



Source: own elaboration from INE data.

The 1960s marked a change in the economic growth model of the Canary Islands. Lanzarote's economy experimented a new expansion phase, now driven by the tourism industry. Tourism became the most important sector in the economy. The island of Lanzarote became highly touristic and attracted several millions of tourists each year. Immigration explains the vigorous demographic increase of the last decades of the 20th century. This "tourist miracle" was sustained by improvements in hydraulic infrastructures in the 1960s and the international airport constructed in 1970. Water scarcity has been a challenge for the islands' inhabitants since ancient times. Runoff water storage was achieved thanks to the construction of *maretas*, hydraulic infrastructures that were improved with the construction of big walls since aboriginal times. The Great Mareta of Teguise had a huge relevance in the main urban core. At the beginning of the 20th century, the water supply was insufficient and, in later decades, galleries, numerous wells, cisterns and above all large deposits (*maretas*) were constructed. Most were supplied with water transported by steamships and tankers from other islands.

A final step for drinkable water endowment was the five-year Hydraulic Plan from 1961–1965, that planned the continuation of water tank construction, the collection of groundwater and the carrying out of drilling, reforestation and the effective development of important infrastructures, among which a large desalination plant built in 1965 stood out (Díaz Rijo, 1998). The water supply network continued until the end of the 20th century, conditioned by the residential construction development, the services and the push of national and international tourism. Between 1970–1980, agriculture ceased to be decisive although it was transformed by technical innovations, some traditional, such as the *jable* or the *enarenado*, -volcanic sand with which certain crops are covered to conserve the humidity of the soil, avoiding the evaporation of water and thermal differences in the soil, that spread and increased the vineyards for wine production. These techniques made it possible to improve the productivity of rainfed soils in Lanzarote. Since the decade of the 1970s, the decline of the powerful fishing fleet (mainly sardine boats), after the decolonization of Western Sahara and its occupation by Morocco, did not impede the maintenance of small artisanal fleets that are still important for fish consumption, a key part of the familiar diet. Livestock also suffered a deterioration, which mainly affected the goats that supplied milk to the traditional cheese industry (majorero cheese). In fact, its demand in the regional Canarian market was reactivated at the end of the 20th century, again promoting the development of the cheese industry (Perdomo, 1998).

The main objective of this case study is to identify the evolution of biological wellbeing from the anthropometrics' history of San Bartolomé, a rural based municipality located at the center of the island with a strong component of peasantry population. In fact, the Monument to Peasantry, from the artist César Manrique, was installed in this locality in 1969 next to the House-Museum. We show the relationship among anthropometrics changes, mainly in heights, with the nutritional processes and the economic modernization. Using heights, weight and BMI, we want to disentangle the possible environmental factors that determine the trends of these indicators. Assuming that adult height, is a good indicator of the biological life standards and inequality in the net nutritional status, we focus our attention mainly in the relationships between economic growth and inequality in the heights' evolution and its disparity. We verify that the relationships are not identical with BMI's dynamics.

3.3. Materials, methods and representability

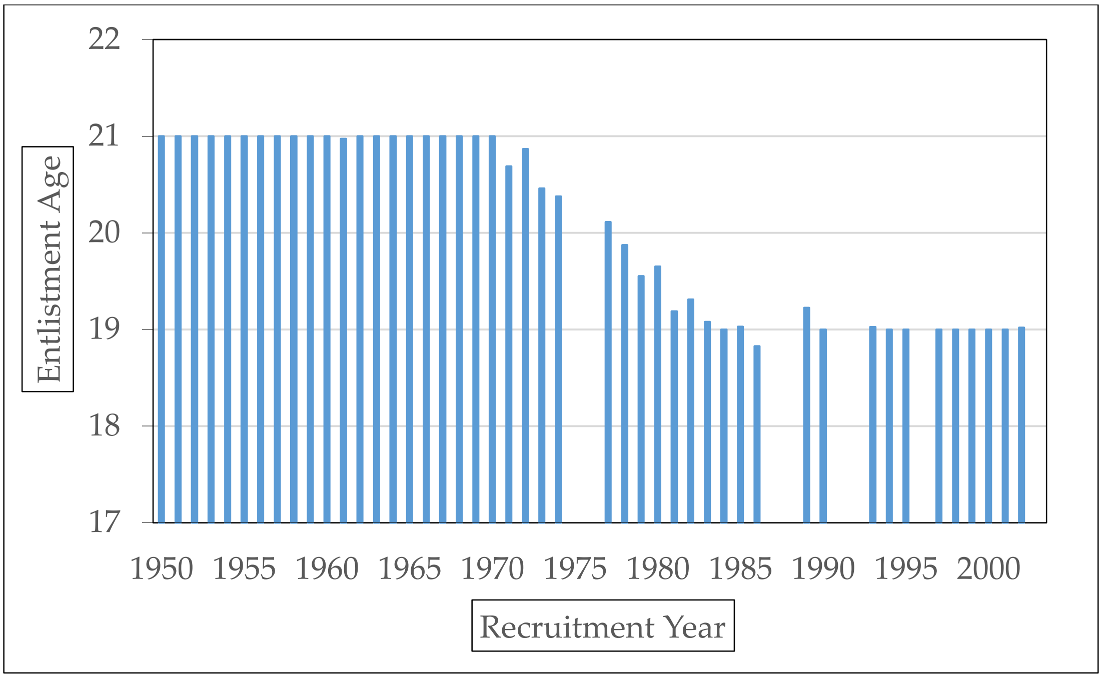
3.3.1. Data source

The municipality's selection was determined by the availability and quality of the data and they are very representative Lanzarote's population. The territory of the municipality of SB has an area of 40.89 km^2 and represents 4.8% of the island's area.

However, its population represents something else in the island's demography: 9.4% in 1887, 10.11% in 1950 and 13.5% in 2001. The urban nucleus is located in the center of the island, composed mainly of a peasant population until the decade of the 1960s. The territory produces the agricultural cultivations mentioned in the previous section and it has access to the sea, allowing fishing. The township belongs administratively to the province of Las Palmas, with Lanzarote being the easternmost of the Canaries and the closest one to the African coast (Figure 3.1.). Not all the islander populations show the same environmental and socioeconomic characteristics, but they present many similarities. We consider that the municipality sample is a good prototype of the island.

Our anthropometric measures are homogeneous in age between 1906 and 1970 (cohorts from 1885 to 1949) when conscripts were measured at the age of 21 years old. However, the regulation of 1969 set the recruitment age at 20 years old from the following year. Later, between 1970 and 1986 the regulation changed the entry age from to 19 years old. This fact could have affected height and weight, especially the latter. It has been observed that Spanish populations—the majority with healthy food consumption standards—finish their growth at 18 years old (García, Hernández & Palacios, 1972). The age changes became stable from 1988 (Figure 3.3.). Given that the growth of the height of the Spanish population is characteristic in modern populations since the 1980s, we do not use height correction techniques nor do we standardize height at age 21 years from this date. We consider that at the age of 19 years the growth of the analyzed populations was completed. The use of age-specific standardization techniques is often done for historical populations that have been under nutritional stress and whose growth lasts until their twenties or twenty-one years of age, even older.

Figure 3.3. Changes in the recruitment regulatory age between 1969 and 1986



Source: AMSB, ACDS. Own elaboration.

The measurement system also changed and became simpler. The municipalities ceased to carry out their function of enlisting and classifying the recruits, whose control passed to the military recruitment centers (*Caja de Reclutas*) from the 1980s through the presentation of the National Identity Card. This system of *quintas* remained valid until December of 2001. There were also changes in the measurement of heights. Until 1969, height was measured in millimeters, and since then, it has been in centimeters. Equally, the duration of the military service fluctuated in the 20th century. In 1912, military service changed to three years, in 1940, to two years, and in 1986 it was set between fifteen and eighteen months. Finally, in 1991 and in the field of professionalization of the armed forces, the new Law of Military Service shortened the duration to nine months. Universal military service ended on the 31st of December in 2001. In Spain, since the 1st of January 2002, all soldiers, including those of the Royal Navy, are professionals.

We use height, weight and BMI data as biological living standard measures of nutritional health. As in other Spanish anthropometric studies, the data from the analyzed municipality are drawn from the Actas de Clasificación y Declaración de Soldados (ACDS) (Soldiers' Classification and Declaration Acts) that are preserved in the Quintas Section of the SB Historical Municipal Archive (AMSB, hereafter). These documents are filed in boxes by recruitment year and have been available at a municipality level in all the Spanish state since the military legislation of 1857. In addition to height and weight, the year of birth, occupations and literacy levels are registered, among other variables. The time series covers the period from 1907 until 2001, corresponding to the cohorts born between 1886 and 1982. The sample comprises all the *quintos* or recruits that showed up for the measurement act or "*talla*" during the period under analysis. In contrast to height, that was measured for all the recruits in the whole period, weight is only reported in later years, for 1912 recruits and from 1955.

In total, we have collected information about 2172 records of conscripts that were called up for military enrollment. The number of observations that report information about height reduces to 1921 cases and 1286 observations report information about weight. Table 3.1. shows a brief summary of the number of cases for each variable of interest.

Table 3.1. Sample size by variable of interest

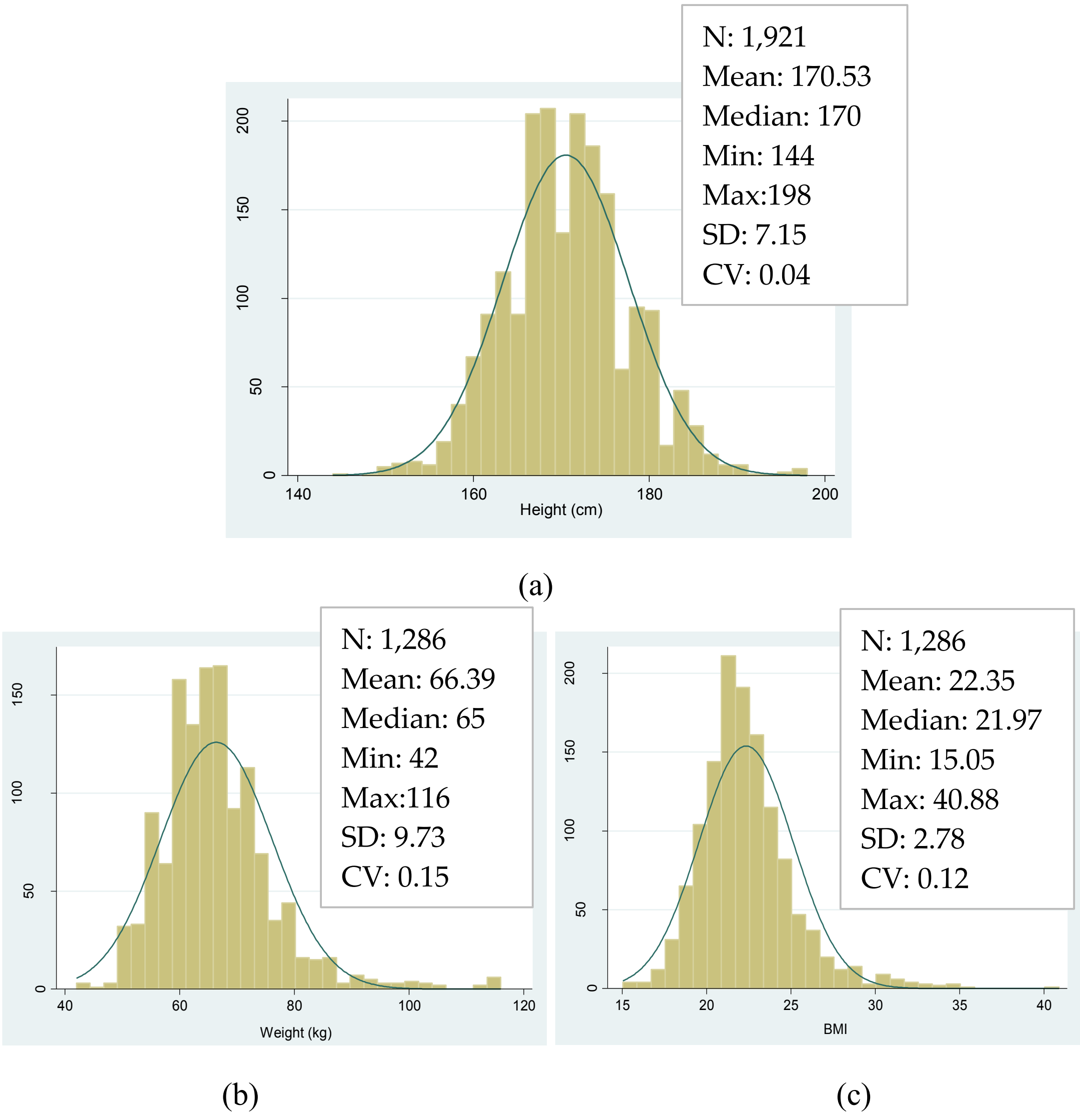
Variable of interest	Observations
Number of young men called up	2,172
Height	1,921
Missing height information	251
Weight and BMI	1,286
Missing weight & BMI information	886
Literacy	1,941
Missing literacy information	231
Occupation	1,523
Missing occupation information	649

Source: AMSB, ACDS. Own elaboration.

As can be seen in Figure 3.4., our final series are not affected by censored data nor are they truncated. This is important because these used to be some of the main problems of samples that were collected from military records (Komlos, 2004). The frequency distributions of the three main variables of interest in our study follow a quasi-normal distribution (Gaussian) (Figure 3.4.).

Our results consider that height is a measure of adults' health and also a good informative indicator about economic and epidemiological conditions during childhood. The final adult height reflects the environmental conditions in the first twenty years of life, in which childhood and adolescence are two critical periods for growth. Due to that, the data are presented by birth cohort. In contrast, BMI is an indicator that reports information about the nutritional health status from a certain population at the time of measurement, given that it is conditioned by weight, a variable that changes more frequently from one year to another. In this case, BMI data are presented by year of recruitment. BMI value classification is as follows: low weight (BMI < 18), normal weight (18.5 ≤ BMI < 25), overweight (25 ≤ BMI < 30) and obese (MBI ≥ 30), allowing us to explore consumption habits and healthy routines with respect to nutrition.

Figure 3.4. Histograms. (a) Height distributions in SB, birth cohorts 1886–1982. (b) Weight distributions in SB, birth cohorts 1886–1982. (c) Body mass index in SB, birth cohorts 1886–1982



Source: AMSB, ACDS. Own elaboration.

3.3.2. Methodology

The methodology we use to study malnutrition is based on z-score computations according to international references used by the WHO (2007) and the national references from Orbegozo, 2001 and Carrascosa, et al, 2008. Next, we explore the evolution of inequality using dispersion measures, examining the weight of malnutrition through those that have short height (stunting), using the coefficient of variation (CV), percentiles compared with standards of modern populations and a socioeconomic analysis of the evolution of anthropometric indicators by educational and social class groups. The coefficient of variation (CV) seems to show inequality better than other dispersion measures (Baten, 2000, Cámara, Martínez-Carrión, Puche & Ramon-Muñoz, 2019). In some cases, in order to smooth the trends, we use three-year moving averages.

3.4. Results

Table 3.2. summarizes the main statistics for the whole sample by ten-year birth cohorts. Body mass index (BMI, kg/m^2) is only calculated for some decades of the 20th century for which we have weight data available.

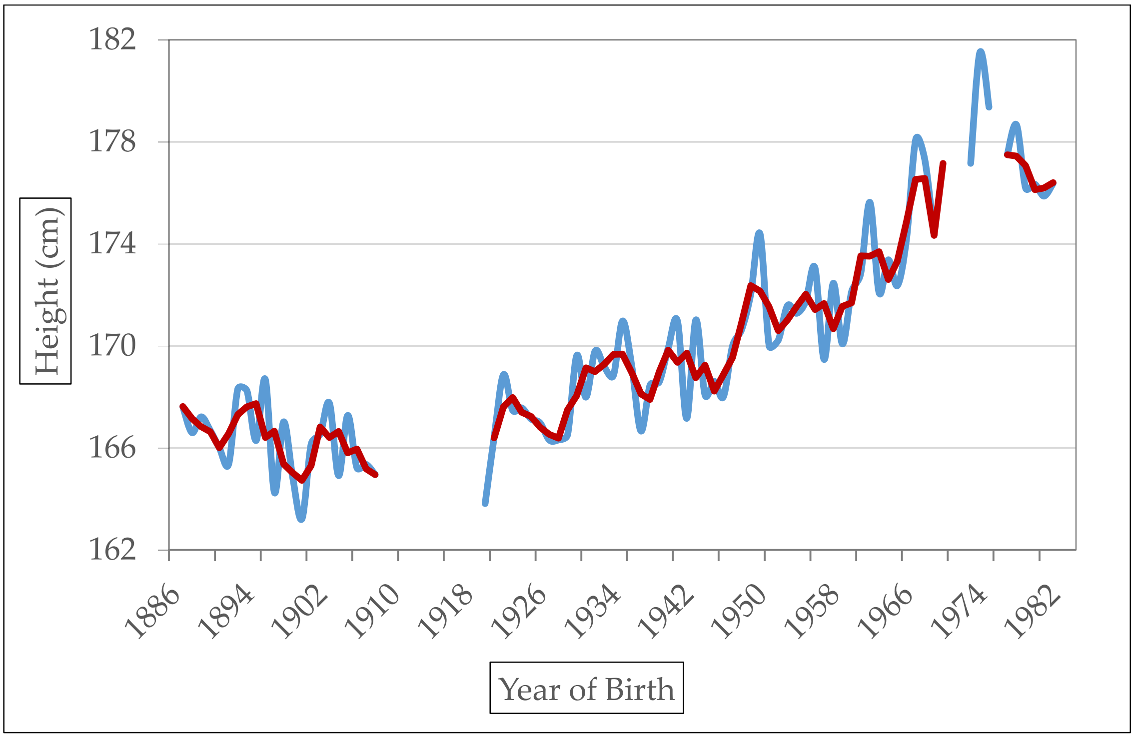
Table 3.2. Descriptive statistics by decade of birth/recruitment

		Height (cm)				Weight (kg)				IMC			
Decade of Birth	Decade of recruitment	N	Mean	SD	CV	N	Mean	SD	CV	N	Mean	SD	CV
1886-1889	1907-1910	65	167.08	5.957	0.036	1	57.00	.	.	1	24.38	.	.
1890-1899	1911-1920	153	166.59	6.022	0.036	22	62.32	6.578	0.106	22	22.74	1.690	0.074
1900-1909	1921-1930	175	165.75	5.385	0.032	.	.	.	.	.	.	.	.
1910-1919	1931-1940	1	163.10			.	.	.	.	.	.	.	.
1920-1929	1941-1950	169	166.87	5.778	0.035	.	.	.	.	.	.	.	.
1930-1939	1951-1960	229	169.01	5.845	0.035	140	63.39	7.505	0.118	140	22.21	2.194	0.099
1940-1949	1961-1970	272	169.54	6.344	0.037	269	64.64	7.982	0.123	269	22.45	2.211	0.098
1950-1959	1971-1980	241	171.19	6.070	0.035	241	67.73	9.608	0.142	241	23.06	2.570	0.111
1960-1969	1981-1990	360	173.74	6.434	0.037	360	66.87	9.217	0.138	360	22.15	2.811	0.127
1970-1979	1991-1999	83	178.06	7.169	0.040	81	67.68	9.428	0.139	81	21.38	2.535	0.119
1980-1982	2000-2001	173	176.14	7.228	0.041	172	68.69	13.655	0.199	172	22.09	3.976	0.180
Total		1,921	170.53	7.154	0.042	1,286	66.39	9.726	0.146	1,286	22.35	2.778	0.124

Source: AMSB, ACDS. Own elaboration.

Figure 3.5. presents the trend of average heights for recruits born between 1886 and 1982. We use 3rd order moving averages in order to smooth the trend given that there are some years that fluctuate a lot because they contain few observations. The series of average heights shows an ascendant trend over time although there are some periods which show a regression. The average height for those conscripts that were born before 1950 was under 170 cm, while for those born from the 1970s onwards we observe an accelerated and more constant increase over time, reaching values above 175 cm. Within those born from 1887–1889 and 1980–1982, the average height went from 167.2 to 176.2 cm, registering an increase of 9 cm.

Figure 3.5. Annual average heights in SB. Cohorts 1886–1982. Estimate with 3rd order moving averages

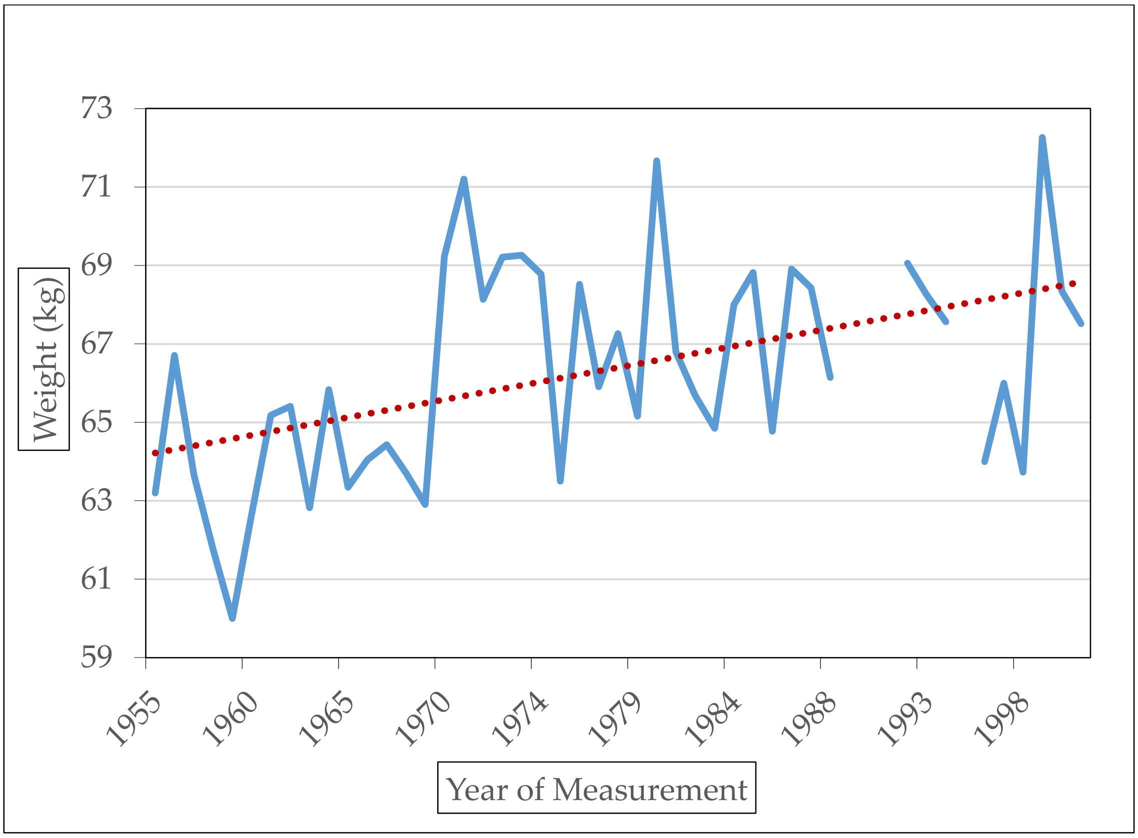


Source: AMSB, ACDS. Own elaboration.

The periods with greater increases in height are documented at the end of the 1940s (p-values < 0.005) and 1960s (p-values < 0.005) (p-values are calculated from the regression of the variable of interest (height, weight and BMI) as the dependent variable and year of birth/recruitment as dummy independent variables, no other covariates are included). Those of regression among those born at the end of the 19th century (p-values > 0.005) and the beginning of the 20th century (p-values = 0.000). Among the cohorts from 1887–1889 and 1906–1908, the average height reduced two centimeters, somewhat less if we widen the comparison between 1887–1891 and 1904–1908, with a decrease of 1.3 cm.

Figure 3.6. shows the weight trend that increases 4.5 kg among the recruits of the five-year groups of 1955–1959 and 1978–1982. We verify that by 1970 there was an accelerated increase caused mainly by conscripts measured in 1970–1974 (p-values ≤ 0.05). In 20 years (1955–1974), an increase of 6.2 kg is registered, which we see above all in military recruits at the end of the Spanish "economic miracle" stage. However, during the next decades the average weight seems to stagnate, although in the last years of the 20th century (p-values < 0.05) there is a growth rebound that even exceeds the average weight of 68 kg.

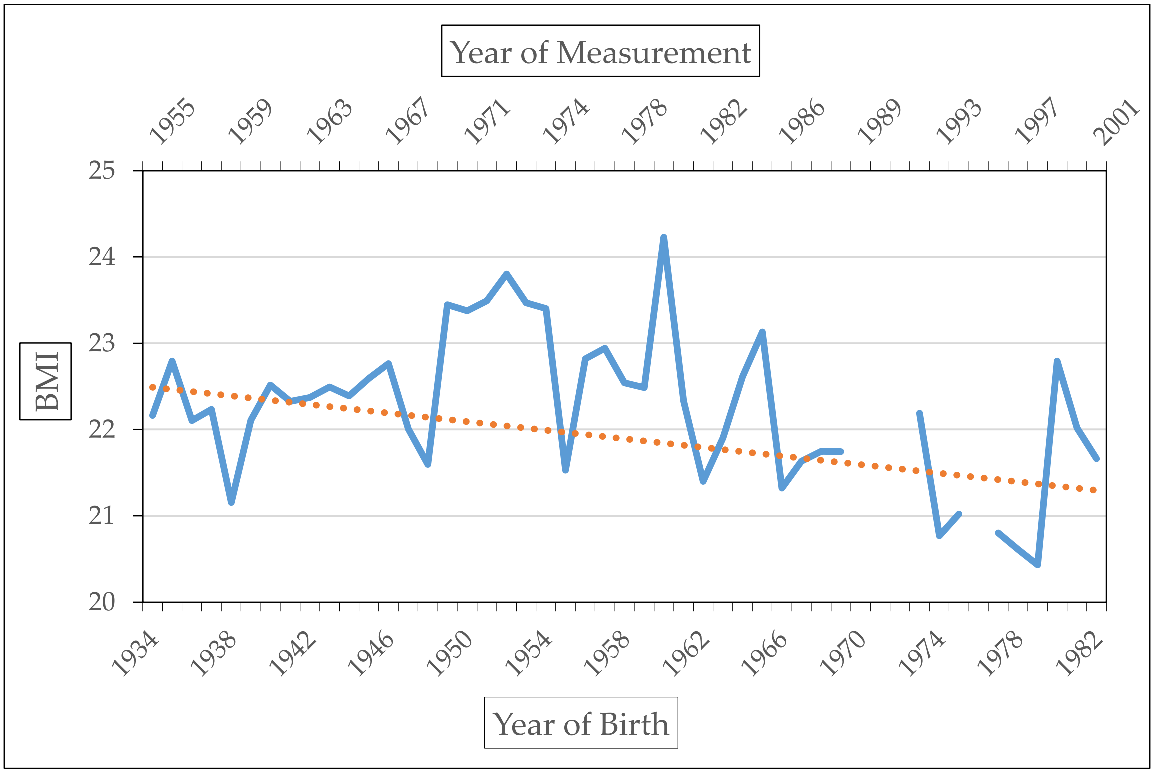
Figure 3.6. Annual average weights (1955–2001) in SB. Trend line



Source: AMSB, ACDS. Own elaboration.

Figure 3.7. presents the average BMI trend by year of birth and recruitment. Average BMI has experienced a continuous decline since the 1970s (p-values < 0.05) and stagnated at average values close to 21.5 in the last years of the sample (p-values > 0.05). This fact can be attributed to increases in height that are more pronounced with respect to intergenerational weight gains. Furthermore, mean values of BMI for all conscripts analyzed present values that are considered as a healthy weight (18.5–24.99), as is shown in Table 3.3.

Figure 3.7. Annual average BMI (1955–2001) in SB. Trend line



Source: AMSB, ACDS. Own elaboration.

Table 3.3. Statistical information by BMI classification and decade of birth/recruitment

Decade of birth	Decade of recruitment	Total	Low weight		Normal weight		Overweight or obesity	
		N	N	%	N	%	N	%
1930s	1950s	140	1	0.7	126	90.0	13	9.3
1940s	1960s	269	5	1.9	239	88.8	25	9.3
1950s	1970s	241	2	0.8	189	78.4	50	20.7
1960s	1980s	360	26	7.2	294	81.7	40	11.1
1970s	1990s	81	7	8.6	69	85.2	5	6.2
1980s	2000s	172	19	11.0	126	73.3	27	15.7
Total		1,263	60	4.8	1,043	82.6	160	12.7

Source: AMSB, ACDS. Own elaboration.

3.4.1. Malnutrition analysis

In this section, we present z-score evidence for the variable height in order to compare our data with other population standards (Table 3.4.). We use reference values around 18 years old, because we are aware that growth becomes stable from 18 to 20 years old (Ogden, et al., 2002). We have selected the 50th percentile value for the ones registered by the WHO, 2007 at 19 years old (height: 176.54 cm, SD: 7.30), the values of Carrascosa, et al., 2008 for Spaniards at the age of 18 years old (height: 175.97, SD: 6.06) and for adults (height: 177.33, SD: 6.42) and the ones calculated by the Obergozo Foundation, 2001 that are also for 18-year-old individuals (height: 176.27, SD: 5.69).

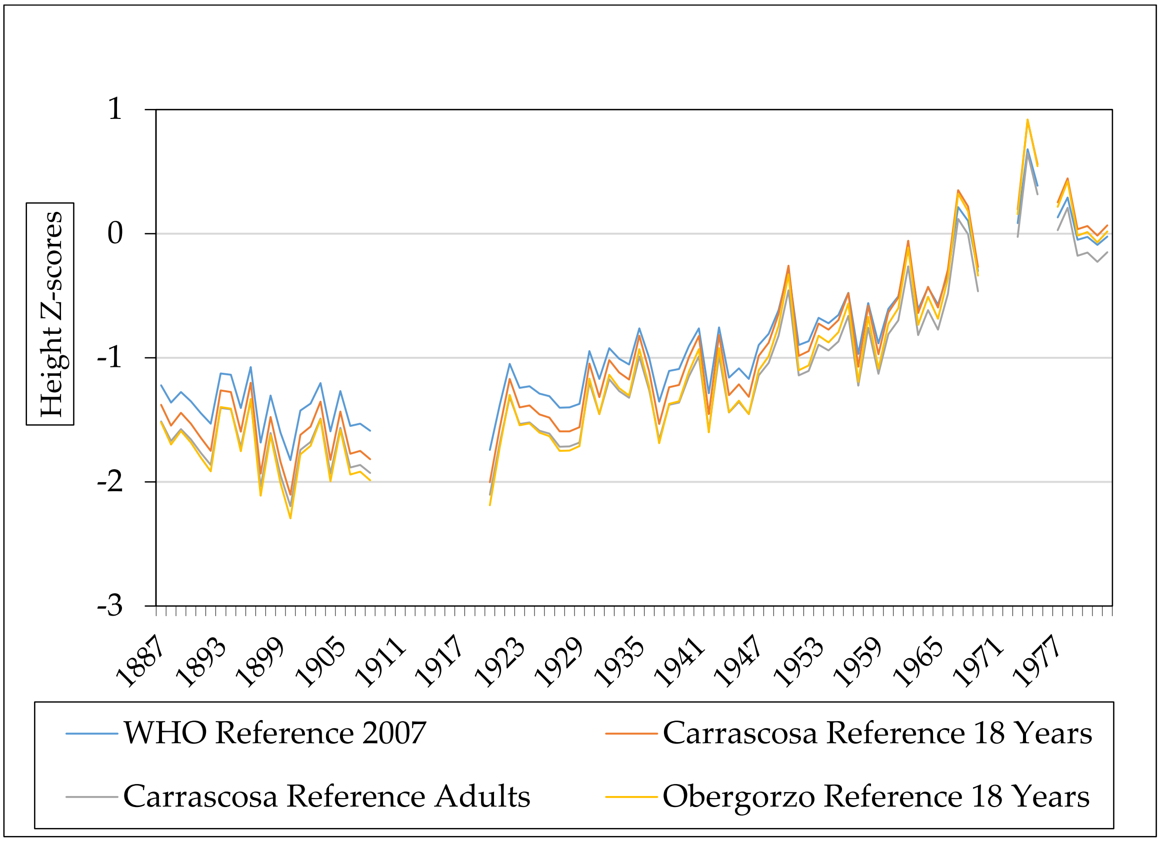
Table 3.4. Stunting rates according to the WHO (2007) by decade of birth/recruitment

Decade of birth	Decade of recruitment	N	Standard HAZ < -1 Cases	%	Standard HAZ < -2 Cases	%
1880s	1900s	64	64	100	.	
1890s	1910s	153	153	100	.	.
1900s	1920s	175	175	100	.	.
1910s	1930s					
1920s	1940s	169	169	100	.	.
1930s	1950s	229	229	100	.	.
1940s	1960s	272	113	41.54	.	.
1950s	1970s	241	.	.	.	.
1960s	1980s	360	.	.	.	.
1970s	1990s	83	.	.	.	.
1980s	2000s	173	.	.	.	.
		1,919	903	47.06	0	0

Source: AMSB, ACDS. Own elaboration. No data for 1930 recruitments due to emigration and crisis.

Figure 3.8. presents the four annual HAZ series using different international and national data references. The four HAZ series show an almost identical evolution, independently of the reference considered for their construction. For the whole period analyzed, malnutrition is irrelevant, and it only stands out at the beginning of the 20th century. Although there are not enough observations due to strong emigration, the first decades of the last century are the most vulnerable. Since the 1920s, we observe a remarkable reduction in malnutrition that increases for those cohorts born after 1950–1960.

Figure 3.8. Annual height z-scores (HAZ) by year of birth

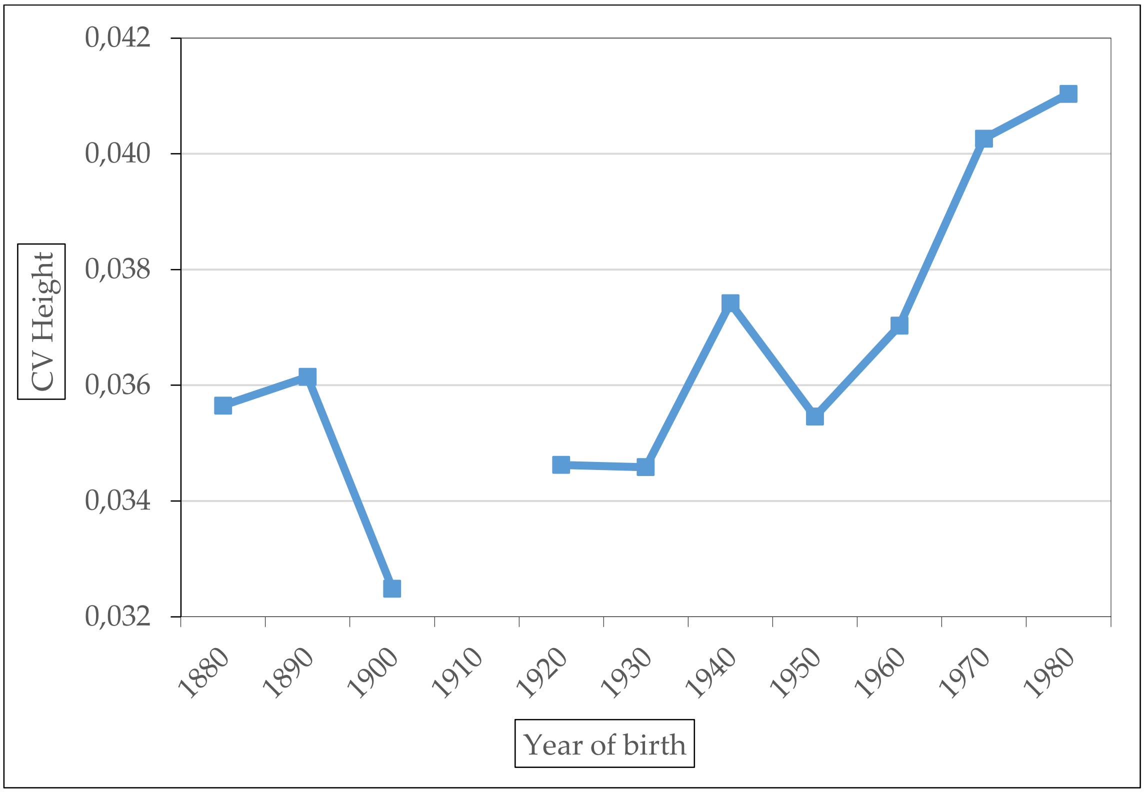


Source: AMSB, ACDS. Own elaboration.

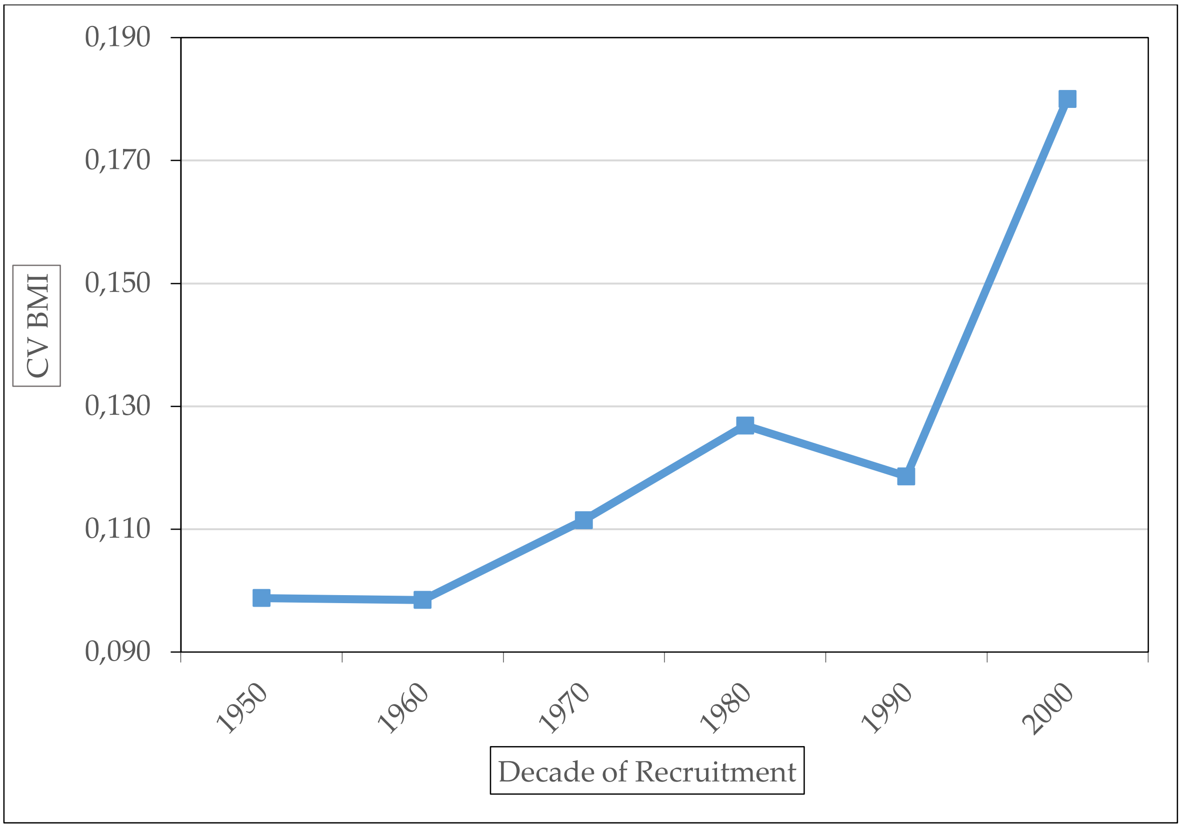
3.4.2. Inequality analysis

In this section, we estimate inequality using different measures such as CV, percentiles and the evolution of height and BMI by educational and social class groups. According to some previous studies, it seems that CV expresses inequality better than other dispersion measures (Baten, 2000, Cámara, et al., 2019). A seminal work (Baten, 2000) found a high correlation between the coefficient of variation and differences in average height from different social groups. Based on this evidence, this statistical heterogeneity indicator has been used as an indirect measure of anthropometric inequality and therefore socioeconomic inequality. In this case, we present in Figure 3.9. the evolution of the CV for heights and BMI for the full sample. The results suggest that height inequality diminished at the beginning of the 20th century, increased in the decade of the 1940s, decreased in the next one and experienced a higher increase from 1960. The BMI inequality analysis suggests that it increased between 1960 and 1980 and at the end of the period.

Figure 3.9. (a) Height coefficient of variation by decade of birth. (b) BMI coefficient of variation by decade of birth



(a)



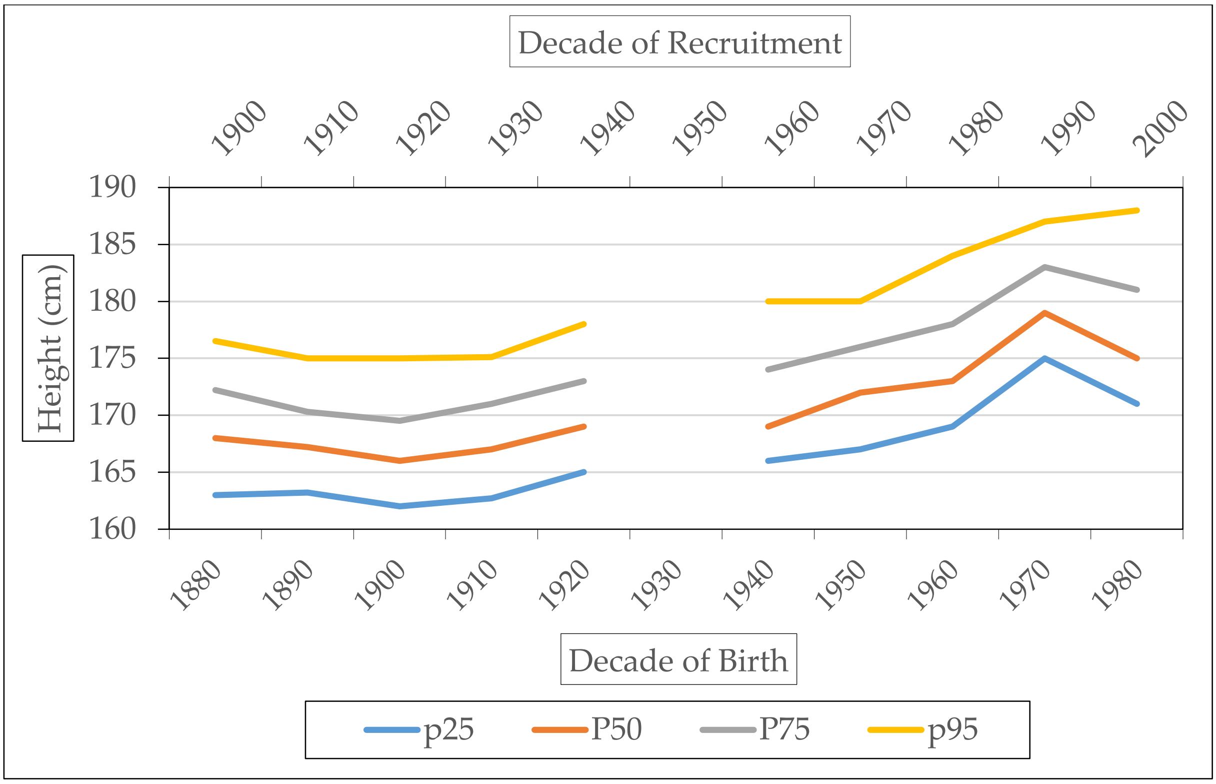
(b)

Source: AMSB, ACDS. Own elaboration.

Figures 3.10. and 3.11. show the trend of height and BMI percentiles by decade of birth/ recruitment. Height percentiles present a very similar trend for the four percentiles defined (Figure 3.10.). We observe that the 95th percentile shows an upward trend for birth cohorts born after 1970, while the other three percentile categories reflect a downward trend for these birth cohorts. The results in Figure 10 suggest an increase in heights for the tallest at the end of the period while there is a decrease for the rest.

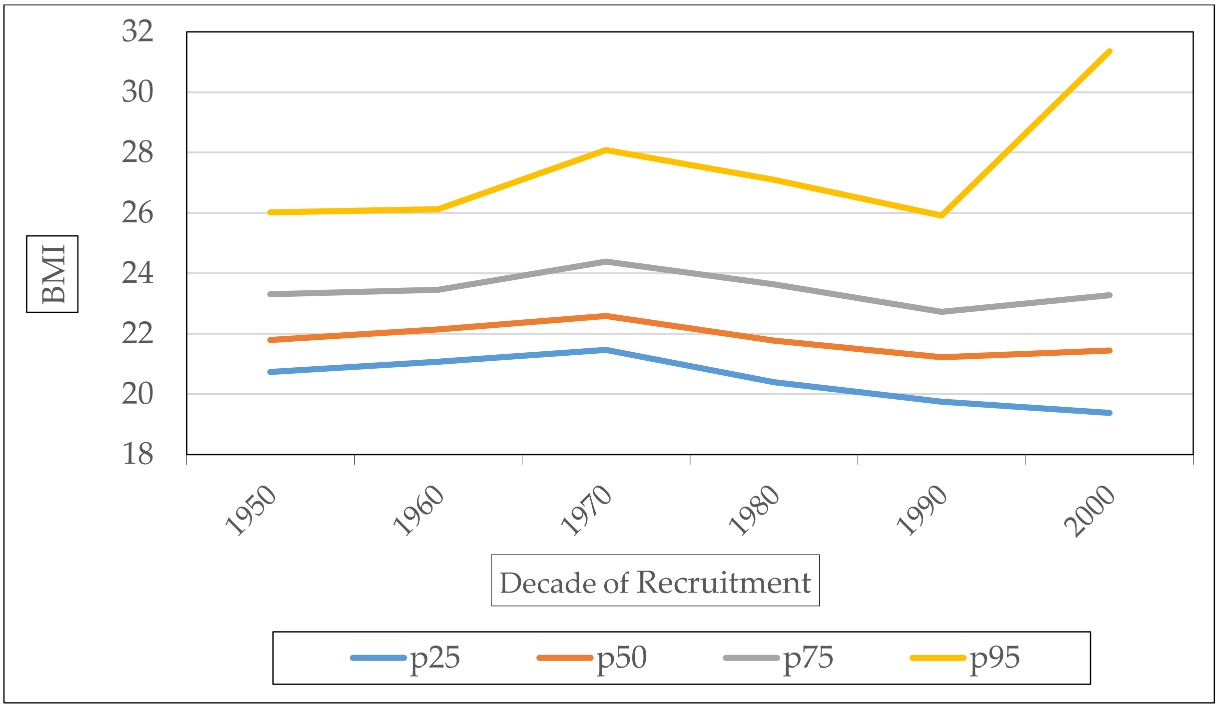
Figure 3.11. shows the trend for the four BMI percentiles defined. The 25th, 50th and 75th percentiles present a parallel and constant evolution over time. In contrast, the 95th percentile presents a rapid increase in BMI values for birth cohorts born after 1970. There is an increase of more than 5 kg/m^2.

Figure 3.10. Height percentiles by decade of birth/recruitment



Source: AMSB, ACDS. Own elaboration.

Figure 3.11. BMI percentiles by decade of recruitment



Source: AMSB, ACDS. Own elaboration.

In order to make comparisons of the evolution of height and BMI, we grouped our data into several social class categories. The social class groups have been defined according to HISLASS classification: students, non-manual workers, manual workers, farmers and farm workers. Table 3.5. presents the main statistics of height and BMI by social class group for the whole period, given that some groups are not sufficiently represented due to the absence of information in some historical sections. Differences are noticeable and stand out for students, who are the tallest, compared to farmers and farm workers, who show the lowest heights. The height gap between occupations is associated with agrarian activities and the difference of white collar or non-manual workers and students is more than four centimeters. Between the ranks of the tallest and the shortest in stature (students versus farmers and farm workers), the differences reach 6.7 cm. The results do not differ from other studies about the Spanish population in the 20th century, that reveal the biologic well-being inequality among occupational groups and social classes, even among neighborhoods in the same city. (Martínez-Carrión, 2019, Terán & Sánchez-García, 2021, Cámara, 2019, Ayuda & Puche, 2014, Linares-Luján & Parejo-Moruno, 2021)

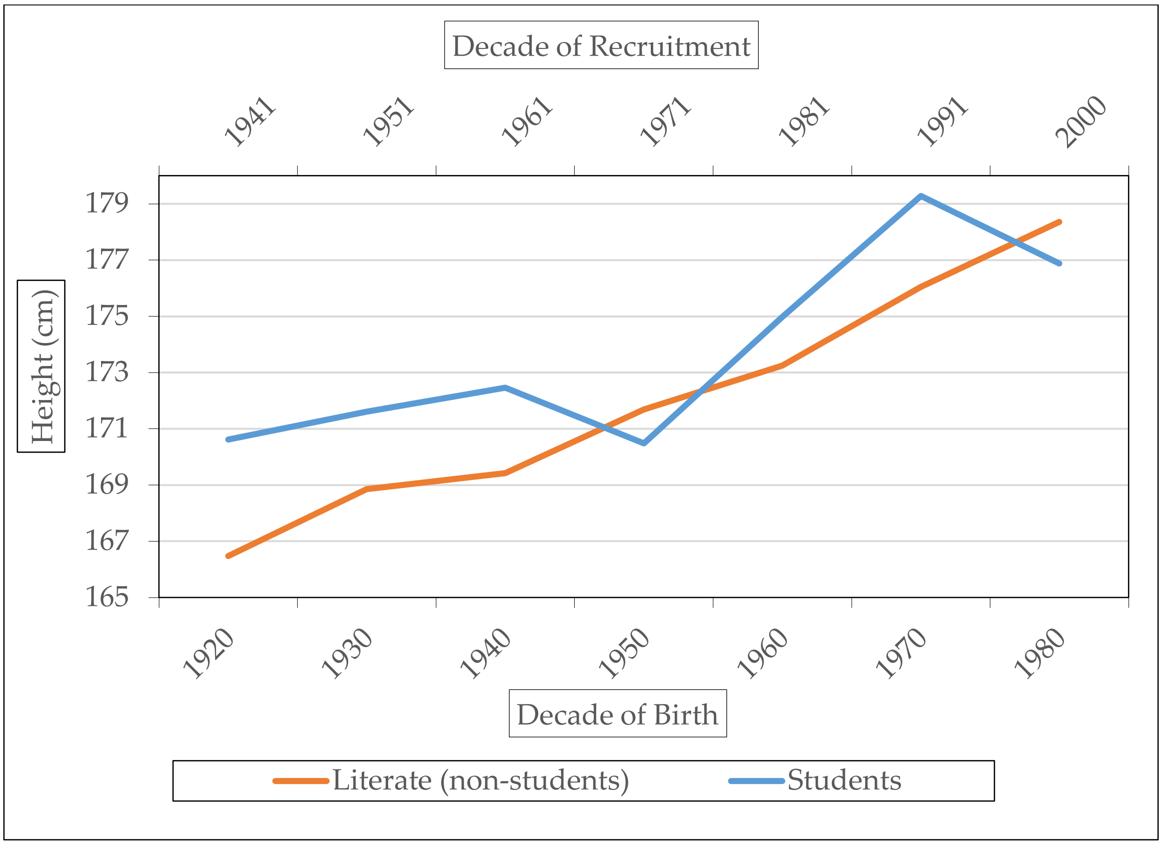
Table 3.5. Summary statistics by social class group (full sample)

	Height (cm)					BMI				
	N	Mean	SD	Min	Max	N	Mean	SD	Min	Max
Students	318	175.32	7.11	158	197	303	22.26	3.30	16	41
Non manual workers	174	173.36	6.95	156	190	165	22.22	2.69	17	32
Manual workers	350	171.68	5.99	152	198	332	22.50	2.62	15	33
Farmers	220	168.63	6.18	149	184	132	22.62	2.63	18	35
Farm workers	389	168.59	6.18	144	190	226	22.37	1.90	18	31
Total	1,451	171.39	6.97	144	198	1,158	22.38	2.70	15	41

Source: AMSB, ACDS. Own elaboration.

Another inequality dimension can be observed through educational attainment. Figure 3.12. shows the average height evolution for youths that can only read and write (literate population) compared to students aged 19–21 years, a population group with a higher educational level. In general, we observe an increase in average height for both groups over time. The differences between the two groups were important until the cohorts of the 1940s, and again in the 1960s and 1970s, which favored students. The exception in the 1950s is probably due to the fact that the number of individuals classified in the category of students is low.

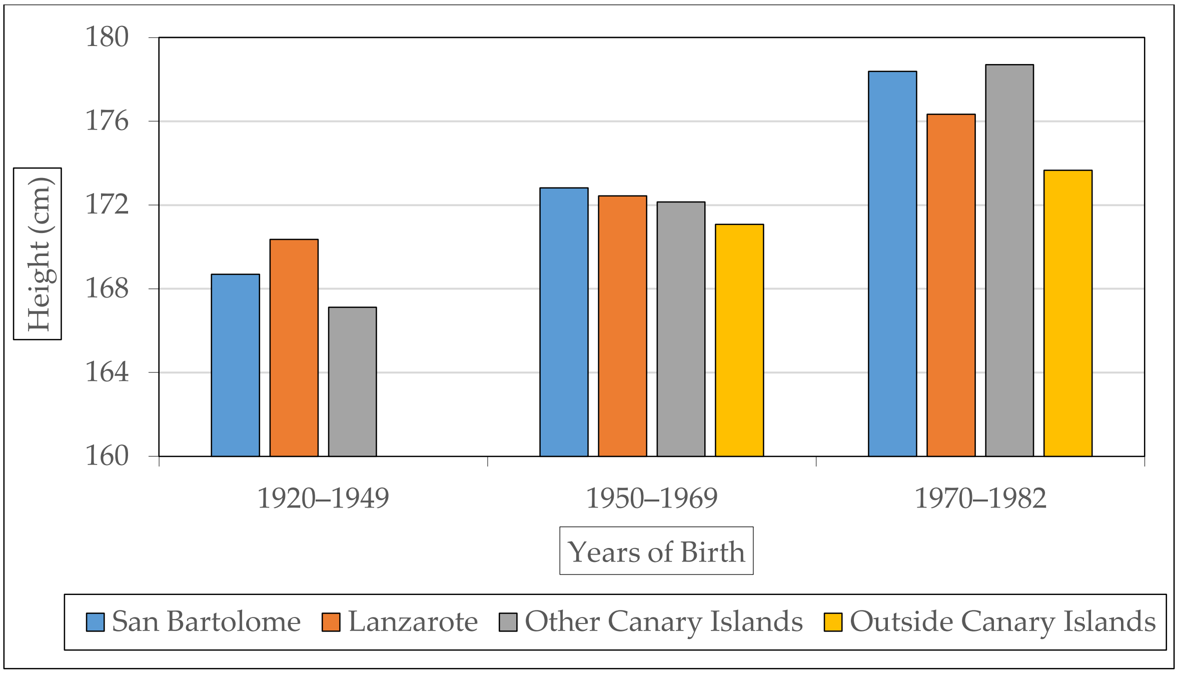
Figure 3.12. Average height by literate non-students and students by year of birth/recruitment



Source: AMSB, ACDS. Own elaboration.

Finally, Figure 3.13. shows the evolution of average height according to the place of origin, that we divide into four groups. Firstly, those born in SB (n = 1539), secondly, those born in Lanzarote but in a municipality different to SB (n = 225), thirdly, those born on a Canary Island different to Lanzarote (n = 55), and, lastly, those born outside the Canaries (n = 42). The data suggest that mobility among islands was present during the whole period and that immigration was noticeable in the last two decades of the 20th century. With height data, we observe an increase over time for all origin groups. Those born in the Canary Islands seem to be taller than those born outside the Canaries for the last two periods. In the period of the "economic miracle" (1950–1960) it stands out that those born in SB are somewhat taller than those from the rest of Lanzarote or the Canaries. Even in the 1970–1982 period, they present an average height somewhat higher than the rest of the individuals from Lanzarote, which indicates the good nutritional status of the population analyzed since 1950.

Figure 3.13. Average height by origin and year of birth



Source: AMSB, ACDS. Own elaboration.

3.5. Discussion

Preliminary investigations, some of them very early, with data from military records at a regional level had shown that the height of the male inhabitants of the Canary Islands was among the highest in the Spanish regions since the end of the 19th century (Quiroga, 2001, Martínez-Carrión, 1994, Cámara & García-Román, 2014, Martinez-Carrión & María-Dolores, 2017). More recently, case studies with data on male heights from military records, from recruitments from the municipalities of the province of Santa Cruz de Tenerife (Western Canary Islands) for the cohorts from 1870 to 1915, also confirmed the relative advantage of the male height of island populations versus peninsular Spanish populations. The set of anthropometric history studies suggested that the biological standard of living, an expression coined by Komlos (1993) from adult height, was somewhat higher in the historical populations of the islands than in those of the Iberian Peninsula. It should be noted that, until the middle of the 20th century, the average height of Spaniards was among the lowest of Western European people (Floud, et al., 2011, Martínez-Carrión & María-Dolores, 2017, Ogasawara & Yumitori, 2019). On the other hand, preliminary archaeological investigations carried out a long time ago with skeleton data from the ancient and primitive inhabitants of these islands (guanches) suggested that the nutritional status was also relatively favorable, since male heights easily reached 170 cm (Bethencourt Alfonso et al., 1991, Garcia-Talavera, 2016). However, the results obtained by physical anthropologists, in addition to referring to populations from more than four centuries ago, are very scarce and fragmentary. In any case, the investigations carried out to date from different fields pointed to the superiority of the male heights of the Canary Islands with respect to the average of those of the Spanish population. Environmental factors, such as climate and access to nutrients, are variables that explain the relative improvement in height and the biological standard of living of the populations analyzed. This paper yields important results that improve the knowledge of the anthropometric history of the Canary Islands for several reasons. It is the first study to address the evolution of height at the end of adolescent growth in the eastern Canary Islands during the nutritional transition and modernization. The 20th century witnessed dramatic changes in the economy and demography that affected the biological standard of living. With data from the municipality of SB on the island of Lanzarote, the easternmost island of the Canary Islands and close to the African continent, it addresses secular change in a transcendental period of Spanish economic and social history, from the end of the 19th century to the beginning of the 21st century. To do this, we use the male heights of the cohorts from the 1880s to the early 1980s. In addition, unlike previous studies that were more focused on male height, this study analyzes the body mass index with regularly available weight data since 1955. Thus, we discuss the effect of the nutritional transition in individuals and the effects caused by the improvements of economic well-being and of the diet on physical or biological well-being. This is important since we analyze a very broad historical period, at least with height data, which in theory extends from a context of malnutrition or deficient nutrition due to scarcity (late 19th century) to another of satisfactory nutritional status (late 20th century).

This study reveals that cohorts born at the end of the 19th century in Lanzarote were even somewhat taller than estimated averages for the Canary Islands as a whole. In the mid-1880s, the average height in the Canary Islands was 165.6 cm (Cámara & García-Román, 2014) while that of SB was 169.6 cm. If we compare the average of

Mediterranean Spain—currently, the most robust study on heights of Spanish populations—at the end of the 19th century, when the height deteriorates or stagnates almost everywhere and decreases in the case studied, the average of SB was relatively taller (166.7 cm), higher than that of the average Spaniard who was 163.6 cm (Cámara, et al., 2019)

The height differences between Canarian and Mediterranean men decreased with island emigration, a phenomenon that the Canary Islands suffered from the beginning of the 20th century. The difference became only 0.9 cm in the 1905–1909 cohorts. During the 1920s the difference was 1.5 cm and in the autarchy decade (1940–1949) it was 2.2 cm. In the 1960s, in the midst of economic modernization, the average height in SB was 1.4 cm higher than that of the Mediterranean man, who on average was 171.8 cm. At the end of the period, we can compare with the Spanish average provided by the INE. In the 1973–1982 cohorts, SB averaged 177.7 cm, with a difference greater than that of Spain of 3.4 cm. The data suggest that the gains were important for the lanzaroteños or conejeros. The divergence with the height of the Spanish widened in the second half of the 20th century. If we compare the male height in SB with the data available for the Canary Islands as a whole, we verify that the balance was also favorable to the analyzed population. Thus, the difference in the 1934 cohorts (1955 recruitment) was 1.3 cm, 2.9 cm in 1941, 1 cm in 1961 and 0.8 cm in 1981 (2000 recruitment). The Canary Islands were then in the first place in the Spanish regional ranking together with the Basque Country (Martínez-Carrión & María-Dolores, 2017).

As seen in other studies on the evolution of adult height, the main indicator of biological living standards (Craig, 2016, Komlos, 2019, Ogasawara & Yumitori, 2019, Quanjer & Kok, 2020), the SB data show a close relationship with the economic cycles of the island. At the end of the 19th century, the insular advantage was probably due to the improvements in foreign trade driven by the establishment of free trade. However, the turn of the century economic crisis impaired biological well-being. Emigration to Cuba and Venezuela deepened this deterioration in the first decades of the 20th century. Then, the divergence of biological well-being decreased compared to the rest (Canary Islands and Spain).

The situation has improved since the 1940 cohorts. The height growth trend reached its greatest upward inflection from the 1950s, in line with the strong economic growth in the "Spanish economic miracle" stage. The traditional economy, such as the fishing activity in the Saharan fishing grounds and the canning fishing industry, registered a strong impulse after their capitalization and a deep technological transformation in their catches and commercial transformation, generating employment and income gains (Cámara, et al., 2019, Odgen, 2002). However, the development of the tourist industry was the economic engine of the islands. In this context, important improvements in transport, communications and drinking water infrastructures stand out (Macías Hernández, 2009). The change in the economic model could have been the basis for the strong increase in height recorded between the 1940 and 1975 cohorts (Figure 5). The mean height increased 9.5 cm when it went from 169.9 to 179.4 cm. This was a large increase when compared to increases reported in other Spanish and European anthropometric studies (Komlos, 2004, Ayuda & Puche-Gil, 2014, Linares-Luján & Parejo-Moruno, 2021).

The environmental transformations and the economic growth occurred jointly with demographic and epidemiological changes that modified the mortality and fecundity patterns. For the discussion, it is interesting to focus on health indicators, such as mortality. Around 1901–1905, the average infant mortality rate in the Canary Islands was very high, 180.6 infants dead per 1000 that were born and, in the 1940–1945 period, it was 70.1 per 1000, having diminished more than a half (Dopico, 1985). Since the 1930s the sequence of the demographic and epidemiological transition of the islands has been well documented. According to INE data, infant mortality has decreased considerably since then. In 1940, 109.8 infants per 1000 born died before their first birthday in the eastern Canary Islands, the province of Las Palmas de Gran Canaria, and this rate was almost half in 1950, at 61.7 per 1000, and, in 1970, it was 30.4 per 1000. In 1991, the general gross mortality rate in Lanzarote was 14.6 per 1000 in 1940 and decreased to 7.2 per 1000 in 1956–1960, under the Spanish average that was 9.1 per 1000. In 1981–1985 it was 5.6 per 1000 against the Spanish rate of 7.7 per 1000 (Martón Ruiz, 1985). The environmental changes produced since the 1940s, without neglecting the effect of the islands' benign climate may have favored islander health in this period since the middle of the 20th century after the diffusion of antibiotics (penicillin), sulfonamides and compulsory vaccination in the 1960s. The infant mortality rates in 1940 and 1950 in the province were also slightly lower than the average in Spain.

Numerous studies show the long-term adverse effects of early exposure to a wide range of infectious diseases on health and socioeconomic outcomes in adulthood. In the past, infectious diseases related to poor water infrastructure and poor food conditions were responsible for high infant mortality mainly associated with diseases of the digestive system. Early exposure to infectious diseases and epidemics caused stunting. The intensity of exposure had an effect on the prevalence of stunting (Ogasawara & Inoue, 2021, Carson, 2020, Haines, Craig & Weiss, 2003). A statistical method to evaluate the growth and nutritional status of infants and adolescents with anthropometric parameters, such as height, weight and BMI, is the z-score (de Onis & Blössner, 2003). Disseminated by pediatricians and the WHO, z-scores have been used by historians and specialists to assess malnutrition and stunting in historical populations (Llorca-Jaña, et al., 2020, Salvatore, 2020, Salvatore, 2019). In the population analyzed, stunting is irrelevant.

Another health indicator that, like infant mortality, is inversely related to height is life expectancy (Marco-Gracia & Puche, 2021, Fogel, 1994). In the eastern Canaries, life expectancy at birth was 51.2 years in 1940, while in Spain it was 50.1 years. Thirty years later, in 1970, it stood at 71.9 and 72.4 years, respectively. Spanish populations improved their standards of living and health as measured by this indicator during the years of outstanding economic growth. For later dates, the dynamics of life expectancy at birth in men and women are better documented. For the former, it went from 69.9 years in 1972 to 74.7 years in 2000, somewhat lower than the Spanish averages, 70 and 75.6 years, respectively (Blanes, 2007). However, in any case, the Spanish are among the people with highest gains in longevity (Guijarro & Pélaez, 2008). The combination of social, economic, sanitary and epidemiological improvements explains the evolution of life expectancy and they are also behind the increase in height. It would be interesting to explore the role of these two indicators with more precise data from the island and the population analyzed to explore the relationships established between health and anthropometrics. We cannot rule out that the relative insular geographic isolation also became a relative advantage in the face of epidemics that frequently sowed disease and death in the peninsular populations. However, this matter requires further study.

Diet also contributed to the improvement of their nutritional status. The data show that the height analyzed in Lanzarote was as high or higher than the averages of the Canary Island inhabitants as a whole throughout the 20th century. Likewise, we know that the Canaries were, together with the population of the Basque Country, the tallest populations in Spain, where the consumption of meat and especially milk was decisive at the beginning of the 20th century (Muñoz-Pradas, 2011). An abundant body of literature shows that the consumption of animal proteins, mainly milk and meat, determines the nutritional status in the two critical stages of child growth: childhood and adolescence (Tirtasaputra, Puspasari & Lucretia, 2019, Bogin, 2020). Milk is a complete and well-balanced source of the nutrients and energy necessary to ensure child growth and development (Wiley, 2014). Evidence suggests the positive effects of dairy products and particularly milk proteins on post-neonatal linear growth even in adolescents, who could regain some of the growth lost due to malnutrition in critical phases of childhood (Yackobovitch-Gavan, Philipp & Gat-Yablonski, 2017, Herber, Bogler, Subramanian, Vollmer, 2020).

We do not have precise data on the evolution of animal protein consumption for the case analyzed, not even for the island or the whole of the Canary Islands, but we do have some data that confirm the high consumption of calcium derived from milk among the Canary Island inhabitants. In addition to high levels of energy, protein and micro and macronutrients, milk contains calcium and insulin-like growth factor 1, which are of great importance for the development and growth of children (Herber, et al., 2020). Recent studies on the evolution of dairy consumption in Spain show its growing importance from the first decades of the 20th century and especially since 1960 (Muñoz-Pradas, 2011, Adell, Pradas & Pujol-Andreu, 2019, Pujol & Cussó, 2014, Collantes, 2020). In Lanzarote and other Canary Islands, there were advances in sheep and goat farming, as well as pigs, and the consumption of milk from goats of the *majorera* breed has been well documented since the 15th century (Ministerio de Agricultura, Pesca y Alimentación). In the mid-1960s, an investigation carried out on nutrient needs in Spain revealed that the province of Las Palmas de Gran Canaria, which includes the island of Lanzarote, stands out for its high consumption of milk calcium with the highest proportion in Spain, including the western Canary Islands (Varela Mosquera, García Rodríguez & Moreiras-Varela, 1991)

In addition to calcium from dairy products, one must consider fish consumption which has traditionally been high in the region due to its favorable local income. Finally, a nutritional singularity of the island of Lanzarote is gofio, a product made from ground flours of various toasted cereals, generally wheat and corn or millet, introduced from America. This food preparation carried out mainly in flour windmills, very typical milling devices of the island of Lanzarote (Figure 3.14), spread in the 19th and early 20th centuries, also using barley, wheat and even lentils. Due to its high nutritional content, it became the basic food of the Canary Island peasant inhabitants and was essential to alleviate the times of famine that the archipelago suffered in successive periods. SB became one of the great gofio-producing centers from the mid-19th century (Diario de Lanzarote, 2017).

Figure 3.14. Flour mill of SB (1870), erected by Baltasar Fermín and acquired by José María Gil in 1919, today declared a Site of Cultural Interest (BIC)

3.6. Conclusions

This paper's findings can be summarized as follows. Firstly, the height trend is in line with what we know about average heights for the Canarian Island inhabitants, who have historically been taller than the average in the Spanish population in the 19th and 20th century. The data suggest that the biological well-being of the Canary Island inhabitants was slightly healthier than those of the Iberian Peninsula. Secondly, the evolution of height was not linear for all social groups. Inequality persists at the beginning and the end of the period, and results based on coefficients of variation (CVs) and percentiles even show an increase in inequality levels from the 1960s until the end of the 20th century.

This article provides knowledge on the evolution of the physical well-being of the Spanish Atlantic populations. Based on a case study of the eastern Canary Islands, the findings show the impact of socioeconomic processes on the biological standard of living and inequality. They also show the importance of the relationships between physical growth and economic growth, such as the nutritional and epidemiological transition. Among the main determinants of the advantage of the Canary Island height with respect to that of the Iberian Peninsula, the uniqueness of the diet and the improvement of environmental conditions stand out. The findings are important for the implications for economic history, but also for physical anthropology that analyzes plasticity and biological variability.

We can state that the definitive prevention of any manifestation of malnutrition (serious or chronic) might be due the improvement of the diet and hygiene and the distribution of drinking water, among others factors, since the beginning of the 1960s and also because of the increases in BMI.

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CHAPTER 4
Biological well-being in the Basque rural area as a reflection of the urban area, 1860s-1960s

4.1. Introduction

Studies on biological standards of living based on data of the male population show that the Basques were among the tallest in the Spanish peninsula at the end of the nineteenth century and beginning of the twentieth century. They also indicate that the rural areas had better anthropometric records than the urban environment, at least in Biscay at the beginning of the Basque industrialization process. How large did the rural-urban gap become with economic growth and subsequent industrialization in the Basque Country? Was the rural advantage over the urban Basque area maintained? Was there a convergence of the two environments (rural and urban) with industrialization and economic growth?

In this study we attempt to answer these questions by extending the analysis to the whole of the twentieth century. First, we review the recent historiography on the rural-urban gaps in height and Spanish anthropometric history. The interest in researching the Basque population and the importance of investigating the Basque advantage of net nutritional status are highlighted. Next, we present preliminary results on the evolution of heights in the rural and urban environments with data from Biscay, exploring the socioeconomic inequalities. The study based on data of non-standardized heights and at different ages shows that the differences between the two environments, observed during the Industrial Revolution in the decades of 1880-90, in which the rural population prevailed, persisted until the cohorts born in the 1940s. Among the determining factors, we can highlight that the improvements in nutrition and health in the rural environment were due to access to nutrient sources (mainly proteins) and, among others, an institutional framework that was more favorable to human well-being than that provided in the villages. The study extends to the cohorts born in the 1940s, in order to test whether the improvements in living standards produced by industrialization and economic development led to the convergence of human well-being.

4.2. The rural-urban gap in height during economic growth

Anthropometric history has documented the existence of urban-rural gaps in stature that reveal notable differences in living standards and nutritional health, at least since the onset of industrialization and urbanization. In the long term, heights exhibit a wide variability in both the rural and urban environments. However, at the beginning of the Industrial Revolution the decrease in urban height was noteworthy, when industry took off and urbanization accelerated, mainly in Great Britain and the United States. Studies on the first industrialization in Great Britain show the advantage of the rural area, although with contradictory results depending on the level of geographical detail in the definition of rural areas and according to the nature of the anthropometric records studied: recruits, soldiers, marines, volunteer soldiers, convicts, or those including women and schoolchildren. The average height in many of the English cities and industrial areas was usually below the average rural heights, with episodes of 'urban penalty' being documented even in small and medium-sized cities (Cinnerella, 2008a). Higher rural heights have been associated with better access to fresh food (or at least cheaper than in the urban world) and lower exposure to endemic infections in towns and cities, which are more prone to infections due to demographic pressure caused by concentration and mobility (Komlos, 1998).

In the European continent, the findings paint a more diverse rural anthropometric picture. In Flanders, rural biological living standards were more favorable than in coastal and urban areas (Depauw, 2018, Kok, Beekink, Bijsterbosch, 2018). Until well into the nineteenth century, the less market-oriented, rural inland Dutch regions enjoyed higher biological standards of living, but by the early twentieth century, the urban penalty disappeared and was replaced by the urban premium, at least for the small and medium cities (Tassenaar, 2019). In many parts of rural Europe there were situations of nutritional stress at least until the mid-nineteenth century. This was the case in some German states between the beginning and the middle of the nineteenth century. (Baten, 2000, Ewert, 2006). In Saxony, the decline in height observed in the first half of the nineteenth century was much more pronounced in rural environments than in urban areas, despite the advantage of the former in the late eighteenth century (Cinnerella, 2008b). In the subalpine region of Bavaria, in the decades prior to 1840, height also decreased in predominantly agricultural areas (Lantzsch & Schuster, 2009). In the mid-nineteenth century, in the small towns of eastern Belgium, poverty was widespread and explains why the average heights in the rural world were very low, around 160 cm (Alter, Neven & Oris, 2004). The prevalence of nutritional status, poverty and malnutrition was most widespread in many rural populations of southern and eastern Europe. The shortest stature is so far documented in the Mediterranean island of Sardinia (Manfredini, Breschi, & Mazzoni, 2017). The Sardinians have the shortest mean body heights of the ethnic groups documented to date (Pes, Tognotti, Poulain, Chanmbre & Dore, 2017). Since the mid-nineteenth century, the heights of rural areas have tended to grow in almost all European regions and, despite large local variations, they converged in the early decades of the twentieth century (Heyberger, 2007).

In the long debate regarding living standards during the Industrial Revolution, pessimists claim that deteriorating health conditions in cities undermined the positive effects that rising real incomes had on biological standards of living. Recent studies using comparative data for British, European and American cities and selected rural populations find abundant evidence of widespread increases in mortality between 1830 and 1870. The phenomenon mainly affected the infant population, with scarlet fever being one of the main causes of death, among other infectious diseases, and was not limited to 'new' or industrial cities. Anthropometric evidence from military recruits suggests that the decline in height up to the 1870 cohorts was a widespread phenomenon, even in rural settings. The ubiquity of observed patterns in urban and rural highlands up to 1870 indicates that the decline in the biological standard of living was not directly a function of urbanization or industrialization (Davenport, 2020).

In rural areas with a poor transport infrastructure, it has been found that the cohorts born in the 1860s show a significant deterioration in nutritional status as a result of the impact of agricultural crises and epidemics. The effects of the last subsistence crises may have had a negative impact on height, as reflected in the decline of almost two centimeters in the average heights of those born in the central provinces of the Russian empire between 1851-55 and 1861-65 (Lebedeva, Groth, Hermanussen, Scheffer & Godina, 2019). Although after the official decree on the abolition of serfdom, male height began to increase by 3 to 4 cm over the next thirty years (Mironov, 2012), another episode of nutritional deterioration was recorded among Russian peasants born in 1891-95, possibly larger than the previous one. Some studies analyze the effect of the liberal reforms of the second half of the nineteenth century in Central and Eastern Europe, and reveal that the end-of-the-century agrarian crisis could have been due to the cessation of height growth in the generations born after the mid-nineteenth century from 1880 in Poland and elsewhere (Kopczyński, 2007, 2011).

On the other side of the Atlantic, most anthropometric studies from the United States reveal a decline in nutritional status that affected rural heights in the decades before the Civil War (Komlos & A'Hearn, 2019, Zimran, 2019). One group that was exempt from declining nutritional status was that of self-sufficient farmers, isolated from the effects of rising food prices by not being integrated into the commercial economy and producing their own food (Sunder 2004). This deterioration in net nutrition lasted until the end of the nineteenth century, but it is noted that rural heights were somewhat higher than urban ones. The effect of rural settings on height is illustrated by the fact that agricultural workers were taller than ordinary workers (Carson, 2015a). The body mass index of those living in agricultural conditions was higher than that of individuals living in urban conditions due to proximity to nutrients and increased net nutrition as a result of the decline in the relative price of food during the turn-of-the-century agrarian depression (Carson, 2015b, 2019). Adult slaves on southern cotton plantations constituted another group with an adequate nutritional intake for efficiency and labor productivity on the part of the owners (Steckel, 1986a, Carson, 2009, Haines, Craig & Weiss, 2011, Komlos, 1998, 2019).

Diversity is also documented in the processes of reducing the urban-rural gap. The divergence of biological well-being between the two environments has been reduced in recent times. Heights converged during the interwar period and especially after World War II in high-income countries, but environmental differences, especially in child height, persisted in developing countries (Fox & Heaton, 2012, Paciorek, Stevens, Finucane & Ezzati, 2013, Zhang, Wang & Wang, 2019). In these countries, the rural areas have been shown to be at a disadvantage compared to urban areas due to the scarce provision of health infrastructure and the problems of financial and physical access to healthy food (FAO 2018). Rural undernutrition in poor countries and regions is well documented in terms of wasting and stunting and, in recent decades, in the increase in overweight and obesity (the double burden of undernutrition) indicating nutrient deficiencies and excessive consumption of low-quality calories (Tzioumis & Adair, 2014, Akombi, Chitekwe, Sahle & Renzaho, 2019, Bixby, Bentham & Zhou, 2019, NCD-RisC 2019, Grosso, Mateo, Rangelov, Buzeti & Birt, 2020).

In recent decades, our knowledge of urban-rural differences in Spain has improved considerably. The findings offer a fairly rich and nuanced view of the impact of socioeconomic processes on net nutrition and physical health in the short and long term, especially urbanization and industrialization processes. Various studies have shown that the gap was pronounced until well into the twentieth century in favor of the urban environment. In the southeast of Spain, for example, where the municipal districts are territorially extensive and are among the largest in the country, we can observe more clearly the differences between the urban nucleus or head of the municipality (village, city or capital) and the rural area, composed of small populations of concentrated habitats (villages and farmhouses) or scattered habitats, mainly in orchard areas. Thus, within the same municipality, even characterized as rural due to the weight of its active population, we find strong differences in height between the "urban" area and the rural one. During the nineteenth century, in most municipalities the urban-rural differences were significant and in some the gap reached up to four centimeters, always in favor of the urban environment (Martínez Carrión, 1994, Martínez Carrión & Pérez Castejón, 1998, 2002, Martínez-Carrión, Pérez-Castroviejo, Puche-Gil J & Ramón-Muñoz, 2014). Within the municipality of Murcia, some rural areas with orchards with a high prevalence of malaria (the rural districts closest to Bajo Segura) had differences of up to 7 cm in relation to the city average. Also, in the municipality of Cartagena, there were notable contrasts between the city and the extensive rural world, including the mining districts, which had among the lowest average heights in Spain, at least as far as we know (Martínez Carrión, 2004).

In regions with higher GDP per capita and greater industrial development, the rural penalty was lower, although this depended on time and place. In the case of Catalonia, the studies carried out by Ramon-Muñoz (2009, 2011) and Ramon-Muñoz and Ramon-Muñoz (2016, 2018) show that in around 1850 the heights of rural boys in Western Catalonia were higher than those of residents of certain urban and industrial areas. On the other hand, between the 1860s and the early years of the twentieth century, the heights of the former tended to diverge from those of the latter, in part due to the stagnation of heights in the rural areas during the second half of the nineteenth century. Ramon-Muñoz and Ramon-Muñoz (2021) finds that of the cohorts born in 1890, the heights of the conscripts who lived in the rural areas were lower than those who lived in towns with more than 20,000 inhabitants. For the Basque Country, the contribution of Pérez-Castroviejo and Martínez-Carrión (2018) shows that the gap was favorable to the rural areas, before and after the industrial upsurge that took place at the end of the 1870s. The authors attribute the taller heights in the countryside than in the city to the availability and proximity to the sources of nutrients, mainly animal proteins (meat, milk and cheese), and the benefits and functionality of institutions with strong agrarian roots such as the Basque farmhouse. In any case, in Catalonia and in the Basque Country before the Civil War (1936-39) there was a favorable trend towards rural-urban convergence: among the Catalans due to advances in the rural world and among Basques due to the achievements of the urban environment. In the Region of Valencia, the anthropometric picture between rural and urban populations was also varied, with notable contrasts and differences depending on the industrial nature of urban areas (Puche, 2011, Ayuda & Puche, 2017).

Some long-term analyses explore the differences in heights in rural environments of the same region. Puche, Ayuda and Martínez-Carrión (2018) verify that the processes of productive specialization according to the type of agriculture (rainfed or irrigated), with different agricultural yields, show disparate results of nutritional status. This is the case of the Valencian countryside: with a more intensive, diverse and higher productivity of agricultural production, the irrigated areas registered the tallest heights compared to the dry lands, which recorded the lowest values. It is suggested that the differences are probably attributable to the different availability of resources and productive diversification, to the size of the farms and agricultural productivity, but also to different degrees of socioeconomic inequality in one area or another.

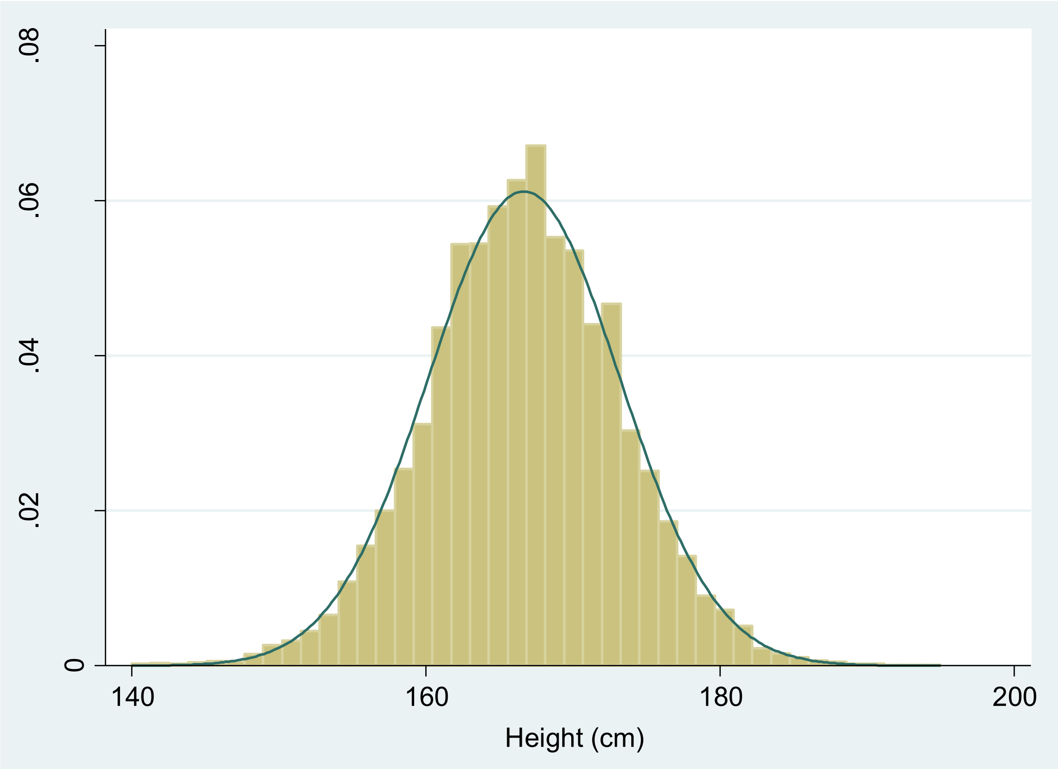
The penalty of rural height is noted in the poorest regions despite the fact that the differences with the urban areas reduced over time. Recent studies carried out on the heights of young men from Extremadura born between 1855 and 1979 (recruits from 1876 and 2000) confirm the urban advantage over the rural environment throughout the entire period (Linares & Parejo, 2020, 2021). The differences found for the nineteenth century were not as extreme as those of the southeast, probably due to the extension of poverty in the region that even affected the urban areas. The results show that the height of recruits in cities and large towns was always higher than that of the recruits in towns and small towns. The average difference was 1.3 cm, although it exceeded 2 cm between 1875 and 1884. On the other hand, it was also found that the difference increased not only throughout the agrarian crisis at the end of the century, but also during the 1920s, a decade in which the negative effects inherited from the First World War converged with the perverse consequences of the Spanish Civil War and the postwar period (Linares & Parejo, 2020). The municipality of Hellín in Castilla-La Mancha, with a strong rural component and which converges with Murcian lands, had extremely low biological living standards until the mid-twentieth century and the urban area had a clear advantage over the village environment until 1980. At the beginning of the 1960s, the average rural height was 163 cm, similar to that of the early twentieth century, revealing the extent of rural poverty and malnutrition at the beginning of modernization. The advances were notable in the following two decades but insufficient to reach the national average, which was above three centimeters (Cañabate, 2016, Cañabate & Martínez Carrión, 2017).

There is a wealth of historical evidence on the evolution of the rural-urban gap in adult heights for a good part of the country. The best known territories, in this respect, continue to be mainly those of the southern and Mediterranean regions. However, the rural-urban areas and their differential dynamics in northern Spain are less well known. This study on the rural-urban gap in the Basque province of Biscay seeks to contribute to filling this gap, at least in the context of a highly industrialized region. In addition, the region is characterized by high levels of education and good health indicators. The analysis focuses on the long term, which allows us to observe the trends and processes of change, taking into account well-defined economic and political conjunctures, with the change of regime after 1939. The study of the nutritional status in both environments includes anthropometric measurements used in the comparison of reference patterns on growth. This is the case of percentiles, which provide information on the distribution or the percentage of the population that is above and below the average. Meanwhile, the z scores (Z-score) indicate, for a given measure, the distance from the mean value.

4.3. Data and methodology

This study analyzes differences in the height of young men called up to military enlistment between 1876 and 1969 in different towns of the Basque Country. The sample contains information on young men from three municipalities located in rural areas: Amorebieta, Bermeo and Dima (N=7,323) and from three municipalities located in an urban environment: Portugalete, San Salvador del Valle and Sestao (N=17,298). Figure 4.1. presents the height distribution for the whole sample under analysis.

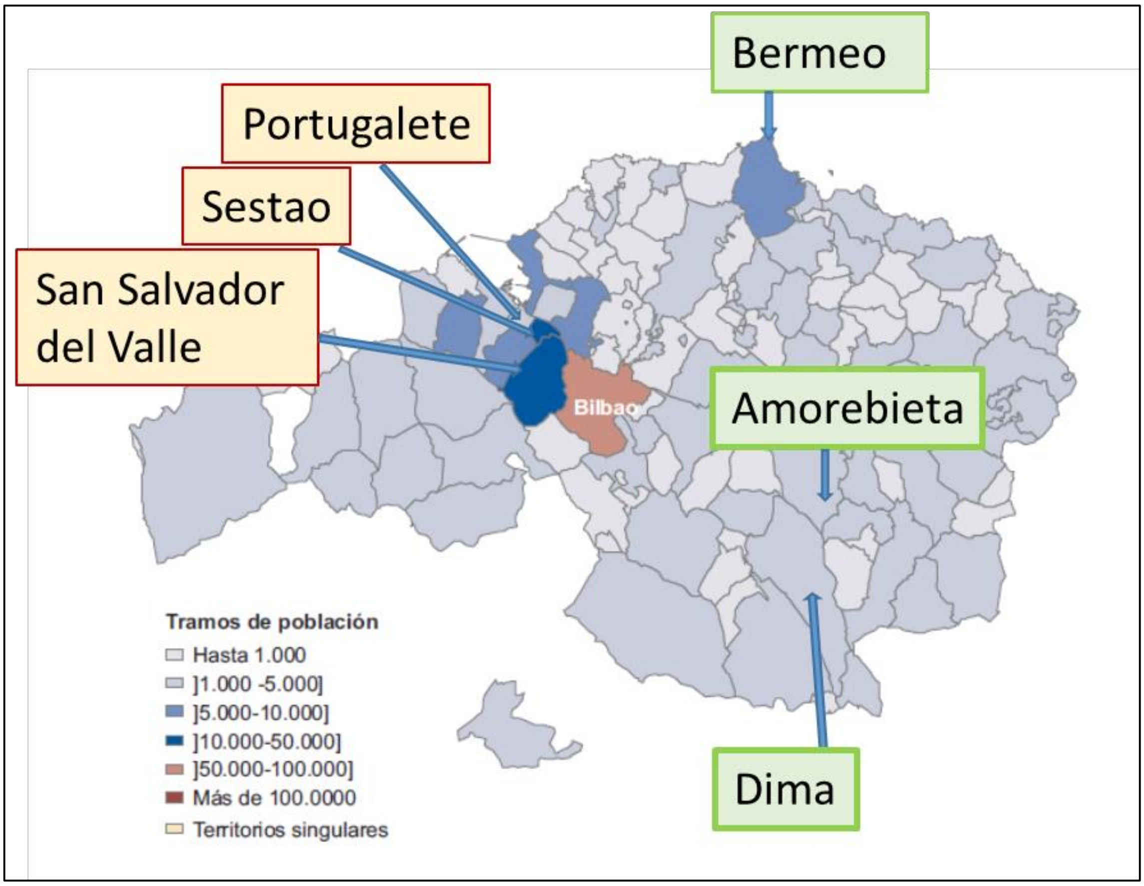
Figure 4.1. Histogram standardized heights at age 21, 1878-1969



Source: Own elaboration based on *ACDS y Expedientes Generales.*

Table 4.1. shows the descriptive statistics of the heights of these recruits measured in each of the six municipalities and grouped into two categories according to rural or urban environment. The sample is made up of a total of 24,621 observations, 30% of whom came from rural environments and 70% from urban areas. We assume that heights have not been standardized at the age of 21 years, which affects the data and trends of the cohorts born in the nineteenth century. Figure 4.2. presents the location of the six municipalities of the sample in the province of Biscay.

Figure 4.2. Map of Biscay with the municipalities of the sample analyzed and their population in 1900



Source: La población de Vizcaya. Cuadernos Fundación BBVA. Available in www.fbbva.es

Table 4.1. Descriptive Statistics

	N	Mean	Median(cm)	SD	Min	Max	CV	% over total sample
Amorebieta	3348	1679.99	168.00	64.288	1407	1888	0.038	13.60
Bermeo	2354	1657.22	165.72	70.211	1400	1900	0.042	9.56
Dima	1621	1663.83	166.38	62.604	1400	1900	0.038	6.58
Rural	7323	1669.09	166.91	66.681	1400	1900	0.040	29.74
Portugalete	4981	1671.71	167.17	66.905	1400	1950	0.040	20.23
San Salvador	3808	1649.08	164.91	65.220	1400	1880	0.040	15.47
Sestao	8509	1664.00	166.40	64.145	1400	1910	0.039	34.56
Urban	17298	1662.94	166.29	65.680	1400	1950	0.039	70.26
Full sample	24621	1664.77	166.48	66.038	1400	1950	0.040	100

Source: Own ellaboration based on *ACDS y Expedientes Generales*.

The main source of data for this study is the Acts of Classification and Declaration of Soldiers (ACDS, hereafter) and the Personal Records of the fifth section of each of the selected municipalities. The series begin with the young men measured in the 1876 enlistment at the age of 20, which corresponds to those born in 1856, and extends to the 1948 cohort, measured in the 1969 enlistment at the age of 21. In addition to the heights of the conscripts, military records sometimes offer information on the occupation of the recruits. In total, we have 1,909 recruits with identified occupations, this means information on the occupation for 20% of the total sample. Table 4.2. presents the percentage of individuals by economic sector and replacement cohort groupings every 20 years.

Table 4.2. Percentage of the sample size by productive sectors and birth years of cohorts

	1850-1869	1870-1889	1890-1909	1910-1929	1930-1949
Primary Sector	50.63	24.08	22.44	13.38	8.59
Farmers	100	100	100	99.48	95.73
Farm workers				0.52	4.27
Secondary Sector	38.88	64.32	61.67	67.47	64.33
Construction	21.86	5.48	6.51	9.22	17.35
Wood	15.35	5.71	6.93	6.30	5.46
Metal	3.26	2.28	16.52	22.13	30.29
Textile and footwear	8.37	2.05	2.10	2.31	1.63
Other	51.16	84.47	67.95	60.04	45.28
Tertiary Sector	10.49	11.60	15.88	19.15	27.08
Business and services	74.14	62.03	66.30	66.97	58.03
Professionals and students	25.86	37.97	33.70	33.03	41.97
No information available	67.72	86.24	68.66	69.91	79.05
Total of observations	1713	4950	7392	9615	9113
Available	553	681	2317	2893	1909

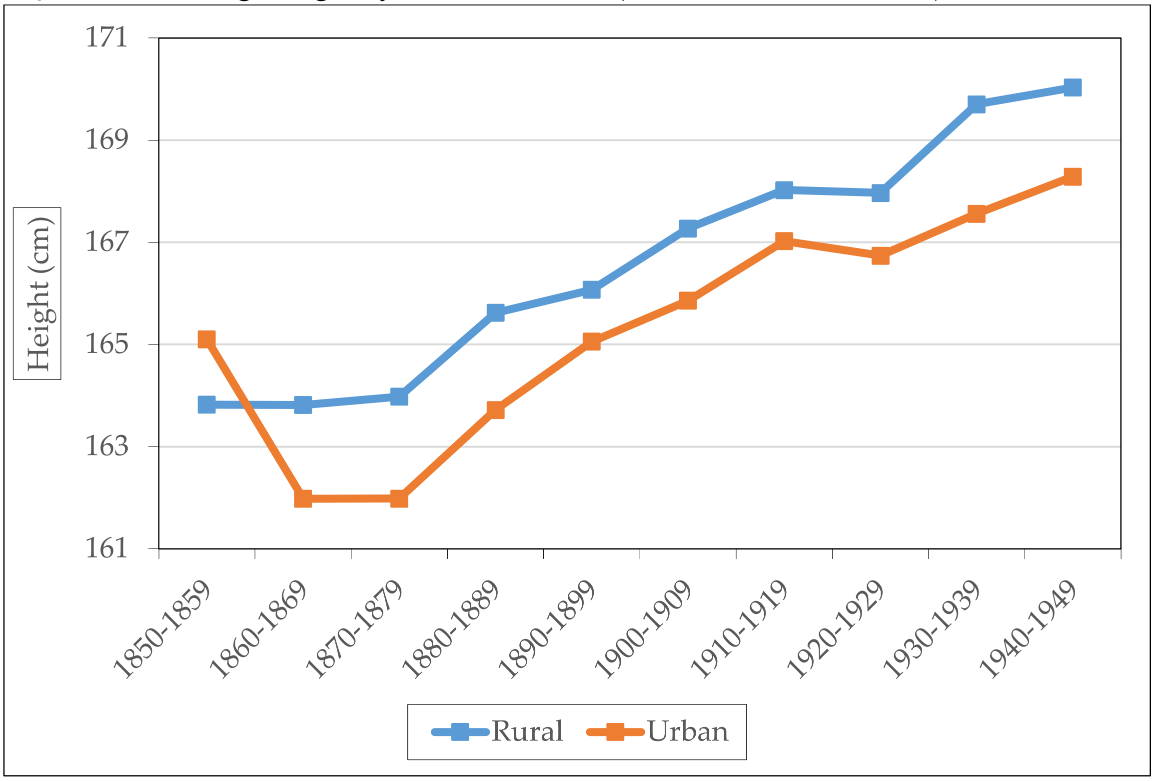
Source: Own elaboration based on *ACDS y Expedientes Generales.*

When we analyze the evolution of the weight represented by the occupations of the recruits in the three economic sectors of the economy, we can observe that for those born between 1850 and 1869, when they were called up, around 50% carried out an activity in the primary sector. This percentage halved in the final decades of the nineteenth century and the number of young men born between 1930 and 1949 who declared to be employed in an activity in the primary sector represented less than 10% of the sample. The secondary sector is the main beneficiary of the transfer of workers born in the second half of the nineteenth century from the primary sector. While 39% of the group of cohorts born between 1850 and1869 were employed in the secondary sector, of those born between the final decades to the nineteenth century and the end of the first half of the twentieth century, those working in this sector represented more than 60% of the sample. The tertiary sector incorporated workers more gradually, tripling its weight throughout the century from 10% to 27% between the cohorts born in 1850 and 1949.

4.4. Results

This section includes the main results of this case study research. Figure 4.3. shows the evolution of the average heights of young men born between 1850 and 1949, according to area of origin. The average height of the recruits from rural areas displays an upward trend for the entire period of our study, although there is a stagnation in height among the cohorts born during the first decades of the twentieth century. This stagnation in height is also observed for young men from urban areas. From the beginning of the 1860s until the last decade of our analysis, 1940, the average heights of recruits from urban areas were always below those of young men from rural areas. In the final decades of the nineteenth century and the beginning of the twentieth century, this difference was around one centimeter, but doubled for the cohorts born during the civil war and the following years. Therefore, we can observe that for the last birth cohorts of our study, the gap in height between the rural and urban areas increased significantly.

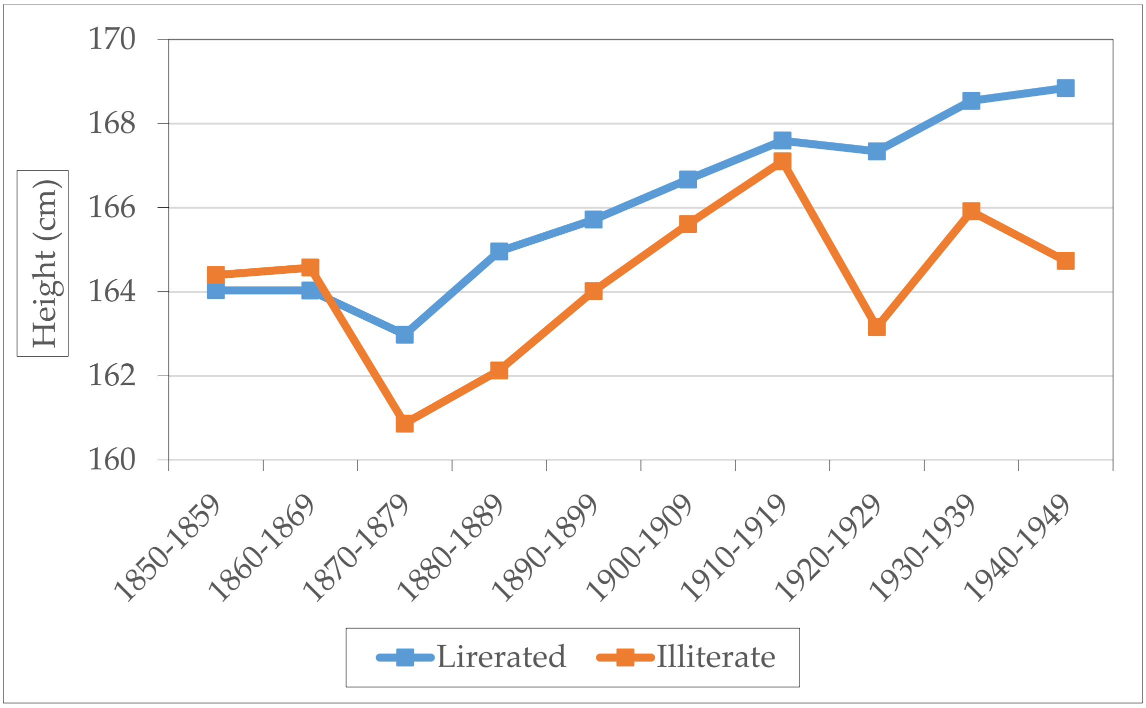
Figure 4.3. Average height by rural/urban area (birth cohorts 1850-1949)



Source: Own elaboration based on *ACDS y Expedientes Generales.*

In addition to the occupation of the conscripts, the military records also include information on the level of literacy of the recruits. Figure 4.4. shows the evolution of the average heights of the conscripts according to their literacy level.

Figure 4.4. Average height by literacy level (birth cohorts 1850-1949)



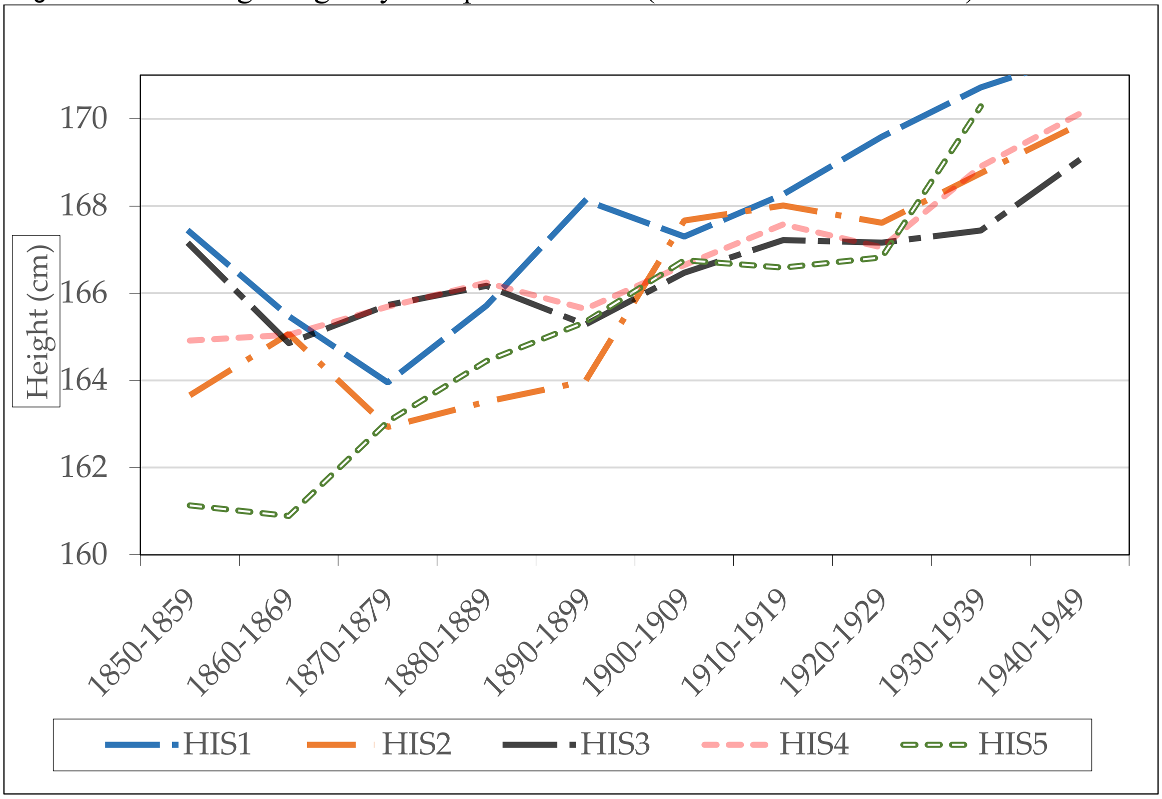
Source: Own elaboration based on *ACDS y Expedientes Generales.*

There was a difference of over two centimeters in the average height of cohorts born between 1870 and 1889 between those who could read and write and those who could not. This difference was even greater for some cohorts born in the twentieth century, for example, those born in the 1920s who knew how to read and write had a height advantage of more than four centimeters compared to their non-literate counterparts. This difference can also be observed in those born in the 1940s. However, it should be noted that, for the last cohorts of our study, the number of cases of illiterate conscripts reduced considerably. This scarcity of observations also occurs for the 1850s, for when there are few observations of the two educational categories, so graphic interpretations must be considered with caution.

Figure 4.5. shows the evolution of the average heights by occupational level. These groupings have been made taking into account the HISCLASS classification. The first category (HIS1) is made up of professionals and technicians. The second category (HIS2) includes occupations related to administration, management, clerks and civil servants. The third category (HIS3) is made up of sales and service workers. The fourth

category (HIS4) includes agricultural and forestry workers and the fifth and final category (HIS5) production and transportation employees.

Figure 4.5. Average height by occupational level (birth cohorts 1850-1949)



Source: Own elaboration based on *ACDS y Expedientes Generales*.

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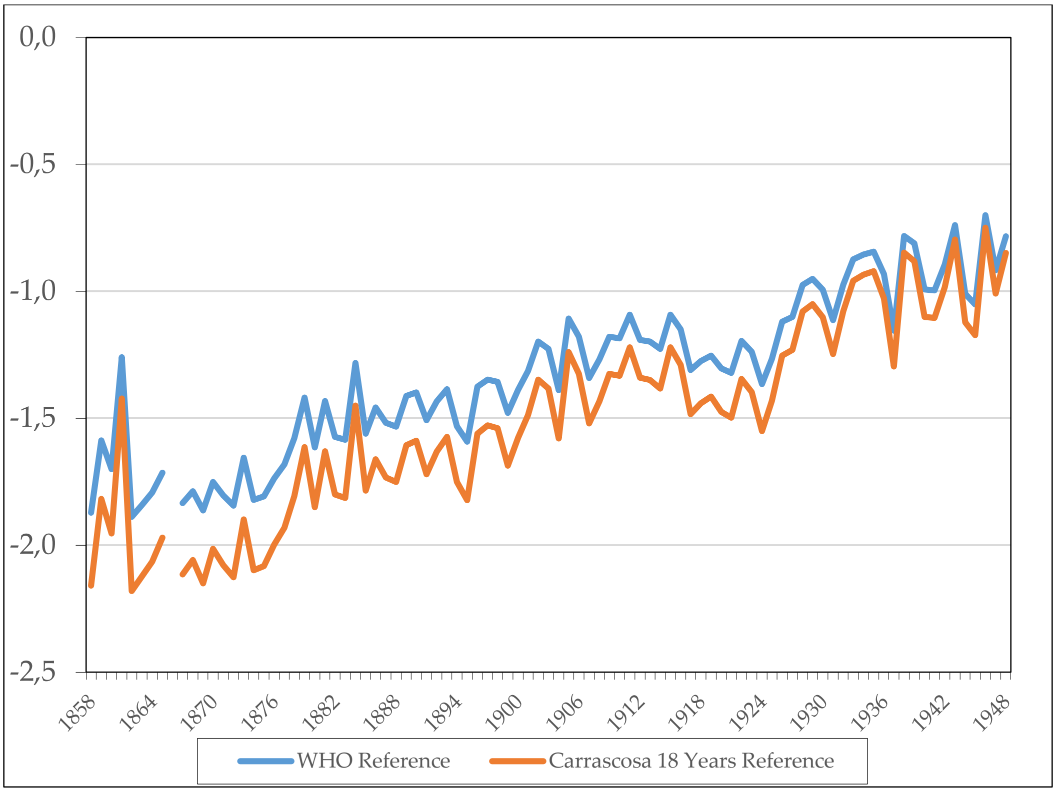
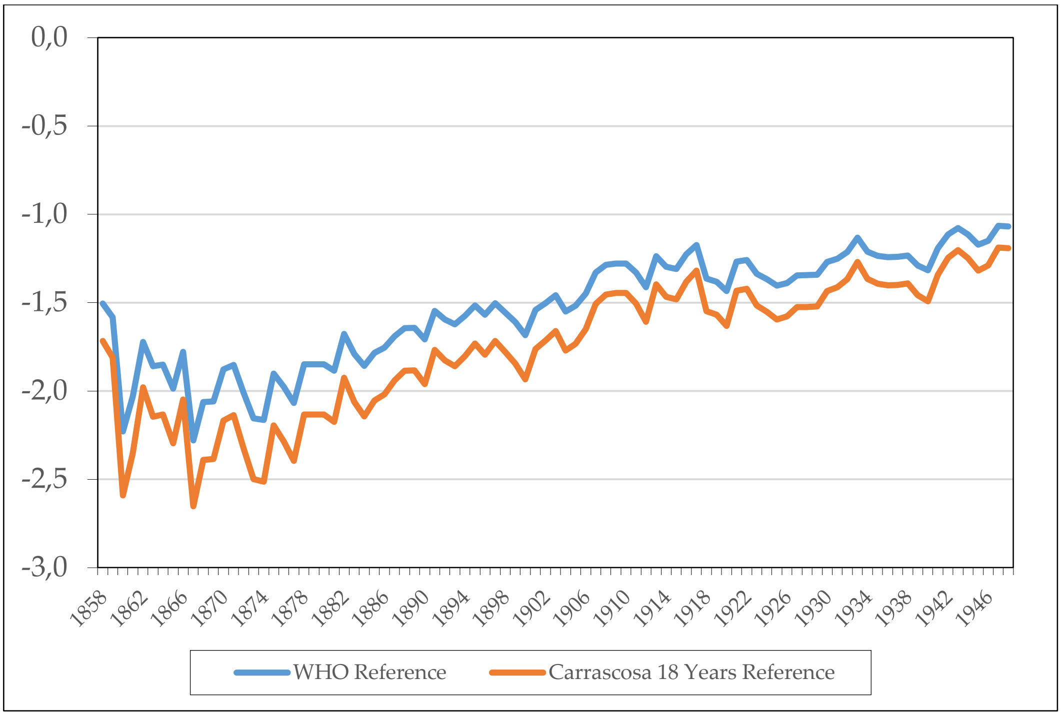
The evolution of average heights by occupation level shows a certain convergence in the trends over time. The greatest differences in mean heights are found in the first decades of the second half of the nineteenth century. But as the twentieth century progressed, a reduction in the differences in mean heights by occupational level can be observed. It is noteworthy how the average height of the recruits included in the last occupational category (HIS5), experienced rapid growth until it reached the average height of the highest occupational category (HIS1) for the last birth cohorts for whom information on occupation is available.

Figure 4.6. presents the annual height for age z-scores (HAZ, hereafter) trends for the rural and urban subsamples using the international reference values proposed by the WHO, 2007 at 19 years and also according to national reference values for the male population, Carrascosa et al. (2008).

Figure 4.6. Height z-scores rural/urban (birth cohorts 1850-1949)



(a) Rural



(b) Urban

Source: Own elaboration based on *ACDS y Expedientes Generales.*

Figure 4.6A shows that height z-scores take values of around -1 and -2.5 standard deviations from the reference values of the national and international references for the rural subsample. Using the national reference, malnutrition was present in the rural area between 1858 and 1878. Furthermore, the z-scores are over -2, reflecting that malnutrition was not relevant in later decades. In the last years studied, HAZ values are over -1 and there is a significant reduction in HAZ values over time. In the case of the urban area, Figure 4.6B shows that malnutrition was present using both the national and the international level until 1880. HAZ values are around -1 and -3 standard deviations during the whole period analyzed and as in the rural area there is a reduction in HAZ values over time, although this decline is less accelerated and attenuates, almost stagnating between the 1920s and the 1940s. In general, we can say that for both subsamples the standard deviations reduce over time, in the last years of our study they reach values of over -1 in the rural area and close to -1 in the urban case. In the Appendix we report the percentile results by birth decade for the rural and urban areas and for the full sample.

For the whole period analyzed, malnutrition was irrelevant, and was only significant at the beginning of the twentieth century. Although there are not enough observations due to high levels of emigration, the first decades of the last century were the most vulnerable. From the 1920s, we can observe a remarkable reduction in malnutrition that increased among those cohorts born after 1950–1960.

4.5. Discussion and conclusions

Research on the rural-urban height gap in the Basque Country contributes to the debate on biological standards of living in Spain during the industrialization. The debate is still one of the most vigorous in the literature on the economic history of Europe. The results of the research allow us to address several questions. First, it places the average height of the Basque population among the highest in Spain. Basque municipalities were among the populations with the highest average heights from the middle decades of the nineteenth century. This situation contrasts with that of southern Spain, which had relatively lower average heights (Martínez Carrión, 2016).

But the discussion should focus on the most relevant finding, that is, that rural areas enjoyed better biological living standards compared to urban standards, including those of the rest of Spain. In general, Spanish cities had the tallest populations as a result of access to food markets throughout the year. In addition to access to quality nutrients, the higher rents and incomes due to the greater weight of professions in industry and services meant that the cities were earlier equipped with health institutions and social provision, including education (schools) and hygiene infrastructures. While in the Spanish countryside there was misery and high rates of poverty until well into the twentieth century, in the cities there were greater resources and care provision (Cañabate & Martínez Carrión, 2017). Only in some industrious cities, with high child employment until the end of the nineteenth century and the beginning of the twentieth century, height was somewhat higher in the rural areas than in the urban ones (Martínez & Pérez Castejón, 1998; Martínez & Moreno, 2007).

The findings of our research are important for the Spanish case. Unlike the research carried out for the whole of Spain, the Biscay height data suggest that the Basque rural environment enjoyed a higher nutritional status. The data show that the differences in height between the two areas, despite annual fluctuations, ranged on average between 1 and 2 cm throughout almost the entire period (see Figure 4.2.). Only in the recruitments of the beginning of the industrialization do we find that the differences were scarce as we do, again, during the years of the Civil War of 1936-39 and the postwar period. In this last period, a new convergence between the heights of the two areas can be observed, a consequence of the strong deterioration of the rural environment. The height penalty observed in cohorts born in the middle decades of the nineteenth century was lower, even when compared to other places in Spain where industrialization took place (Puche & Cañabate, 2016).

The nutritional deterioration of the first birth cohorts recorded during the 1860s and 1870s could have been related to subsistence and local crises, as a consequence of the bankruptcy of the General Credit Company of Bilbao and the Company of the Railway from Tudela to Bilbao. The prices of the main consumer products experienced, first, a fall during the years 1865-66, particularly affecting cereals, wine, oil and two characteristic products of Basque agriculture: beef and bacon. Then, in the recovery phase of Biscayan trade between 1867-69, they rose considerably in cereals and other consumer items (Basas, 1970; Sesmero Cutanda, 2000). In both cases, the conjuncture of a fall and subsequent rise could cause distortions in the biological standard of living of the Basque peasants.

Likewise, the effects of the last Carlist War (the Third Carlist War, 1872-76) should be considered, which led to the besieging of Bilbao, causing supply problems in many surrounding locations. The burning of crops by the combatant armies and forced recruitment, especially in the countryside, could have undermined the economy of many villages. These were deprived of the work of the most active members, fathers and older brothers of many children who were left in the care of their mothers and some older relatives. In the 1880s, the stagnation of the heights of urban recruits were attributable to the costs of industrialization, the degradation of the urban environment, poor hygienic and working conditions in factories and workshops, and even overcrowding in housing as a consequence of the avalanche of immigrants coming from other regions (mainly Castile). The low nutritional status of these immigrants also probably played a role in the stagnation of urban height until those born in 1880.

After the Third Carlist War, stature in both areas grew, although with sluggishness in the rural environment during the last two decades of the nineteenth century. However, the nutritional advantage of rural households was maintained throughout the period. This could be due to the income from the farming activities of the farmhouses, the variety of diet and caloric intake, the conditions of access to basic nutrients (mainly meat and milk), the resistance to diseases and the incidence of morbidity. Finally, institutional factors (farmhouse) may have played a no less relevant role in the Basque rural environment, through access to peasant property. In this turn-of-the-century period, a strong meat and dairy specialization of cattle developed in northern Spain, particularly in the Basque Country. Some authors highlight this phenomenon as a true "livestock revolution" (Berriochoa Azcárate, 2013).

The monotonous diets that characterized Biscay until the end of the nineteenth century, made up of bread, vegetables, wine and some meat, characteristic of urban areas undergoing industrialization, were not the same in the countryside, which consumed part of its production and marketed the rest. The development of the railway and the improvement of the network of highways and local roads enabled agricultural products to access urban markets and facilitated their commercialization. Together with improvements in the distribution and production of food, the increase in real incomes contributed to increasing consumption and the variety of subsistence goods. At the start of the twentieth century, the Biscay diet included different varieties of meat: beef, pork and sheep; local drinks such as *txakoli* or cider; assorted legumes; cod; potatoes, and milk, fresh fish and eggs were integrated into the daily diet in urban-industrial areas (Pérez Castroviejo, 2006). The main subsistence items produced and consumed in the countryside were meat, milk, eggs, fruits and vegetables. The consumption of livestock products had been traditional in the Basque farmhouse (Berriochoa, 2013), despite the fact that the size of the farms reduced the growth possibilities of the Biscayan livestock herd (Delgado, 2009). The farmers cultivated products for the demand of the cities due to the security provided by the owned or leased farmhouse. The guarantee resided in the peculiar system of inheritance, and in the stability of income from previous centuries (Fernández de Pinedo, 1972).

Health conditions and mortality conditioned the different evolution of height according to rural and urban residence. Diseases influenced the evolution of height and represented a high risk for the normal growth of children, damaging the metabolism and impairing the physiological processes of human growth (Alter et al, 2004). The overcrowding and poor living and hygiene conditions suffered by workers in mines and factories in Biscay during the early stages of industrialization (Pérez Castroviejo, 2005) were not present in the countryside. The situation of farmers and ranchers was somewhat more favorable than in the city and there was less suffering from environmental diseases.

Cholera did not attack the countryside and the most frequent respiratory diseases (which affected children and the elderly) affected the urban-industrial area more than the rural world. The temperate climate, a dispersed population and low-pressure residential occupation caused a low number of epidemic invasions and a reduced propensity for contagion (Pérez Castroviejo, 2005). Fewer lethal epidemics and fewer infections among the child population that lived in somewhat healthier rural environments explain the improvement in the biological well-being of young Basque farmers.

An indicator that links environmental factors with physical or biological well-being at the time of the test and warns of possible inequalities is the BMI. This is an excellent indicator of possible diseases and the risk of death (Fogel, 2009) that allows robustness to be analyzed and to verify deficiency situations or lack of weight. At the beginning of the second decade of the twentieth century, young Basques were especially robust compared to the Spanish average, since they were heavier and taller (Martínez, Cámara & Pérez, 2016). The industrialization of the province was advancing in parallel with the nutritional transition. The improvement in purchasing power during those years translated into an increase in the consumption of basic subsistence products and in an expansion of the shopping basket with products already known but little consumed. Studies on BMI show that it was slightly higher in the countryside than in the city (Pérez Castroviejo & Martínez Carrión, 2018). The rural population enjoyed the proximity to sources of nutrients, such as meat and milk.

From the beginning of the twentieth century, improvements were made in urban infrastructure, drinking water and housing, and working conditions and height increased, to a greater extent in the urban-industrial area. The prevalence of malnutrition also decreased, as revealed by the Z-score estimates. The population was able to regularly acquire a wide variety of food products and enjoy municipal services that had been improving over time. These factors led to an increase in height, as can be seen in the heights of the cohorts from the end of the nineteenth century. At the beginning of the Civil War in 1936, there was a greater convergence of height. The analysis by education and social differentiation shows significant improvements for the popular classes. The Civil War and the period of autarchy interrupted the process of improving welfare. The driving forces of a new wave of industrialization in the 1950s and 1960s continued with improvements in biological standards of living although inequality in terms of social groups still persisted. There were height differences of 3 cm among the 1930s and 1940s cohorts, who lived the final years of their adolescence in the 1950s and 1960s.

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4.7. Appendix

Table 4.3. Percentiles rural area by birth decade

Birth decade	1	3	5	10	15	20	25	50	75	80	85	90	95	97	99
1850	151,0	153,0	153,8	156,0	159,2	160,0	160,8	164,3	167,5	168,4	169,0	170,7	171,5	173,3	179,3
1860	146,5	149,8	152,5	155,0	156,5	158,5	159,8	164,2	168,5	169,3	170,4	172,0	174,1	175,3	180,0
1870	148,9	152,4	153,5	156,0	158,0	159,3	160,0	164,0	168,0	169,1	170,5	171,5	173,8	175,0	179,2
1880	149,1	153,0	155,5	157,7	159,8	160,8	162,0	165,5	170,0	170,8	171,9	173,5	175,4	176,8	179,0
1890	150,5	154,9	156,5	158,5	160,0	161,1	162,0	166,0	170,0	171,0	172,0	174,0	176,5	177,0	181,4
1900	153,0	155,4	156,8	160,0	161,6	162,3	163,5	167,5	171,4	172,2	173,4	175,0	176,2	177,8	180,2
1910	152,0	156,0	157,6	160,8	162,0	163,1	164,1	168,0	171,9	173,3	174,4	175,5	178,0	179,7	182,7
1920	151,4	155,0	157,0	159,8	161,0	162,3	164,0	168,0	172,1	173,2	174,3	176,0	178,3	180,0	184,0
1930	152,0	157,4	159,0	162,0	163,8	165,0	166,0	170,0	173,8	175,0	176,0	177,5	180,0	181,0	183,5
1940	153,0	157,5	159,7	162,0	163,5	164,8	165,8	170,0	174,2	175,8	177,0	178,0	180,4	182,0	185,0

Source: Own elaboration from *ACDS y Expedientes Generales.*

Table 4.4. Percentiles urban area by birth decade

Birth decade	1	3	5	10	15	20	25	50	75	80	85	90	95	97	99
1850	154,5	154,5	157,0	159,0	160,0	161,3	161,8	165,0	168,0	169,5	170,0	170,9	172,0	180,0	180,0
1860	142,3	148,9	151,0	153,4	155,0	156,5	157,7	162,8	166,4	167,4	168,1	169,5	171,8	173,0	177,3
1870	143,3	148,2	150,1	153,5	155,4	156,6	157,6	162,1	166,2	167,2	168,4	170,0	172,5	175,0	178,5
1880	149,5	152,5	154,0	155,9	157,3	158,5	159,7	163,7	167,7	169,0	170,0	171,5	173,7	175,6	179,0
1890	150,5	153,8	155,3	157,5	158,9	160,0	161,0	165,0	169,2	170,0	171,0	172,6	175,2	176,8	180,0
1900	151,3	154,5	156,0	158,0	159,7	160,8	161,7	166,0	170,0	171,0	172,0	173,3	176,2	178,0	180,4
1910	152,5	155,6	157,3	159,3	161,0	162,0	163,0	167,0	171,0	172,1	173,2	175,0	176,7	178,1	180,9
1920	151,3	155,1	156,8	159,0	160,4	161,5	162,6	166,7	171,0	172,0	173,1	174,7	177,5	179,0	182,2
1930	152,4	155,7	157,0	159,3	161,0	162,3	163,5	167,3	172,0	173,0	174,1	175,7	177,8	179,0	182,2
1940	152,9	155,7	157,4	160,0	162,0	163,0	164,0	168,0	172,7	174,0	175,0	176,5	179,0	180,7	185,0

Source: Own elaboration from *ACDS y Expedientes Generales.*

Tabla 4.5. Percentiles full sample by birth decade

Birth decade	1	3	5	10	15	20	25	50	75	80	85	90	95	97	99
1850	151,0	153,7	154,0	157,2	159,3	160,0	160,8	164,5	167,5	168,5	169,6	170,7	171,6	173,3	180,0
1860	146,5	149,5	152,0	154,3	155,9	157,5	159,0	163,5	167,5	168,5	169,7	171,0	173,2	175,0	178,8
1870	146,5	149,7	152,1	154,8	156,2	157,6	159,0	163,0	167,1	168,2	169,5	171,0	173,3	175,0	178,7
1880	149,4	152,6	154,2	156,4	157,9	159,4	160,5	164,5	168,6	169,7	170,8	172,2	174,7	176,2	179,0
1890	150,5	154,2	155,6	157,8	159,2	160,4	161,2	165,5	169,4	170,3	171,3	173,0	175,5	177,0	180,2
1900	151,7	154,9	156,1	158,4	160,1	161,2	162,1	166,3	170,4	171,2	172,4	174,0	176,2	178,0	180,4
1910	152,3	155,6	157,3	159,5	161,1	162,1	163,2	167,3	171,2	172,3	173,5	175,0	177,0	178,7	181,0
1920	151,4	155,1	156,9	159,1	160,6	161,7	162,8	167,0	171,1	172,1	173,4	175,0	177,6	179,1	182,5
1930	152,4	155,8	157,3	160,0	161,6	162,9	164,0	168,0	172,3	173,5	174,8	176,2	178,2	180,0	182,4
1940	152,9	156,0	158,0	160,6	162,0	163,3	164,3	168,7	173,0	174,0	175,2	177,0	179,8	181,0	185,0

Source: Own elaboration from *ACDS y Expedientes Generales.*

5. Conclusions

In this thesis we offer results and new evidence for the biological standards of living in the Spanish case over the last few centuries. We can conclude that determining the nutritional status and inequality in health requires a multidimensional approach and an in-depth debate between social sciences and biological and medical sciences. If we know the dimension and the evolution of biological living standards in the past, we can better understand the current problems and design appropriate policies.

The questions formulated in the introduction have been discussed throughout the chapters. In the first chapter, the aim was to study height differentials in Spain in the second half of the twentieth century, determining the role of both individual and household-level factors. In order to do this, we used educational attainment and social class as two different proxies for SES among Spanish men and women born between 1940 and 1994. The multivariate regression analysis conducted shows that height differentials by educational attainment have diminished over time, whereas differences by social class have been more persistent over the period studied. These results indicate the need for further qualification when describing the process of convergence in biological well-being indicators across social groups. For instance, the progressive enrollment of a greater proportion of the population in higher educational levels may distort the analysis or lead us to underestimate the real differences between socioeconomic groups, while other proxies of SES still clearly indicate the persistence of such differences.

Previous studies have shown that season of birth correlates to a wide range of health conditions throughout life measured by anthropometrics. However the link between the seasonal variability and the month of birth has received little attention. In the second chapter, we explore whether the month of birth and climate during gestation influence male adult height, based on Spain's rural population before the end of the modernization process. Using a database of heights from conscripts who reached the age of 21 between 1908 and 1985 (birth cohorts 1886-1965) and using two different methodologies: a harmonic regression using sinusoidal covariables and a random forest model, we find that being born at the end of the summer and during the autumn was favorable to height. The results show that the birth month with the highest statures is September, with heights 0.5 cm above the annual average and 0.9 cm above February, the birth month with the lowest average height. Furthermore, we observe that rainfall and temperature during gestation had little additional influence due to a substitution effect with the birth month variable. Our results suggest that the seasonal effects on height can be significant and can be partially affected by environmental factors during early life. Our results are consistent with previous research that suggests that solar light received by the mother during pregnancy can be relevant as it determines the exposure to vitamin D and also with studies that claim that periods that imply fruit harvests and income gains have positive effects on health. However, although we contribute to the literature and our findings might be of interest for low-income populations and developing rural societies, more research is needed on this topic.

Very little research has been conducted on the behavior of insular population groups, at least in the Spanish case. In order to learn about the evolution of insular adults' growth, we present a study based on heights during the nutritional transition in the Canary Islands. We have conducted a long-term anthropometric study using two approaches: a malnutrition and growth retardation approach and an inequality perspective. In the first one, we use the methodology recommended by the WHO that is based on z-scores. In the second one, we implement several inequality dimensions such as the CV, percentiles and an analysis for height and BMI evolution by five socioeconomic categories. One of the main contributions of this research is that it is the first study that analyzes the height trends in the eastern Canary Islands during the nutritional transition and modernization. This period was characterized by dramatic changes both in the economy and demography that affected biological living standards. The results suggest that improvements in biological well-being can be attributed to advances in nutrition after the 1960s and that infant nutrition is sensitively associated with economic growth and demographic and epidemiological changes.

Finally, despite the vast literature about the rural-urban gap in biological living standards for Spain, in the last chapter we analyze height data for the nineteenth and twentieth centuries in the Basque Country. The main objective was to study whether differences between the rural and urban world were maintained with industrialization.

The results confirm that the rural areas in the Basque Country enjoyed better biological living standards with the industrialization and economic growth in comparison to urban areas. This contrasts with the rest of Spain, where poverty was concentrated in the rural areas. This Basque rural advantage could be explained by the fact that nutritional sources such as milk and animal proteins were more accessible to peasants and also due to the institutional factors (farmhouses) that determined the access of peasants to property.

Further research should continue to explore the effects of public provisions and how the public policies and the role of public and private institutions in determining the differential in biological living standards. More case studies on identifying the factors that enable people to escape from poverty and poor health conditions would enrich this thesis.