Gender Equality in Health: Its Measurement, Determinants, and Long-Run Evolution

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A Introduction

A.1 Motivation

Gender inequality remains one of the most persistent and consequential forms of social disparity worldwide. Recognizing its importance, the United Nations has established gender equality as one of its core development priorities: Sustainable Development Goal (SDG) 5 aims to "achieve gender equality and empower all women and girls". This goal encompasses a wide range of targets, including ending discrimination, eliminating harmful practices such as child marriage, recognizing and reducing unpaid care work, securing women's reproductive autonomy, and ensuring equal participation in education, leadership, and economic life (United Nations, n.d.). Despite global commitments and substantial investments in gender-equality programs, progress has been uneven and remains insufficient to meet these targets (United Nations, 2023). At the current pace of change, it is estimated that it will take, for instance, 300 years to end child marriage and 140 years to achieve equal representation in workplace leadership (United Nations, 2023).

A central mechanism through which gender inequality manifests is son bias, which is the preferential treatment of boys over girls within households. Son bias arises from deep-rooted cultural, economic, and institutional factors. As a consequence, societies with a strong son preference have higher rates of sex-selective abortion and excess female mortality rates in infancy and childhood, often caused by overall neglect with respect to food and health care in infancy and early childhood (Beltrán Tapia and Szołtysek, 2022; Sen, 1990). The negative health consequences for females can be observed, for instance, in shorter breastfeeding duration, lower vaccination rates, and stunting (Borooah, 2004; Jayachandran and Kuziemko, 2011; Khera et al., 2014; Schwekendiek and Baten, 2019). Amartya Sen's (1990) concept of "missing women" captures the scale of this phenomenon: more than 100 million women worldwide are estimated

to be missing due to gender-discriminatory practices.[1] These dynamics also influence final adult stature: where girls systematically receive inferior nutrition or health care, their height lags behind that of men by more than what biological dimorphism would predict. Understanding such gender health gaps is therefore essential for studying gender inequality in contexts where socio-economic data are limited. Relative to gender gaps in income or labor market outcomes, which are strongly shaped by contemporary institutions, gender equality in health often evolves more gradually and reflects deeper social norms and intra-household dynamics. Height offers a useful proxy for gender equality in health, as it reflects cumulative net nutrition and disease burdens experienced during early life and has been used in several studies (e.g., Costa-Font and Gil, 2008; Gray and Wolfe, 1980; Guntupalli and Baten, 2009; Ridolfi, 2024; Schwekendiek and Baten, 2019). Importantly, height can be measured across a wide range of historical and socio-economic contexts, including those lacking administrative or survey data. This opens new opportunities for examining long-run gender equality and allows us to analyze societies for which other indicators are unavailable.

Historical analysis plays a crucial role in understanding how gender norms originate, persist, and change. Studying the determinants of gender inequality across different institutional settings—such as socialist versus non-socialist regimes—helps to understand how political systems shape gender roles and how effectively states can alter persistent social norms. Socialist states, for example, often explicitly promoted gender equality through policies designed to increase women's education and labor-force participation (Campa and Serafinelli, 2019; Fuchs-Schündeln and Masella, 2016). Examining these institutional environments allows us to identify how they can accelerate or hinder changes in gender norms. Using adult height also makes it possible to investigate and compare gender dynamics in Indigenous societies, such as those of Native Americans. Systematic comparative evidence on gender equality across prehistoric and historic Indigenous societies in the Americas remains scarce. Analyzing gender equality in these communities offers insights into the origins of gender roles and how they vary with agriculture and other subsistence systems. It further allows us to study the impact of European settlement and colonization on gender equality. Understanding how these transformations affected women

[1] For slightly newer estimates, see Klasen and Wink (2003). Historical estimates for Europe are provided by Beltrán Tapia and Szołtysek (2022).

relative to men provides a more comprehensive picture of the long-term consequences of colonialism.

In sum, global gender inequalities, persistent social norms, and overall slow progress toward international gender targets motivate a deeper investigation into the determinants and long-run measurements of gender equality. Understanding how gender norms emerge, evolve, and change is essential for both historical research and contemporary policy debates. This dissertation contributes to answering these questions by developing and applying a long-run measure of gender equality in health using height as a proxy and by analyzing the role of subsistence systems and institutional settings across diverse historical contexts.

A.2 Measuring Gender Equality

Gender equality is a multidimensional concept that encompasses disparities in health, education, labor market opportunities, politics, legal rights, and the allocation of unpaid care and domestic work. No single indicator can fully capture this complexity. As a result, a range of composite indices has been developed to quantify different aspects of gender inequality, each with its own strengths and limitations.

A group of measures focuses on cross-country comparisons in the modern period. The Gender Development Index (GDI) and the Gender Inequality Index (GII)[2], for example, are published by the United Nations Development Programme (UNDP) and build on the Human Development Index by incorporating gender gaps in life expectancy, education, income, maternal health, and political representation (UNDP, 2025). Similarly, the Global Gender Gap Index (GGGI) constructed by the World Economic Forum combines gender differences in health, educational attainment, economic participation, and political empowerment (World Economic Forum, 2025). Other indices are, for instance, the Gender Equality Index (GEI), developed to measure progress for men and women toward equality in European countries (European Institute for Gender Equality, 2025), and the Social Institutions and Gender Index (SIGI), which focuses on underlying discriminatory social institutions (OECD, 2023). These indicators have been invaluable in

[2] The GII was introduced in 2010 and largely replaced the Gender Empowerment Measure (GEM), which, together with the Gender-related Development Index (GDI), was introduced in 1995.

documenting global progress and cross-country variation in gender equality since the late twentieth century. They provide relatively simple summary measures that are widely used in policy debates. More recently, first attempts to construct gender-equality measurements for the past, most notably the Historical Gender Equality Index (HGEI) (Dilli et al., 2019), have offered valuable insights into long-term trends. However, even such historical indices rely on gender-disaggregated administrative data and therefore remain restricted to the post-1950 period and countries with sufficient statistical coverage. For long-run and historical analysis, these limitations are particularly restrictive. Many societies, especially before the twentieth century, left no systematic gender-disaggregated statistics on health, income, schooling, labor or political participation. Even in more recent periods, coverage is incomplete for many low-income countries. To understand how gender equality evolved over centuries or millennia, it is necessary to rely on indicators other than modern composite indices.

One promising approach is to use anthropometric measures, in particular adult height, as a proxy for gender equality in health. Height is a well-established indicator of the biological standard of living, reflecting intra-household resource allocation with respect to nutrition, care, and disease burden during childhood. Adult stature is strongly cohort-specific: it captures conditions in the birth decade. This makes height conceptually distinct from other common health indicators, such as life expectancy, which are more sensitive to lifestyle choices and living conditions across all age groups. Another advantage is that height data are available for a far wider range of countries and time periods than most socio-economic indicators. For the twentieth century, anthropometric information comes from conscription records, health examinations, and household surveys; for prehistoric or non-literate societies, it can be recovered from skeletal remains. Moreover, as height was historically not a policy target, there was little incentive for governments to manipulate or "dress" these data. At the population level, genetic differences in height potential are small (see, for instance, Baten and Blum, 2012; Perkins et al., 2016; Steckel, 1995, 2008). Historical evidence shows that once environmental conditions improve, average height rises across all regions. This pattern was observed during the twentieth-century global health transition and was driven by better sanitation, nutrition, and medical care rather than genetics. This means that height differences across time largely reflect living conditions, not biological endowments.

Using height to measure gender equality, however, requires accounting for biological dimorphism. Men are naturally taller than women, and this gap increases as populations become healthier (Bogin et al., 2017; Gray and Wolfe, 1980). Relying on raw male-female height differences would therefore reflect not just social and environmental factors but also biological ones. To separate them, a benchmark is needed for the expected biological gap under low gender discrimination. One approach identifies high-GDI countries and cohorts, i.e., settings with relatively low gender inequality, to estimate how the height gap "inflates" with rising average stature (Schwekendiek and Baten, 2019). This inflation factor can then be used to adjust height gaps in other populations. If the observed gap exceeds the expected biological component, the excess can be interpreted as evidence of gender inequality in health and nutrition. This gender equality in height index can therefore be interpreted as reflecting gender bias in early-life investments across countries and historical periods.

While existing composite indices such as GDI, GII, or GGGI are indispensable for monitoring recent trends in gender equality, they offer limited scope for long-run and cross-civilizational analysis. Anthropometric measures, such as stature, provide a valuable complementary perspective.

A.3 Consequences of Gender Equality

Gender equality is not only a normative goal but also a central determinant of economic and social development. This idea has been widely emphasized by international organizations, most prominently in the World Development Report on Gender Equality and Development, which describes gender equality as "smart economics" because it boosts productivity, improves development outcomes, and enhances prospects for the next generation (World Bank, 2012). In other words, when half the population is constrained in its choices and opportunities, the overall use of talent and human capital becomes necessarily suboptimal. Societies with higher levels of gender equality, and policies that support and strengthen these rights, benefit not only women but also men, as measured by higher levels of life satisfaction and subjective well-being (Audette

et al., 2019; Tesch-Römer et al., 2008). As Malala Yousafzai[3] succinctly put it in her speech at the United Nations Youth Assembly 2013, "we cannot all succeed when half of us are held back." Consistent with this broader perspective, evidence from low- and middle-income settings suggests that female empowerment is positively associated with human development outcomes, including higher investment in human capital as well as improvements in economic outcomes such as employment, income, and savings (Balasubramanian et al., 2024).

A central mechanism linking women's agency and empowerment to development is intra-household allocation. Women with the necessary resources and decision-making power invest more in children's education and health (Duflo, 2003, 2012; Thomas, 1990, 1993). Evidence from Brazil shows that unearned income controlled by mothers has substantially larger effects on child health and survival than income controlled by fathers (Thomas, 1990). This is consistent with findings that women spend more on "human capital" goods (health, education, household services) and improve nutrient-related allocations (Thomas, 1993). Complementing this, Duflo's analysis (2003) of South Africa's old-age pensions shows that transfers received by grandmothers improve girls' health outcomes (measured by height-for-age and weight-for-height), whereas pensions received by men do not produce the same pattern.

Investing in girls' education can generate positive externalities: higher educated mothers tend to invest more in their children's health and schooling, leading to lower child mortality and intergenerational human capital spillovers (Abu Ghaida and Klasen, 2004; Mare and Maralani, 2006; Schultz, 2002). At the same time, the evidence does not imply that fathers are irrelevant. Some studies find that paternal education is similarly important for child outcomes (Holmlund et al., 2011; Duflo, 2012). Baten and de Pleijt (2022) show that higher female autonomy in the past, proxied by female age of marriage, supported long-run human capital formation. The authors argue that later marriage increased women's opportunities for skill acquisition and, because women were historically responsible for their children's upbringing, these skills were more likely to be passed on to the next generation.

At the firm and labor market level, gender-diverse teams are associated with higher innovation and productivity, more impactful research, and more efficient work processes

[3] Malala Yousafzai is an education activist from Pakistan and the youngest Nobel Peace Prize laureate.

(Hemmert et al., 2024; Sunder et al., 2025; Yang et al., 2022). At the macro level, lowering gender (and racial) barriers in the labor market accounted for a sizeable share of market and household output in the United States between 1960 and 2010, as estimated using an occupational choice model in which the key mechanism is improved allocation of talent across occupations (Hsieh et al., 2019; similar work for OECD countries: Cuberes and Teignier, 2016, 2018). Empirical evidence points in the same direction: gender inequality in education and employment is associated with lower economic and household productivity, thereby slowing down economic growth (Klasen and Lamanna, 2009). The relationship appears to be particularly strong for gender gaps in education relative to gender gaps in the labor market (Klasen, 2018). However, reverse causality between economic growth and gender equality needs to be carefully addressed, and the underlying mechanisms need to be further analyzed (Cuberes and Teignier, 2014; Duflo, 2012; Kabeer and Natali, 2013). Beyond economic outcomes, gender equality is also linked to social and political stability. Greater female political representation and smaller gender gaps in education are associated with lower risks of intrastate conflict and less abuse of personal integrity rights (e.g., political imprisonment, torture) (Caprioli, 2005; Melander, 2005).

A.4 Determinants of Gender Equality

As already mentioned above, a key driver of gender inequality is son bias, which is linked to traditional labor division due to subsistence systems and technological progress. Informal institutions such as religion, patriarchal norms, customs like the dowry system, early marriage, views about female purity, etc., intensify strict gender roles and inequality (World Bank, 2012). Preindustrial subsistence systems appear to have long-run persistence effects on gender norms and gender equality. Alesina et al. (2013) argue that the historical adoption of plough agriculture, relative to shifting hoe cultivation, generated a stronger gender division of labor because plough cultivation requires more upper-body strength. Hence, men's work concentrated in the fields while women specialized more in home-based activities. This in turn shaped beliefs about the "appropriate" role of women. These cultural beliefs persist until today, influencing female labor force participation, entrepreneurship, and female political participation (Alesina et al., 2013). Similarly, Baten and de Pleijt (2022) estimate that in dairy-farming oriented economies, women

had a comparative advantage, leading to higher female autonomy with persistent effects on long-term human capital development. Ebenstein (2021) argues that the historical adoption of intensive agriculture generated incentives for the emergence of patrilocality (sons remaining near parents and daughters leaving after marriage) and patrilineal inheritance, which influences modern son bias. The deep roots of gender inequality in social norms and long-term institutional systems, like family systems, structures, policies, and religion, are shown by various studies (for instance, Carmichael et al., 2016; Dilli et al., 2015; Morgan, 1987; Schnabel, 2016; Szołtysek and Poniat, 2025).

At the same time, gender systems are not fully predetermined. Economic growth and technological progress can accelerate the transition toward a more gender-equal society, but the relationship is bidirectional. However, it is not automatic: development alone does not eliminate gender inequality, especially when strong patriarchal norms exist, and sustained progress typically requires targeted policy interventions (Duflo, 2012; Jayachandran, 2015; World Bank, 2012). Formal institutions and rules, such as political regimes, legal reforms, and policy interventions, that strengthen and protect the rights of women can shift norms and women's opportunities. Democracies tend to adopt more gender-equal legislation across family law, education, labor markets, and political participation (Andersen, 2023; World Bank, 2012). State-socialist regimes went further by implementing explicit policies to increase women's labor-force participation and human capital. Evidence from East and West Germany illustrates that exposure to socialist institutions produced lasting effects on gender norms, female employment, and attitudes toward work (e.g., Campa and Serafinelli, 2019; Wyrwich, 2019).

A.5 Outline of Thesis

This dissertation consists of three chapters, each representing a stand-alone study intended for publication. Hence, these studies are sometimes referred to as papers or articles throughout this work. At the time of submission, one study has already been published. Chapter B and Chapter C are co-authored with Prof. Jörg Baten, Chapter D is single-authored. The dissertation concludes with Chapter E.

Chapter B introduces and validates a measure of gender equality in health using adult stature as a proxy. Drawing on cohort-based male and female height estimates, the chapter compares gender equality in health under socialist and non-socialist regimes in twentieth-century Europe and Asia. Because many socialist countries promoted policies that increased female labor-force participation and expanded girls' access to education, socialism provides a meaningful institutional setting to examine shifts in gender equality. The results indicate a robust positive relationship between socialism and gender equality in health, mirrored by improvements in gender equality in education.

Chapter C applies the same indicator to periods without modern statistical sources using bioarchaeological evidence. Stature is reconstructed from maximum femur length, the long bone most closely correlated with adult height. The chapter describes long-run patterns of gender equality among Indigenous populations in the Americas from 6000 BCE to 1500 CE and documents substantial geographic and temporal variation. It relates these patterns to subsistence strategies, showing systematic correlations. For instance, early phases of maize cultivation are associated with relatively high gender equality, whereas later dominance of maize and population growth coincide with lower gender equality in comparison to mixed agriculture subsistence. These findings are interpreted as suggestive evidence that economic organization and demographic conditions are linked to gender roles within the household and the division of labor.

Chapter D extends the analysis to the post-contact period by examining how European settlement was associated with gender equality in health among Indigenous populations. It uses a binary indicator capturing whether Indigenous communities lived close to European settlements and were therefore more likely to experience disruptions to traditional lifeways. The chapter finds a significant negative association between settlement exposure and gender equality in height. It further documents heterogeneity across colonial activity types, consistent with differences in institutional environments and in the nature and intensity of disruptions to land, labor, and livelihoods.

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B Gender Equality in Asia and Europe During the 20th Century: The Role of Socialism[4]

Abstract

Whether socialism improved gender equality, or whether the double-burden effect of socialism lowered gender equality, is an unresolved debate. A novel indicator allows to address this question for 88 countries during the 1910s to 1980s period: the adjusted height gap between males and females. Both biological and economic determinants of height gaps need to be considered. The proposed measure is validated through comparisons with relative life expectancies and the Gender Development Index (GDI), demonstrating its utility for tracing gender equality trends. Regression analysis reveals a significant relationship between socialism and improved gender equality within Europe and Asia. The results are confirmed by comparing them to gender equality in education. Robustness checks using staggered difference-in-differences methods and instrumental variable estimation suggest a robust and consistently positive relationship between socialism and gender equality.

[4] This chapter is based on an article by Jung and Baten (2025), published in Journal of Comparative Economics. The version included in this dissertation is identical in content, with only minor textual differences. I was responsible for approximately 80 percent of the conceptual development and writing, while Jörg Baten contributed the remaining 20 percent.

B.1 Introduction

Gender equality is clearly crucial for at least half of humanity. However, gender equality is currently declining in a number of countries, most notably in Afghanistan, but also in some of the rich OECD countries (for example, in Italy, 2000–2015 the gender wage gap increased, see Ortiz-Ospina et al., 2018). The other half of humanity benefits from gender equality as well, as a number of studies have shown that in situations of high gender equality, welfare rises for both males and females (Klasen and Lamanna, 2009; skeptical: Deaton, 2019; differentiated view: Duflo, 2012; supporting the role of gender equality in the long run: Baten and de Pleijt, 2022). Apart from the welfare benefits, understanding the determinants of and the mechanisms underlying gender equality is important for reaching the United Nations' Sustainable Development Goal 5, which is to promote and achieve gender equality as a fundamental human right as well as to empower all women and girls. A number of potential factors have been identified, including differences in agricultural specialization ("Women and the Plough": Alesina et al., 2013). One debated aspect of the political economy is the role of women under socialism.

Alesina and Fuchs-Schündeln (2007) argued that politico-economic regime types, such as socialism, could change the attitudes toward social equality and redistribution among the population in Eastern Germany during its socialist period, compared to Western Germany (see also Fuchs-Schündeln and Schündeln, 2020). Campa and Serafinelli (2019) found that this effect can also be observed in Eastern Germany for gender equality in particular. The assessment strategy is based on the idea that Eastern Germany's socialist era can be interpreted as a natural experiment, while Western Germany remained a market economy. After World War II, the Soviet Union created a socialist state in Eastern Germany. However, Becker et al. (2020, 2021) argued that the case study of Eastern Germany versus Western Germany can be problematic because important differences existed even before 1945. For example, Eastern Germany's southern part (i.e., Saxony) was one of the earliest industrialized regions of Germany, resulting in early worker movement activities. Saxony and Thuringia had some of the highest voter shares for the Communist Party in the 1920s and early 1930s (before the National Socialists came to power). We contribute to this debate by providing a large number of country cases in which the

introduction of socialism might have resulted in higher gender equality in one important area of human well-being, namely health and nutritional quality.

In this study, we use human stature of males and females as an indicator of their relative health development. We document how heights can be employed to trace gender equality during the health transition, but only if human biology is taken into account. This new indicator based on height provides crucial insights by complementing other proxy indicators such as gender-specific life expectancy and education. The quality of measurement of these other indicators is debatable for the early decades of the twentieth century. Apart from the frequent lack of statistical reporting in some world regions, some countries used life expectancies and educational progress for "window-dressing", i.e., making their country's performance look better than it was. In contrast, human stature is an indicator that was not considered relevant; hence, we can expect more unbiased results. Heights are also relatively easy to measure (Baten and Blum, 2014a; Komlos, 2009; Steckel, 1992). The NCD Risk Factor Collaboration has produced an important foundation for female and male heights on which we can build, but this dataset needs to be carefully assessed, as done in this article—we counter-checked the results obtained from male and female height differences by comparing them with other health indicators for a subset of periods and countries in which both were available.

To investigate the determinants of gender equality, we exploit the emergence of socialism as an institutional-political force. This political ideology proclaimed higher gender equality by promoting equal labor market participation and other policies. We assess whether this resulted in higher gender equality or whether it was just a matter of official statements.

Hence, in our study, we assess three hypotheses:

(1) The gap between female and male heights can be employed as an indicator of gender inequality if biological factors are taken into account.

(2) Socialism improved gender equality with respect to height (and by inference, health).

(3) We hypothesize parallel changes in gender-specific life expectancy and education (for sometimes smaller samples).

The setting of our study was based on a multi-country sample for Asia and Europe for the period from the 1910s to the 1980s. This is justified by the broad availability of relatively

representative height data for this period and substantial variation in the socialism variable.[5] We concentrate on Asia and Europe because a substantial number of countries became socialist at different points in time, and an even more substantial number remained market economies. Outside of these world regions, there were relatively few socialist economies. Moreover, the few socialist experiment countries in Africa, for example, often did not establish gender equality policies de facto to the same extent that European and Asian socialist countries did (Najjar, 1968).[6]

As a preview of our results, we find a consistent and robust effect on gender equality in height of about 0.17 index points of the overall variation in Europe and Asia. We test the validity of our results by including control variables for religion and family systems and employing a large set of robustness checks. We find that even though some of these factors play a modest role, socialism itself remained statistically and economically significant, implying that childhood living conditions improved relatively more for girls than for boys under these governments.

We confirm our results by using an instrumental variable (IV) estimation, instrumenting socialism by distance to the most important socialist country at the time, the Soviet Union (i.e., distance to Moscow). To investigate whether gender equality also improved in other dimensions in socialist states, we test the effect of gender equality on education using educational attainment data calculated by Barro and Lee (2013). Overall, our research provides evidence suggesting that gender equality, with regard to health and human capital, was improved by socialist countries.

We cannot make empirical statements about the mechanisms using our multi-country macroeconomic data. However, based on related detailed country studies on (a) gender-specific evidence on socialist economies and (b) human height studies, we can formulate the most likely mechanism as follows: expectedly, the fact that a country turns socialist does not automatically impact the relative heights of males and females. Alesina and Fuchs-Schündeln (2007) described a similar mechanism for the transmission of socialist ideas into preferences for equality. They

[5] After the birth decade of the 1980s, the evidence is characterized by a small number of observations; hence, we do not include the 1990s. Moreover, some samples are affected by the late growth of teenagers because available data sources included height measurements of 17-year-olds. 17-year-olds are sometimes still growing and hence are not directly comparable to the heights of fully grown adults.

[6] Many countries claiming socialism in other world regions were more hesitant to interfere in the family and private lives of their citizens, for example Tanzania and Senegal. One exception is Cuba, which has been ruled since the 1960s under a communist government following a Marxist-Leninist approach.

focused on (1) the indoctrination performed by the socialist state, and (2) the socialist state's control over schools, work, and other institutions in which the citizens were confronted with the state's policy, i.e., the institutional setting. In our case, gender equality was a factor that was intensively promoted, not only in typical propaganda but also in cultural products such as movies, romantic novels, and similar media (Winkler, 2014). The behavior of "modern" men and women is portrayed in these cultural and entertainment products, and consumers sometimes adapt their behavior without feeling really "indoctrinated". This reflects a potential cultural change in attitudes. Moreover, in school, the socialist government emphasized that girls should obtain similar opportunities as boys. Socialist governments introduced legal and institutional changes to increase equality. For example, the Soviet Union enshrined gender equality in its constitution in the 1920s. Similarly, in the 1950s, when China became communist, they entrenched laws in their constitution protecting the rights of women. Moreover, access to education and health care facilities was expanded, and most importantly, women were encouraged to enter the labor market, with measures introduced to lower the barriers for them, e.g., expanding child care or guaranteeing equal wages. These measures of education and labor market opportunities changed the incentives which families faced; we might expect that families responded slightly more rapidly to these, while the cultural change mentioned above might take more time.

In short, the parents of young boys and girls were confronted with a wide range of governmental promotion of gender equality. It might be possible that a former son bias, leading to giving more high-quality nutrients and more medical and hygienic care to male children, was modified into a more equitable distribution of resources among young children and teenagers of both genders (Schwekendiek and Baten, 2019). Hence, while we have no empirical data on the individual components, we hypothesize that a combination of these components would be the most likely mechanism.

Our study contributes to the literature by assessing whether these legal and political proclamations resulted in real gender equality. Many studies have raised doubts about the existence of higher gender equality in socialist countries due to the "double burden" effect, where women often face both official labor market work and household work, resulting in lower welfare for them (Schwekendiek and Baten, 2019). While we acknowledge that we cannot draw conclusions regarding the subjective well-being of women under socialism, we can measure

whether, for example, the son bias that might have led to unequal parental investment in boys and girls tended to diminish over time under socialist governments.

We also contribute to country studies on socialism that employed the "natural experiment" approach to analyze the relationship between socialism and gender equality. Between-country analysis of gender equality in North and South Korea is limited due to scarce data and literature on North Korea. While North Korean heights for both males and females did not increase much—quite in contrast to South Korea—gender equality in stature in North Korea tended to be high (Goodkind, 1999; on South Korea: Pak et al., 2011).

In the case of East and West Germany, several authors have used this natural experiment to investigate the (long-lasting) impact of state socialism on attitudes toward gender roles within the family and the labor market (Alesina and Fuchs-Schündeln, 2007; Becker et al., 2020, 2021; Campa and Serafinelli, 2019; Cooke, 2006; Fuchs-Schündeln and Schündeln, 2020; Grundig, 2008; Komlos and Kriwy, 2002a, 2002b; Pfau-Effinger and Smidt, 2011; Wyrwich, 2019).

We also contribute to the methods of measuring gender equality from a long-term perspective. Quantitative multi-country studies on the development of gender equality over extended periods are scarce. Most research focuses on the late 20th and early 21st centuries, analyzing gender differences in labor force participation, life expectancy, policy participation, and income (one exception: Klasing and Milionis, 2020). Consistent data for these variables has been available for most countries only since the late twentieth century. Thus, well-known gender equality indices like the Gender Inequality Index (GII), the Gender Development Index (GDI), or the Gender Empowerment Measure (GEM) are only calculated from 1995 onward (with few exceptions, such as Dilli et al., 2021). Dilli et al. (2019) introduced the Historical Gender Inequality Index (HGEI) as an approach for analyzing gender equality development in the twentieth century. The HGEI began in the 1950s and is calculated for 129 countries based on health (life expectancy), household (sex ratio, age of marriage), political (parliamentary seats), and socioeconomic (average schooling years and labor force participation) factors. However, if we want to shed light on gender discrepancies for a broad set of countries in the early twentieth century, we need to expand this concept to alternative variables. Some scholars have experimented with using height gaps between females and males (see, for instance, Costa-Font and Gil, 2008, for Spain; Koepke et al., 2018, for Switzerland; Schwekendiek and Baten, 2019, for China and

Korea). However, this indicator was never evaluated in large cross-country analyses. With our proposed indicator, we close this gap and provide new possibilities for assessing gender equality in the past. By establishing and evaluating measures for gender equality in the long run, we can shed light on path dependencies and understand the factors that influence gender equality today. Our study is the first to employ this concept in a multi-country study, which is a substantial contribution to the literature.

B.2 Data and Methods

B.2.1 Gender Equality

For our main dependent variable, gender equality in height, we rely on the NCD Risk Factor compilation dataset (NCD-RisC, 2016). This dataset is the product of a large-scale cooperation among numerous scholars worldwide. The height estimates were calculated using a cohort approach; for instance, estimated heights of the birth decade of the 1940s were calculated using height measurements from the 1980s. The height estimates were initially estimated for birth years and subsequently aggregated to birth decades, which we use in our main analysis—we use the yearly dataset and aggregates for half-decades as robustness checks. For our estimations, we use data on height for males and females covering 88 countries across Europe and Asia for birth decades from the 1910s to the 1980s.

How can heights be used to analyze gender equality? Gray and Wolfe (1980), Costa-Font and Gil (2008), Guntupalli and Baten (2009), and Schwekendiek and Baten (2019) argue that the variation of gender-specific height differentials over time and across regions can be used as a proxy indicator of gender equality. The mechanism behind this indicator is that parental behavior regarding the provision of more high-quality food and more medical and hygienic resources to male offspring during childhood and teenage years results in larger or smaller height differences between male and female adults. The strongest effect is observed post-weaning, at ages two to five. Therefore, most studies aggregated height data by birth decade. An additional important effect occurs during the teenage growth spurt, around ages 14 to 16 (Tanner, 1990). This behavior is, in turn, influenced by the value system, which might be changed by propaganda (here in a positive sense) and institutional settings by socialist governments, as described above. The four

aforementioned studies utilized different measures to trace gender inequality of height. The first three studies employed intuitively sensible measures, while Schwekendiek and Baten (2019) systematically compared and correlated all suggested measures with the widely accepted GDI and other measures of gender equality, identifying the measures that correlated best with other indicators of gender equality (see Schwekendiek and Baten, 2019, for the discussion on the following two pages).

The challenging issue is that height inequality by gender cannot be analyzed simply by comparing the heights of both genders, as complex biological factors influence the relative development of male and female heights (Gray and Wolfe 1980; see also Appendix B.7.2). For example, even if female height increased more rapidly than male height, this would not automatically indicate an increase in gender equality. Conversely, an increase in male height relative to female height does not necessarily imply more gender inequality if average heights rise simultaneously. Unfortunately, the height gap between males and females tends to decrease when average height levels of both genders decline, hence an easy measure is not appropriate (Gray and Wolfe, 1980). Guntupalli and Baten (2009) suggested deflating the gap by average male height. However, it turned out that even this deflated ratio increases as average height increases, as Schwekendiek and Baten (2019) observed using the largest global dataset on female and male heights available to date (NCD-RisC, 2016).[7] In other words, the gender height gap accelerates relative to average height. Hence, in this study, we employ the method suggested by Schwekendiek and Baten based on the large international NCD-RisC sample and a systematic comparison with other gender-equality evidence.

One methodological challenge is separating the "biological" component of the height gap from the economic (nutritional/health) component. Schwekendiek and Baten utilized a pragmatic strategy to select a sample of countries with relatively average or "typical" gender equality based on non-anthropometric data (the Gender Development Index[8]: education, longevity, and income). For this relatively homogeneous group, the estimated "height gap-to-average" relationship would

[7] The NCD-RisC group (NCD Risk Factor Collaboration, 2016) followed the strategy to include representative samples of both female and male heights from almost all countries.

[8] The Gender Development Index (GDI) is the most widely accepted measure of gender equality. Carmichael et al. (2014) calculated the GDI for a long-run sample of 20 countries in the 20th century.

be mostly but not exclusively biological. A suitable gender inequality index would be the residual from this formula—numerically positive deviations to the upper left of a regression line would indicate higher gender inequality and numerically negative deviations to the lower right would indicate lower gender inequality (Schwekendiek and Baten, 2019). In other words, these residuals would reflect the nutritional/health gender inequality, not the biological component of the height gap.

Figure B.1 presents the different birth decades of the middle group, consisting of nine countries that Schwekendiek and Baten documented to have a sample of the middle GDI group of "close-to-average gender equality", which was formed of countries for which the GDI was neither very high nor very low. Thereafter, they estimated the relationship between the height gaps from the average height. The R-squared values were very high, and the coefficient was consistent in various robustness checks. The resulting formula for gender inequality of height, based on the regression result, was as follows:

$$GI_h = H_m - H_f - (-33.75 + 0.276 \cdot H_{mf}) \quad (1)$$

where H_m and H_f are the height values for males and females, respectively; H_{mf} is the average height of both genders; and GI_h represents gender inequality of height.

Multiplying the whole formula by -1, we obtain the gender equality measure utilized below. Estimating nine robustness check regressions (leaving out one country at a time) resulted in very similar values of coefficients and constants (the standard deviation of the coefficients of these nine estimations was only 0.01, per details available from the authors).

In Figure B.2, we add information about economic (nutritional/health) differences. Most of the observations presented in this figure represent the GDI sample of 9 "typical"/"close-to-average" GDI countries. The regression line shows the relationship between the height gap ($H_m - H_f$) and the average height (H_{mf}). On the upper left, Bangladesh (value for 1920) represents an extreme case of low gender equality for nutritional/health reasons, driven by son bias. The height gap was 14.4 cm, with an average height of less than 154 cm. The residual for this observation was our indicator of gender height inequality (or its inverse: the indicator of gender height equality). It should be noted that Russia is, on average, in the middle group of GDI values from

the 1910s to the 1980s. However, its gender height inequality value for 1990 has a substantial residual, indicating significant gender equality after 70 years of socialism. Even though socialism ended in the 1980s, parental behavior apparently did not change within a decade. The gender equality value of Russia in the 1990s was actually similar to that of Denmark in the 1960s, a very gender-equal country (not shown in the figure). Russia in the 1990s is included here as a special case; otherwise, we do not include the 1990s (excluding it from the estimation does not substantially change the results).

It is visible how Russia, from the 1910s (starting with the socialist revolution in 1917) to the 1920s and 1930s, began to move toward more gender equality. Hence, even though Russia was included in the group of nine countries that were relatively homogeneous in terms of gender equality (based on the GDI, which estimates the biological component), a small amount of variation is also influenced by nutritional/health factors.

Schwekendiek and Baten (2019) (see their Appendix) evaluated this new measure by comparing it with the relative life expectancies of both genders since 1890, which was a similarly widely accepted measure of gender equality. In addition, they compared the measure with the GDI for all countries since 1995 (Carmichael et al., 2014). The gender inequality of height measure was found to be consistently associated with all of these measures, as evidenced by simple Pearson correlation coefficients, as well as by country-fixed effects regressions that controlled for country-specific unobservable factors (Schwekendiek and Baten, 2019). The correlation between the measures was observable for all world regions and periods of the twentieth century, except for Western Europe and North America over the last four decades (when nutritional quality became sufficiently independent of income).

One issue could be the height loss of older ages. Height at age 25 and height at 50 are virtually identical. However, height at age 60 is affected by a certain amount of height loss, which needs to be adjusted to obtain estimates comparable to height at age 50 or earlier (Fernihough and McGovern, 2015; Huang et al., 2013; Kim et al., 2017). Heights of socialist countries are included starting in the 1970s, hence for the earliest birth decades of the 1910s of our sample, ages are around 60. The authors of the NCD-RisC dataset used a pre-adjustment of height loss, which is well documented in the literature. It is also standard in the anthropological literature (Baten and Blum 2014a, 2014b; Bogin, 2020; Tanner, 1990; see also Appendix B.7.5).

We compare this new measure of gender height inequality to gender differences in life expectancy data for other Asian countries during the 1960s (Figure B.3). Bangladesh, India, Maldives, Nepal, and Pakistan have some of the lowest gender equality in Asia, and this corresponds to the worst relative values of gender-specific life expectancy, as well as low gender height equality. The values for Singapore and Mongolia were the most gender-equal for the birth decade of the 1960s, whereas China, for example, performed slightly better in gender equality in height than in gender equality in life expectancy. It should be noted that gender equality in height reflects investment during the first years of life and during teenage years, whereas gender equality in life expectancy reflects equality over the entire lifetime, especially the last years before death. In general, we observe a moderate positive correlation between both variables. The Pearson correlation coefficient between gender equality in height and gender equality in life expectancy was 0.50 (p=0.00) in the 1970s and 0.42 (p=0.00) in the 1960s.[9]

Another potential issue could be selective mortality, especially in Asia, which is known for the "missing women" phenomenon. Survivorship bias in anthropometric research is a well-discussed issue. Bozzoli et al. (2009) speculated that the difference between height and life expectancy in West Africa might have been caused by selective survivorship. However, they emphasized that their argument outlines the theoretical possibility, while it is sometimes overlooked that their study does not provide empirical evidence. Moradi (2010) studied this in detail by using both surviving and dying children in West Africa. He observed that while survivorship bias plays a role, it is not quantitatively significant. Moreover, Guntupalli and Baten (2009) studied survivorship bias by using people of more and less educated backgrounds, expecting that people of more educated backgrounds might have a higher probability of survival. For India during the early twentieth century, Guntupalli and Baten do not observe this survivorship bias empirically. We conclude based on this and Moradi's (2010) study that missing girls and survivor bias play a role, but this effect is relatively small and hence does not bias our results.

[9] If one outlying case is removed (Afghanistan). Otherwise, it is 0.44 (p=0.00) in the 1970s and 0.34 (p=0.00) in the 1960s. Alternative measures are discussed in Appendix B.7.4.

B.2.2 Definition of Other Variables

To test the reliability and validity of our gender equality measurement, we compare our estimates with other dimensions of gender equality, such as education and life expectancy. For the former, we use the gap between female and male overall school enrollments, using educational attainment data from Barro and Lee covering 75 countries (Barro and Lee, 2013). This measure was inspired by Klasing and Milionis (2020), who provided comprehensive evidence on gender equality in education. For life expectancy, we collected data from the Human Mortality Database, the Human Life Table Database (see Appendix B.7.3), and Clio Infra for over 81 countries in the second half of the twentieth century, as well as the smaller number of countries (28) which Klasing and Milionis (2020) used for the early twentieth century. Gender equality in life expectancies is defined as the gap between female and male life expectancies. Therefore, our indicators for gender equality were always designed in a way that higher values indicated greater gender equality. Additionally, we use the Gender Development Index for further comparison (UNDP, 2022). The gender equality in life expectancy and the GDI were used in the previous section for measurements and the country case study below.

Before delving into the policy and social changes that occurred under socialist rule, it is important to clarify what we consider socialist states in this study. Identifying political systems as socialist is challenging as there are many dimensions to consider and no common definition. Typical socialist states, like the USSR or China, are often referred to as communist states. However, communism is originally seen as a conceptual theory based on Marxist-Leninist ideology, whereas socialism is the practical implementation of communist theory (Kornai, 1992). While the Soviet Union can unquestionably be categorized as socialist, it is arguable whether Iraq, which is seen as a representative of the so-called "Arab socialism" (Kadri, 2016), was a socialist state par excellence at the time. While socialism in the USSR and China was characterized by a strict atheistic doctrine, representatives of Arab socialism believed in the harmonization of Islam and socialism (Najjar, 1968). Another challenging factor is the difficulty of finding commonly available data that can aid classification. Within the context of a macroeconomic approach, most economists focus on market socialism and define socialism as the degree of intervention of the state in the economy and the associated degree to which the means of production, distribution, and exchange are owned or extremely regulated by the state with the

aim of benefiting the population, especially the poorest parts (Council of Economic Advisers, 2019; Schumpeter, 1950). Other indicators used were the ratio of the combined public consumption expenditures for health, education, and welfare to the factor price of the gross national product for their analysis (Flagg and Flagg, 1970). However, socialist systems affected the economy in more ways than the aforementioned factors, and one key value and goal of socialism itself is to provide equal chances for everyone. This was reflected in changes to constitutions through the inclusion of laws protecting and strengthening female rights and lowering the barriers for women to enter the labor market, for instance, by providing child care, paid maternity leave, and free health care (Pascall and Manning, 2000). This was supported by changes in family policy, including improved marriage rights and liberalization of reproductive rights after states transitioned to socialism (George and Manning, 2021; Molyneux, 1985; Pascall and Manning, 2000). Despite the abundance of qualitative research on socialism, there is a shortage of studies using a commonly available quantitative measure for a large set of countries in a long-term perspective. We classify states as socialist if they were ruled by a one-party state that identified itself as socialist and followed a Marxist theory in their political orientation, following a similar definition as in Kornai (2000).

Hence, our main variable of interest, socialism, identifies the years in which the sole ruling party identified as socialist. One of the primary goals of socialism is achieving gender equality. We find that 37 countries across Europe and Asia were one-party states with socialist regimes in the twentieth century. Figure B.4 is a map of all states we define as socialist in the 1980s, as well as the year the socialist party came to power (see also Appendix Table B.7 for more details on the socialist states). The first country to be classified as socialist is Russia. Here, the Bolsheviks seized power in 1917 during the October Revolution, marking the beginning of socialist Russia. This was followed by states of the former Soviet Union, which existed from 1920 onward. We define a state as socialist when the sole ruling party identifies with socialism and has been in power for at least five years. Since height is calculated by birth decade, we similarly define a decade as socialist if the country adopted socialism in that decade. We perform several robustness tests to identify whether our results were sensitive to this timing definition (they were not, per results available from the authors). We include only single-party states in the consideration of whether a state is socialist or not, as this is the common definition according to Marxist-Leninist

views. It involves a change in the constitution and has the advantage of a clear distinction from democracies with a governing socialist party that pursues and implements socialist values.

All of our regressions were estimated using fixed effects for country and birth decade. For several robustness tests, as well as for the instrumental variable estimation below, we also use a set of control variables to account for persistent cultural and religious factors that might influence socialism and gender equality. Moreover, we add control variables for legal origin, based on the work of La Porta et al. (2008). Legal origins influence institutions and affect a variety of economic outcomes, such as corruption, unemployment, or financial development, and can be divided into English, French, German, Scandinavian, and Socialist legal systems (La Porta et al., 2008). Religion and family systems were included to cover the effect of "long-lasting institutions" (Dilli et al., 2015). Religion measures the average share of the population that adheres to either Catholicism, Protestantism, or Islam using the World Religion Dataset and World Religion Project (Zurlo, n.d., https://www.worldreligiondatabase.org/). The definition of family systems relied on the classification by Todd (1985), who identified seven different family systems (absolute nuclear, African, anomic, authoritarian, egalitarian nuclear, endogamous community, and exogamous community) based on three characteristics: liberty with regard to marriage choice, symmetry with regard to inheritance, and endogamy. Each country falls into one of these groups. Hence, controlling for family systems allowed us to control for time-constant cultural practices and norms relevant to explaining country-specific differences in gender equality. The data for family systems was provided by Rijpma and Carmichael (2016), who combined data from Todd (1985) and Murdock's (1967) ethnographic atlas into a larger and more detailed dataset. Most countries are predominantly Catholic and follow the "exogamous community family system," followed by the "egalitarian nuclear family system".

For further robustness checks, we include economic growth by using GDP per capita data collected using the Maddison Project Database (Bolt and van Zanden, 2020). For an overview of the summary statistics of the main dependent and independent variables, refer to Table B.1. Our main variable of interest, gender equality in height, ranged from around 0.09 to almost 0.90. The relative life expectancy ranged from an advantage for males of 2.4 years to a very large advantage for women of 19.3 years. The latter was an exceptional situation in Finland in the 1940s, probably

related to the Winter War between Finland and the Soviet Union (1939–1940), when war-related mortality among Finnish males was exceptionally high.

B.3 Results

B.3.1 Descriptive Results

We first discuss the descriptive results of socialist countries versus other countries before turning to the regression results below. Directly comparing the countries that became socialist early (before 1950) with countries that never became socialist yielded the clear result that gender equality in height was higher in the former group (Figure B.5). Taking all countries together, both later socialist and never-socialist countries started at values around 0.20 index points. Already in the 1940s, socialist countries reached 0.31 index points, whereas the never-socialist countries only rose to values around 0.25. The largest difference was circa 0.07 index points in the 1950s. The gap remained until the 1980s, even though the last decades saw a small decline in both populations.

However, this dramatic development could be due to aggregation issues, as countries were heterogeneous. Hence, we focus on two neighboring countries, one of which became socialist while the other remained a market economy or traditional economy (as in the case of Iran). This is the case with gender equality development in Azerbaijan and Iran. These two countries are well-suited for a gender equality comparison, as they have shared similar historical experiences for most of their history. In 1918, Azerbaijan became an independent state; before that, it was mostly under the same rule as its neighboring Iran and strongly influenced by Persian culture. However, its independence did not last long, as it became officially part of the USSR in 1922. Despite Azerbaijan being part of the Russian Empire in the nineteenth century, Persian culture and values persisted, and it was not until it became part of the Soviet Union that Azerbaijan's culture and society began to change substantially (Heyat, 2002; Yilmaz, 2013). The Sovietization of Azerbaijan impacted women on a social, economic, and political level: women were better integrated into the labor market, achieved higher educational levels, and were more often represented in political institutions (Heyat, 2002). The USSR tried to undermine religious, ethnic, and class differences and promoted the socialist way of life, which fostered gender-equal values

(Heyat, 2002). Hence, it is plausible to assume that behaviors, values, and traditions that influence gender equality and female roles were similar in both countries until the formation of the USSR. Figure B.6 shows the development of gender equality in height in Iran and Azerbaijan after Azerbaijan became part of the Soviet Union. We can observe a clear distinction between the development in Iran and socialist Azerbaijan. In the 1920s, gender equality was even lower in Azerbaijan than in Iran but consistently increased. After the 1920s, we observe a dramatic increase in female height compared to male height in Azerbaijan. Apparently, the previous son bias had led to the provision of more resources (in terms of quality of nutrition and health care) for male children compared to female children. This unequal distribution persisted in Iran but not in Azerbaijan. This corresponds with female labor force participation and female education during the socialist era (Tohidi, 1996). Despite this success in gender equality, it is important to mention that conservative values and norms persisted, and women seemed to suffer from the double burden caused by their traditional obligations toward their family and work (Tohidi, 1996).

Sabi (1999) provided additional context to the gender situation in socialist Azerbaijan in comparison to the pre-Soviet situation and in comparison to Iran, Turkey, and Iraq. She explained that the socialist regime had the theory that if child care and domestic work could be socialized, then women could work outside their homes and oppression would be eliminated (Sabi, 1999). Instruments employed were, for example, daycare for children and public lunch and dining rooms to reduce domestic work. Low wages for both males and females during the Soviet period also motivated a high female labor share because otherwise, household income would have been insufficient. Hence, women's participation rate was very high, at around 80 percent of those of working age. Nevertheless, the double burden of the remaining domestic work and the work on the official labor market also applied to Azeri women. Immediately after the revolution, the first wave of legal secularization of family laws ensued. For example, polygamy was prohibited, and several issues in Islamic family customs were resolved. During the late 1920s, the local government of the Azerbaijan Socialist Republic and the Soviet Union government initiated a massive campaign to liberate women. Sabi (1999) described these initiatives as relatively successful. The liberation of Azeri women was evident, especially when compared to their pre-Soviet status as well as in comparison to Iran, Turkey, and Iraq. By the time of the Soviet Union's dissolution in

1989, 43 percent of the labor force in Azerbaijan was female, whereas in Iran at the same time, it was only 10 percent. Female literacy levels were relatively high, and life expectancy was substantially higher for females in comparison to neighboring Turkey in 1994 (Azerbaijan: 74.9; Turkey: 70.6), while male life expectancy was almost the same in both countries (Azerbaijan: 65.9; Turkey: 66.8) (Sabi, 1999). However, despite these achievements relative to the pre-Soviet era and neighboring countries, Sabi still saw Azerbaijani society as ruled by a strong patriarchy, especially in the private sphere. Additionally, the high employment share was characterized by occupational segregation, with more agricultural and manual farm work performed by women, while they were nearly absent in high managerial positions during the 1990s when Sabi wrote her article. Nevertheless, for our study, the significant increase in gender equality during the Soviet era is relevant. Sabi did not have access to meaningful quantitative time series; hence, she discussed several advantages and disadvantages of the Soviet transformation without reaching an overall conclusion. In contrast, we can draw a conclusion based on Figure B.6.

B.3.2 Regression Results

We analyze the effect of socialism on gender equality by estimating equation 2. The dependent variable GE_{it} is one of the above-mentioned measures of gender equality—either gender equality in height or education or a combination—and varies over country i and time decade t. S_{it} is the main variable of interest and is unity if a state is defined as socialist and zero otherwise. We include country-fixed effects μ_i to control for time-invariant unobservable factors, and year-fixed effects ϑ_t. The error term is ε_{it}. Standard errors are clustered at the country level. We include birth decades from the 1910s to the 1980s in our regression analysis.[10]

$$GE_{it} = \alpha_{it} + \beta_1 \cdot S_{it} + \mu_i + \vartheta_t + \varepsilon_{it} \tag{2}$$

[10] In order to show that our results do not change depending on the periods included we estimate the effect covering differing periods onwards in Appendix Table B.10. To achieve a high data quality, we do not include the decades for 1890 and 1900 as height for socialist countries is only available from census data starting in the 1970s and 1980s. Consequently, height measurements for earlier birth decades are adjusted for height loss, which may be subject to substantial measurement errors.

Table B.2 shows the results of equation 2 using gender equality in height as the dependent variable. We find a consistent positive effect on gender equality in height, even after controlling for country- and decade-fixed effects. The effect is significant and positive, indicating a 0.17-index-points-increase in gender equality in height for Europe and Asia combined. To check whether the coefficient for socialism in Eurasia was driven by different regions, we estimate the effect for the continents separately. The results are shown in columns 2 and 3. The effects on both continents are very similar. Our results suggest that during this socialist period, there was a decline in the previously existing son bias (parents' preference for sons over daughters), which had previously led to worse education, nutrition, and general health care for girls. One method to assess the economic relevance of a coefficient is to relate its size to the standard deviation. The coefficient of socialism (0.17, Table B.2) represents about half the size of the standard deviation (0.31, Table B.1), hence we might conclude that the coefficient is not only statistically significant, but also of economically relevant size.

To provide more evidence for our hypothesis that gender equality increased in socialist states, we use gender equality in education as an outcome. Carmichael et al. (2014) suggested that socialist states invested in educational facilities and promoted equal schooling rights for both boys and girls. Table B.3 shows that the effect was especially pronounced in Asia, with socialism resulting in additional female educational attainment by over one year. Girls were allowed to stay longer in school and obtained higher levels of education. The smaller effect in Europe is likely explained by the already high school enrollment rates for both boys and girls in the early twentieth century. Nevertheless, educational attainment for girls still increased by almost half a year in socialist states. Since higher education is correlated with improved labor opportunities, among other outcomes, our results might imply an increase in the economic returns for women under socialism (Carranza, 2014; Majlesi, 2016).

Overall, our results indicate that socialist governments succeeded in increasing gender equality within the population, suggesting a mitigation of the son bias. This positive shift in gender equality, after the adoption of socialism, indicates a change in parents' behavior toward more equal treatment of their children, with respect to not only nutrition but also education.

B.3.3 Robustness Checks

One alternative mechanism might be the fact that rising income could have increased gender equality; hence, we need to control economic growth and welfare using data on GDP per capita. However, since there is the possibility of reverse causality or that economic growth and gender equality mutually affect each other, GDP can be seen as a "bad" control variable. Hence, we introduce it only as a robustness check in a subsidiary regression, not in our preferred regression. Moreover, information on GDP has been consistently available for only 41 states since the 1910s resulting in a significant reduction of the sample size and introducing the risk of selection bias since countries with available GDP data in the early twentieth century might systematically differ from all countries with earlier data. Column 1 of Table B.4 shows that GDP is not significantly correlated with gender equality in Eurasia. The coefficient of socialism is still high and significant at the 1 percent level, indicating that the effect on gender equality in height persists even after controlling for economic development.

Another way to control a nation's welfare is to include the average height. Average height has been shown to be strongly correlated with the biological standard of living, life expectancy, and economic development (see, for instance, Komlos, 1985; Steckel, 1995). Column 2 of Table B.4 shows a slightly positive effect of height on gender equality in height, but the socialist variable remains significant. Moreover, we include the first lag of the socialism variable to investigate if the effect was immediate or delayed. We observe an additional delayed effect of socialism (Table B.4, column 3). Adding region-specific time trends of the dependent variable slightly decreased our coefficient of interest to 0.12 index points (Table B.4, column 4). To ensure no socialist outliers were driving our results, we also utilize a stricter definition of socialism, excluding states that did not follow the classical socialism model. In Asia, this relates to the states of Iraq and Syria. Both were initially defined as socialist during the 1960s/1970s and onward. Excluding these states does not affect the coefficient of socialism, although the standard error is marginally smaller (Table B.4, column 5). Lastly, column 6 includes the full set of control variables, including GDP per capita, average height, the first lag of socialism, and controls for a decade- and country-fixed effects. The coefficient of socialism was at 0.09 index points and was statistically significant. Overall, these robustness checks suggest that the effect on gender equality in height remains

robust even after including various control variables, supporting the finding that socialism has a positive effect on gender equality in height.

B.3.4 Instrumental Variable Estimation

The use of an instrumental variable (IV) approach is important for this analysis as it helps to address concerns about the endogeneity of the socialism variable. This means that the relationship between socialism and gender equality in height may be driven by other factors that are not accounted for in the analysis. Given that women also played a role in socialist revolutions, though often not fully recognized, a direction-of-causality issue might also exist (Clements, 1997; Farnsworth, 1976). We instrument socialism by distance to Russia, using distance to Moscow, the political center of the former Soviet Union. This instrument was recently suggested and successfully employed by Baten et al. (2024). The idea is that after the first successful revolution in Russia, most subsequent socialist takeovers occurred in relative geographic proximity to Russia. The location of the first revolution in Russia itself was quite unexpected to observers at the time. They expected proletarian revolutions in the most industrialized nations, such as the UK and Belgium, around 1900 (Baten et al., 2024). The Russian Revolution was partly enabled by war enemy Germany, who allowed the main Russian revolutionary protagonist, Lenin, to be brought in a sealed train from Switzerland to Russia via Germany. This turned out to be one of the determinants of the success of the first socialist revolution. This determinant was military power politics and was hence not endogenous to the economic model.

In the instrumental variable analysis, we could not employ country-fixed effects because we have a time-invariant instrumental variable that would be perfectly correlated with country-fixed effects. We include the next higher geographic units and specify fixed effects for eight world regions within Eurasia (defined according to the United Nations geoscheme). We additionally control variables related to family systems, religion, legal origins, and regional trends.[11] The results are reported in Table B.5, confirming the positive effect of socialism on gender equality. The first stage of the regression analysis showed that the instrument (distance to Moscow) was

[11] Since including world region FE instead of country FE affects the coefficient size of socialism, we estimated equation 2 for gender equality in height using world region FE as well as regional trends, family system, religion, and legal origin controls in Appendix Table B.11. Socialism has an impact of 0.16 index points of gender equality if world region FE are used.

highly significant (F-Stat 39 to 57) and had a negative coefficient in both regions, indicating that countries further from Moscow were less likely to adopt socialist policies. In the second stage, the socialism coefficient was positive and significant, suggesting that socialism had a positive effect on gender equality in height. It was even slightly larger than in the OLS model, likely because measurement error was less of a problem in instrumental variable regressions (Becker, 2016).

Since our instrument, the distance to Russia, might be inversely correlated with the distance to London and the distance to the United States, which reflect the distance to technological frontiers during the twentieth century, we include the logarithm of these two variables to address potential concerns regarding the exclusion restriction. Although the distance to London in itself had no impact on gender equality in height, it also increased the effect of socialism. Neither this distance nor the one to the United States removes the significant effect on gender equality instrumented by the distance to Moscow. Overall, the use of an IV approach strengthens the validity and robustness of our analysis by addressing concerns of endogeneity and providing more credible and reliable estimates of the causal effect of socialism on gender equality in height.

B.3.5 Staggered Difference-in-Differences Estimation and Dynamic Effects

Staggered difference-in-differences methods have been developed to address situations where treatment is not adopted simultaneously for all units. Since socialism was adopted at different times across different countries, we can estimate its effect on gender equality in height and education using a staggered difference-in-differences estimation. We rely on the model proposed by Callaway and Sant'Anna (2021), who adapted the difference-in-differences estimation for events introduced at different points in time. One key assumption for Callaway and Sant'Anna's (2021) estimation method is the "non-reversibility of treatment", which means that once a state adopted socialism, it maintained this status until the end of the observation period. Since we include birth decades only until the 1980s and the fall of socialism began with the Revolutions of 1989 and the subsequent collapse of the Soviet Union in 1991, the "non-reversibility of treatment" assumption holds for our data. Table B.6 shows a significant positive effect of socialism on gender equality in height and education, after controlling for decade fixed effects (FE), country FE, and regional trends of the dependent variable. We further notice no change in

the coefficient size, whether the control group consists of never-treated units (i.e., states that never adopted socialism) or of never-treated plus not-yet-treated units.

To observe the influence of socialism over time and analyze if there was already a pre-trend toward gender equality in countries that have adopted socialism, we employ an event study approach, following Callaway and Sant'Anna (2021). Estimating the dynamic effects allows us to obtain the effects of years prior to and after a country switched to a socialist government. In other words, if the coefficients on the lead dummy variables of socialism have a value of zero, this can be interpreted as a test for the identifying assumption. Figure B.7 and Figure B.8 demonstrate the results of socialism over time for gender equality in height and education, respectively. We observe a delayed, significant, and positive effect after the treatment. The coefficients are not statistically different from zero before the adoption of socialism, except for the birth decade just prior to socialism for gender equality in height. As noted above, height is mostly, but not solely, influenced by the birth decades. The following decade, when boys and girls experience their puberty growth spurt, is also strongly influenced by nutrition and health and can have a substantial additional impact (Tanner, 1990). The deviation in the t minus 10 period would be compatible with changing parental behavior not only toward children but also toward teenagers. Overall, the analysis of staggered difference-in-differences is in line with the hypothesis that socialism has a positive effect on gender equality, although we discussed the possibility of a pre-trend in the gender equality in height.

B.4 Conclusion

In this study, we develop a novel index for measuring gender equality based on the difference in male and female adult heights (expanding on the discussion of Schwekendiek and Baten, 2019). Our gender equality index has several advantages over other measures; it is unlikely to suffer from window dressing (such as the 1910s to 1940s) and is available for early decades. However, we cannot capture all dimensions of gender inequality, such as the double burden that might have reduced subjective well-being or gender pay gaps.

Using this index, we estimate the impact of regime changes on gender equality. By controlling for unobserved factors through a fixed effects model, we find robust evidence that a socialist

government—not aiming to downplay all its other issues—led to relatively higher female stature and improved living conditions for girls. We estimate a coefficient of socialism of 17 percent. We assess the economic effect size of these coefficients in relation to the standard deviation of this variable. The coefficient of socialism represents about half the size of the standard deviation, hence we conclude that the coefficient is of economically relevant size.

We cannot make empirical statements about the mechanisms using our multi-country macroeconomic data. However, based on related detailed country studies on (a) gender-specific evidence in socialist economies and (b) human height studies, we can propose the most likely mechanism. The fact that a country turns socialist does not automatically impact the relative heights of males and females. Alesina and Fuchs-Schündeln (2007) describe a similar mechanism for the transmission of socialist ideas into preferences for equality, focusing on (1) indoctrination by the socialist state (affecting changes of culture) and (2) its control over institutions such as schools and workplaces (changing incentives). In our case, gender equality was heavily promoted through propaganda, cultural products like movies and novels, and school curricula. Socialist governments also introduced legal and institutional changes to increase equality. Additionally, access to education and health care was expanded, women were encouraged to enter the labor market, and measures like expanding child care and guaranteeing equal wages were implemented. We assume that both aspects, cultural change and changes to the incentive structure, were at work. However, while cultural change most likely takes place at a slower pace, sometimes lasting a whole generation, parents might react to changes in incentives (such as education-related incentives) within a shorter period. Given that our staggered difference-in-differences models show relatively quick changes (from decade to decade), the incentive changes might have been even more relevant than the cultural change at first, although we need to remain cautious about making strong statements based on macro-data.

However, some caveats need to be mentioned. Socialist states were not motivated to make this investment only because they wanted to emancipate women and improve gender equality but also because socialist states were interested in the female labor force and used educational institutions as a tool to shape the belief system (Schwekendiek and Baten, 2019). Nevertheless, this suggests that policy interventions under socialism decreased the opportunity costs of sending daughters to school, leading to higher educational levels for girls. In line with this, we show an

increase in female education levels relative to males, suggesting that women achieved higher levels of education under socialism, an important factor for female empowerment. We address endogeneity issues by using an instrumental variable estimation and a staggered difference-in-differences design.

Taken together, our study highlights the relevance of political interventions in promoting gender equality and mitigating the significant son bias that existed in the early twentieth century in many societies. The results suggest that gender equality can be addressed in policymaking. Socialist systems implemented effective policy measures to achieve this goal. Our study provides new insights into the relationship between political ideology and gender equality in more detail. This application shows that a new and robust indicator for measuring gender equality in multi-country studies is informative, unlocking new ways of analyzing gendered welfare in the long run.

B.5 References

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B.6 Figures and Tables

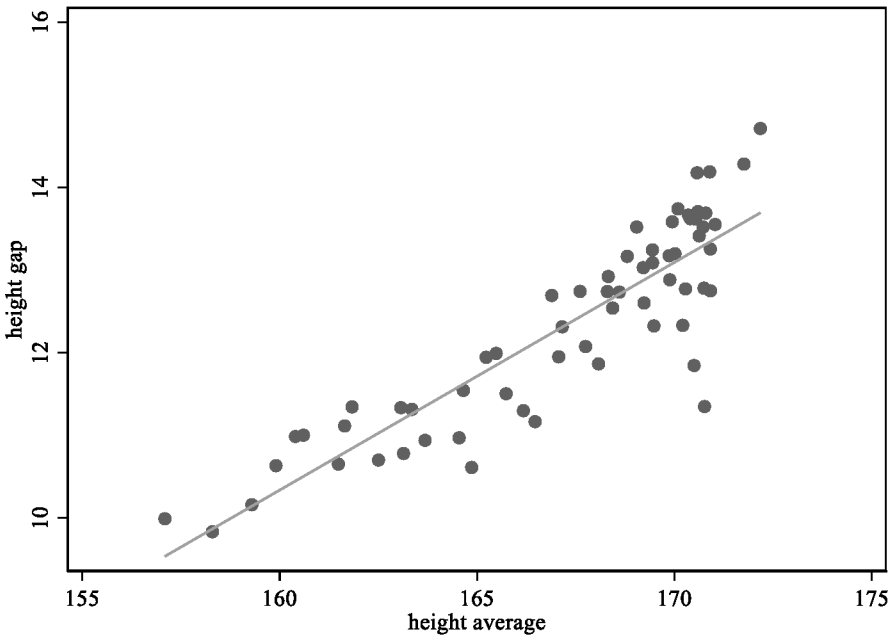


Figure B.1: Height gap and height average, using the sample with "mostly biological" variation

Notes: Height gap is defined as the difference between male and female height (in cm). Among the 20 countries for which Carmichael et al. (2014) calculate the GDI, only those in the middle of the distribution are included, that is, countries with average levels of gender equality according to criteria other than height. Included countries are: Canada, China, France, Poland, Russia, Spain, Thailand, US, UK.

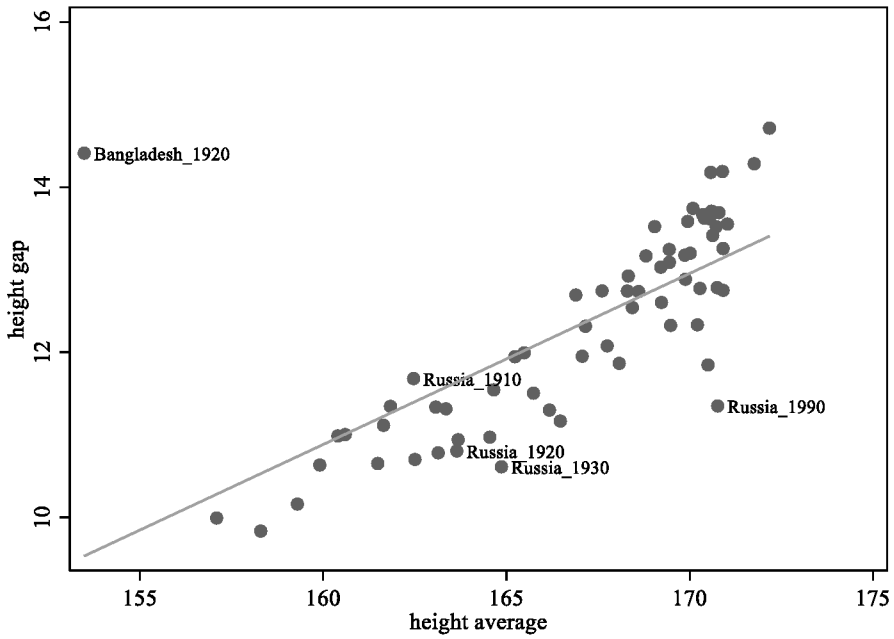


Figure B.2: Adding some economic (or nutrition/health) gender inequality to Figure B.1

Notes: Height gap is defined as the difference between male and female height (in cm). Among the 20 countries for which Carmichael et al. (2014) calculate the GDI, only those in the middle of the distribution are included, that is, countries with average levels of gender equality according to criteria other than height. Canada, China, France, Poland, Russia, Spain, Thailand, US, UK.

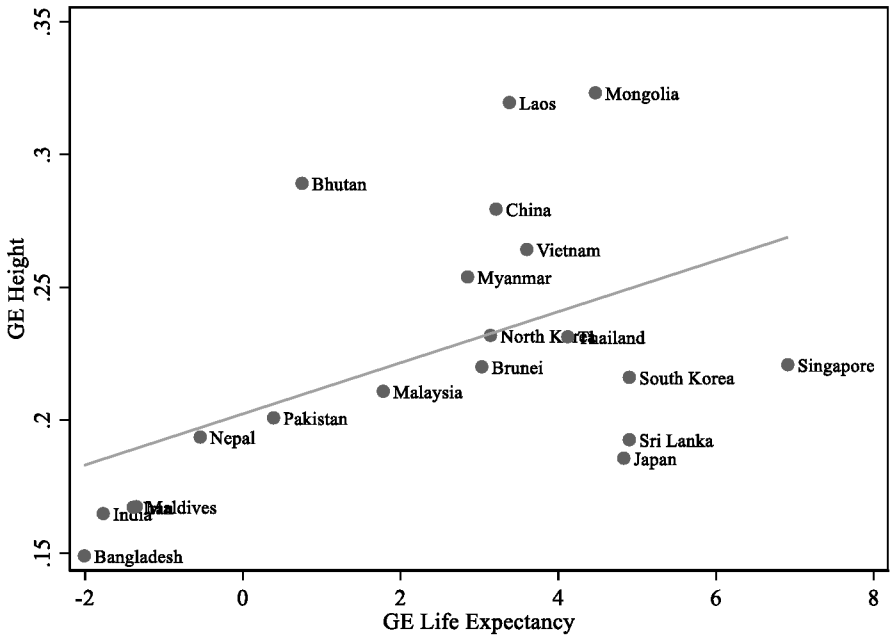


Figure B.3: Gender equality in life expectancy and height, Asia 1960s

Notes: Gender equality in life expectancy is defined as the gap between female and male life expectancy at birth (in years). Gender equality in height is based on the gap between male and female height. Countries included are from East Asia, Southeast Asia, and South Asia.

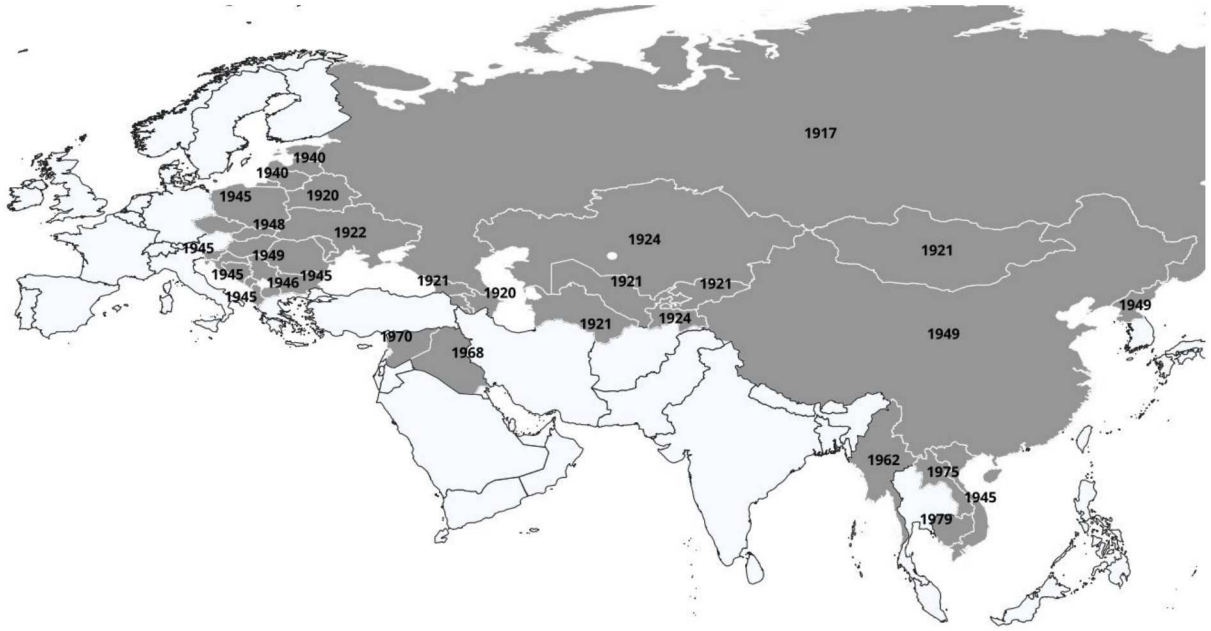


Figure B.4: Socialist countries in 1980

Notes: The map shows in gray countries that were socialist in 1980. The black numbers indicate the year a country adopted socialism.

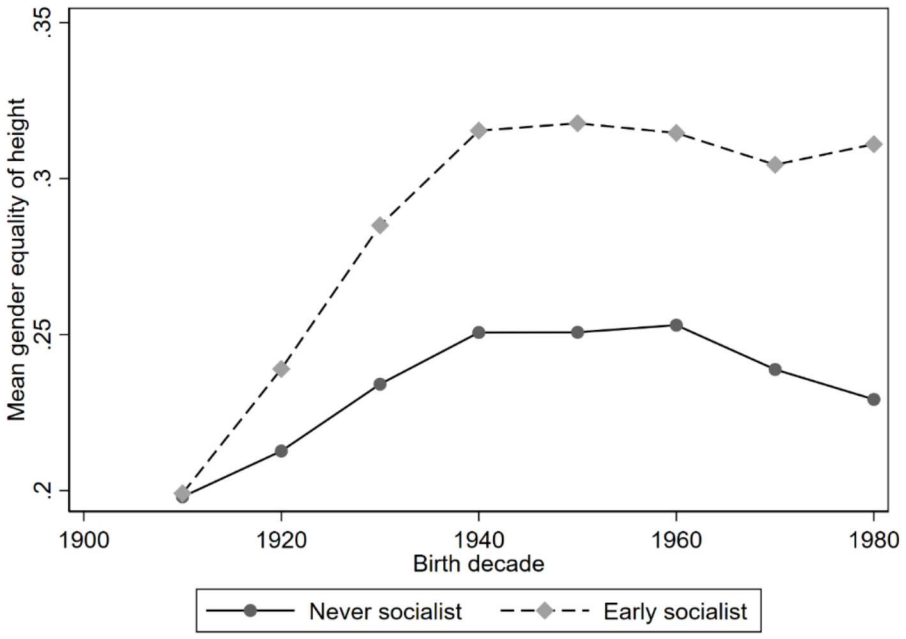


Figure B.5: Gender equality in height: countries that became socialist early versus countries that never became socialist

Notes: We only included the countries that became socialist early, i.e., during the main waves of the 1910s to 1940s, not the "late-comers" such as Cambodia, Laos, etc.

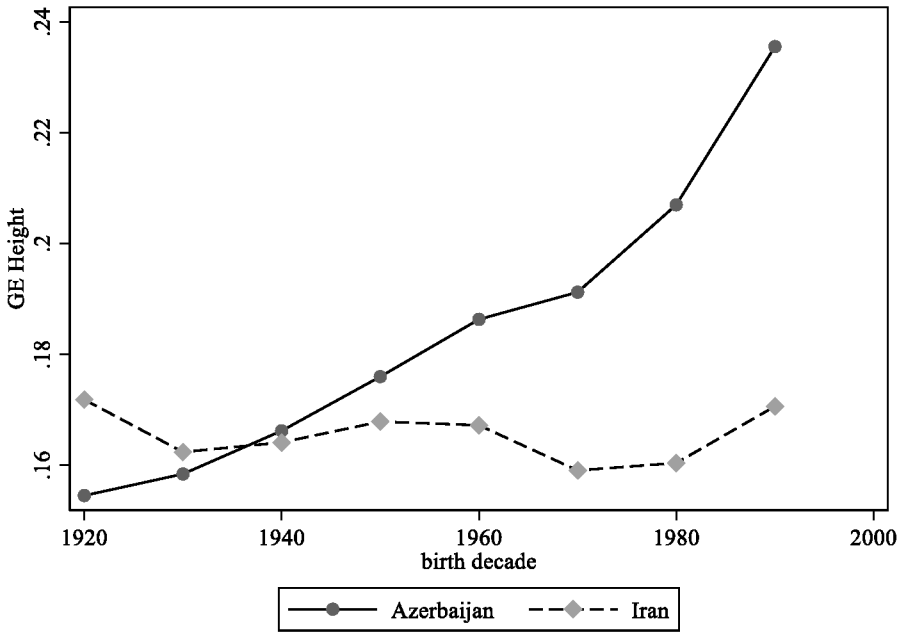


Figure B.6: Gender equality in height in Azerbaijan and Iran, 1920–1980

Notes: Gender equality in height is based on the gap between female and male heights. For the 1910s, insufficient data are available.

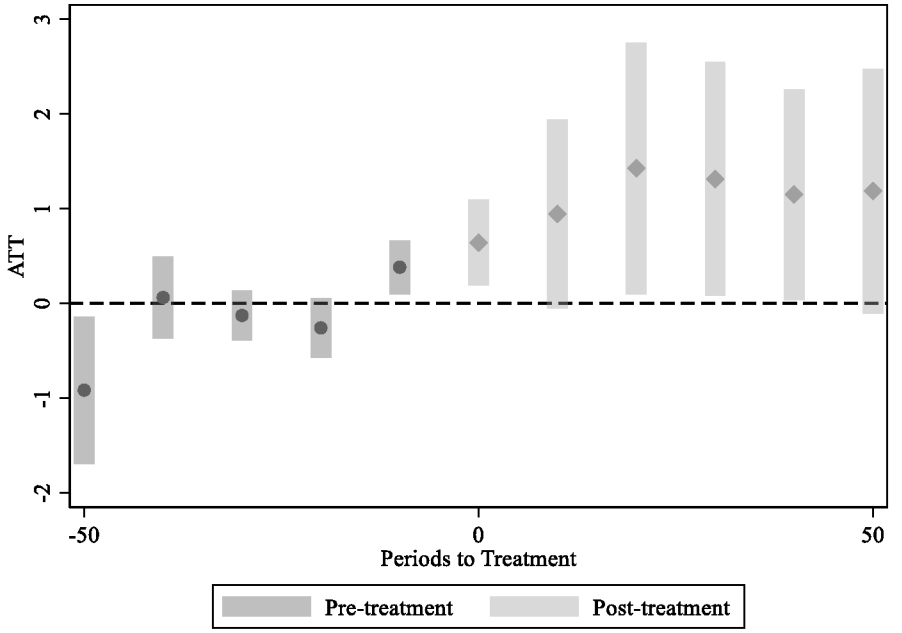


Figure B.7: Dynamic effects for gender equality in height

Notes: Effects are estimated following Callaway and Sant'Anna (2021). Periods to treatment refer to the number of years until a country became socialist. The dashed horizontal line is at y = 0. Vertical bars represent the 95% confidence interval.

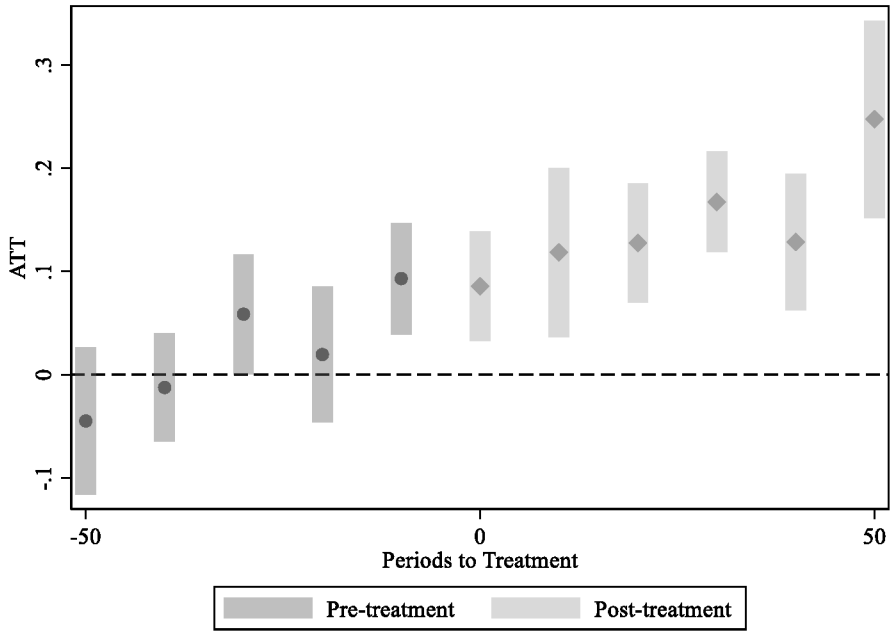


Figure B.8: Dynamic effects for gender equality in education

Notes: Effects are estimated following Callaway and Sant'Anna (2021). Periods to treatment refer to the number of years until a country became socialist. The dashed horizontal line is at y = 0. Vertical bars represent the 95% confidence interval.

Table B.1: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
GE height	704	0.251	0.09	0.09	0.898
GE height (ln)	704	-1.435	0.312	-2.403	-0.108
Height gap	704	11.74	1.35	7.972	15.493
GE education	608	-0.766	1.134	-5.855	2.406
GE life expectancy	321	4.77	2.764	-2.4	19.28
Height male (cm)	704	169.516	5.939	155.277	182.559
Height female (cm)	704	157.776	5.169	144.552	168.945
Height average (cm)	704	163.646	5.526	150.951	175.716
Education male	608	7.939	3.45	0.012	14.534
Education female	608	7.173	4.132	0.012	14.868
Life Expectancy male	321	60.338	8.854	31.44	73.39
Life Expectancy female	321	65.107	10.068	30.81	80.07
Socialism	718	0.269	0.444	0	1
Anomic fam. system	718	0.045	0.206	0	1
Authoritarian fam. system	718	0.167	0.373	0	1
Endocom fam. system	718	0.245	0.43	0	1
Exocom fam. system	718	0.331	0.471	0	1
Egalitarian nuclear fam. system	718	0.167	0.373	0	1
Share Catholic	715	0.286	0.395	0	1
Share Protestant	718	0.101	0.262	0	0.995
Share Islamic	715	0.305	0.39	0	0.984
Legal origin English	718	0.201	0.401	0	1
Legal origin French	718	0.468	0.499	0	1
Legal origin German	718	0.234	0.424	0	1
Legal origin Scandinavian	718	0.056	0.23	0	1
Legal origin Socialism	718	0.022	0.148	0	1

Notes: Summary statistics are calculated for Europe and Asia for the birth decades 1910 to 1980s. GE denotes gender equality and is the measure used in the respective regression. GE height is our own indicator and described in detail in the text. GE education and GE life expectancy are the difference between female and male education and life expectancy, respectively. Height gap is the difference between male and female height.

Table B.2: Effect of socialism on gender equality in height, 1910-1980s

	(1)	(2)	(3)
	Eurasia	Asia	Europe
Socialism	0.17***	0.16***	0.15**
	(0.030)	(0.028)	(0.062)
Constant	-1.66***	-1.55***	-1.68***
	(0.028)	(0.035)	(0.064)
Decade FE	Y	Y	Y
Country FE	Y	Y	Y
Observations	704	400	304
R-squared	0.925	0.931	0.822

Notes: Dependent variable is the logarithm of gender equality in height. Birth decades from the 1910s to 1980s are included. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table B.3: Effect of socialism on gender equality in education, 1910-1980s

	(1)	(2)	(3)
	Eurasia	Asia	Europe
Socialism	0.99**	1.36**	0.48**
	(0.478)	(0.526)	(0.199)
Constant	1.39***	1.85***	-0.29*
	(0.470)	(0.493)	(0.163)
Decade FE	Y	Y	Y
Country FE	Y	Y	Y
Observations	608	328	280
R-squared	0.790	0.798	0.778

Notes: Dependent variable is gender equality in education. Birth decades from the 1910s to 1980s are included. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table B.4: Robustness checks with additional controls: effect of socialism on gender equality in height, 1910-1980s

	(1)	(2)	(3)	(4)	(5)	(6)
	Eurasia	Eurasia	Eurasia	Eurasia	Eurasia, less ME	Eurasia
Socialism	0.19***	0.17***	0.11***	0.12***	0.18***	0.10***
	(0.031)	(0.034)	(0.025)	(0.028)	(0.028)	(0.022)
ln(GDP p.c.)	-0.02					-0.07
	(0.054)					(0.060)
Height avg.		0.01				0.02
		(0.012)				(0.014)
Lagged Socialism			0.08***			0.01
			(0.025)			(0.029)
Regional Trend				0.78***		0.72***
				(0.214)		(0.252)
Constant	-1.67***	-4.00**	-1.65***	-0.44	-1.66***	-2.60
	(0.433)	(1.867)	(0.026)	(0.338)	(0.028)	(2.008)
Decade FE	Y	Y	Y	Y	Y	Y
Country FE	Y	Y	Y	Y	Y	Y
Observations	287	616	616	616	616	287
R-squared	0.946	0.936	0.936	0.936	0.936	0.949

Notes: Dependent variable is the logarithm of gender equality in height. Birth decades 1910 to 1980s included. Family systems include anomic, authoritarian, endogamous community, and exogamous community, the reference category is egalitarian nuclear. Religion includes protestant, Islamic, or catholic, the reference category is other religions. Column 1 adds GDP pc as control (information on GDP is only consistently available for 41 states since 1920), column 2 the national height average, column 3 the first lag of the variable socialism, column 4 includes region specific trends of the dependent variable, column 5 codes Iraq and Syria as non-socialist ("less ME", i.e. without these two Middle Eastern countries), and column 5 includes all control variables including for GDP pc., thus, the reduced sample size. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table B.5: IV Estimation: effect of socialism on gender equality in height, 1910-1980s

	(1) Eurasia	(2) Eurasia	(3) Eurasia	(4) Asia	(5) Asia	(6) Asia
First stage						
Distance to Moscow	-0.11***	-0.12***	-0.11***	-0.11***	-0.27***	-0.17***
	(0.017)	(0.017)	(0.017)	(0.017)	(0.036)	(0.023)
F-stat	41.03	54.22	39.81	44.63	57.42	44.27
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Second stage						
socialism	0.29**	0.31***	0.28**	0.36**	0.48***	0.79***
	(0.135)	(0.117)	(0.140)	(0.150)	(0.112)	(0.198)
ln(distance to London)		0.02			0.09	
		(0.023)			(0.097)	
ln(distance to US)			-0.05			0.75***
			(0.139)			(0.274)
Decade FE	Y	Y	Y	Y	Y	Y
Region FE	Y	Y	Y	Y	Y	Y
Region Trends	Y	Y	Y	Y	Y	Y
Controls	Y	Y	Y	Y	Y	Y
Observations	672	672	672	384	384	384

Notes: Dependent variable is the logarithm of gender equality in height. Birth decades 1910 to 1980s included. Socialism is instrumented using distance to Moscow. Results for Europe are excluded due to a low F-statistic (smaller than ten). Controls for Family systems, religion and legal origins are included. Family systems include anomic, authoritarian, endogamous community, and exogamous community, the reference category is egalitarian nuclear. Religion includes the average share for protestant, Islamic, or catholic, the reference category. Legal origins includes English, French, German, Scandinavian and Socialist origins. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** $p < .01$, ** $p < .05$, * $p < .1$.

Table B.6: Staggered difference-in-differences estimation: effect of socialism on gender equality in height, 1910-1980s

	(1)	(2)	(3)	(4)
	Callaway and Sant'Anna (2021)			
	DV: GE height		DV: GE education	
	Eurasia		Eurasia	
Socialism	0.14***	0.14***	1.09***	1.09***
	(0.037)	(0.037)	(0.492)	(0.473)
Control Group	Never	Not yet	Never	Not yet
Decade FE	Y	Y	Y	Y
Country FE	Y	Y	Y	Y
Region Trends	Y	Y	Y	Y
Observations	704	704	608	608

Notes: Dependent variable is the logarithm of gender equality in height (GE height) and gender equality in education lagged by ten years (GE education). Birth decades from 1910 to 1980s included. Control group "Never" includes only the never treated units and "Not yet" the never and not yet treated units as comparison group. Regression is weighted by population. Standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

B.7 Appendix

B.7.1 Country List and Additional Robustness Tests

Table B.7: Socialist countries

Continent	Region	Country	Definition	Years
Asia	East Asia	China	Asian socialism	1949–present
Asia	East Asia	North Korea	Asian socialism	1949–present
Asia	East Asia	Mongolia	Asian socialism	1921–1992
Asia	East. Eur./Cntr. Asia	Kyrgyzstan	USSR	1921–1991[1]
Asia	East. Eur./Cntr. Asia	Kazakhstan	USSR	1921–1991[1]
Asia	East. Eur./Cntr. Asia	Tajikistan	USSR	1921–1991[1]
Asia	East. Eur./Cntr. Asia	Turkmenistan	USSR	1921–1991[1]
Asia	East. Eur./Cntr. Asia	Uzbekistan	USSR	1921–1991[1]
Asia	Southeast Asia	Cambodia	Asian socialism	1979–1989
Asia	Southeast Asia	Laos	Asian socialism	1975–present
Asia	Southeast Asia	Myanmar	Asian socialism	1962–1988
Asia	Southeast Asia	Vietnam	Asian socialism	1945–present[2]
Asia	Western Asia	Armenia	USSR	1920–1991[3]
Asia	Western Asia	Azerbaijan	USSR	1920–1991[3]
Asia	Western Asia	Georgia	USSR	1920–1991[3]
Asia	Western Asia	Iraq	Arab socialism	1968–2003[4]
Asia	Western Asia	Syria	Arab socialism	1970–2000
Europe	East. Eur./Cntr. Asia	Bulgaria	Satellite	1945–1989
Europe	East. Eur./Cntr. Asia	Belarus	USSR	1920–1991[3]
Europe	East. Eur./Cntr. Asia	Czech Republic	Satellite	1948–1989
Europe	East. Eur./Cntr. Asia	Hungary	Satellite	1949–1989
Europe	East. Eur./Cntr. Asia	Moldova	USSR	1940–1991
Europe	East. Eur./Cntr. Asia	Poland	Satellite	1945–1989
Europe	East. Eur./Cntr. Asia	Romania	Satellite	1947–1989
Europe	East. Eur./Cntr. Asia	Russia	USSR	1917–1991
Europe	East. Eur./Cntr. Asia	Slovakia	Satellite	1948–1989
Europe	East. Eur./Cntr. Asia	Ukraine	USSR	1922–1991[3]
Europe	Northern Europe	Estonia	USSR	1940–1991
Europe	Northern Europe	Lithuania	USSR	1940–1991
Europe	Northern Europe	Latvia	USSR	1940–1991
Europe	Southern Europe	Albania	Satellite	1945–1992
Europe	Southern Europe	Bosnia and Herzegovina	Yugoslavia	1945–1992
Europe	Southern Europe	Serbia	Yugoslavia	1945–1992

Table B.7 (continued)

Europe	Southern Europe	Croatia	Yugoslavia	1945–1990
Europe	Southern Europe	Montenegro	Yugoslavia	1945–1992
Europe	Southern Europe	Macedonia	Yugoslavia	1946–1991
Europe	Southern Europe	Slovenia	Yugoslavia	1945–1989

Notes: The table shows the years we define states to be socialist. "Asian socialism" is our own notation and indicates socialist states in Asia, that were not part of the Soviet Union. "USSR" indicates all states that were part of the Union of Soviet Socialist Republics (USSR). "Arab socialism" only refers to Iraq and Syria, the kind of socialism implemented in these two Arab states, which was not traditionally rooted in the Marxist-Leninist ideology. "Satellite" indicates all Eastern European nations under control of the Soviet Union during the Cold War. "Yugoslavia" indicates the states that formed the Socialist Federal Republic of Yugoslavia.

[1] In 1924 the Turkmen SSR, the Uzbek SSR (with today's Tajikistan as an autonomous republic (Tajik ASSR)), the Kazakh ASSR and the Kyrgyz ASSR were created as part of the RSFSR (Russian Soviet Federative Socialist Republic). For Kyrgyzstan and Kazakhstan it was not until 1936 and for Tajikistan it was not until 1929 that they became officially established as parts of the Soviet Union. Already before 1924, in 1921 the Turkestan ASSR (covering todays Turkmenistan, Uzbekistan and Kyrgyzstan) was created, but existed as a single entity for only a few years (Mamirjonovna, 2022).

[2] North and South Vietnam became only united in 1976. Before 1976 North Vietnam was already a socialist state (Democratic Republic of Vietnam) since 1945.

[3] Armenia, Georgia, and Azerbaijan were part of the Transcaucasian SFSR (which was part of the republic of the Soviet Union) from 1922 to 1936. Before 1922 and after 1936 they were already part of the Soviet Union as SSRs. Belarus was before 1922 also a SSR.

[4] The state was also called "Ba'athist Iraq" because it was under the rule of the Arab Ba'ath Socialist Party. In contrast to other socialist states, state atheism was not implemented in Iraq (and Syria) and but instead Islam was pro-claimed as the state religion (Najjar, 1968).

Table B.8: NCD-RisC data sources for height

World region	(1) Number countries	(2) Total sample size Female	(3) Total sample size Male
East Asia	7	2,636,553	3,069,698
Eastern Europe and Central Asia	15	108,833	207,190
South Asia	9	723,307	469,212
Southeast Asia	11	600,384	458,339
Western Asia	18	144,580.97	59,032.956
Northern Europe	10	1,494,797	3,157,070
Southern Europe	11	162,050	1,123,803
Western Europe	7	242,393	596,290

Notes: Total number of male and female individuals that were used to calculate the height averages for the birth decades 1910 to 1980s.

Table B.9: Robustness checks for GE height and GE education: yearly and half-decade data, 1910-1980s

	(1) GE height Yearly	(2) GE education Yearly	(3) GE height Half-decade	(4) GE education Half-decade
Socialism	0.15***	0.92**	0.16***	0.93**
	(0.025)	(0.389)	(0.027)	(0.418)
Constant	-1.69***	1.41***	-1.67***	-0.58
	(0.026)	(0.425)	(0.025)	(0.450)
Time FE	Y	Y	Y	Y
Country FE	Y	Y	Y	Y
Observations	7,120	5,920	1,424	1,184
R-squared	0.920	0.792	0.924	0.791

Notes: Dependent variable is the logarithm of gender equality (GE) in height and gender equality in education. Birth decades 1910 to 1980s included. Time FE means yearly and half-decade fixed effects for the yearly and half-decade dataset, respectively. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table B.10: Robustness checks for GE height: different periods

	(1)	(2)	(3)
	1900-1980s	1910-1980s	1920-1980s
Socialism	0.18***	0.17***	0.16***
	(0.027)	(0.030)	(0.035)
Constant	-1.70***	-1.66***	-1.58***
	(0.033)	(0.028)	(0.023)
Decade FE	Y	Y	Y
Country FE	Y	Y	Y
Observations	792	704	616
R-squared	0.912	0.925	0.935

Notes: Dependent variable is the logarithm of gender equality in height (GE height). Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table B.11: Robustness checks for GE height: religion and family system controls, 1910-1980s

	(1)	(2)	(3)
	Eurasia	Asia	Europe
Socialism	0.16***	0.11**	0.12***
	(0.026)	(0.052)	(0.030)
Anomic fam. system	0.02		0.11
	(0.112)		(0.125)
Author fam. system	-0.06	0.11*	-0.13
	(0.045)	(0.057)	(0.109)
Endocom fam. system	-0.04		-0.04
	(0.078)		(0.106)
Exocom fam. system	0.10***	0.07	0.08
	(0.036)	(0.044)	(0.112)
Share Catholic avg.	-0.01	0.04	-0.23
	(0.061)	(0.034)	(0.161)
Share Protestant avg.	0.23	0.31*	-1.45
	(0.188)	(0.179)	(1.842)
Share Islamic avg.	0.04	-0.06	0.03
	(0.100)	(0.164)	(0.137)
Legal origin English	-0.13	-0.08	-0.22
	(0.155)	(0.121)	(0.162)
Legal origin French	-0.09	0.07	-0.14
	(0.058)	(0.049)	(0.087)
Legal origin German	-0.04		-0.01
	(0.057)		(0.085)
Legal origin Scandinavian	-0.02	-0.15	
	(0.175)	(0.122)	
Regional Trends	0.69***	0.85***	0.69**
	(0.197)	(0.226)	(0.304)
Constant	-0.56	-0.45	-0.52
	(0.356)	(0.344)	(0.556)
Decade FE	Y	Y	Y
World Region FE	Y	Y	Y
Observations	704	304	400
R-squared	0.796	0.563	0.803

Notes: Dependent variable is the logarithm of gender equality in height (GE height). Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

B.7.2 Potential Biological Root Causes of the Height Differences Between Males and Females

What might be the biological mechanism that resulted in the specific form of gender equality in height that we observed? The biological reason for the rising height gap with increasing stature is complex and not fully understood yet (Gray and Wolfe, 1980). Biologists and anthropologists argue that the physiological need to provide minimal space for human organs at low heights is certainly one boundary issue that can be cited to explain a small height difference at low levels of average stature. When height increases, on the other hand, the human body offers more flexibility. For ex-ample, males often specialized in hunting during much of human history, over many millennia of human evolution. This is an activity that benefits from taller stature. Hence, if average nutrition allows a taller stature, it seems likely that societies with relatively taller males have a survival advantage (Gray and Wolfe, 1980).

B.7.3 Using Life Expectancy

For life expectancy before 1950, Klasing and Milionis (2020) used life expectancy data for 28 countries. However, the high-quality part not only includes today's economically wealthy countries, with little evidence about countries that were socialist during the specific time period. Hence, the tests we performed cannot be conducted with the same data taken from the Human Mortality and Life-Course Database for the pre-1950 period. Moreover, Klasing and Milionis' (2020) cause-specific mortality data is not gender-specific. They utilized the gender-specific effect of vaccination on mortality when employing this variable.

Klasing and Milionis (2020) utilized two databases available for relative life expectancies: the Human Mortality Database (HMD) and the Human Life Table Database (HLD). We believe that using the Human Mortality Database is justifiable due to its consistent quality control. However, this database is limited to statistically well-documented countries that publish high-quality vital statistics. The authors emphasized that the Human Mortality Database is designed to include only developed countries or areas with "reliable population estimates and good quality vital statistics" (Shkolnikov et al., 2017). Hence, our Eastern European analysis cannot rely solely on the Human Mortality Database, as much of their early (pre-1960) data did not meet the quality criteria.

The Human Life Table Database, on the other hand, covers more countries for earlier periods. However, the authors caution that their data collection and state that the life tables were compiled by individual researchers, frequently refer to regional or ethnic subpopulations, and therefore do not ensure full comparability across time or populations (Shkolnikov et al., 2017). Including the Human Life Table Database would not be appropriate for the reasons mentioned by its authors. It could even be misleading, given that the Soviet Union and other socialist countries published life expectancy data for males and females to promote their political system, often depicting pre-Soviet welfare in a negative light (Mironov, 2012). The advantage of using height is that it circumvents this window-dressing effect, as contemporaries did not perceive it as a proxy indicator for success. Nevertheless, even if we ignore the possibility of biased data that is not comparable across time and populations, we observe that in the Human Life Table Database, our basic results are confirmed. For example, the life expectancy advantage for Russian females increased from 2.2 years in 1896 to 5.4 years in 1926, and then to 8.5 years in 1960.

Another challenge of gender-specific life expectancy changes is that, as found by Klasing and Milionis (2020), male and female longevities responded differently to the introduction of new vaccines during the twentieth century. This technology and the majority of the response to it were not necessarily country-specific or socialism-specific, but global. This suggests that relative education and relative heights influenced the son bias or its gradual reduction over time, while life expectancy is influenced not only by policies and son bias preferences but also by global technology that affected relative gender specific life expectancy data in an exogenous way.

B.7.4 Alternative Formulas for Measuring Gender Equality in Height

In this appendix, we assess which measure of height differences between males and females might be the most appropriate. In the main text, we explained the procedure adjusted for the biological increase of the gender height gap alongside the height increase. However, this results in a relatively complicated formula that isolates the biological factor to identify the nutritional/health components. Here, we test whether this complicated formula is necessary. We compared it to two alternative approaches based on (1) the residuals of a regression of the gender height gap on average height, controlling for country- and year-fixed effects; and (2) the residuals of a regression of both female and male heights on gender by country- and period-fixed



Figure B.9: Correlation between three different measurement options of gender equality in height

effects (Figure B.9). We also experimented with country and gender trends to create these residuals. The advantage is that these measures reflect potential genetic differences across countries and genders and also model shocks like conflicts and epidemic events. When comparing these two approaches with the widely established Gender Development Index, we observe that for some periods, such as the 1930s, they were closely correlated. However, during other periods, such as the birth decade of the 1970s, they were not consistently correlated. Sometimes, the correlation is even negative, as in the 1950s. In contrast, our complicated measure consistently showed a substantial correlation between the gender equality in height and the Gender Development Index, decade by decade from the 1910s to the 1980s.

B.7.5 Height Loss Adjustment

Height at age 60 is affected by a certain amount of height loss that needs to be adjusted to obtain estimates comparable to height at age 50 or earlier. The authors of the NCD-RisC data set used an adjustment for height loss at higher ages, but they did not perform regression analyses. Using regressions is a good option when the height loss is uncorrelated with other variables, which unfortunately is not the case in this specific sample. In such a situation, pre-

adjustment of height loss (which is also well-documented in the literature) is probably the most sensible method. It is also a standard in the anthropological literature (Baten and Blum, 2014a, 2014b; Bogin, 2020; Tanner, 1990).

C Gender Equality Among Precolonial Indigenous Americans: The Last 8,000 Years[12]

Abstract

We build the largest sample of male and female height estimates for precolonial America based on femur lengths, reflecting 6,900 skeletons from 203 site-period observations. Height is an important proxy indicator for the biological standard of living, because the literature has demonstrated its correlation with life expectancy and health. Potential selectivities of the new bioarchaeological data set are carefully checked. For the main analysis, we use relative femur length of females versus males as an innovative gender equality indicator. This indicator corresponds with gender equality in health, but has the crucial advantage of being available for early periods in history. We find that agricultural specialization mattered for gender equality in the Americas before 1500 CE, because women could contribute differently to household incomes in these different economic systems. For example, a specialization on maize as the dominant crop had initially a positive relationship with gender equality. Later, in the period of tougher competition for resources within households due to stronger population pressure, the relationship turned negative. Hunting initially had a positive correlation with gender roles, but this economic specialization turned negative later. Mixed agriculture was generally beneficial.

[12] This chapter is based on joint work with Jörg Baten. I was responsible for approximately 80 percent of the conceptual development and writing, while Jörg Baten contributed the remaining 20 percent.

C.1 Introduction

Gender equality is a key dimension of economic and social development, as gender disparities have persistent economic consequences. Alesina et al. (2013) famously argued that early differences in economic (esp. agricultural) specialization had substantial effects on today's gender equality, whereas others interpreted this type of persistence result as a "compression of history" (Austin, 2008, 2016). In order to clarify the role of economic specialization on gender equality, we need to measure its long-run trends. Thereafter, we will be able to analyze relationships in dynamic settings. Until now, not much quantitative evidence is available about gender equality in precolonial societies (for a recent review, see Merouani and Perrin, 2022). This study addresses the gap by providing systematic long-run evidence on gender equality in precolonial societies, allowing us to assess whether observed patterns of gender equality vary systematically with economic and ecological conditions.

We examine height levels and trends among pre-contact American females and males over the last 8,000 years. Our study builds on the pioneering work of Steckel and Rose (2002), who initiated the systematic use of archaeological and anthropological evidence for the Western Hemisphere from an economic history perspective by using a variety of anthropological indicators and separate samples, including the work of many anthropologists and economic historians. In their concluding chapter, they observed a long-term declining trend of health among Western Hemisphere inhabitants. We develop their approach further by focusing on a single, well-established measure of biological well-being, human height (with some comparisons to other indicators). This allows us to address a question that has received insufficient quantitative attention in economic history: how did different forms of economic specialization shape gender equality in precolonial societies?

Existing research on gender relations among Indigenous societies[13] of the Americas offers mixed conclusion. Klein and Ackerman (2000) suggested that many Native American societies

[13] Throughout the paper, we use the term Indigenous societies/populations to refer to peoples who lived in the Western Hemisphere prior to European contact and their descendants. We use Native American to refer to people whose ancestral homelands are in what is now the United States. While these labels are commonly used in contemporary scholarship, we recognize that they are imprecise.

showed relatively high gender equality, highlighting matrilineal clans, women's central role in agriculture, and their influence in community affairs. Their study, however, relied primarily on cultural descriptions, cosmology, and Indigenous historical narratives. Similarly, LaFromboise et al. (1990) and Burnette (2015) confirmed these findings, further emphasizing the importance of Indigenous perspectives in understanding historical gender dynamics. Ralston (2023) uses a bioarchaeological approach and suggests that gender roles were complex and diverse among Native Americans from thirteenth century Turkey Creek Pueblo, located in present-day Arizona.

One key question in our study is whether women's contributions to household income affected gender equality in the Americas before 1500, as they had in Europe during the medieval and early modern period (Alesina et al., 2013; Baten and de Pleijt, 2022; Diebolt and Perrin, 2013 on growth implications; Voigtländer and Voth, 2013). Similar relationships have been observed in many developing countries in recent decades (Gruen and Klasen, 2008; Klasen and Lamanna, 2009; ambivalent: Duflo, 2012). In the European case, cattle and grain were important, as cattle farming allowed women to contribute strongly to household income, resulting in higher gender equality, while grain cultivation, with its reliance on male upper body strength, did not. These two main agricultural specializations in Europe did not play a role in the Americas, because cattle and Old World grain were not available in the pre-Columbian Western Hemisphere. However, maize may have played a role for gender equality similar to grain in Europe, since its cultivation requires a lot of upper body strength. In many societies, males were often able to define their own contribution to the maize production as particularly salient, especially during the last two millennia before contact, when American societies became increasingly specialized and within-family competition for resources intensified due to population pressure. Hence, we expect lower gender equality in such specialized maize-based economies.

Similarly, hunting activities were traditionally executed by males in hunter-gatherer societies. Even though women may have contributed to processing hunted animals, societies characterized by big-game hunting might have developed a cultural and institutional setting from which males benefited relatively more.

"Mixed agricultural societies" differed in important ways. They often practiced small-scale animal husbandry, including camelid pastoralism with llamas and alpacas in the Andean highlands (Anzellini and Toyne, 2020). Moreover, horticulture, i.e. small-scale cultivation of

diverse crops such as squash, chilis, and beans, played a strong role and was often seasonally supplemented with hunting and gathering. Usually, these sites represented communities transitioning from a hunter-gatherer lifestyle to a more sedentary one with greater reliance on agriculture. Because this system was not dominated by maize cultivation or big-game hunting, it might have allowed women to contribute more substantially to household income, with horticultural tasks in particular creating additional opportunities for female participation.

Finally, hunter-fisher lifestyles required substantial upper body strength. We might therefore expect fishing-based subsistence systems to decrease gender equality. On the other hand, male fishers sometimes spent a large share of the year on fishing campaigns. In such settings, women tend to take over the local mixed agricultural and other work necessary in primarily fishing societies. The "seasonally absent male" effect often results in higher gender equality (Alexopoulou and Baten, 2023).

Based on the current state of research, we formulate the following hypothesis:

(1) Hunting societies may have been associated with lower levels of gender equality. For example, the societies of the Great Plains, which specialized in bison hunting might have had lower gender equality. Given the physically demanding and male-dominated nature of big-game hunting, we would expect these societies to develop cultures in which less high-quality food is provided to girls relative to boys.

(2) Maize cultivation likely had a positive impact on gender equality in its early stages, as it provided a stable source of calories, especially when population densities were lower and competition for food within households was less intense. However, as populations grew and food competition became more pronounced, the impact of maize cultivation may have shifted, potentially having a negative effect on gender equality, similar to the impact of grain cultivation in Europe.

(3) Mixed agricultural subsistence, combining small-scale agriculture, animal husbandry, hunting, and gathering are expected to be associated with higher gender equality. These systems typically required less upper body strength and emphasized horticultural activities, which may have allowed for more balanced gender roles and greater equality within the household and community.

(4) Fishing implied an ambivalent relationship with gender equality due to the frequent absence of male fishers from daily agriculture and other work routines, that were mainly executed by females on the one hand, and physical requirement of fishing on the other.

C.2 Literature Review

We structure the literature review in two parts: the first section outlines key findings from European studies on gender inequality, including the roles of poverty, family systems, and subsistence strategies; the second turns to the Americas, summarizing existing research on gender roles and kinship structures among Indigenous societies, with particular attention to archaeological and ethnohistorical evidence.

C.2.1 Gender Equality in Europe

To identify the background of the potentially relevant explanatory variables for our study area, the Americas, we review a range of evidence from other world regions. Beltrán Tapia and Szołtysek (2022) provided in a recent review about "missing women" a number of correlates on gender inequality. One potential determinant could be poverty, as competition for resources within households was likely stronger in societies under pressure, where poverty was widespread. Hence, parents often allocated more resources to male children, whom they expected to provide greater security and material support in old age.

Another substantial factor is family structure (Szołtysek et al., 2019). In Europe, strong emphasis has been placed on the contrast between small nuclear families, in which only the married couple lived together, and extended families that included grandparents. In larger households, the values and authority of grandparents often contributed to lower female status. Additionally, women frequently moved into their husband's household (patrilocal systems) and were thereby positioned as outsiders, limiting their influence. By contrast, neolocal nuclear families, where couples established independent households, have been associated with greater autonomy for women. A relevant question is, of course, whether the household formation is exogenous in the long run: it could arise from the development over many centuries as a reaction to other factors (such as the relative income contribution of women, given the underlying soil qualities and factors such as lactose tolerance benefitting cattle farming).

Moreover, violence and conflict similarly influenced gender roles. For example, studies on nineteenth and early twentieth century Greece suggest that frequent conflicts preceding the country's full independence from the Ottoman Empire may have reinforced male dominance and contributed to women's relatively low status (Alexopoulou and Baten, 2023). This was partly due to the need for physical and moral protection. As for religion, while it is often cited as a key factor in shaping gender roles in South and East Asia, may have been comparatively less influential in Europe.

European case studies such as Perrin et al. (2023) highlight regional differences in gender equality. Their study on Sweden indicates that in the 1870s, gender equality varied significantly across regions. It was particularly high in Älvsborg (west of Sweden and east of Gothenburg) where women had substantial employment opportunities in textile mills. However, despite their economic role, their participation in political life remained limited. The link between women's economic contribution to household income and gender equality is also stressed by Baten et al. (2017) who found that female contribution especially in cattle and dairy agriculture was strongly associated with higher autonomy. The age at marriage reflected gender dynamics quite closely: in regions where women's work in agriculture, particularly dairy farming, was economically important, girls tended to marry later ("girl power": De Moor and van Zanden, 2010). In contrast, early marriage was often associated with reduced social standing for women. This pattern (of strong female autonomy) is particularly evident in northeastern and southeastern Russia, as well as in northwestern Europe, and the Alpine regions of the Czech Republic and Slovenia. Baten et al. (2017) analyzed this phenomenon in early nineteenth century Eastern Europe, while Baten and de Pleijt (2022) extended the scope of the study to nearly 30 European countries and 300 regions from the fifteenth to the nineteenth century, showing long-term patterns of female autonomy across the continent. In the case of France, Perrin (2022) found relatively high gender equality for mid-nineteenth century Normandy, Lorraine, Alsace, and parts of the Jura region bordering Switzerland, which are consistent with high cattle specialization and dairy farming. This study uses, among other indices, an index of wage ratio and employment ratio to capture the employment possibilities for women. Moreover, Perrin examines gender equality in education and health and, for the latter, uses indicators such as relative mortality, relative life expectancy, and relative live births for boys and girls.

Further evidence for the role of subsistence strategies is provided by Hansen et al. (2015), who argue that societies with early adoption of the agricultural revolution developed stronger patriarchal norms due to the gender division of labor and increased fertility associated with sedentary life, linking the rise of patriarchal structures in Europe to the Neolithic Revolution.

The female income contribution-equality mechanism is culturally transmitted. It should not be imagined as an explicit economic contract (e.g., women contributing x working hours resulting in y female status), but rather as a cultural process: in societies that benefited more from female work, cultural narratives developed that enhanced the perceived value and social role of women, with feedback effects on broader gender norms within the society (Michalopoulos and Xue, 2021). Hence, factors such as female labor market opportunities play a crucial role in shaping long-run gender dynamics via cultural processes, particularly reflecting women's contributions to household income.

C.2.2 Gender Equality in the Americas

The findings based on European studies provide valuable context for analyzing gender dynamics among Indigenous societies. We will assess whether contributions to household income also mattered for early American gender equality. However, the precolonial period in North America relies primarily on archaeological evidence, oral histories of later-born Native Americans (with scholars assuming persistence), and the accounts of early European colonizers, that may be prone to observer bias. Due to the scarcity of written records before European contact, much of the recent scholarship in Indigenous studies has focused on the postcolonial period and the lasting impacts of colonization on Native American culture, traditions, health and economic outcomes (e.g., Dippel, 2014; DuVal, 2024; Feir et al., 2024).

Ethnohistorical studies have shaped the view that societies with higher female autonomy were common in parts of North America, particularly among the Iroquois-speaking societies (Haudenosaunee, Wendat), and Puebloan societies. Graeber and Wengrow (2021) published a highly influential study on early societies, in which they examined varying degrees of patriarchy and challenged the notion of the emergence of universal patriarchy. The authors focus on matrilineal societies, like the Indigenous Wendat population, who lived around the Great Lakes in present-day Canada, and suggest that women held considerable authority, controlled land, and

influenced decision-making processes. Their analysis incorporates an interview with a Wendat leader and utilizes Baron de Lahontan's travel report from the late 17th and early 18th centuries as a key source in their research. Another relatively well-studied example of a matrilineal society, is the Haudenosaunee (Iroquois) Confederacy. In this society, lineage and inheritance were traced through the mother, married couples typically resided in the wife's household, and women actively contributed in agricultural production (Mann, 1997; Pearsall, 2018). Women, particularly "Clan Mothers", held significant political power such as selecting and advising chiefs (Mann, 1997; Pearsall, 2018). Additionally, evidence from fishing communities such as the Coast Salish in the Pacific Northwest and the Great Lakes regions suggests that matrilineal structures may have emerged, in part, due to the seasonal absence of men during extended fishing expeditions, leaving women responsible for household management and social continuity (Peck, 2022).

Some descriptions of recent (nineteenth and twentieth century) populations indicates that women were responsible for agricultural work in Indigenous societies. This included maize cultivation and many other agricultural crops, like beans and squash. For colonial Yucatán (today's Southeast Mexico), Hunt Espejo-Ponce and Restall (1999) show that despite the imposition of patrilineal norms, Maya women continued to play key roles in agriculture and market exchange. However, it is unclear whether post-contact evidence reflects long-term persistence of high female status, or might have changed over the centuries, for a variety of reasons. Perhaps the pre-contact situation was different. Archaeological evidence seems promising to understand pre-contact gender equalities without these uncertainties.

For example, archaeological evidence from Classic Maya societies indicates that women, particularly those of elite status, held important ritual and economic roles in the textile production and maize cultivation, as analyzed by artifacts, paintings, and figurines (Hendon, 1997). Further, Ogilvie and Hilton (2011) support the view that women played a central role in agricultural production (for the Pottery Mound precolonial Pueblo) by analyzing the robustness of the upper limbs.

In contrast, other Indigenous societies, especially those heavily reliant on big-game hunting, like the bison hunting societies of the Great Plains (e.g., Sioux, or Cheyenne) women held more domestic roles with primary responsibilities centered in the household (Hassrick, 2012). This kind of hunting was an activity dominated by men, which elevated the status of males and reinforced

patriarchal norms (Hassrick, 2012). A recent study by Haas et al. (2020) challenges these traditional assumptions about the sexual division of labor in early hunting societies though, presenting archaeological evidence that women may have participated in big-game hunting at significantly higher rates than previously believed.

Women's roles and status thus varied considerably across regions and subsistence systems. This variation highlights the need for context-specific analysis. Hence our study addresses these issues by using skeletal and ecological data across a wide spatial and temporal range. Finally, while much of the existing literature is qualitative or case-specific, systematic, continent-wide quantitative analyses of gender equality in Indigenous societies of the Americas are still scarce. Our study contributes by offering a new, large-scale empirical assessment of gender equality using bioarchaeological data.

C.3 Methods

Our methodology is based on femur length as a health indicator, the longest bone of human body. Among all the bones it has the highest correlation with adult stature and is also a relatively strong bone making it more likely to be preserved. The femur allows us to estimate average stature or height (using the formula provided by Ruff et al. (2012)). We use "height", "stature" and "femur length" synonymously here. Using evidence from Europe, we demonstrate in Figure C.17 (Appendix) that stature correlates with other indicators of malnutrition, such as hypoplasia (Baten et al., 2019).

Bereczki et al. (2019) evaluated Native American skeletal data from the last two millennia recovered from excavations of multiple archaeological sites (published in Steckel and Rose, 2002). They observed a significant and statistically significant positive correlation between low femur length and the proportion of linear enamel hypoplasia (LEH). Analysis using the ecological variables of 65 sites dataset from the Western Hemisphere module of the Global History of Health Project (GHHP) with the LEH index values from Steckel and Rose (2002) yielded a correlation coefficient of height and LEH of 0.40 ($p = 0.06$).

We use relative femur length of females and males to assess gender equality. This can be supported using recent research about human stature, or height, which is a close correlate of

femur length (Steckel et al., 2019). Clearly, a large part of the height gap between males and females (and similarly their femur length gap) is caused by biological factors. However, a certain part is also caused by higher or lower son preference, because in some societies, women are particularly short (in South Asia, for example), whereas in Sweden both genders are more similar in height. According to several studies by Gray and Wolfe (1980), Costa-Font and Gil (2008), Guntupalli and Baten (2009), and Schwekendiek and Baten (2019), the variation in sex-specific height differences can serve as an indicator for gender equality. This is because parental behavior, such as providing better resources and nutrition to male offspring during childhood and adolescence, leads to differences in height between male and female adults. The studies used different specifications to determine gender inequality in body size, with the first three using intuitive measures such as the gap or the ratio between male and female height. Overall, the findings highlight the relationship between size differences and gender equality. Schwekendiek and Baten (2019) proposed alternative methods, taking into account the fact that gender equality increases in a nonlinear way with average height of both genders. By systematically comparing gender equality in height with other measures of gender equality, Schwekendiek and Baten (2019) and Jung and Baten (2025) arrive at the formula:

$$GE_h = -[H_m - H_f - (-33.75 + 0.276 \cdot H_{mf})] \quad (3)$$

where H_m and H_f are the average height values (measured in cm) for males and females, respectively; H_{mf} is the average height of both genders; and GE_h represents gender equality in height. The term in brackets represents gender inequality; multiplying it by -1 transforms it into the gender equality measure used in this study.

We first use twentieth century data to forge the methodological tool, before applying it later to archaeological data. In Figure C.13 (Appendix), we consider for a sample of Asian countries the gender equality in height index on the vertical axis in comparison to the gender equality in life expectancy on the horizontal axis. The birth decade of the 1960s is considered. We justify the use of Asian countries with the fact that in Asia, gender inequality was higher for the birth decade of the 1960s, which allows us to assess the correlation clearly. For Latin America, the correlation is similar and statistically significant, but slightly lower (results available from the

authors). Basically, a value of zero here means that women and men live the same number of years. For example, in Pakistan in the birth decade of the 1960s, women and men both had a life expectancy of ca. 50 years. In some countries, life expectancy was more unequal: males lived 2 years longer than females, while women have a biological survival advantage in situations of equally provided resources. Typically, women tend to live 6 to 8 years longer than males, as it was the case in Singapore and Bhutan. If height was very unequal, women were relatively short compared to males. We observe high values of inequality for countries such as Bangladesh and India. On the other side of the Asian spectrum, Singapore and Bhutan had low values. Gender equality in height corresponds with gender equality in life expectancy (Pearson correlation coefficient of 0.61 for Figure C.13). High values correspond with high values, and low values correspond with low values.

Maravall and Baten (2019) provided a similar scattergram for bioarchaeological samples that were available for Europe during the last two millennia, though with more variation due to much smaller samples (Appendix Figure C.18). The ratio between the male and female share of hypoplasia occurrence is reported on the vertical axis in this scattergram, while the femur length ratio is shown on the horizontal axis. High values of the male share of hypoplasia occurrence divided by the corresponding female share represent gender equality. Similarly, female femur length divided by male femur length stands for gender equality. High gender equality values according to the indicator on the vertical axis correspond with high values on the horizontal axis, and vice versa. Although there is some noise in this relationship, a correlation between the two indicators of gender equality is confirmed. In conclusion, the correspondence of these two measures for the bioarchaeological record of Europe during the last 2000 years supports the idea that gender equality values can be assessed using the ratio of femur lengths between males and females, which we will apply to the American situation.

One potential issue is the hypothesis of "female buffering." Female bodies might be more adaptable for surviving famine or other catastrophes. This led biologists to hypothesize that female bodies' height might also be more resilient. These and other biological factors that vary intrinsically with sex can be confused with preferential treatment (Bogin et al., 2017; Guatelli-Steinberg and Lukacs, 1999). However, some studies raise doubts about the relevance of female buffering under pre-modern conditions, where malnutrition and adverse disease environments

existed almost permanently (Koepke and Baten, 2005). It is not clear whether a more-than-normal level of deprivation increases the female buffering effect disproportionally, and a number of studies reject this (see, for instance, Guntupalli and Baten, 2009). Importantly, the female buffering hypothesis implies that equal shares of stress markers (e.g., stunting or LEH) among males and females already indicate unequal resource allocation, as buffering reduces the visibility of stress among girls. Such a linear effect does not affect our analysis in a problematic way. In a similar vein, Guatelli-Steinberg and Lukacs (1999) conclude that any distorting effects (beyond the normal level effect) are probably minimal, a view consistent with Thompson (2021), who likewise argues that observed sex differences in growth and stunting are largely shaped by social and environmental processes.

C.4 Data

For the Indigenous population, we compiled a sample that covers almost 8,000 years from the late Archaic period to the colonial period around 1500 CE. We have altogether 6,900 skeletons from over 400 excavations sites of Indigenous societies in the Western Hemisphere. Sites were clustered based on regional distance. We aggregated the data by site and period, resulting in 203 site-period observations, with some sites contributing data for multiple periods (for a full overview of all site-period observations included in our analysis, see Appendix Table C.7). Our dataset is sampled from 37 anthropological studies (see Appendix Table C.7). Moreover, we added data from the Global History of Health project, which was made publicly available by Steckel and Rose (2002) and their team.

We included only sites that contained both data on males and females. Roughly half of the total number of human remains in our sample were females. We have about 1400 individuals for the early period before the year 1 CE, and about 5500 individuals for the period 1 to 1500 CE (see Appendix Table C.4). Hence, the more recent period is better documented which reflects larger population sizes and the general challenges that older remains are less likely to be preserved. Excavations cover 13 different modern countries, spanning the whole American regions from Alaska to Tierra del Fuego in Argentina. Most of our data are from the US, Mexico and Peru. We assess potential selectivities of our data set in the discussion section below.

We considered a number of right-hand side variables that might explain gender equality in height (see Table C.1 for summary statistics). Some variables refer to subsistence indicators such as whether the society relied mainly on (1) maize, (2) hunting (of bison), (3) fishing, or (4) mixed agriculture combined with some hunting and gathering. These mutually exclusive binary indicators characterize the various societies during their respective periods as predominantly relying on either one of these subsistence strategies. Half of our sample relied predominantly on maize, which was typically supplemented with other plants (especially squash and beans, known as the "Three Sisters"), and very popular in the Americas especially during the later millennia. Further, 12 percent of our societies were primarily hunter-gatherers (hunting), 23 percent were hunter-fisher-gatherers (fish) and the remaining ones were based on mixed agriculture Table C.1). Mixed agriculture refers to societies that practiced horticulture of diverse crops alongside occasional or seasonal hunting and gathering, often representing communities in transition from foraging to a more sedentary lifestyle.

We assume that these subsistence strategies shaped gender equality through their implications for labor division, mobility, and household structure. For example, agricultural systems are almost perfectly correlated with a sedentary lifestyle which are typically associated with greater household stability and a more defined domestic role for women (Hansen et al., 2015), while hunting-based societies may foster male dominance due to the centrality of physically demanding, high-status activities (Hassrick, 2012).

In addition to subsistence variables, we included land use variables for grazing and whether the soil was suited for cropland on a regional (state) level. These variables are coded as percentage shares of land use of the total state area and available from the HYDE project (an updated version of HYDE 3.2 (Klein Goldewijk et al., 2017). Population and population density estimates were also obtained from the HYDE reconstructions. To control for climatic conditions, we include regional-level temperature estimates in degrees Celsius from the Temp12k project (Kaufman et al., 2020), available through the Linked Paleo Data (LiPDverse) database. Moreover, we added a variable from McCoy et al. (2025) capturing the presence of fortifications at a given site, as a proxy for defensive military technologies and how communities mobilized resources for protection. So far, proxies of this kind have not been systematically explored in earlier studies of gender equality. In collaboration with local archaeological experts, the authors classified sites as fortified

when substantial defensive infrastructure, such as walls, ditches, or palisades, was present and contemporaneous with residential occupation (McCoy et al., 2025). Fortifications are not a direct measure of violence or war, but their construction reflects collective concerns for community security. Hence, they represent an archaeological indicator of social coordination and shared investment. In our context, we use the binary fortified variable to examine whether environments requiring collective defense and protection had systematic effects on gender equality.

One factor we are not able to include in our analysis of pre-contact societies are family systems. Family systems capturing kinship structures, inheritance practices, and household authority could have had long-lasting effects on gender hierarchies, female autonomy, and development outcomes (Alesina and Giuliano, 2010; Carmichael et al., 2016; Szołtysek and Poniat, 2025; Szołtysek et al., 2019). Although family systems are likely to have played an important role in shaping gender relations, data limitations prevent us from including direct indicators of kinship or household structure. Datasets like the ethnographic atlas compiled by Murdock (1967) are typically drawn from observations made in the late nineteenth or early twentieth century, after major disruptions caused by colonization, missionary work, and reservation policies. The assumption of strong persistence over centuries and millennia seemed too daring to us.

C.5 Results

C.5.1 Geographic Patterns

Looking at the geographic distribution of the early period (before the year 1 CE), substantial spatial heterogeneity emerges across the Americas. Gender equality was relatively high in the Southeastern United States and in what is today California. In contrast, lower levels are observed in the interior of the modern territory of the United States, especially in the Great Basin region (Appendix Figure C.14). In Mesoamerica, gender equality differs across early cultural regions. Societies located in the area of the earliest region of maize cultivation around the Balsas River Valley in today's central Mexico (Li, 2024) show lower values compared to the pre-classic Maya[14]

[14] To facilitate interpretation, we occasionally refer to well-documented cultural groups associated with particular sites. However, cultural attribution is not always available or consistent across excavations.

period in the Lowlands of today's Belize and Guatemala, with slightly higher gender equality (Appendix Figure C.15). In western South America, we see a relatively low gender equality, notably including the Pacific coast and the Andean highlands of today's Peru and Bolivia, one of the centers of ancient American civilizations. The Southern part of the continent (Patagonia in today's Argentina and Chile) displayed high values for gender equality (Appendix Figure C.16).

For the later period, from 1 to 1500 CE, several of these geographic patterns persist (Figure C.1). Gender equality remains high in eastern North America (though not limited to the Southeastern United States, as in the previous period, but also including the Great Lakes and Northeastern Woodland regions). These areas include societies such as the Iroquoian groups, known for matrilineal social organization. We still observe high values in today's California, a region characterized by predominantly hunting-fishing-gathering subsistence systems. Lower gender equality is observed in parts of the south-center of today's United States and in the Arctic regions. Again, we have a Northwest-to-Southeast difference within Central America with lower values in predominantly Maya regions characterized by intensive maize cultivation (including today's central and south Mexico, Belize, and Guatemala) (Figure C.2). In South America, we still have high gender equality in the southern regions, as well as in parts of the Atlantic coast (southeast of today's Brazil), and the Andean highlands (associated with the Chachapoya society, a pre-Inca culture) (Figure C.3). These patterns contrast with lower values observed along the Pacific coast as well as in the Colombian highlands (including societies under Inca imperialism) and parts of the Pampas region in today's Argentina.

We have traced the geographic distribution of agricultural specialization (Figure C.4 and Figure C.5). In the early period very few regions cultivated maize as a main subsistence crop. The early centers were located in Central America, especially in today's Guatemala and southeastern Mexico. We have predominantly hunter-gatherer societies in the interior of today's United States, and hunter-fisher-gatherer societies at the coasts, and also a number of primarily hunting societies in South America. The spread of maize cultivation becomes dramatic in the subsequent period from 1 CE to 1500 CE (Figure C.5). Maize was spreading within South

America along the west coast, within Mesoamerica, and similarly into the southwestern region of today's United States, as well as eastward along the Mississippi River, for example. North American cultures increasingly relied on maize cultivation, but still some societies, especially in the Southeast, used a mixed subsistence system combining agriculture with fishing or hunting. Bison-hunting remained prevalent in the Great Plains.

In conclusion, we observe a notable expansion of maize cultivation which allowed a higher population density. Regions with higher gender equality that we observed above (northern Mexico, eastern United States, southern South America), are characterized by a greater prevalence of mixed subsistence systems compared to maize-specialized regions (south of Mexico/Central America, southwestern United States, and parts of western and northern South America).

C.5.2 Regression Results

In order to quantify how gender equality in height varies systematically across the major subsistence strategies, maize cultivation, fishing, and hunting, we run a two-way fixed effects regression accounting for region-specific and period-specific factors. As control variables, we include land use, population density, and climatic conditions, which are similar to the controls used in related studies on the long-term determinants of gender equality (Alesina et al., 2010; Baten and de Pleijt, 2022) and the biological standard of living (Baten and Maravall, 2021). Land use and population density capture variation in resource availability and subsistence intensity, which influence nutritional stress and intra-household allocation, while climatic conditions proxy long-run disease environments and agricultural productivity. The coefficient on a given subsistence indicator (e.g., maize specialization) is interpreted relative to mixed agricultural subsistence, which serves as the reference category, and is captured by the constant. We use a log specification of gender equality to account for the right-skewed distribution of the outcome variable. Given the long-run archaeological nature of the data and the absence of plausibly exogenous shocks, we cannot use quasi-experimental identification. Instead, the analysis documents robust long-run associations that reveal how ecological conditions and subsistence strategies are correlated with gender equality in health. The results are shown in Table C.2 using seven different model specifications. Our regression analysis includes the full sample of 203

different excavation site-period observations, relying on 6,900 individuals (see Appendix Table C.5 for results on a restricted sample).

For the early period (6500 BCE–1 CE), we find that maize, hunting, and fishing are positively associated with gender equality, relative to the reference category of mixed agriculture represented by the constant. In the later period (1–1500 CE), however, maize has a negative coefficient, suggesting that it was detrimental to gender equality. This likely reflects increased competition for food within households due to rising population density. Hunting also shows a negative relationship. In contrast, fishing is not statistically significant during this period, suggesting no clear difference from mixed agriculture, despite the possibility that greater male absence due to longer fishing trips may have affected intra-household gender dynamics. The third column in Table C.2 combines both early and late periods. We also conduct a series of robustness tests, including different control variables (columns 4-7). With the exception of one model (column 5), we find a relatively consistent negative coefficient for maize in the later-period and full-sample specifications. Hunting shows a consistently negative coefficient as well, except in the early period. We also assess the role of population density and climate, but the relationship is not statistically significant (Table C.2, column 7).

Table C.3 shows the results on the presence of fortifications, our proxy for collective defensive military technology, and their relationship with gender equality. We aggregate the fortification variable by half-millennium and country. Overall, we find that fortified settlements have a positive coefficient in the regression of higher gender equality. This result aligns with findings from McCoy et al. (2025), who noted that fortification did not always correlate with greater inequality, especially in collective or cooperative societies where defense was a public good.

C.6 Discussion

C.6.1 Potential Selection Bias

Like all large-scale archaeological datasets, the skeletal evidence used in this study might be subject to potential selection processes that might influence which sites are discovered, excavated, and preserved. For example, the likelihood that human remains are recoverable depends on environmental conditions affecting bone preservation (for instance, tropical and acidic soils are

rather detrimental for bone preservation (Pestle and Colvard, 2012)), and burial practices, settlement type, and historical research priorities, which vary across regions and periods, can also play a role. Earlier research which assessed the selectivity of soil did actually not observe systematic biases in similar research settings (Koepke and Baten, 2008; Steckel et al., 2019). The strategy of these studies was to compare different indicators that were less sensitive to soil selectivity bias to the same degree (such as longevity). Another strategy was to exclude extreme soils (Koepke and Baten, 2008). With respect to preservation-related selectivity, only skeletal material characterized by sufficient levels of bone preservation was included in the analysis. In most cases, preservation quality could be assessed on the basis of excavation documentation such as grave drawings, preservation charts, or detailed inventories of cranial remains, following established bioarchaeological standards (Baten et al., 2023). This restriction ensures that key morphological features could be consistently evaluated across sites and periods. While the quality of preservation assessments cannot be directly verified for all cases and some degree of measurement error cannot be fully excluded, limiting the sample to sufficiently preserved remains substantially reduces the risk that incomplete or fragmented material systematically affects the results. In particular, this approach helps to avoid distortions that might arise if poorly preserved remains were unevenly distributed across regions or time periods.

Burial customs can also influence the survival of bones. However, even extreme burial customs such as cremation did not affect trends (Koepke and Baten, 2005). Moreover, differences in soil conditions and burial customs primarily influence the likelihood that skeletal remains are preserved and recovered, rather than the relative patterns observed within regions or sites. As our analysis relies on the ratio of female to male femur length, soil- and burial related selectivity is unlikely to substantially distort observed relationship.

We also study potential regional and social selectivity. Regional selectivity was not a substantial problem, as we could include sites from all major regions of the Americas and across all principal time periods under study. In addition, we took care to include excavations from many different topographical settings, including coastal and inland locations, as well as different settlement types. This approach reduces the likelihood that the observed patterns are driven by region-specific environmental conditions or by a narrow set of site characteristics.

We took care that the composition of our samples reflected a broad coverage of social contexts (not only elite graves, for example). Moreover, observations stem from urban settlements, non-urban villages, burial sites, and pre-urban communities, resulting in a relatively balanced distribution across settlement types. We avoided an exclusive focus on prominent or socially exceptional sites. This strategy aims to mitigate biases arising from selective excavation of particular social groups or institutional contexts.

Data availability may also reflect differences in excavation intensity and research focus. For example, famous buildings such as Maya temples or the pyramid buildings of Teotihuacán of central Mexico might have resulted in more excavations. A higher density of excavation might under certain conditions result in a broader social spectrum of excavated individuals. Similarly, Californian sites might be particularly well excavated due to the neighboring presence of leading archaeological departments in the universities of this US state. Fortunately, those local centers of excavation activities represent different types of early American societies. California, for example, was rather a backwater of early American development, whereas Central Mexico was certainly one of the more advanced and urbanized economies.

Taken together, these procedures suggest that potential biases related to differential preservation, site context, or excavation practices are unlikely to fundamentally distort relative comparisons within sites or regions. Although perfect representativeness cannot be claimed for any large-scale archaeological dataset, the combination of broad geographic coverage, heterogeneous site types, and taking into preservation-based inclusion criteria enhances the plausibility and robustness of the observed patterns. Moreover, for measuring gender equality, these biases are less likely to generate systematic bias in male-female comparisons within sites, as adult men and women are recovered from similar burial contexts and subject to the same preservation and excavation processes (Bello et al., 2006; Walker et al., 1988).

C.6.2 Data Plausibility Checks

As a background, we reconstructed the overall trend for male and female heights from 5000 BCE to 1500 CE (Figure C.6). First, we observe a decline in both male and female heights around 3000 BCE, which coincides with the beginning of strong population growth. Following this, there

is a recovery from still relatively high levels for both sexes. However, after 500 BCE we see a sharp decline in stature, which only slightly recovered thereafter.

We also assess the consistency of trends between similar regions. If neighboring regions which share a number of environmental similarities display similar trends, this can be interpreted as a hint that the trends are quite plausible, and not driven by some unusual values of specific sites (for example, caused by site-specific selection biases). To assess time series plausibility, we document trends in male and female adult stature for selected subregion where data availability was the highest (Figure C.7 to Figure C.12). Figure C.7 and Figure C.8 compare trends across California and the Southwestern United States; these neighboring regions were similarly characterized by long-standing foraging or mixed subsistence traditions. The stature series exhibit quite parallel and remarkably stable trends in these neighboring regions over the full period considered. Male stature displays slightly greater variability, including a decline at around 1 CE in Southwestern US. But overall levels decline similarly after 500 CE. Figure C.9 and Figure C.10 focus on the Great Lakes and the Southeastern United States. In both regions, male and female stature increased steadily until around 1000 BCE, followed by a modest decline over the subsequent two millennia. After approximately 1000 CE, male stature shows signs of recovery, whereas female stature remains comparatively stable, suggesting differential responses to long-run demographic or subsistence changes. Again, these neighboring regions show similar trends. Figure C.11 and Figure C.12 document trends in the neighboring regions of Central Mexico, South Mexico, Guatemala, and Honduras, revealing a relatively consistent decline in both male and female stature in these neighboring regions.

In sum, the similar temporal evolution of height trends between neighboring regions (and the absence of sharp discontinuities) suggests that the documented patterns are plausibly not artifacts of selective data sampling, but instead reflect persistent long-run differences in gender equality in health.

C.7 Conclusion

In sum, we build the largest sample of male and female height estimates for precolonial America based on femur lengths, offering a long-run quantitative perspective on gender equality

in health in the Western Hemisphere. We carefully check potential selectivities. Although potential biases are always a possibility when working with modestly sized data sets, we perform a number of strategies reducing the selectivity as far as possible. Hence our results appear not perfectly, but sufficiently representative, as many different potential issues are taken into account.

Agricultural specialization mattered in shaping gender equality in both Europe and the Americas, but its effects varied. For the European experience, we reviewed the existing literature. For the Americas, we present a substantial new bioarchaeological data set. In the Western Hemisphere of the Americas, maize cultivation had initially a positive relationship with gender equality, consistent with its role in stabilizing food supply in low-density settings. However, in later periods, as population densities increased and competition within households intensified, the relationship between maize specialization and gender equality turned negative. Hunting-based subsistence systems were initially associated with higher gender equality but became negative over time. Societies relying on fishing were only positively correlated with gender equality (likely due to the seasonally absent male effect) in the early period but showed no statistically significant differences to a mixed agriculture subsistence in the later period. We also include a measure of settlement fortification as a proxy for defensive military technology. Interestingly, fortified settlements were related to higher gender equality, suggesting that collective coordination and social organization may have contributed to it.

Taken together, our findings highlight that women's contributions to household income mattered for gender equality in the Americas, much as previous research has shown for Europe. By providing the first large-scale quantitative evidence on gender equality in health in precolonial American societies, this study demonstrates that gender equality reflects long-run dependencies on subsistence systems.

C.8 References

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C.9 Figures and Tables

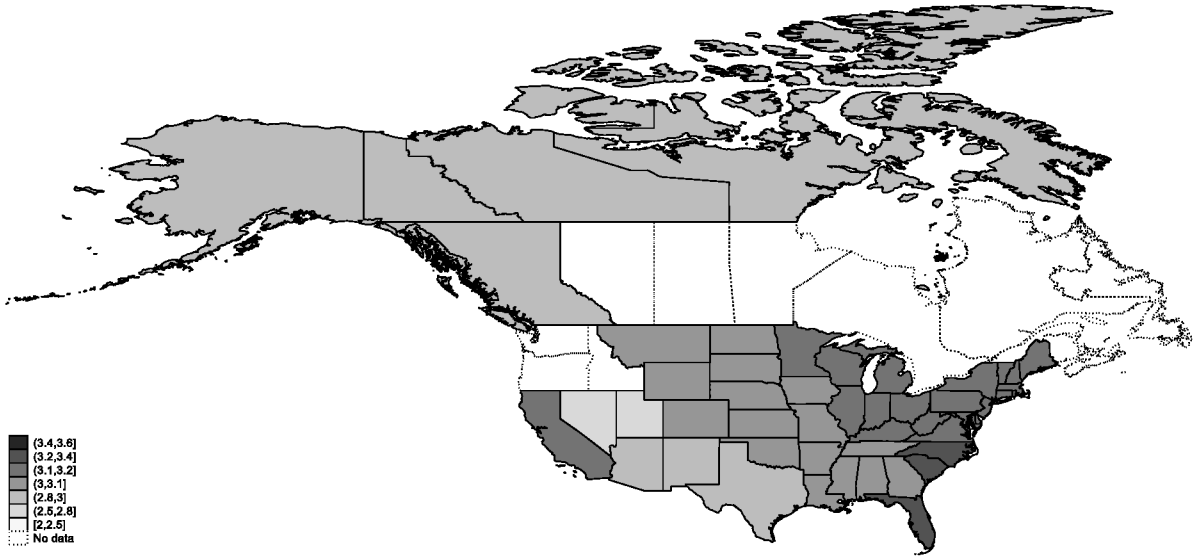


Figure C.1: Gender equality, 1–1500 CE – North America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: California, East Coast US, Florida, Great Basin, Great Lakes, Great Plains, Northeastern Woodlands, Pacific Northwest, US Southeast, Southern Great Plains, US Southwest, and Western Arctic.

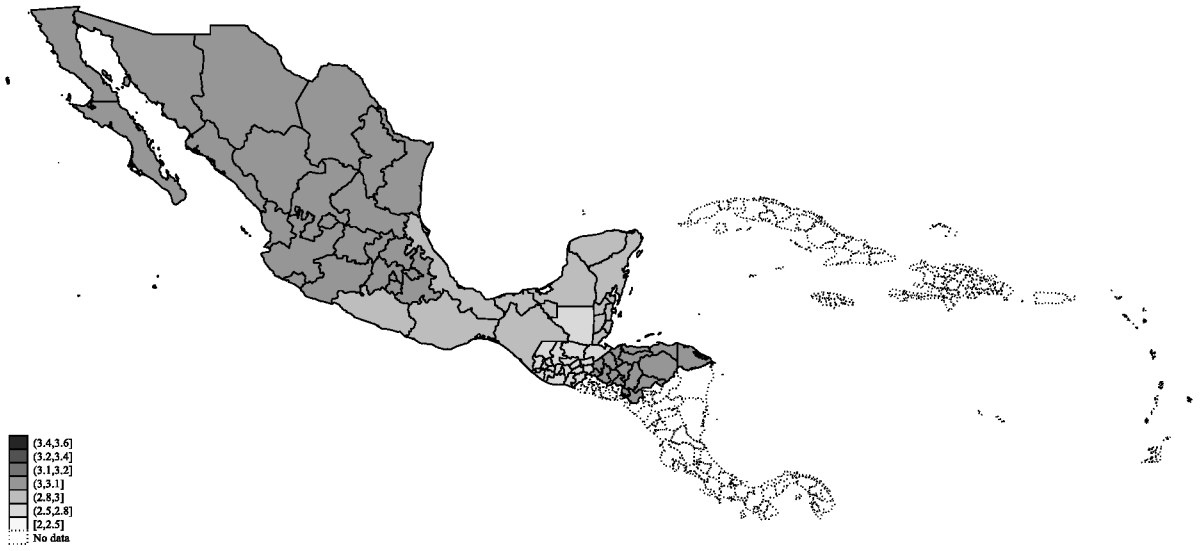


Figure C.2: Gender equality, 1–1500 CE – Central America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: Belize, Honduras, Mexico North, Mexico Central, and Mexico South.

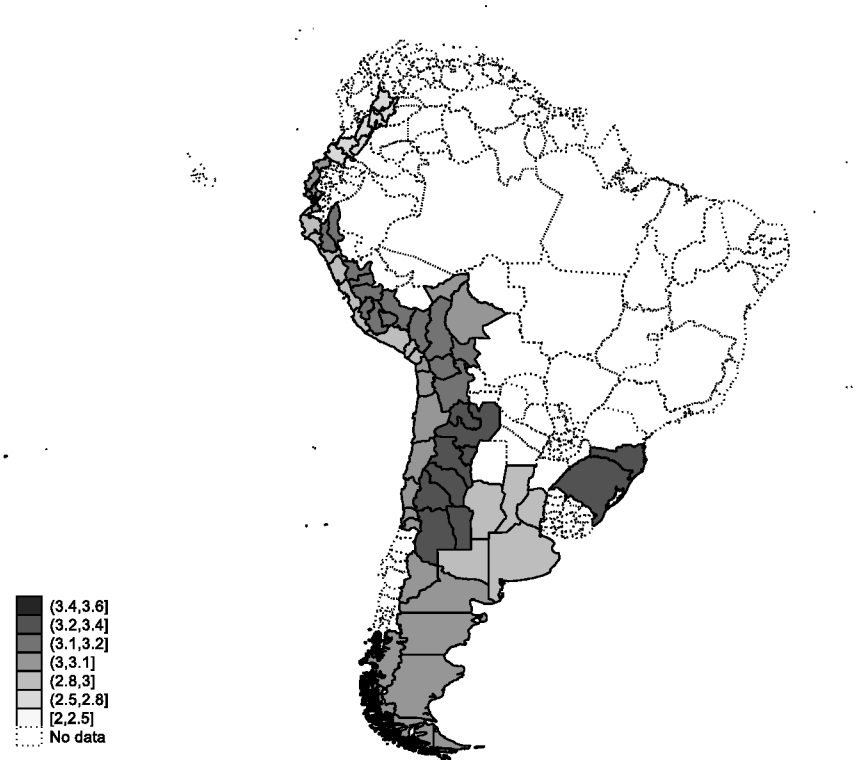


Figure C.3: Gender equality, 1–1500 CE – South America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: Amazon Basin, Andean Highlands, Argentinian Highlands, Brazilian Coast, Brazilian Highlands, Chile North Coast, Colombia Highlands, Ecuadorian Coast, Ecuadorian Highlands, Guatemala, Pampas, Patagonia, and Peru Coast.

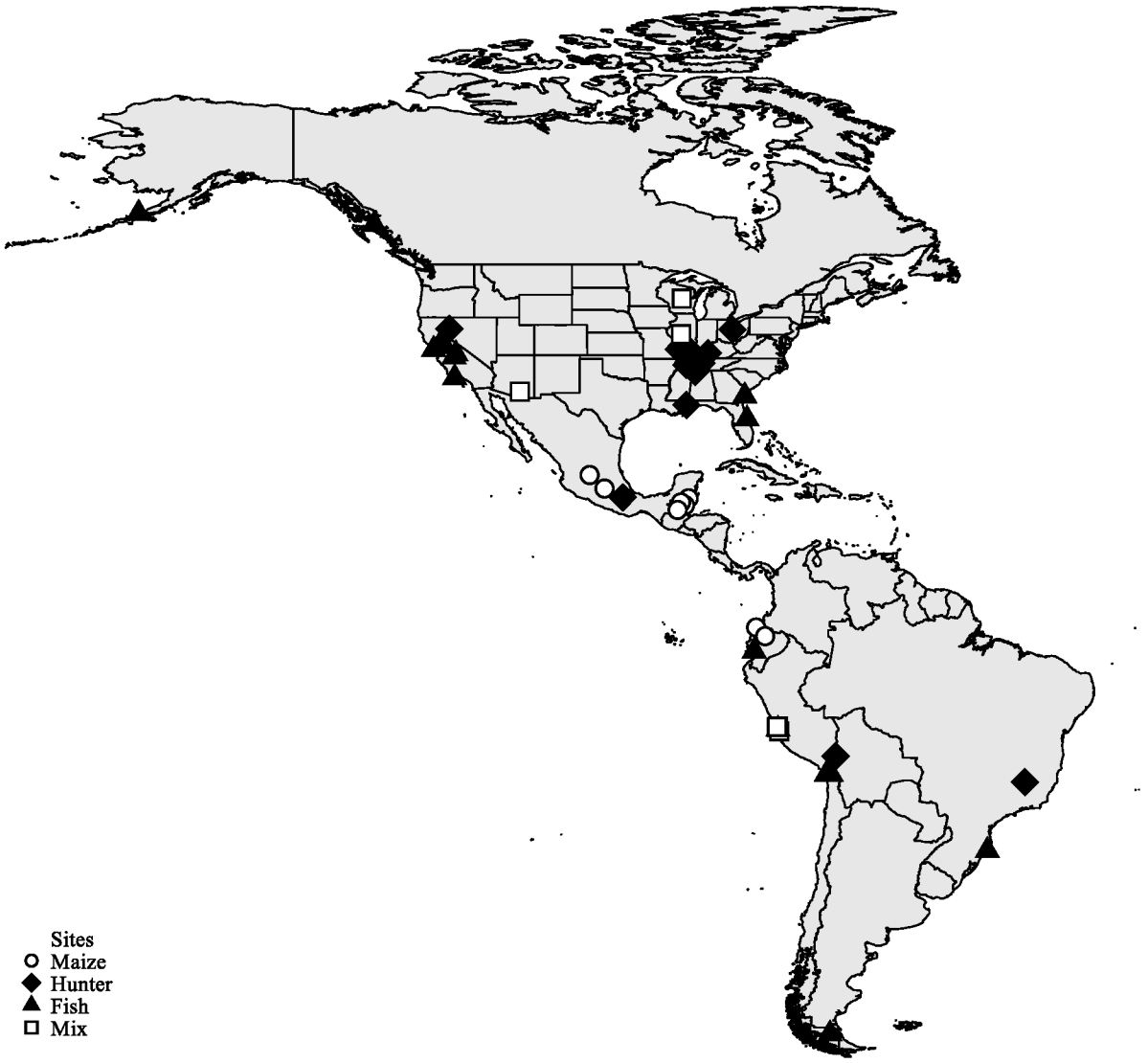


Figure C.4: Subsistence strategies before 1 CE

Notes: Each symbol represents a site-period observation. Hollow circles indicate maize, diamonds indicate hunting, triangles indicate fishing, and hollow squares indicate mixed dominant subsistence.

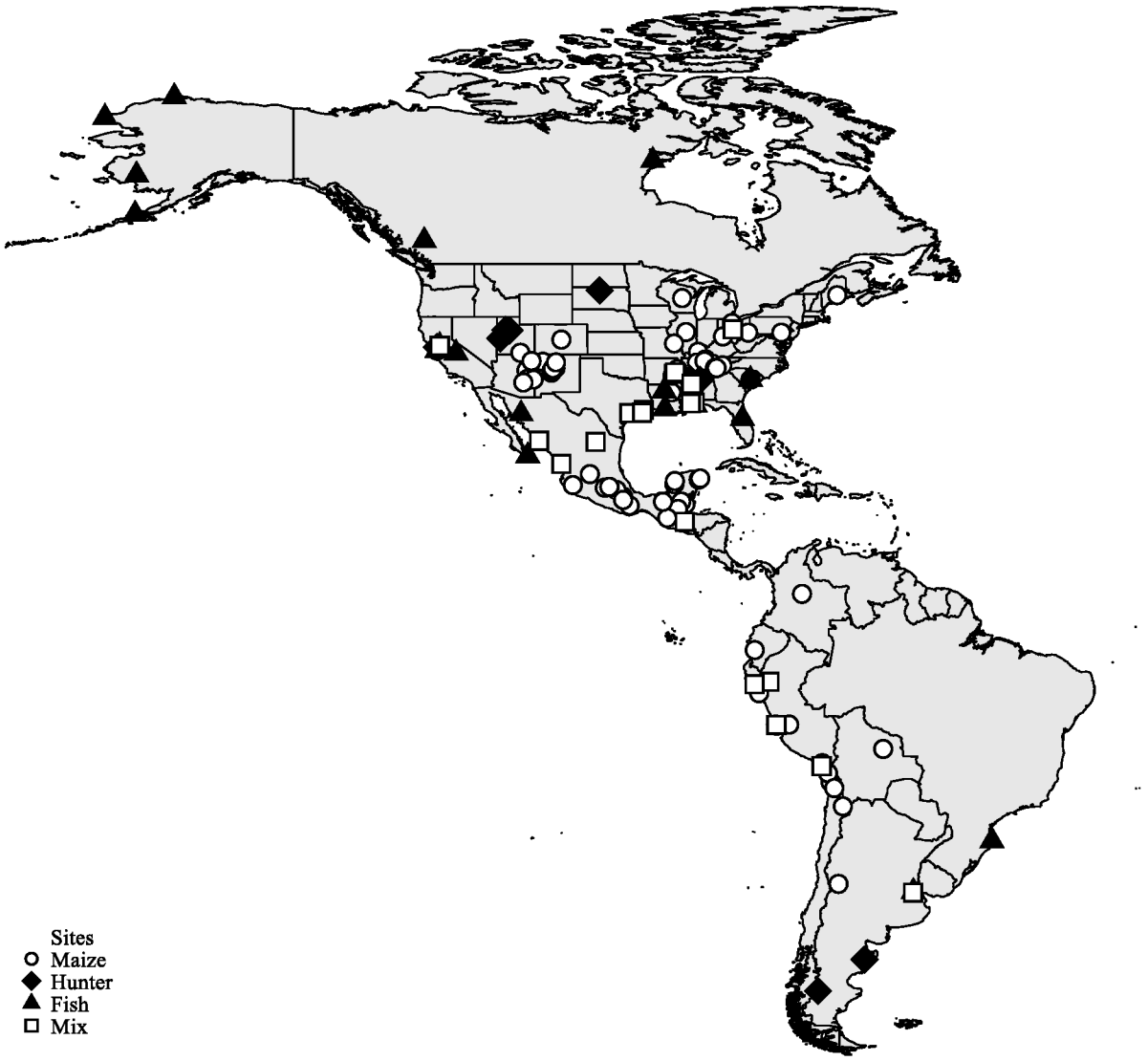


Figure C.5: Subsistence strategies, 1–1500 CE

Notes: Each symbol represents a site-period observation. Hollow circles indicate maize, diamonds indicate hunting, triangles indicate fishing, and hollow squares indicate mixed dominant subsistence.

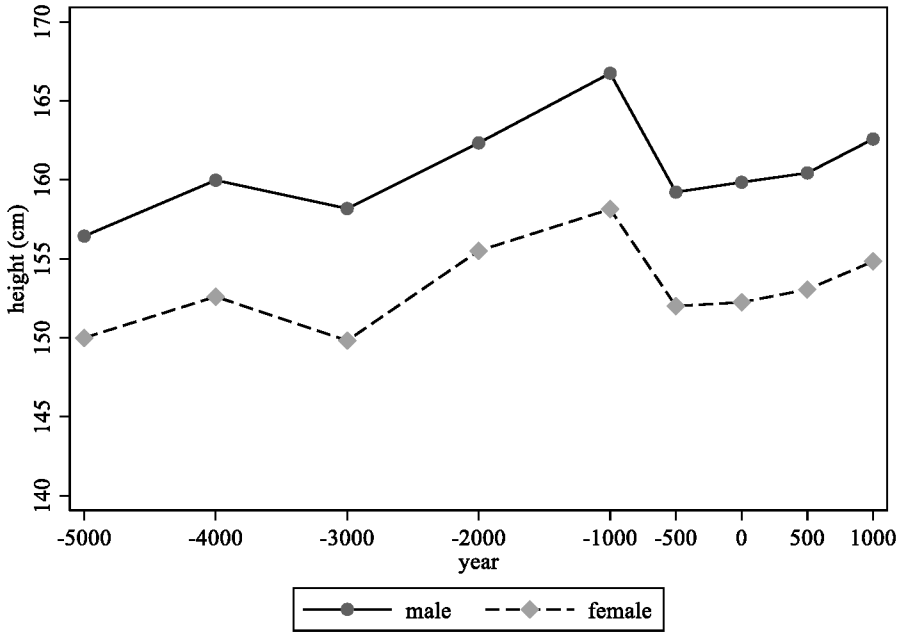


Figure C.6: Trends of male and female heights in the Americas

Notes: Average heights (estimated based on femur length) are shown for samples with at least 30 individuals per site-period observation and are weighted by number of individuals. Averages are calculated over millennium intervals prior to 1000 BCE and over half-millennium intervals after 500 BCE and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a millennium (before -1000), or a 500-year period (thereafter).

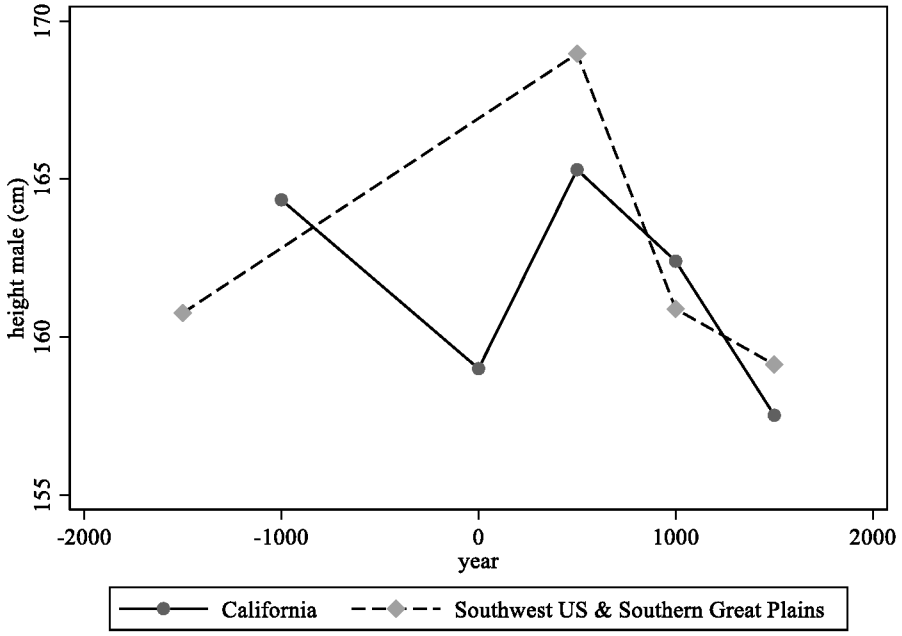


Figure C.7: Regional trends of male heights – North America West

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

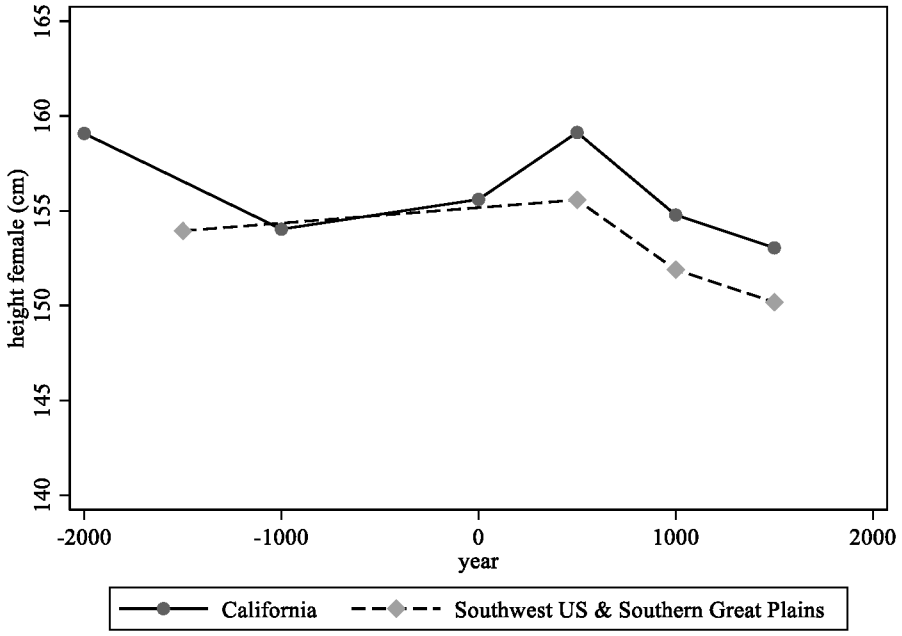


Figure C.8: Regional trends of female heights – North America West

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

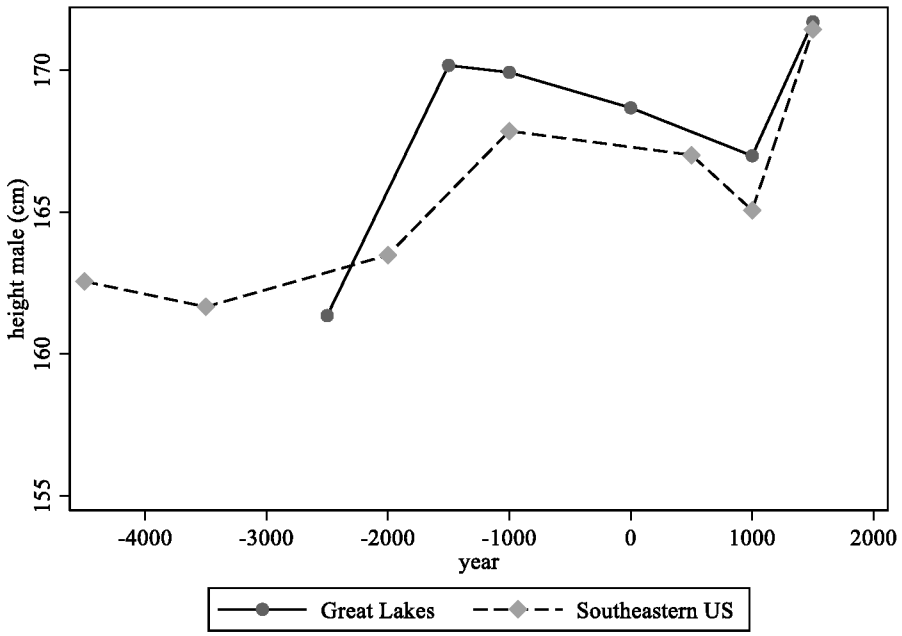


Figure C.9: Regional trends of male heights – North America East

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

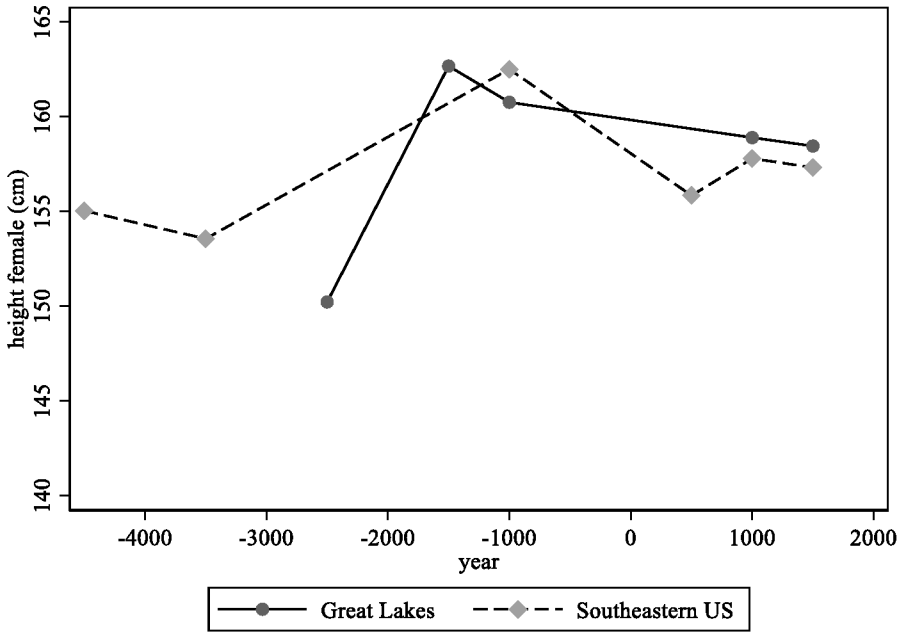


Figure C.10: Regional trends of female heights – North America East

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

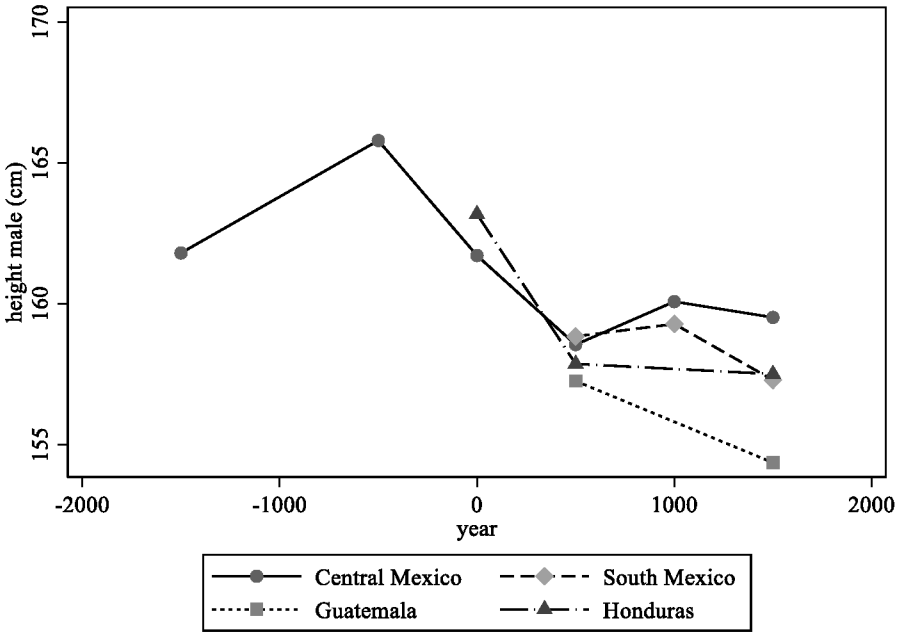


Figure C.11: Regional trends of male heights – Mesoamerica

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

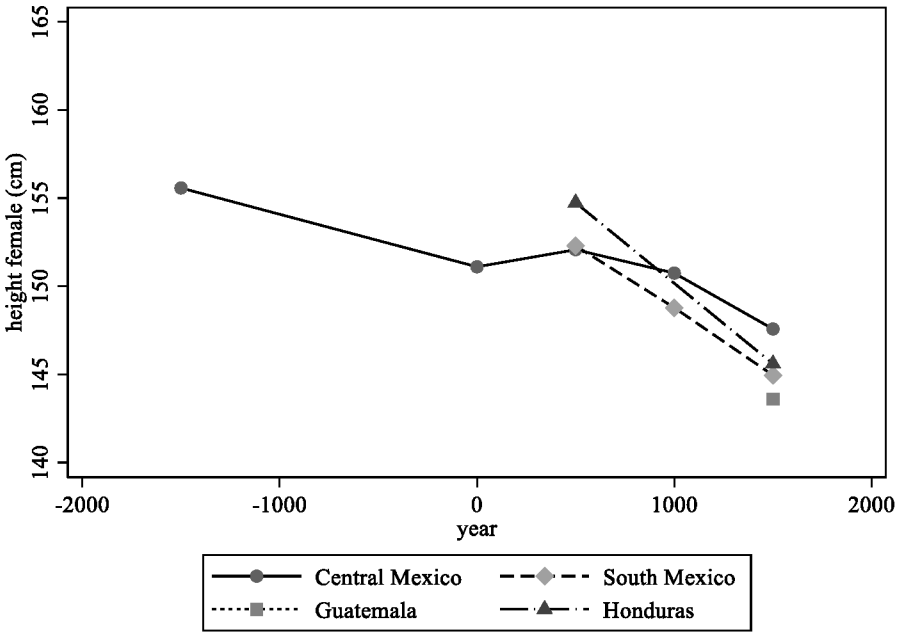


Figure C.12: Regional trends of female heights – Mesoamerica

Notes: Average heights (estimated based on femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by number of individuals. Observations are aggregated over half-millennium intervals and displayed at the corresponding lower bound of each interval. "0" refers to the year 1 CE. The years refer to the beginning of a 500-year period.

Table C.1: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
GE height (ln)	203	3.039	0.257	1.668	3.456
Maize	203	0.527	0.5	0	1
Hunting	203	0.118	0.324	0	1
Fish	203	0.232	0.423	0	1
Mixed	203	0.123	0.329	0	1
Grazing	203	4.958	9.352	0	53.212
Cropland	203	3.949	6.588	0	38.629
Population density	203	0.535	0.719	0.005	2.364
Temperature (°C)	203	13.963	6.614	-5.059	25.15
Fortified	162	0.154	0.362	0	1

Table C.2: Effects of different specializations on gender equality in height

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Maize	0.32**	-0.13**	-0.11*	-0.13**	-0.12	-0.11*	-0.11*
	(0.042)	(0.045)	(0.083)	(0.012)	(0.120)	(0.083)	(0.089)
Hunting	0.89**	-0.36***	-0.27***	-0.24***	-0.28***	-0.27***	-0.27***
	(0.025)	(0.003)	(0.009)	(0.001)	(0.009)	(0.009)	(0.007)
Fish	0.59*	-0.07	-0.03	-0.02	-0.06	-0.03	-0.04
	(0.059)	(0.256)	(0.444)	(0.732)	(0.230)	(0.444)	(0.285)
ln(pop. density)							-0.02
							(0.831)
Temperature							0.00
							(0.479)
Other controls	Y	Y	Y	N	N	Y	Y
Period	pre-1CE	1-1500CE	All	All	All	All	All
Time FE	Cent	Cent	Cent	Half-mill	Cent	Cent	Cent
Constant	1.86***	3.12***	3.28***	3.21***	3.30***	3.28***	3.19***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Obs.	54	149	203	203	203	203	203
R-squared	0.885	0.310	0.305	0.187	0.300	0.305	0.306

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 3. Columns 1-3 show the effect for different periods. Columns 4-7 show the effect including different control variables. Other controls include grazing and cropland. All regressions include world regions fixed effects. Time FE indicates century or half-millennium fixed effects. Maize, Hunting, and Fish are binary variables indicating the dominant subsistence strategy. The reference category is mixed subsistence strategy. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table C.3: Impact of fortification on gender equality in height

	(1)	(2)
Maize	-0.11**	-0.12*
	(0.015)	(0.082)
Hunting	-0.27***	-0.30**
	(0.000)	(0.010)
Fish	-0.05**	-0.06***
	(0.019)	(0.001)
Fortified	0.27*	0.16
	(0.081)	(0.128)
Other controls	Y	Y
Time FE	half millennium	century
Constant	3.00***	2.92***
	(0.000)	(0.000)
Observations	162	162
R-squared	0.234	0.319

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 3. We include the binary variable "fortified" averaged over half-millennium and country. Other controls include grazing, cropland, and world region fixed effects. Maize, Hunting, and Fish are binary variables indicating the main subsistence strategy of the society. The reference category is mixed subsistence strategy. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** $p < .01$, ** $p < .05$, * $p < .1$.

C.10 Appendix

C.10.1 Methods and Descriptives

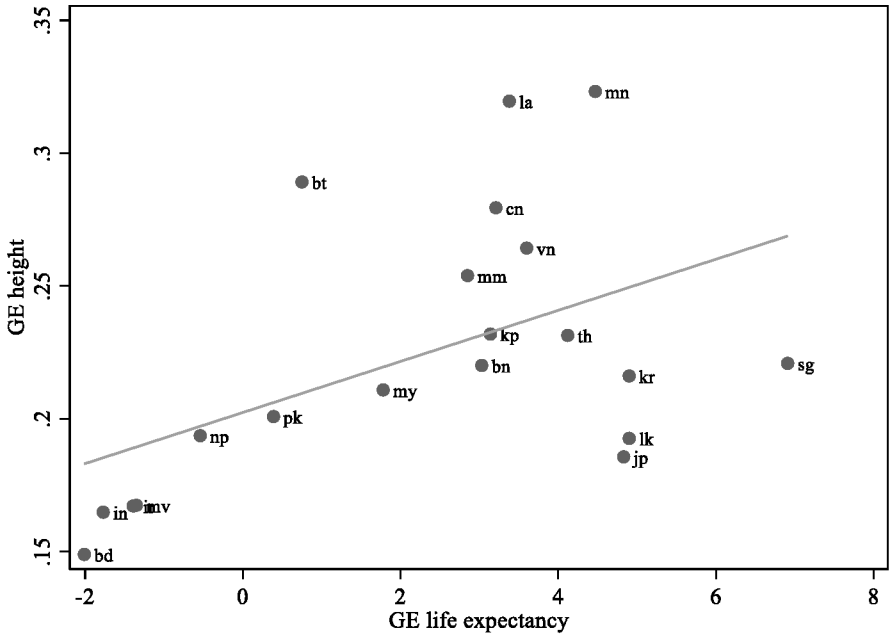


Figure C.13: Gender equality in height and life expectancy in Asia (1960s birth cohorts)

Notes: Gender equality in life expectancy is defined as the gap between female and male life expectancy at birth (in years). Gender equality in height is constructed using equation 3. Countries included are from East Asia, Southeast Asia, and South Asia: Bangladesh, Bhutan, Brunei, Cambodia, China, Hong Kong, India, Indonesia, Iran, Japan, Laos, Macao, Malaysia, Maldives, Mongolia, Myanmar, Nepal, North Korea, Pakistan, Singapore, South Korea, Sri Lanka, Taiwan, Thailand, Timor-Leste, Vietnam.

Table C.4: Number of individuals and sites for the early and late period

			Dominant subsistence strategy			
	Males (no. individuals)	Females (no. individuals)	Maize (no. sites)	Hunting (no. sites)	Fish (no. sites)	Mixed (no. sites)
Before 1CE	719	658	9	15	24	6
1-1500 CE	2832	2704	98	9	23	19
Total	3551	3362	107	24	47	25

Notes: Number of sites refers to site-period observations. Maize refers to a maize-dominant subsistence strategy; hunting to hunter-gatherers; fish to hunter-fisher-gatherers; and mixed to mixed agriculture combined with hunting and gathering.

Table C.5: Robustness checks

	(1)	(2)
Maize	-0.11*	-0.09
	(0.097)	(0.101)
Hunting	-0.28**	-0.11*
	(0.010)	(0.092)
Fish	-0.04	-0.03
	(0.234)	(0.456)
Other controls	Y	Y
Time FE	Y	Y
Constant	3.31***	3.16***
	(0.000)	(0.000)
Observations	198	178
R-squared	0.187	0.178

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 3. All periods are included (6500 BCE to 1500 CE). Column (1) is winsorized at the 1% level, trimming the most extreme upper and lower outliers. Column (2) additionally excludes sites with small sample sizes. Other controls include grazing, cropland, and world region fixed effects. Time FE refers to century fixed effects. Maize, Hunting, and Fish are binary variables indicating the main subsistence strategy of the society. The reference category is mixed subsistence strategy. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table C.6: Number of individuals by big region and half millennium

	Mesoamerica		North America		South America	
Half mill.	males	females	males	females	males	females
-4500	.	.	18	17	44	36
-4000	.	.	.	.	22	19
-3500	.	.	40	39	15	12
-3000	.	.	.	.	16	12
-2500	.	.	27	27	39	51
-2000	.	.	29	16	.	.
-1500	99	117	51	40	17	13
-1000	.	.	148	130	.	.
-500	20	13	14	.	51	29
1	67	41	110	150	140	126
500	172	175	276	284	319	391
1000	385	286	1089	934	274	317
1500	5239	2930	1662	1385	198	141

Notes: Number of individuals used in Figures C.7 to C.12. Dots indicate that number of individuals was below 10. The year in the first column represents the first of a 500-year period. The 1500-2000 period is only included in the Figures C.7 to C.12, but excluded in all other analyses.

C.10.2 Additional Maps

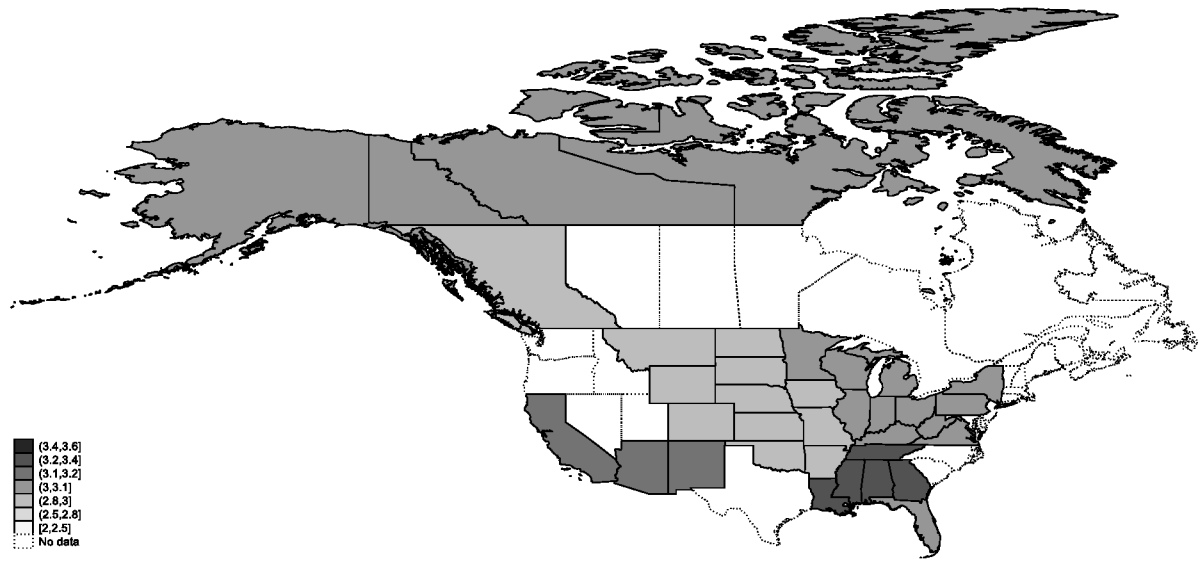


Figure C.14: Gender equality before 1 CE – North America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: California, East Coast US, Florida, Great Basin, Great Lakes, Great Plains, Northeastern Woodlands, Pacific Northwest, US Southeast, Southern Great Plains, US Southwest, and Western Arctic.

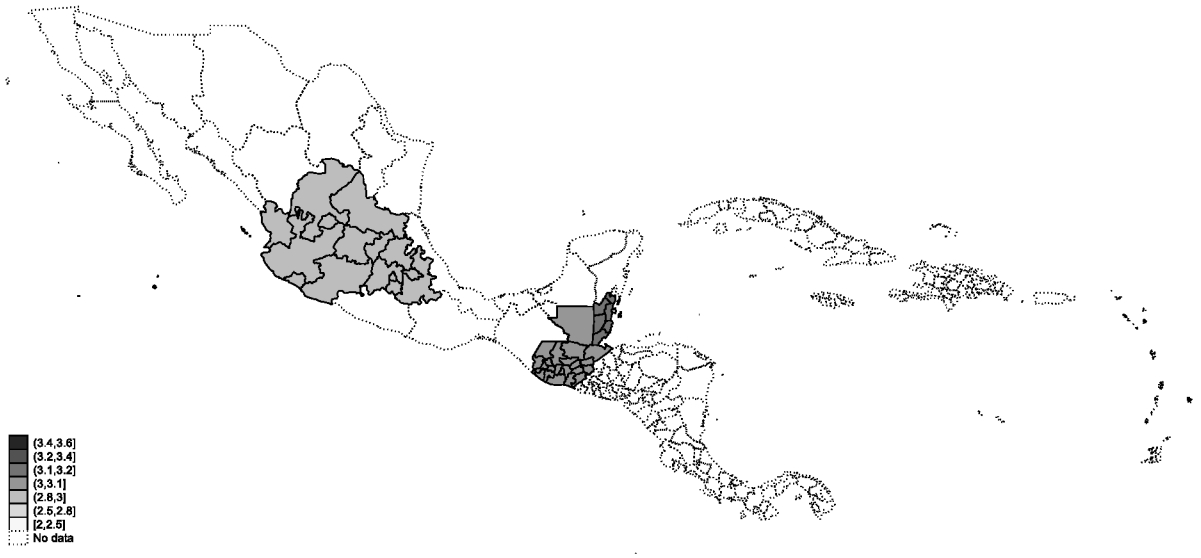


Figure C.15: Gender equality before 1 CE – Central America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: Belize, Honduras, Mexico North, Mexico Central, and Mexico South.

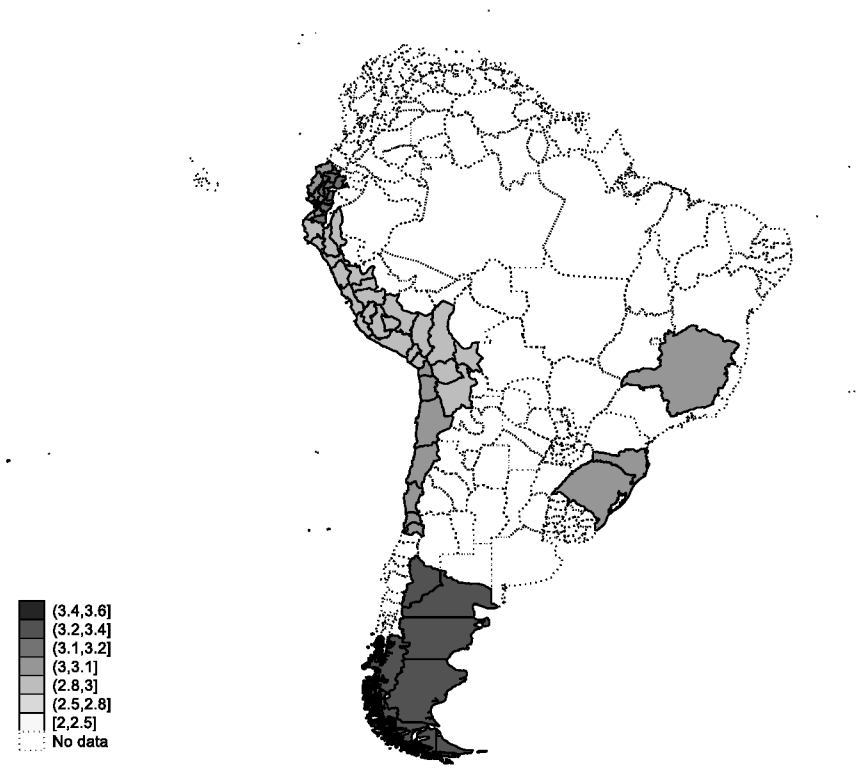


Figure C.16: Gender equality before 1 CE – South America

Notes: Darker values represent higher gender equality in height. Dotted lines represent missing states. Values are averaged for the following regions: Amazon Basin, Andean Highlands, Argentinian Highlands, Brazilian Coast, Brazilian Highlands, Chile North Coast, Colombia Highlands, Ecuadorian Coast, Ecuadorian Highlands, Guatemala, Pampas, Patagonia, and Peru Coast.

C.10.3 Comparing Femur Length, Hypoplasia, and Dental Health

Bereczki et al. (2019) observed that femur length correlates with other health indicators such as the absence of hypoplasia. The hypoplasia indicator is a malnutrition and other stress signal (disease, among others), based on horizontal grooves on the teeth (Bereczki et al., 2019). For Figure C.17 enamel hypoplasia shares were transformed into a health index which considers high and low values of the absence of this indicator of malnutrition and poor health (Steckel et al., 2019). For example, in Figure C.17 this health index shows positive values in the early medieval period in Europe (the period from 500 to 1000 CE). Thereafter, the European population declined in health according to the three indicators documented in this figure: the hypoplasia index, the femur length index, and also an index of dental health, which reflects abscesses and caries and other dental diseases. These were heavily influenced by availability of high-quality protein before the industrial period. Only during the eighteenth and the nineteenth century, sugar consumption reached a level that sugar became important as a determinant of low dental health (Steckel et al., 2019). Before this period, dental health was related to the availability of high-quality protein nutrition. In sum, all three archaeological indicators move relatively parallel, which supports the hypothesis that they measure health and nutritional quality for early periods in a reliable way.

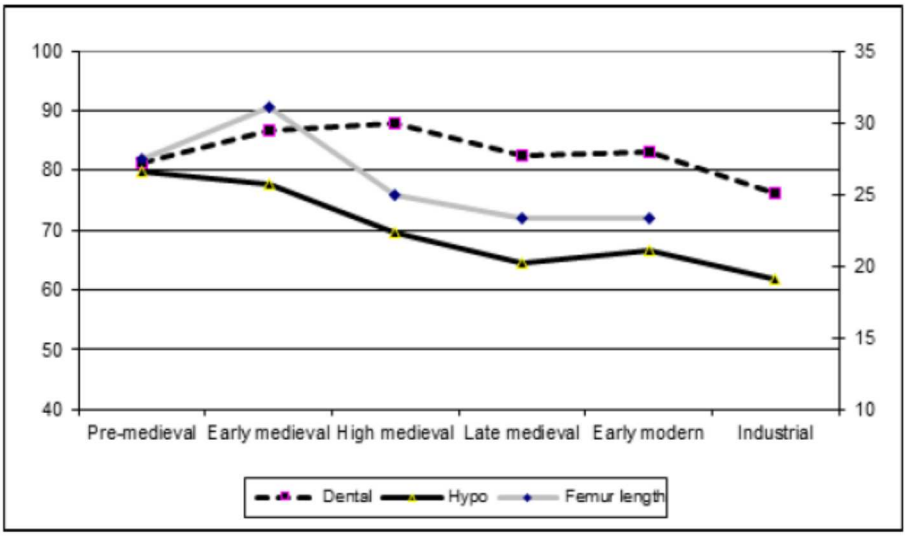


Figure C.17: Correlation of different health indicators, Europe, 500–1900 CE

Notes: This figure presents a health index based on hypoplasia incidence, femur length, and dental health indicators. Pre-medieval refers to the period before 500 CE, early medieval to 500–1000 CE, high medieval to 1000–1300 CE, late medieval to 1300–1500 CE, early modern to 1500–1800 CE, and Industrial to the period after 1800 CE.
Source: Baten et al. (2019).

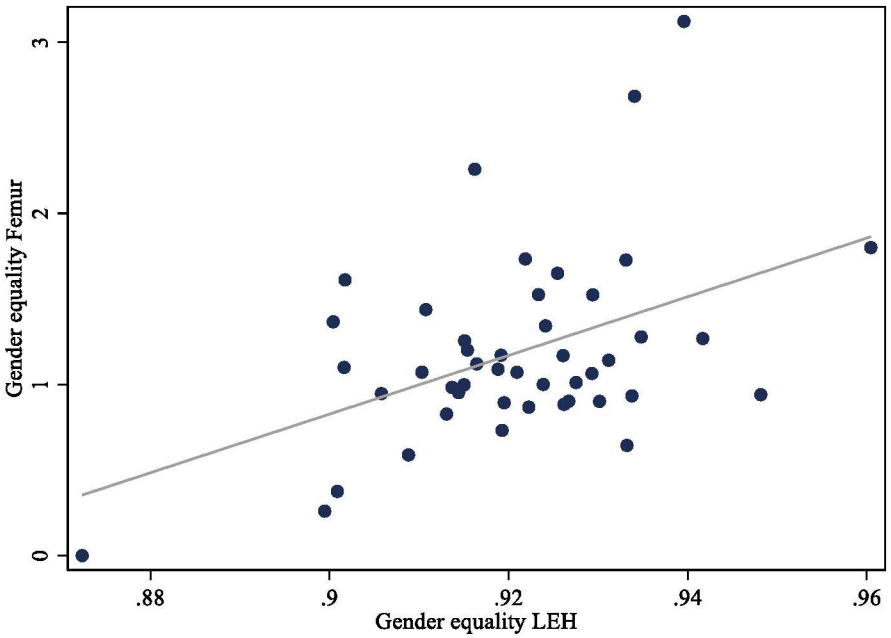


Figure C.18: Correlation between gender equality in LEH and femur length, Europe

Notes: Gender equality Femur is defined as the ratio between female and male femur length, such that higher values indicate more equality. Gender equality in linear enamel hypoplasia (LEH) is defined as the ratio between male and female LEH, such that higher values indicate more equality. Each dot represents a site-period observation from Europe, dated to periods after 1 CE.
Source: Own illustration based on Maravall and Baten (2019).

C.10.4 Data Sources

Table C.7: Overview of data sources for height

Paper	Site	Site age avg (BP)	Table
Akins (1986)	AMNH Room 33 (Pueblo Bonito)	862	Table Appendix D.2./ Table 6.2.
Akins (1986)	BC51-57, 29SJ#, TU257,29 CK#4	862.5	Table Appendix D.2./ Table 6.2.
Alfonso-Durruty et al. (2015, 2017)	Estancia Morro Chico, Posesion (Olimpia), Daniel, San Gregorio-12, Bahia Gente Grande, Myren-1, Rio San Martin, Caverna 3 Pto. Natales, Bahia Felipe, Laguna Flamenco, Lengua de Vaca	5500	Table 3 (Alfonso-Durruty et al., 2017)
Anderson (1965)	Tehuacan Valley	7850	Text, p. 496
Anzellini and Toyne (2020)	Kuelap	732.5	Table 1
Auerbach and Ruff (2010)	Bear Creek	3750	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Blossom	3650	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Caldwell Village	825	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Candy Creek	800	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Canyon del Muerto	750	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Caplen	700	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Carrier Mills	2750	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Carter Ranch	775	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Chaco Canyon	950	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Chamisal	500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Channel Islands	2750	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Coast Salish	500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Cook	3000	Table 2 for stature, Table 1 for no. individuals

Table C.7 (continued)

Auerbach and Ruff (2010)	Dickson	650	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Ebenezer	2750	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Elizabeth	2000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Evans	800	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Fort Ancient	700	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Gallina Springs	650	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Glen Canyon	730	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Grasshopper	612.5	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Ikogmiut	550	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Indian Knoll	4250	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Karlo	3000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Kiklewait	550	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Kinishba	625	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Kuhlman	1150	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Kuskowagamiut	550	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Libben	1000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Loeve Fox	1250	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Maine	600	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Mitchell Ridge	500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Mobridge	475	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Modoc Rock Shelter	4000	Table 2 for stature, Table 1 for no. individuals

Table C.7 (continued)

Auerbach and Ruff (2010)	Need 1	500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Neo-Aleut	700	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Paa-Ko	600	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Palmer	1850	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Point Barrow	1000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Point Hope Ipiutak	1800	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Point Hope Tigara	550	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Point of Pines	582.5	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Polley-Secrest	1000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Pottery Mound	550	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Pre-Aleut	2500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Prince Rupert Harbor	2500	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Ryan Mound	950	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Sacramento Valley	1000	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Thompson Village	700	Table 2 for stature, Table 1 for no. individuals
Auerbach and Ruff (2010)	Yerba Buena	2500	Table 2 for stature, Table 1 for no. individuals
Beresford-Jones et al. (2021)	Morro I	5333.5	Table 2
Boyd and Boyd (1989)	Anderson (40WM9)	6450	Table 1
Boyd and Boyd (1989)	Averbuch (40DB60)	600	Table 1
Boyd and Boyd (1989)	Cherry (40BN74)	6450	Table 1
Boyd and Boyd (1989)	Dallas (40HA1)	500	Table 1
Boyd and Boyd (1989)	Eva (40BN12)	5050	Table 1
Boyd and Boyd (1989)	Ledbetter Landing (40BN25)	3950	Table 1
Boyd and Boyd (1989)	Ledford Island (40BY13)	500	Table 1
Boyd and Boyd (1989)	Rymer (40BY11)	500	Table 1
Boyd and Boyd (1989)	Toqua (40MR6)	500	Table 1

Table C.7 (continued)

Boza-Cuadros (2010)	El Brujo	1575	Appendix II
Boza-Cuadros (2010)	Maranga	1450	p. 83
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	750	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1150	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1350	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1550	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	2000	Table 9
Broughton (2010)	CA-SJO-68, -142	2500	Table 9
Broughton (2010)	CA-SJO-68, -142	2650	Table 9
Broughton (2010)	CA-SJO-68, -142	2850	Table 9
Broughton (2010)	CA-SJO-68, -142	3850	Table 9
Broughton (2010)	CA-SJO-68, -142	4450	Table 9
Béguelin (2011)	Chubut	1450	Table 1
Béguelin (2011)	Sierra Colorada	1450	Table 1
Corruccini (1972)	Pueblo Bonito	925.5	Table 3
Corruccini (1972)	Puye Cliff Dwellings	477	Table 4
Da Gloria (2012)	Lapa da Amoreira, Lapa Mortuaria,Cerca Grande, Lapa de Boleiras, Lapa de Carrancas, Harold Walter, Lapa do Santo, Santana do Riacho 1	8500	Table 6.173
Danforth (1994)	Barton Ramie/Baking Pot	1975	Table 1
Danforth (1994)	Barton Ramie/Baking Pot	1225	Table 1
Danforth (1994)	Seibal	1225	Table 1
Danforth (1994)	Seibal	1975	Table 1
Danforth et al. (1997)	Cuello	3000	Table 2
Danforth et al. (2007)	1Pi33	750	Table 5.3
Danforth et al. (2007)	1Pi61	1225	Table 5.3
Danforth et al. (2007)	Andrew's Place (1BA1)	750	Table 5.5
Danforth et al. (2007)	Arnold	750	Table 5.2
Danforth et al. (2007)	Austin	1225	Table 5.4
Danforth et al. (2007)	Bonds	1225	Table 5.4
Danforth et al. (2007)	Brown	750	Table 5.2
Danforth et al. (2007)	Chucalissa	550	Table 5.4
Danforth et al. (2007)	Copeland's Landing	750	Table 5.5

Table C.7 (continued)

Danforth et al. (2007)	Garnier	750	Table 5.2
Danforth et al. (2007)	Harvey (22HR534)	2825	Table 5.5
Danforth et al. (2007)	Humber	550	Table 5.4
Danforth et al. (2007)	Kellogg Village	750	Table 5.3
Danforth et al. (2007)	Lake George	550	Table 5.4
Danforth et al. (2007)	Mangum	550	Table 5.4
Danforth et al. (2007)	Tibbee Creek	750	Table 5.3
Danforth et al. (2007)	Tomotley	700	Table 5.1
Danforth et al. (2007)	West	750	Table 5.2
Davis et al. (2015)	Shady Grove site (22WQU525)	680.5	Table 4
Gagnon (1996)	Shenk's ferry (36La2, 36La6, 36La9, 36La36,36La54)	550	Appendix B
Hogue and Dongarra (2002)	Dust Cave (1LU496), Hill site (22SU535), Bryan Farms site (22CL620)	4725	Table 6
Hogue and Dongarra (2002)	Lyon's Bluff (22OK520), the South Farm site (220K534)	680	Table 6
Hubbe et al. (2018)	Porto do Rio Vermelho 02	1880	Table 3
Juengst et al. (2017)	Muruqullu	4200	Table 1
Mansegosa et al. (2021)	Los Pozos, Agrelo-17, Usina Sur, Potrerillos, Colección del Museo Americanista, Edificio Plaza Huarpe, Los Ciruelos, P. Godoy, Colección Semper	1195	Table 4
Mazza (2019)	Arroyo La Garzab, Arroyo Los Tigresb, Arroyo La Marietab, Arroyo Sarandí, Túmulo II del Brazo Largo, El Cerrillo, Garín, La Argentina/Paraná Ibicuy 1, Los Talas, La Bellaca sitio 1, Cerro Lutz, El Cazador sitio 3, Escuela 31	1750	Table 3
Mazza (2019)	Arroyo Malo, Arroyo La Glorieta, Arroyo Fredes	470	Table 3
Miller et al. (2018)	Tibanica	1200	Table 2
Márquez-Morfín and Hernández-Espinoza (2020)	Jaina	1175	Table 12.3
Márquez-Morfín and Hernández-Espinoza (2020)	Xcaret	725	Table 12.3
Nickens (1976)	Altar de Sacrificios	725	Table 1 and 3
Nickens (1976)	Altar de Sacrificios	1175	Table 1 and 3
Nickens (1976)	Altar de Sacrificios	1550	Table 1 and 3

Table C.7 (continued)

Nickens (1976)	Altar de Sacrificios	2325	Table 1 and 3
Nickens (1976)	Coixtlahuaca, Oaxaca	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Copan	725	Table 1
Nickens (1976)	Guasave, Sinaloa	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	La Candelaria, Coahuila	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Marismas Nacionales	725	Table 1
Nickens (1976)	Palenque	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Pericu	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Seri	725	Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tehuacan	2325	Table 1 and 3
Nickens (1976)	Tehuacan	1175	Table 1 and 3
Nickens (1976)	Tikal	2325	Table 1 and 3
Nickens (1976)	Tikal	1550	Table 1 and 3
Nickens (1976)	Tikal	1175	Table 1 and 3
Nickens (1976)	Tlatilco	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tlatilco II	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tuxcacuesco, Jalisco	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Valley of Mexico	725	Table 1 and Table 3 and 4 in Genoves (1970)
Nickens (1976)	Yagul	725	Table 1
Nickens (1976)	Zaculeu	725	Table 1 and 3
Nickens (1976)	Zaculeu	1175	Table 1 and 3
Nickens (1976)	Zaculeu	1550	Table 1 and 3
Pechenkina and Delgado (2006)	Villa El Salvador XII	1950	Table 2
Pechenkina et al. (2007)	Asia Beach	3125	Table 7.5
Pechenkina et al. (2007)	Cardal	3150	Table 7.5
Pechenkina et al. (2007)	Huaca Huallamarca	1200	Table 7.5
Pechenkina et al. (2007)	Huaca Pucllana	1550	Table 7.5
Pechenkina et al. (2007)	Paloma	5625	Table 7.5
Pechenkina et al. (2007)	Tablada de Lurin	2050	Table 7.5
Pezo-Lanfranco (2020)	Jabuticabeira II	2325	Text, p. 10

Table C.7 (continued)

Pomeroy and Stock (2012)	Azapa Valley (Az-140, Az-141, Az-71; 140 m)	800	Table 3
Pomeroy and Stock (2012)	Chinchorro (Mo-1 Mo-1/6; 60 m)	4450	Table 3
Pomeroy and Stock (2012)	Mantaro Valley	750	Table 3
Pomeroy and Stock (2012)	Pica-8	750	Table 3
Pomeroy and Stock (2012)	San Pedro de Atacama (Toconao Oriente, Solcor-3, Quitor-6, Coyo-3)	1380	Table 3
Sciulli and Hetland (2007)	Ohio Valley	550	Table 1
Sciulli and Hetland (2007)	Ohio Valley	1950	Table 1
Sciulli and Hetland (2007)	Ohio Valley	3450	Table 1
Shuler et al. (2012)	Cofferdam, Shell Bluff, White Springs, 1Pi61, 1Pi33 LW	1100	Table 4
Shuler et al. (2012)	Kellogg, Tibbee Creek, Lyon's Bluff, 1Gr21	650	Table 4
Shuler et al. (2012)	Lubbub village, Lubbub mound	900	Table 4
Shuler et al. (2012)	Moundville	850	Table 4
Trautmann (2024)	Salvatierra	1000	Appendix 1
Watson (2013)	Donaldson, La Playa, Las Capas, Los Ojitos, Los Pozos, Pantano, Rio Nuevo, Santa Cruz Bend, Wetland	2975	Table 3
Wentz et al. (2006)	Windover (8Br246)	8192	Text p. 80
Williams and Murphy (2013)	Armatambo	715	Table 5
Williams and Murphy (2013)	Lambayeque	734	Table 5
Williams and Murphy (2013)	Osmore Drainage	715	Table 5
Zaleski (2013)	Georgia coast (Airport site, Deptford site, Cannons Point, Sea Island Mound, Johns Mound, Marys Mound, Charlie King Mound, McLeod Mound)	2475	Text, p. 39
Zaleski (2013)	Gold Mine (16RI13)	1120	Appendix C
Zaleski (2013)	Morton Shell Mound (16IB3)	1000	Appendix B
Zaleski (2013)	Plash Island (1BA134)	1800	Text, p. 38

Notes: BP means before present (1950 CE). Site refers to site-period observations. All 203 sites are listed, except for 31 sites that were added from the Western Hemisphere Project (Steckel and Rose, 2002).

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D The Impact of European Settlements on Indigenous Health: A Gender Equality Perspective

Abstract

This paper studies how European settlement reshaped gender equality in health among Indigenous populations in the Americas. I compiled a new dataset spanning fourteen countries in North and South America and the last 2,000 years, covering about 17,000 individuals aggregated into 257 site-period observations. The data combine bioarchaeological evidence with historical anthropometric sources. Health is proxied by adult stature, which reflects cumulative nutrition and disease exposure during early childhood. Exploiting variation in settlement timing and location, I estimate two-way fixed effects models comparing site-periods exposed to nearby European settlements to pre-contact levels, controlling for subsistence regimes, climate, land use, and population density. I find that settlement exposure is associated with a statistically significant decline in gender equality in height. The relationship is heterogeneous across colonial activity types and institutional environments, consistent with differential disruptions to access to land and labor.

D.1 Introduction

The arrival of European settlers led to profound disruptions in the lives of Indigenous populations[15] in the Americas over the following centuries. From the very first encounters, Indigenous communities were exposed to novel diseases, warfare, and violence that killed millions of people and led to an unprecedented population collapse (see, for instance, Thornton, 1997, 2005; Kelly et al., 2025). This collapse continued for the following centuries, and for many tribes, population levels have only started to significantly recover in the twentieth century (Thornton, 2005). Yet this drastic decline represents only one dimension of the long-run consequences of European colonization. European rule fundamentally altered Indigenous ways of life, with consequences that persist to the present day. Indigenous populations continue to experience substantial health disparities relative to populations of European descent, including more limited access to health care (Marrone, 2007), higher prevalence of infectious and chronic diseases (Gracey and King, 2009), disproportionate mortality during recent health crises such as the COVID-19 pandemic (Goldman and Andrasfay, 2022), elevated suicide rates in many tribal communities (Van Winkle and May, 1986), higher overall mortality (Dankovchik et al., 2015; Parker and Kelly, 2023), and increased rates of alcohol abuse (Szlemko et al., 2006). Despite a large literature documenting these impacts, far less is known about the immediate health consequences of colonization and whether men and women were affected differently. This study addresses this gap by analyzing how European settlers altered gender equality in health among Indigenous populations in the Americas, using height as a proxy.

One important channel operates through particularly traumatic events such as land appropriation and forced relocation, which led to sudden disruptions in traditional subsistence systems and loss of resources, thereby negatively affecting health outcomes (King et al., 2009; Gish Hill, 2024; Turner and Turner, 2007). Farrell et al. (2021) show that Indigenous nations lost

[15] Throughout the paper, I use Indigenous societies/populations as an umbrella term for peoples who lived in the Western Hemisphere prior to European contact and for their descendants. Where greater precision is needed, I use region- or country-specific terms (e.g., Native American, Alaska Native). While these labels are widely used in contemporary scholarship, I recognize that they are imperfect and cannot fully capture the substantial heterogeneity across Indigenous peoples.

almost all of their historical land base and were often forced onto much smaller, more climatically exposed, and economically marginal territories in present day United States. Spanish missions relocated Indigenous populations into centralized villages with often worse living conditions, leading to higher disease prevalence and mortality (Jackson, 1985; Larsen, 1994). Klaus and Tam (2009) provide evidence that increased population density and resource shortages in *reducción* towns, such as Mórrope in Peru, impacted health outcomes differently for men and women. Depressed female fertility and increased chronic infections, such as degenerative joint diseases, among the Indigenous Mochica women suggest that females suffered from heavy labor demands and malnutrition post-contact (Klaus and Tam, 2009). The expansion of large-scale agriculture (maize and Old World grains) by the Europeans intensified these issues by reducing access to traditional plant and animal food sources (Hutchinson et al., 1998; Larsen et al., 2001; Mailer, 2013). This dietary shift likely contributed to the inability of Indigenous populations to recover demographically from the impacts of infectious diseases introduced during colonization (Mailer, 2013).

The empirical analysis focuses on the impact of European settlers on gender equality in health among Indigenous peoples across North and South America. The measure of gender equality in health is based on a formula developed by Schwekendiek and Baten (2019) and subsequently applied and validated by Jung and Baten (2025). Health is proxied by adult stature, derived from maximum femur length using the formula proposed by Ruff et al. (2012). Stature is a widely used method to assess nutritional status, dietary deficiencies, and physiological stressors such as severe diseases and nutritional shortages during early childhood, thus providing insights into the biological standard of living (see, for instance, Baten and Komlos, 1998; Koepke and Baten, 2005; Steckel, 2008). Throughout the paper, the terms height and stature are used interchangeably. European contact is defined as the period after the foundation of the first documented European settlement within the same modern-day state as the archaeological site.

The dataset draws on multiple sources, including archaeological data from the Western Hemisphere Project (Steckel and Rose, 2002) and anthropometric data. About 17,000 individuals are aggregated into 257 site-period observations spanning the last 2,000 years. Using a two-way fixed effects approach, the results show a significant negative impact of European settlements on gender equality relative to regions pre-contact. This effect varies across colonial activity types

(following the typology of Bruhn and Gallego, 2012), but the estimated relationship remains negative throughout.

Analyzing gender equality using historical data spanning several centuries sheds light on the evolution and roots of gender disparities in health and the role of colonialism and colonial institutions in shaping them. This adds a gendered perspective to the well-documented negative health consequences of colonization for Indigenous populations.

D.2 Literature and Historical Background

The expansion of European empires brought far-reaching transformations for Indigenous populations across much of the world. Anthropometric evidence shows that colonization often coincided with a deterioration in biological living standards among Indigenous populations. In Africa, for example, long-run height trends indicate that the onset of colonial rule lowered average stature, a pattern partially attributed to the introduction of forced labor systems (Baten and Maravall, 2021). Similar processes unfolded in the Americas several centuries earlier.

D.2.1 The Arrival of the Europeans and the Conquest of the Americas

In 1492, with Christopher Columbus's arrival in today's Bahamas, sustained contact between Europeans and Indigenous peoples began, setting in motion the centuries-long colonization of the Americas that would permanently transform Indigenous ways of life. One of the earliest major conquests of the Spaniards was the fall of Tenochtitlan, the capital of the Aztec Empire, in 1521. The expedition led by *conquistador* Hernán Cortés destroyed much of the city and rebuilt on the same site, naming it Ciudad de México (Mexico City) and declaring it the capital of New Spain, marking the beginning of the Spanish rule (Carballo, 2020). From there, Spanish explorers gradually expanded across Mesoamerica, present-day southwestern United States and Florida, and much of South America. In what is now Florida, St. Augustine (1565) became one of the earliest continuously occupied European towns. Soon after the Spanish expeditions Portuguese, Dutch, English and French settlers arrived. In the early seventeenth century settler colonies multiplied along the Atlantic coast (e.g., Jamestown, 1607 and Plymouth, 1620 by the English), and France claimed the Great Lakes and Louisiana regions (U.S. Geological Survey and Goetzmann, 1970). By 1820, approximately 2.6 million Europeans had migrated to the Americas

(Clark, 2025). Early migration (before 1700) was dominated by Spanish and Portuguese settlers, whereas later waves were increasingly led by British migrants, particularly in the northern parts of the present-day United States (Clark, 2025; Becker, 2019) Variation in the European origins of settlers paved the way for distinct colonial regimes, characterized by different institutions and treatment of local populations.

D.2.2 Demographic Collapse and Mortality Shocks

After the first European contact, mortality shocks were immediate and health quickly deteriorated for Indigenous populations, especially in areas under close colonial rule (Cameron et al., 2015). Epidemic pathogens such as smallpox, measles, and influenza spread along trade routes well in advance of permanent colonization, causing successive mortality shocks that eliminated (almost) entire communities (Jones, 2003).[16] Over the following 150 years post-contact the Indigenous population declined by up to 90 percent (Cameron et al., 2015). This collapse was driven not only by epidemics but also by warfare, violence and deteriorating living conditions (Cameron et al., 2015; Gutiérrez and Cameron, 2022; Larsen et al., 2001). Warfare involving shifting alliances between Europeans and Indigenous tribes exploiting long-standing local rivalries further intensified population losses. Cook (1973) estimates that in New England between 1620 and 1720 CE approximately one quarter of Native Americans died as a consequence of warfare.

D.2.3 Institutions, Policies, and Labor

Colonial institutions reshaped Indigenous labor systems and household organization. In the Spanish colonies, institutions such as the *encomienda*, *repartimiento*, and the *mita* system allocated Indigenous communities to Spanish settlers for tribute and labor. The *mita* system, expanded and abused by the Spanish Crown in the late sixteenth century, lasted for more than two centuries and required Indigenous men to serve in rotational labor, particularly in the silver mines of Potosí and mercury mines of Huancavelica (Dell, 2010). Work in these mines exposed laborers to extreme altitude, accidents, diseases (e.g., silicosis), and mercury poisoning, which

[16] Also known as "virgin-soil" epidemics, meaning that populations had never previously been exposed to these diseases and therefore lacked the necessary antibodies (Crosby, 1976). However, the magnitude of the "virgin-soil" effect has been debated (see, for instance, Larsen et al., 2001; Gutiérrez and Cameron, 2022).

increased mortality and skewed local sex ratios (Brown, 2001; Carpio and Guerrero, 2021). To meet tribute and labor quotas, men were often absent from their households for months; consequently, women assumed male agricultural and domestic responsibilities, which might have enhanced their bargaining power within households and communities. The extractive nature of the *mita* system had long-lasting impacts, contributing to lower contemporary income, education, and infrastructure levels in these regions (Dell, 2010). To facilitate tribute collection and to integrate Indigenous populations into the colonial economic system, the Spanish Crown implemented *reducción* programs. These programs relocated Indigenous populations into new, centralized towns, sometimes in connection with missions (Saito and Rosas Lauro, 2017). The Catholic Church played a central role in financing and organizing early Spanish colonial settlements, particularly from the mid-sixteenth century onward. These missions aimed not only to convert Indigenous peoples to Christianity but also to reshape social structures and everyday life, including norms around marriage, sexuality, and family size, in line with European ideals of "civilization" (Bolton, 1917; Danforth et al., 1997). Similarly, in Portuguese Brazil, Jesuits established missions along the coast and moved Indigenous to villages starting in the sixteenth century (Cohen and Colombo, 2015).

Gender divisions of labor existed prior to European contact. For instance, in the Sonoran Desert, early agriculturalists exhibited pronounced sexual dimorphism in femoral geometry, reflecting men's higher mobility during foraging and women's specialization in floodplain agriculture (Watson and Stoll, 2013; see also Miller et al., 2018 on Colombia). In northern Chile, the adoption of intensive agriculture (around 500 CE) increased women's participation in demanding fieldwork, leading to greater musculoskeletal stress among females relative to males (Ponce, 2010). However, colonial rule imposed new work obligations and legal structures. Evidence from degenerative joint disease among post-contact Indigenous communities in Andean *reducción* towns indicates heavier workloads for both men and women and a gender division of labor, with male skeletal patterns consistent with increased labor demands under the *mita* system (Klaus et al., 2009). In Yucatán, tribute obligations, such as textile production, placed new pressures on women (Noldner, 2013; Danforth et al., 1997).

European colonizers introduced new values, framed "civilization" in racialized and gendered terms, and strictly defined gender roles: Indigenous men were portrayed as savage and violent,

while Indigenous women were depicted as unfeminine, more often sexualized and subject to subjugation (Glenn, 2015). These classifications justified both conquest and conversion (Glenn, 2015). Colonial legal regimes further reshaped gender norms. Under Iberian and French rule, intermarriage between Indigenous women and European men was common (Fredrickson, 2005; Moran, 2025). In contrast, English North America progressively restricted interracial marriage (e.g., late seventeenth century anti-miscegenation statutes in Virginia) (Moran, 2025).

D.2.4 Forced Relocation and Disrupted Foodways

Prior to European arrival, Indigenous societies across the Americas were regionally specialized and adaptive to local ecological conditions. Societies relying on foraging and hunting were typically taller than those in more agriculture-dependent settings, due to abundant protein sources (e.g., bison) (Mazza, 2019; Taylor, 2010). In contrast, heavier reliance on maize (typically supplemented with beans and squash) has been linked to nutritional deficiencies and higher physiological stress, particularly when it displaced animal protein and dietary diversity (Larsen, 1995, 2006; Steckel et al., 2002; Nickens, 1976).

Colonial authorities implemented a range of institutions and policies to strengthen control and promote conversion, as described above. These measures contributed to land loss through land alienation and forced resettlement, that reduced access to diverse and traditional resources. In North America, both colonial administrations and the later U.S. government pursued policies of forced relocation. An especially tragic case is the Trail of Tears in the 1830s, during which several thousand Cherokee people died from exposure to freezing temperatures, disease, and starvation on forced marches (Thornton, 1984). In Central and South America, forced resettlement was likewise central to colonial governance through *reducción* policies. In the Andean highlands alone, historians estimate that over one million people were resettled in hundreds of newly founded villages (Mumford, 2012). In coastal Peru, dispersed late pre-contact communities such as Mórrope showed low indicators of physiological stress prior to contact (Klaus and Tam, 2009). Following the imposition of *reducción* towns, however, these populations were aggregated into densely settled centers with poor living conditions, resulting in elevated stress and deterioration in multiple health markers, such as stunting in subadults (Klaus and Tam, 2009).

In many regions, Spanish colonial policies expanded agricultural production, increasing reliance on maize while reducing access to animal protein (Larsen et al., 2001). This shift is confirmed by stable isotope analyses of human bone collagen showing higher carbon ($\delta^{13}C$) (greater consumption of domesticated plants) and lower nitrogen ($\delta^{15}N$) values (reduced intake of animal protein) (Hutchinson et al., 1998; Schoeninger, 2009). These changes were associated with a decline in dietary diversity, heavier physical labor, and increased dental and skeletal pathologies (Larsen et al., 2001). Other disruptions to traditional Indigenous diets arose from ecological and economic shocks. For instance, in the nineteenth century, the commercial and government-backed slaughter of bison across the Great Plains led to their near extinction and devastated the subsistence base of the Plains Indigenous peoples (Feir et al., 2024; Taylor, 2011). This resulted in undernutrition and declining stature and forced a shift toward more sedentary and less protein-rich subsistence strategies (Feir et al., 2024; Ostler, 2001).

Taken together, European colonization altered Indigenous ways of life with adverse health consequences. Yet much of the quantitative literature on Indigenous populations in the Americas does not explicitly assess whether these shocks affected females and males differently. Evidence from other parts of the world suggests that external forces, including demographic shocks, institutional change, and changes in access to resources, can reshape gender relations in persistent ways (for an overview, see Anderson, 2025). This motivates the hypothesis that European settlement contributed to a deterioration in gender equality in health among Indigenous populations in the Americas.

D.3 Data and Methodology

D.3.1 Data Sources

The analysis is based on bioarchaeological evidence from the Americas, covering the last two millennia, from the late pre-contact period through European colonization and into the nineteenth century. I collected stature estimates from various archaeological studies, among them data from the Western Hemisphere Project compiled by Steckel and Rose (2002) (see Appendix Table D.9 for an overview of all included data sources). Only site-level estimates of adult male and female stature derived from femur length, the skeletal element most strongly correlated with

total body height, are included (Ruff et al., 2012). Femur length closely correlates with other health indicators such as enamel hypoplasia and life-expectancy differentials (Bereczki et al., 2019; Maravall and Baten, 2019), validating its use as a cross-temporal proxy for the biological standard of living. I additionally included anthropometric observations from Franz Boas's 1890s studies of Native Americans and Johanna Faulhaber's 1970 study of Indigenous people of Mexico and Central America. Boas collected height data for several tribes (for instance, the Sioux or the Cherokee) in the United States and Canada during the late nineteenth century, whereas Faulhaber compiled and analyzed skeletal and archaeological measurements from colonial Indigenous groups in Mexico and Central America from the late nineteenth and twentieth century. The Boas dataset, though not based on random sampling, systematically documents a broad range of Native American tribes at a time when most had already experienced profound transformation through European contact, relocation to reservations, disease, and trade integration (Boix et al., 2014, Steckel and Prince, 2001). The sample comprises 16,983 individuals (9,888 males and 7,095 females, Appendix Table D.5) aggregated into 257 site-period observations across 14 present-day countries. The regional distribution is dominated by Mexico, the United States, and Peru, with additional coverage for Argentina, Belize, Bolivia, Canada, Chile, Colombia, Ecuador, El Salvador, Guatemala, Honduras and Nicaragua.

For each site-period observation I collected contextual information including subsistence strategies like maize agriculture which is closely linked to a sedentary lifestyle, hunting and fishing which is correlated with a nomadic or semi-sedentary lifestyle, and mixed agriculture marking especially the transitional period from a nomadic to a more sedentary lifestyle with small-scale horticulture supplemented with foraging. Because coordinates are rarely reported in anthropological publications, precise site locations were manually determined using excavation reports, historical maps, and Google Maps cross-checking. To account for ecological and institutional heterogeneity, these data were merged with regional-level controls from the most recent HYDE land-use and population reconstructions (updated version of HYDE 3.2; Klein Goldewijk et al., 2017), including measures of urban and rural population density, cropland, and pasture area. To account for climatic variation, regional temperature estimates (°C) from the Temp12k paleoclimate reconstruction (Kaufman et al., 2020), accessed via the Linked Paleo Data (LiPDverse) database, were added. To capture the institutional legacies of colonization, the

framework of Bruhn and Gallego (2012) is used, classifying colonial activities across the Americas into "good," "bad," and "ugly" categories based on their reliance on labor exploitation and economies of scale. Their regional dataset is used to add interaction terms between contact and institutional type to analyze heterogeneous colonial effects.

D.3.2 European Settlement

The key variable of interest, European settlement, is a binary indicator capturing whether an Indigenous site-period observation was exposed to European settlement, defined at the level of the modern first-level administrative division (Admin 1; ISO standard) (see Appendix Table D.10). The term European settlement refers to the first documented establishment intended for a prolonged stay by explorers, missionaries, traders, or settlers. In some cases, European contact preceded settlement by decades or even centuries, as evidenced by early exploratory or trading expeditions. While initial contact may have introduced epidemic diseases, it was typically the establishment of settlements that most profoundly disrupted Indigenous lifeways and gender norms, which is the primary focus of this analysis.

European settlements were founded for a variety of reasons, including missionary activity (e.g., Spanish missions in Tipu, Belize, 1544, and Santa Fe and San Gabriel, New Mexico, 1598), trade (especially in the Great Lakes region and the northern Great Plains; e.g., Loisel's Post, South Dakota, 1802), military fortifications (e.g., Fort Astoria, Oregon, 1811), and, in some cases, permanent residence and long-term land occupation (e.g., Plymouth, Massachusetts, 1620). In some regions, the first colonial settlements still exist today, for instance, Mendoza (1561) in Argentina, numerous early towns in Guatemala (e.g., Huehuetenango, 1524), Mexico (e.g., Mexico City, 1521; Antequera (Oaxaca), 1529; Mérida, 1542), and Peru (Cusco, 1533; Lima, 1535).

Figure D.1 shows a map of the distribution of the excavation sites included in the analysis. Black dots indicate sites that were exposed to European contact due to the presence of a nearby European settlement. For most countries, the sample includes observations from both before and after contact; exceptions are the Arctic regions, which were typically settled only in the twentieth century, and parts of South America, where overall data coverage is more limited.

D.3.3 Gender Equality Estimation and Regression Model

The dependent variable is gender equality in health and is calculated using the formula provided below. Height is used as a proxy for health, and final adult stature is estimated separately for males and females from femur length using the formula provided by Ruff et al. (2012). In bioarchaeology, biological sex is typically estimated from pelvic and skull features (Buikstra and Ubelaker, 1994). When these bones are not preserved, sex can be estimated from femoral measurements (Rissech et al., 2008). Beecause sex cannot be reliably estimated for subadults and the focus is final adult stature, all analyses are restricted to adults. To assess potential selection bias, height trends for males and females are compared across geographically similar regions (see Section C.6.2). While absolute stature levels differ across regions and periods, neighboring areas display highly similar temporal trends, indicating that selective data coverage is unlikely to drive the main results.

Following Schwekendiek and Baten (2019) and Jung and Baten (2025), I calculate gender equality in height GE_h using the following formula:

$$GE_h = -\left[H_m - H_f - \left(-33.75 + 0.276 \cdot H_{mf}\right)\right] \quad (4)$$

H_m and H_f denote average male and female height in cm, and H_{mf} denotes the average height of both sexes. Since the difference between male and female height inherently increases with average height, the biological component of sex differences in height must be isolated. Schwekendiek and Baten (2019) estimated the relationship between average height and the height gap for a sample with similar levels of gender equality according to the Gender Development Index, yielding the equation shown in parentheses. Subtracting this from the height gap and inverting the equation in brackets gives the gender equality index used in the regression below. Differences in this index can be attributed to environmental factors; higher values indicate better nutritional levels for girls relative to boys, i.e. higher gender equality. Jung and Baten (2025) validate this index by showing that it correlates with established measures of gender equality, including the GDI and sex differences in life expectancy, using twentieth-century data.

To assess the impact of European settlement on gender equality, I estimate the following two-way fixed effects model:

$$\ln(GE)_{st} = \alpha + \beta_1 E_{st} + \boldsymbol{X}'_{st}\theta + \boldsymbol{Z}'_{rt}\lambda + \gamma_r + \delta_t + \varepsilon_{st} \quad (5)$$

GE_{st} denotes gender equality in height for site s in period t. E_{st} is a binary variable indicating if the Indigenous population at site s was exposed to European contact through a European settlement in period t (see Section D.3.2). This variable equals one if at least one European settlement existed within the same Admin 1 level as the site-period observation. I include a set of categorical indicators for the dominant subsistence strategy at the site (maize, hunting, fish, reference category is mixed agriculture) $\boldsymbol{X}_{st}$. Subsistence strategies affected the overall health status (e.g., Mazza, 2019; Steckel et al., 2002) and labor divisions (e.g., Watson and Stoll, 2013; Miller et al., 2018; Ponce, 2010). $\boldsymbol{Z}_{rt}$ includes region-level controls (climate (temperature), cropland and pasture shares, and population density). Region fixed effects γ_r and time fixed effects δ_t are included. The error term is $\varepsilon_{s,t}$. Standard errors are clustered at the country level.

To analyze heterogeneity by colonial activity type, I extend this specification by interacting European settlement with "good", "bad", and "ugly" colonial activities as defined by Bruhn and Gallego (2012). Regions with no classified colonial activity type, despite settlements, are coded as "none" (most of Canada, the northwestern United States, the Great Plains, and southern Argentina). These labels refer to long-run institutional development (e.g., measured by GDP per capita), not to the colonizer–Indigenous interactions. "Good" activities (mostly US and north of Argentina) involved small-scale farming, cattle raising, and local manufacturing, with limited use of Indigenous labor. In these regions settlers sought to occupy the land themselves and expansion often proceeded through land alienation and the exclusion of Indigenous communities from productive land and resources. This was followed by relocation to reservations, typically on land regarded as less desirable by Europeans (Farrell et al., 2021). These processes culminated in the nineteenth century, when the Indian Removal Act of 1830 formally authorized the relocation of many Native American groups west of the Mississippi River (Carlson and Roberts, 2006). Consistent with this history, there are now almost no reservations east of the Mississippi (classified as "good"); instead, reservations are scattered across the West and the Great Plains

(classified as "none") (Comenetz, 2003). Areas that relied on exploitation of Indigenous labor are classified as "ugly" (most of Mesoamerica, Peru, and Chile) or "bad" activities (mostly Southeast of United States, Peru, Chile, North of Mexico, and large parts of Brazil). Areas with no economies of scale are defined as "ugly" whereas mining and plantation of cash crops, like sugar, coffee, or cotton, are defined as "bad".

$$\ln(GE)_{st} = \alpha + \beta_1 E_{st} + \beta_2 E_{st} \cdot good_{rt} + \beta_3 E_{st} \cdot bad_{rt} + \beta_4 E_{st} \cdot ugly_{rt} + \beta_5 good_{rt} + \beta_6 bad_{rt} + \beta_7 ugly_{rt} + \boldsymbol{X}'_{st}\theta + \boldsymbol{Z}'_{rt}\lambda + \gamma_r + \delta_t + \varepsilon_{st} \quad (6)$$

Here, β_1 captures the effect of European settlements in regions without classified colonial activities in relation to sites pre-contact. Summary statistics of all variables included in the regression model are reported in Table D.1.

D.4 Results

D.4.1 Descriptive Results

In the sixteenth century, populations of the Great Plains were among the tallest in the sample, with mean statures of about 166 cm for men and 158 cm for women, whereas individuals from the Yucatán Peninsula in southern Mexico were among the shortest, with average statures of approximately 152 cm for males and 144 cm for females (Appendix Table D.6). Populations from present-day Peru were also relatively short. These regional patterns closely align with environmental and nutritional conditions reflecting differences in diet and disease environments: Plains populations benefited from high-protein diet, particularly through bison hunting, and relatively low disease burdens (Steckel and Prince, 2001), while present-day Peru and southern Mexico were characterized by higher population density and an early reliance on maize-dominated diets, contributing to shorter average stature (Larsen, 1995; Nickens, 1976; Williams and Murphy, 2013).

These regional patterns are also visible at broader geographic scales and are illustrated in Figure D.2 and Figure D.3 for male and female height, respectively. Overall, individuals from North America were consistently taller than their counterparts from South America and

Mesoamerica. For males, the biological standard of living improved prior to 1000 CE in North and Mesoamerica, followed by a deterioration thereafter. Notably, although stature increased in both North and South America after 1500 CE, the gains were substantially larger for males than for females, suggesting that males benefited more from this secular increase. In contrast, in Mesoamerica, average stature declined steadily after 1000 CE, with the decline appearing more pronounced among females. These dynamics are reflected in Figure D.4, which shows relatively stable gender-equality values for North and South America until 1500 CE, followed by a sharp decline thereafter. This decline suggests a gender-differentiated impact of European colonization, with lower levels of gender equality in health among Indigenous populations after contact. In Mesoamerica, gender equality also deteriorated in the post-contact period, but the decline begins earlier, starting around 750 CE.

D.4.2 Regression Results

In the following section, we assess whether the timing and institutional context of European settlement are associated with differences in gender equality in health. Table D.2 reports estimates of the relationship between European contact and gender equality in height. The coefficient on European settlement captures changes in gender equality relative to pre-contact conditions and not absolute values. Across all specifications, the settlement dummy is negative and statistically significant, reducing gender equality by about 9 percent (Table D.2, column 3). Relative to comparable sites without a documented European settlement nearby, nutritional health during early childhood was more affected for females than males. The result is robust to including the dominant subsistence strategies (maize, hunting, fish, mixed), environmental controls (regional temperature in °C), and land-use controls (cropland and grazing area).

To analyze heterogeneity by colonial institutions, I interact European settlement with colonial activity types as classified by Bruhn and Gallego (2012) (see Section D.3.3 for definitions). The results are reported in Table D.3 column 3, which presents the preferred specification with the full set of controls and fixed effects. Here, the main settlement coefficient captures the effect in regions without colonial activities (“none”) and remains negative (11 percent). The interaction terms capture the additional effect of regions dominated by “good”, “bad”, or “ugly” activities. Regions classified as “good” are associated with an additional negative

effect on gender equality (12 percent). The coefficient on "ugly" regions is also negative but much smaller in magnitude (2 percent). By contrast, in regions dominated by mining and plantation agriculture (classified as "bad"), the interaction term is positive (9 percent) and thus partially offsets the negative settlement effect, although the combined effect of settlement and "bad" activities remains overall negative. F-test statistics for settlement, interaction term, and colonial activity are all highly significant (Table D.3).

I conducted a series of robustness checks to assess whether the estimated relationship is robust to alternative model and treatment specifications or to sample composition (Table D.4). When restricting the treatment to long-lasting settlements (defined as European settlements that still exist today, thereby excluding short-lived trading posts) the estimated effect becomes slightly smaller but remains highly significant (7 percent; Table D.4, column 1). Further robustness tests are: individual instead of population weights (column 2); using country-region fixed effects clustering geographically similar states (column 3); winsorizing the most extreme upper and lower values of the height gap (column 4); and limiting the sample to pre-1900 observations (column 5). Grouping European settlement based on distance to site confirms that the negative association with gender equality becomes stronger the closer Indigenous communities lived to colonial settlements (Appendix Table D.7). Appendix Table D.8 excludes the three countries with the largest shares of observations one at a time (United States, Mexico, Peru). Overall, the results continue to support the negative relationship between European settlement and gender equality.

D.4.3 Discussion

The descriptive trends and the statistically significant, robust negative coefficients of European settlement indicate that overall gender equality in health in Indigenous populations declined after colonization relative to pre-contact levels. This pattern suggests that early-life conditions deteriorated more for Indigenous females than for males, leading to slower growth and lower relative female adult stature.

The results of the heterogeneity analysis suggest that the association between European settlement and gender equality in health differed across colonial activity types and institutional environments. Notably, even in regions classified as "none" (areas with small settlements but no classified colonial activity, such as the Great Plains), gender equality declined after settlement.

One plausible explanation is that land perceived as relatively unproductive by settlers was disproportionately allocated to reservations. By the second half of the nineteenth century, most Indigenous groups living in the Plains had been confined to reservations (Prince, 1998). Historical accounts of removal and reservation policy document that such relocations disrupted traditional subsistence systems, increased food insecurity, and forced heterogeneous tribal groups to co-reside in unfamiliar environments (Comenetz, 2003; Farrell et al., 2021). Contemporary evidence on American Indian and Alaska Native populations shows that historical traumas linked to land loss and forced relocation are associated with adverse physical and mental health outcomes to this day (e.g., Burns et al., 2021; Evans-Campbell, 2008; Walters et al., 2011). The results from this study suggest that these conditions disproportionately affected female childhood health.

This explanation is also in line with the negative effect observed in "good" regions. "Good" does not imply benign colonial interactions; rather, it often coincided with land alienation and the exclusion of Indigenous communities from productive land and resources. However, post-contact skeletal data on Indigenous populations who remained in these "good" areas alongside European settlers are scarce, and the corresponding estimate relies on only a few observations and should therefore be interpreted with caution. Moreover, the estimate may also be biased away from zero because pre-contact levels of gender equality in health appear to have been relatively high in many "good" regions (e.g., the northeastern United States), so that subsequent deterioration appears larger in relative terms.

By contrast, in regions dominated by labor exploitation and mining/plantation agriculture ("bad") the negative effect of settlement on gender equality is mitigated. The *mita* system, which supplied labor to Andean mines, is documented to have reduced the Indigenous male population through excess mortality and outmigration (Carpio and Guerrero, 2021). Combined with high male absenteeism in mining camps, this often left women in charge of households and taking on additional productive responsibilities, sometimes directly in silver mining, potentially increasing their intra-household bargaining power (Bigelow, 2016; Murillo, 2013).

D.5 Conclusion

The establishment of European settlements coincided with major disruptions to Indigenous health and living standards across the Americas, raising the question of how these changes affected Indigenous men and women differently. By combining bioarchaeological evidence spanning nearly two millennia with variation in the timing and type of European settlement, this study provides new evidence on the consequences of colonization on gender equality in health. Health is proxied by adult stature and a strong indicator for early childhood nutrition and the biological standard of living.

Results from two-way fixed effects regressions show that European settlement is associated with a significant deterioration in gender equality in health relative to pre-contact levels, suggesting that female health was more adversely affected than male health. This finding is robust to controlling for subsistence regimes, climatic and land-use conditions, population density, and a range of robustness checks. Substantial heterogeneity emerges across colonial activity types, consistent with differences in how colonial institutions altered access to land and labor. However, the mechanisms underlying these patterns are not directly tested and remain an important direction for future research. By emphasizing relative changes in health and institutional heterogeneity, the analysis highlights gender as a central dimension of the long-run consequences of colonialism and contributes to a more complete understanding of the historical roots of gender equality in health.

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D.7 Figures and Tables

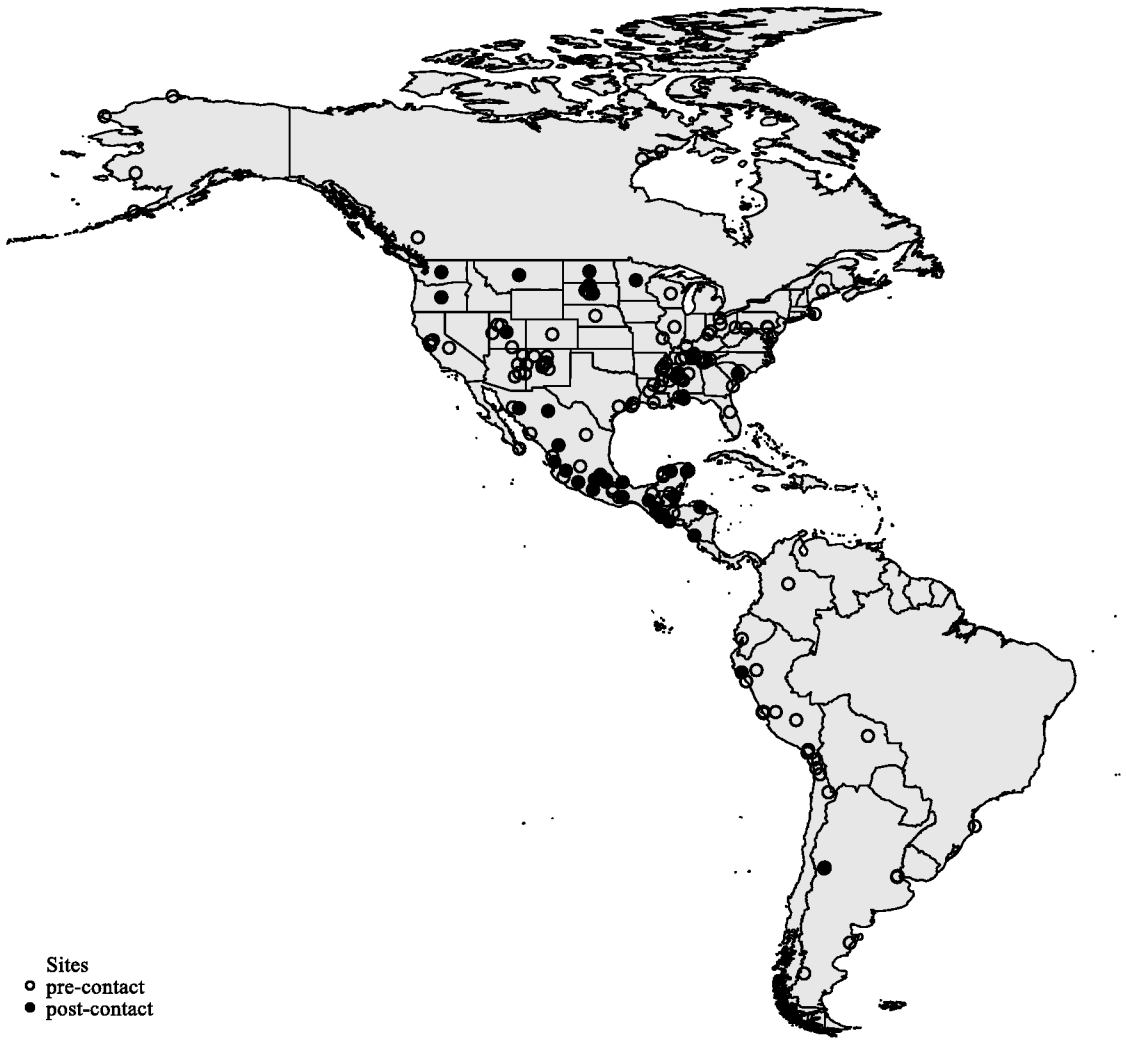


Figure D.1: Sites by European settlement exposure

Notes: Each circle represents a site-period observation. Black circles denote the presence of a European settlement (within the same state and century); hollow circles indicate the absence of such a settlement. All observations are included.

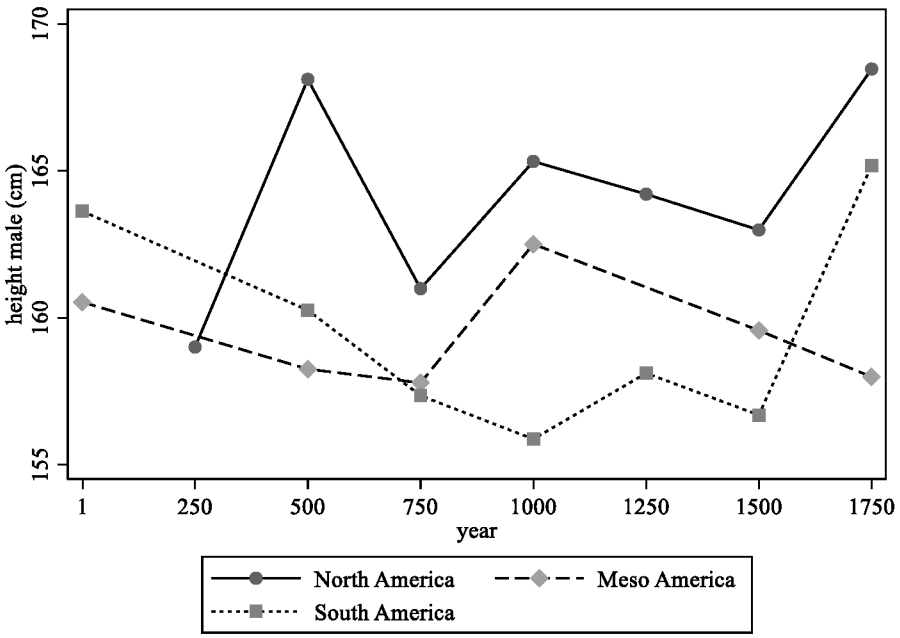


Figure D.2: Trends in male height over the last 2000 years

Notes: Average heights (estimated from femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by the number of individuals. Observations are aggregated over quarterly millennium intervals and displayed at the corresponding lower bound of each interval.

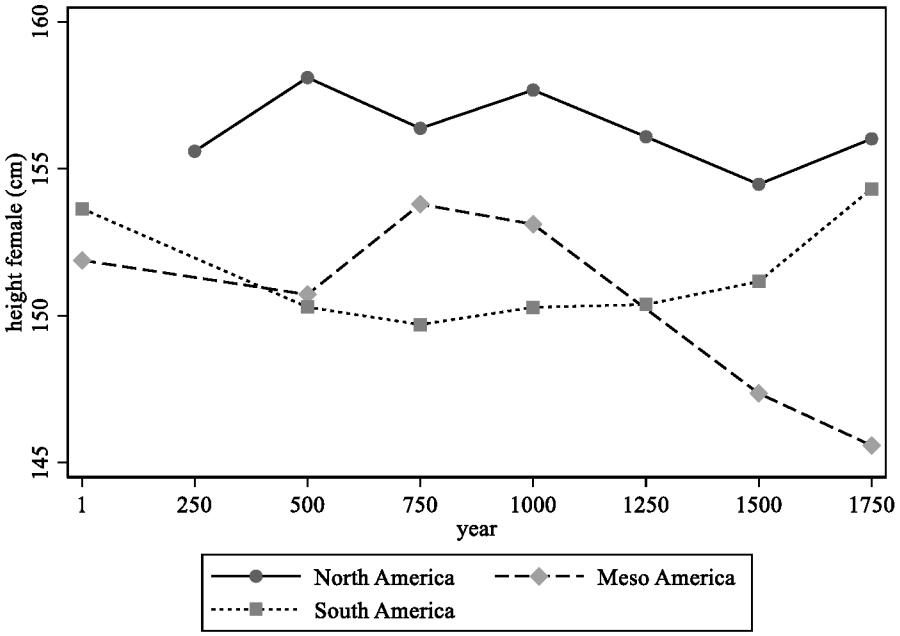


Figure D.3: Trends in female height over the last 2000 years

Notes: Average heights (estimated from femur length) are shown for samples with at least 10 individuals per site-period observation and are weighted by the number of individuals. Observations are aggregated over quarterly millennium intervals and displayed at the corresponding lower bound of each interval.

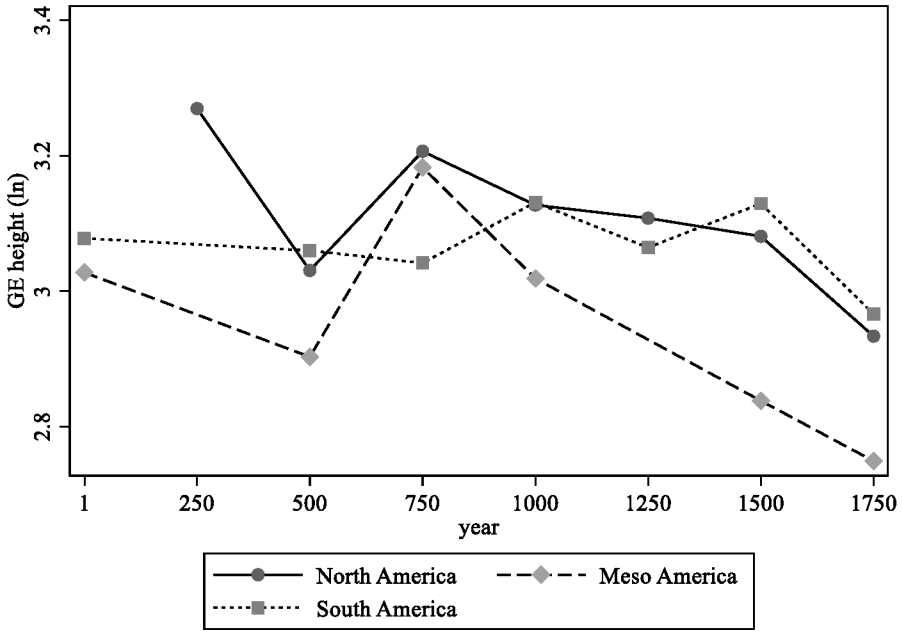


Figure D.4: Trends in gender equality over the last 2000 years

Notes: Average values for gender equality in height (GE height) are shown for samples with at least 10 individuals per site-period observation and are weighted by the number of individuals. GE height is constructed using equation 4. Observations are aggregated over quarterly millennium intervals and displayed at the corresponding lower bound of each interval.

Table D.1: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
GE height (ln)	257	2.964	0.256	1.668	3.456
European settlement	257	0.307	0.462	0	1
Main subsistence: maize	257	0.747	0.436	0	1
Main subsistence: hunter	257	0.047	0.211	0	1
Main subsistence: fish	257	0.101	0.302	0	1
Main subsistence: mixed	257	0.105	0.307	0	1
Grazing	257	5.81	10.173	0	53.212
Cropland	257	4.993	6.931	0	38.629
Population density (ln)	255	0.913	0.904	0.02	2.612
Temperature (°C)	257	14.929	7.002	-5.059	22.883
"Good" institutions	254	0.154	0.361	0	1
"Bad" institutions	254	0.22	0.415	0	1
"Ugly" institutions	254	0.35	0.478	0	1

Table D.2: Effect of European settlement on gender equality in height

	(1)	(2)	(3)
European settlement	-0.07*	-0.08*	-0.09***
	(0.037)	(0.038)	(0.023)
Maize	-0.18***	-0.18***	-0.17***
	(0.020)	(0.021)	(0.023)
Hunting	-0.39***	-0.39***	-0.39***
	(0.037)	(0.039)	(0.039)
Fish	-0.11***	-0.10***	-0.12***
	(0.024)	(0.025)	(0.039)
ln(population density)	0.08***	0.10***	0.11***
	(0.016)	(0.021)	(0.026)
Temperature (°C)			0.01***
			(0.003)
Grazing			-0.00
			(0.001)
Cropland			-0.00**
			(0.001)
Constant	3.06***	3.29***	3.17***
	(0.036)	(0.021)	(0.036)
Time FE	Y	Y	Y
Regional FE	big	small	small
Observations	257	257	257
R-squared	0.456	0.461	0.466

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 4. Maize, Hunting, and Fish are binary variables indicating the dominant subsistence strategy. The reference category is mixed subsistence strategy. All regressions include century fixed effects; column (1) includes world-region (big) fixed effects and column (2)-(3) include country (small) fixed effects. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** $p < .01$, ** $p < .05$, * $p < .1$.

Table D.3: Effects of European institutions on gender equality in height

	(1)	(2)	(3)
European settlement	0.02	-0.10***	-0.11***
	(0.031)	(0.023)	(0.018)
European settlement × "good" institutions	-0.19***	-0.11***	-0.12***
	(0.059)	(0.012)	(0.022)
European settlement × "ugly" institutions	-0.09***	-0.02***	-0.02***
	(0.004)	(0.005)	(0.004)
European settlement × "bad" institutions	0.02	0.09***	0.09***
	(0.043)	(0.014)	(0.014)
"Good" institutions	0.03	-0.02	-0.03
	(0.090)	(0.046)	(0.049)
"Ugly" institutions	0.08***	0.03	0.03
	(0.008)	(0.026)	(0.029)
"Bad" institutions	0.13***	0.07***	0.07***
	(0.024)	(0.013)	(0.013)
Constant	3.03***	3.00***	3.37***
	(0.011)	(0.080)	(0.043)
F-value "good"	945.71	63.28	193.25
F-value "ugly"	303.17	17.38	21.16
F-value "bad"	154.07	57.75	517.52
Controls	N	Y	Y
Time FE	Y	Y	Y
Region FE	big	big	small
Observations	254	254	254
R-squared	0.435	0.482	0.486

Notes: Dependent variable is logarithm of gender equality in height, constructed using equation 4. "Good", "bad", and "ugly" institutions are binary variables based on Bruhn and Gallego (2012) and defined at the Admin 1 (state) level. The reference category is no European settlement and no classified colonial activity "none". Controls include subsistence controls (maize, hunting, fish), ecological controls (grazing, cropland, temperature) and population density (ln). All regressions include century fixed effects; columns (1)-(2) include world-region (big) fixed effects and column (3) includes country (small) fixed effects. Regressions are weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table D.4: Robustness checks

	(1) Permanent settlement	(2) Individual weights	(3) Country region FE	(4) Winsorized	(5) < 1900 CE
European settlement	-0.07***	-0.10**	-0.09*	-0.08**	-0.09***
	(0.016)	(0.035)	(0.046)	(0.033)	(0.025)
Constant	3.16***	3.03***	3.39***	3.22***	3.17***
	(0.042)	(0.080)	(0.392)	(0.063)	(0.037)
Controls and FE	Y	Y	Y	Y	Y
Observations	257	257	257	252	211
R-squared	0.465	0.629	0.519	0.527	0.359

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 4. Column (1) uses a slightly different definition of European settlement namely permanent settlement. Column (2) uses as weights number of individuals. Column (3) uses country region fixed effects. Column (4) is winsorized at the 1% level, trimming the most extreme upper and lower outliers. Column (5) excludes data after 1900 CE. Controls include subsistence controls (maize, hunting, fish), ecological controls (grazing, cropland, temperature) and population density (ln). All regressions include country level and century fixed effects, except if otherwise indicated. Regression is weighted by population, except for column (2). Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

D.8 Appendix

D.8.1 Descriptives and Robustness Checks

Table D.5: Number of individuals and site-period observations per half millennium

Time	No. Males	No. Females	Site	Countries
0-500 CE	274	279	14	7
500-1000 CE	767	850	40	10
1000-1500 CE	1748	1537	92	8
1500 -1900 CE	3356	1993	65	5
>1900 CE	3743	2436	46	5
Total	9888	7095	257	14

Notes: Site refers to site-period observations.

Table D.6: Height trends by region, 16th century

Region	Height males (cm)	Height females (cm)	No. males	No. females
Andean Highlands (Peru)	151.9	146.7	18	18
California	157.2	152.6	40	100
Coastal Peru	160.7	154.8	80	58
Great Lakes	166.1	157.8	13	17
Great Plains	165.2	156.5	70	36
Northeastern Woodlands	167.4	156.7	6	3
South Mexico	152.3	144.1	15	31
Southeast US	167.2	156.1	23	30
Southwest US	159.1	150.2	197	219

Notes: Average heights are weighted by the number of individuals.

Table D.7: Robustness checks: distance between European and Indigenous settlement

	(1)
European settlement < 20 km	-0.20***
	(0.058)
European settlement 20–100 km	-0.13***
	(0.042)
European settlement >100 km	-0.07***
	(0.024)
Constant	3.18***
	(0.036)
Controls and FE	Y
Observations	257
R-squared	0.472

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 4. European settlement is a dummy capturing if a settlement was within 20 km, 20–100 km, or more than a 100 km distance away from the Indigenous site. Controls include subsistence controls (maize, hunting, fish), ecological controls (grazing, cropland, temperature) and population density (ln). All regressions include country level and century fixed effects. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

Table D.8: Robustness checks: excluding individual countries

	(1) Excluding USA	(2) Excluding Mexico	(3) Excluding Peru
European settlement	-0.09***	-0.11	-0.06***
	(0.027)	(0.084)	(0.005)
Constant	2.29**	3.16***	3.20***
	(0.921)	(0.112)	(0.020)
Controls and FE	Y	Y	Y
Observations	131	185	239
R-squared	0.521	0.353	0.457

Notes: Dependent variable is the logarithm of gender equality in height, constructed using equation 4. Controls include subsistence controls (maize, hunting, fish), ecological controls (grazing, cropland, temperature) and population density (ln). All regressions include country level and century fixed effects. Regression is weighted by population. Robust standard errors are clustered at the country level and shown in parentheses. Asterisks denote significance at levels *** p < .01, ** p < .05, * p < .1.

D.8.2 Data Sources

Table D.9: Overview of data sources for height

Paper	Site	Site age avg (BP)	Table
Akins (1986)	AMNH Room 33 (Pueblo Bonito)	862	Table Appendix D.2./ Table 6.2.
Akins (1986)	BC51-57, 29SJ#, TU257,29 CK#4	862.5	Table Appendix D.2./ Table 6.2.
Anzellini and Toyne (2020)	Kuelap	732.5	Table 1
Auerbach and Ruff (2010)	Caldwell Village	825	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Candy Creek	800	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Canyon del Muerto	750	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Cape Cod Bay	400	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Caplen	700	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Carter Ranch	775	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Chaco Canyon	950	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Chamisal	500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Cheyenne River	200	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Coast Salish	500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Dickson	650	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Evans	800	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Fort Ancient	700	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Gallina Springs	650	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Glen Canyon	730	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Grasshopper	612.500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Hiwassee	400	Table 2 for stature, Table 1 for no. Individuals

Table D.9 (continued)

Auerbach and Ruff (2010)	Ikogmiut	550	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Irene Mound	450	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Kiklewait	550	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Kinishba	625	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Kuhlman	1150	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Kuskowagamiut	550	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Kwakiutl	300	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Larson	182.500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Ledford Landing	400	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Libben	1000	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Loeve Fox	1250	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Madisonville	400	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Maine	600	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Mitchell Ridge	500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Mobridge	475	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Montague	450	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Need 1	500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Neo-Aleut	700	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Paa-Ko	600	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Palmer	1850	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Point Barrow	1000	Table 2 for stature, Table 1 for no. Individuals

Table D.9 (continued)

Auerbach and Ruff (2010)	Point Hope Ipiutak	1800	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Point Hope Tigara	550	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Point of Pines	582.500	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Polley-Secrest	1000	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Pottery Mound	550	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Ryan Mound	950	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Sacramento Valley	1000	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Sadlermiut	200	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Sully	200	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Thompson Village	700	Table 2 for stature, Table 1 for no. Individuals
Auerbach and Ruff (2010)	Ward Place	300	Table 2 for stature, Table 1 for no. Individuals
Béguelin (2011)	Chubut	1450	
Béguelin (2011)	Sierra Colorada	1450	
Boas (1899)	Utah	55	
Boyd and Boyd (1989)	Averbuch (40DB60)	600	Table 1
Boyd and Boyd (1989)	Dallas (40HA1)	500	Table 1
Boyd and Boyd (1989)	Ledford Island (40BY13)	500	Table 1
Boyd and Boyd (1989)	Mouse Creek (40MN3)	450	Table 1
Boyd and Boyd (1989)	Rymer (40BY11)	500	Table 1
Boyd and Boyd (1989)	Toqua (40MR6)	500	Table 1
Boza-Cuadros (2010)	El Brujo	1575	p. 83, Appendix II
Boza-Cuadros (2010)	Maranga	1450	p. 83, Appendix II
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	300	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	750	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1150	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1350	Table 9

Table D.9 (continued)

Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1550	Table 9
Broughton (2010)	CA-SAC-06, -43, -60, CA-SJO-154	1750	Table 9
Corruccini (1972)	Hawikuh	424.5	Table 2
Corruccini (1972)	Pueblo Bonito	925.5	Table 3
Corruccini (1972)	Puye Cliff Dwellings	477	Table 4
Danforth (1994)	Barton Ramie/Baking Pot	1225	Table 1
Danforth (1994)	Seibal	1225	Table 1
Danforth et al. (1997)	Tipu	330	Table 2
Danforth et al. (2007)	1Pi33	750	Table 5.3
Danforth et al. (2007)	1Pi61	1225	Table 5.3
Danforth et al. (2007)	Andrew's Place (1BA1)	750	Table 5.5
Danforth et al. (2007)	Arnold	750	Table 5.2
Danforth et al. (2007)	Austin	1225	Table 5.4
Danforth et al. (2007)	Bonds	1225	Table 5.4
Danforth et al. (2007)	Brown	750	Table 5.2
Danforth et al. (2007)	Chucalissa	550	Table 5.4
Danforth et al. (2007)	Copeland's Landing	750	Table 5.5
Danforth et al. (2007)	Garnier	750	Table 5.2
Danforth et al. (2007)	Humber	550	Table 5.4
Danforth et al. (2007)	Kellogg Village	750	Table 5.3
Danforth et al. (2007)	Lake George	550	Table 5.4
Danforth et al. (2007)	Mangum	550	Table 5.4
Danforth et al. (2007)	Tibbee Creek	750	Table 5.3
Danforth et al. (2007)	Tomotley	700	Table 5.1
Danforth et al. (2007)	West	750	Table 5.2
Davis et al. (2015)	Shady Grove site (22WQU525)	680.5	Table 4
Faulhaber (1970)	Carazo	12	Table 2
Faulhaber (1970)	Chiapas	22	Table 2
Faulhaber (1970)	Chiapas	49	Table 2
Faulhaber (1970)	Chihuahua	24.5	Table 2
Faulhaber (1970)	Chihuahua	52	Table 2
Faulhaber (1970)	Colón	12	Table 2
Faulhaber (1970)	Durango	48	Table 2
Faulhaber (1970)	Escuintla	7	Table 2
Faulhaber (1970)	Escuintla	12	Table 2
Faulhaber (1970)	Guatemala	12	Table 2
Faulhaber (1970)	Guerrero	5	Table 2

Table D.9 (continued)

Faulhaber (1970)	Hidalgo	48	Table 2
Faulhaber (1970)	Hidalgo	50	Table 2
Faulhaber (1970)	Huehuetenango	12	Table 2
Faulhaber (1970)	Jalisco	52	Table 2
Faulhaber (1970)	Michoacán	48	Table 2
Faulhaber (1970)	Michoacán	53	Table 2
Faulhaber (1970)	México	32	Table 2
Faulhaber (1970)	México	53	Table 2
Faulhaber (1970)	Nayarit	48	Table 2
Faulhaber (1970)	Oaxaca	-39	Table 2
Faulhaber (1970)	Oaxaca	9	Table 2
Faulhaber (1970)	Oaxaca	50	Table 2
Faulhaber (1970)	Oaxaca	51	Table 2
Faulhaber (1970)	Oaxaca	52	Table 2
Faulhaber (1970)	Puebla	50	Table 2
Faulhaber (1970)	Puebla	52	Table 2
Faulhaber (1970)	Sololá	12	Table 2
Faulhaber (1970)	Sonora	48	Table 2
Faulhaber (1970)	Sonsonate	12	Table 2
Faulhaber (1970)	Tlaxcala	52	Table 2
Faulhaber (1970)	Veracruz	-2	Table 2
Faulhaber (1970)	Veracruz	-1	Table 2
Faulhaber (1970)	Veracruz	49	Table 2
Faulhaber (1970)	Yucatan	15.5	Table 2
Faulhaber (1970)	Yucatan	19	Table 2
Faulhaber (1970)	Yucatan	23	Table 2
Gagnon (1996)	Susquehannock (36La6, 36La7, 36La8, 36La37, 36La54, 36La92)	340	Appendix B
Gagnon (1996)	Shenk's ferry (36La2, 36La6, 36La9, 36La36,36La54)	550	Appendix B
Hogue and Dongarra (2002)	Lyon's Bluff (22OK520), the South Farm site (220K534)	680	Table 6
Hogue and Dongarra (2002)	Rolling Hills (220K593), 220K595, 22OK904, 22OK905	337.5	Table 6
Kirkpatrick (2001)	Oregon (Boas sample)	55	Table 5.1; 6.1
Kirkpatrick (2001)	Washington (Boas sample)	55	Table 4.1

Table D.9 (continued)

Mansegosa et al. (2021)	Los Pozos, Agrelo-17, Usina Sur, Potrerillos, Colección del Museo Americanista, Edificio Plaza Huarpe, Los Ciruelos, P. Godoy, Colección Semper	1195	Table 4
Mansegosa et al. (2021)	San Francisco, La Caridad, La Merced, San Agustín	200	Table 4
Márquez-Morfín and Hernández-Espinoza (2020)	Jaina	1175	Table 12.3
Márquez-Morfín and Hernández-Espinoza (2020)	Xcaret	400	Table 12.3
Márquez-Morfín and Hernández-Espinoza (2020)	Xcaret	725	Table 12.3
Mazza (2019)	Arroyo La Garzab, Arroyo Los Tigresb, Arroyo La Marietab, Arroyo Sarandí, Túmulo II del Brazo Largo, El Cerrillo, Garín, La Argentina/Paraná Ibicuy 1, Los Talas, La Bellaca sitio 1, Cerro Lutz, El Cazador sitio 3, Escuela 31	1750	Table 3
Mazza (2019)	Arroyo Malo, Arroyo La Glorieta, Arroyo Fredes	470	Table 3
Miller (2016)	Tennessee (Boas sample)	55	Table 1
Miller et al. (2018)	Tibanica	1200	Table 2
Nickens (1976)	Altar de Sacrificios	725	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Altar de Sacrificios	1175	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Altar de Sacrificios	1550	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Coixtlahuaca, Oaxaca	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Copan	725	Table 1 in Nickens (1976)
Nickens (1976)	Guasave, Sinaloa	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	La Candelaria, Coahuila	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Marismas Nacionales	725	Table 1

Table D.9 (continued)

Nickens (1976)	Palenque	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Pericu	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Seri	725	Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tehuacan	1175	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Tikal	1175	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Tikal	1550	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Tlatilco	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tlatilco II	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Tuxcacuesco, Jalisco	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Valley of Mexico	725	Table 1 in Nickens (1976) + Table 3 and 4 in Genoves (1970)
Nickens (1976)	Yagul	725	Table 1
Nickens (1976)	Zaculeu	725	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Zaculeu	1175	Table 1 and 3 in Nickens (1976)
Nickens (1976)	Zaculeu	1550	Table 1 and 3 in Nickens (1976)
Pechenkina et al. (2007)	Huaca Huallamarca	1200	Table 7.5 (in Cohen and Kramer, 2007)
Pechenkina et al. (2007)	Huaca Pucllana	1550	Table 7.5 (in Cohen and Kramer, 2007)
Pomeroy and Stock (2012)	Azapa Valley (Az-140, Az-141, Az-71; 140 m)	800	Table 3
Pomeroy and Stock (2012)	Mantaro Valley	750	Table 3
Pomeroy and Stock (2012)	Pica-8	750	Table 3
Pomeroy and Stock (2012)	San Pedro de Atacama	1380	Table 3
Prince (1998)	Minnesota (Boas sample)	55	Appendix A1

Table D.9 (continued)

Prince (1998)	Minnesota (Boas sample)	55	Appendix A1
Prince (1998)	North Dakota (Boas sample)	55	Appendix A1
Sciulli and Hetland (2007)	Ohio Valley	550	Table 1
Shuler et al. (2012)	Cofferdam, Shell Bluff, White Springs, 1Pi61, 1Pi33 LW	1100	Table 4
Shuler et al. (2012)	Kellogg, Tibbee Creek, Lyon's Bluff, 1Gr21	650	Table 4
Shuler et al. (2012)	Lubbub village, Lubbub mound	900	Table 4
Shuler et al. (2012)	Moundville	850	Table 4
Trautmann (2024)	Salvatierra	1000	Appendix 1
Wescott and Cunningham (2006)	Buffalo Pasture, Cheyenne River, Four Bear, Indian Creek, Indian Creek, Leavitt, Mobridge 2, Norvold 1, Oacoma, Oahe Village, Oahe Village, Sully B, Sully E, Swan Creek	235	Table 4 and 6
Wescott and Cunningham (2006)	Fairbanks Village, Norvold 2/3, Mobridge 1, Mobridge 1, Sully A, Sully D, White Tail	375	Table 4 and 6
Wescott and Cunningham (2006)	Leavenworth, Ashley Island, Medicine Crow	137.500	Table 4 and 6
Williams and Murphy (2013)	Armatambo	715	Table 5
Williams and Murphy (2013)	Huaca Huallamarca	449	Table 5
Williams and Murphy (2013)	Lambayeque	307	Table 5
Williams and Murphy (2013)	Lambayeque	734	Table 5
Williams and Murphy (2013)	Machu Picchu	449	Table 5
Williams and Murphy (2013)	Osmore Drainage	715	Table 5
Williams and Murphy (2013)	Puruchuco-Huaquerones	449	Table 5
Williams and Murphy (2013)	Rinconada Alta	449	Table 5
Zaleski (2013)	Gold Mine (16RI13)	1120	Appendix C
Zaleski (2013)	Morton Shell Mound (16IB3)	1000	Appendix B
Zaleski (2013)	Plash Island (1BA134)	1800	Text, p. 38

Notes: BP means before present. All 234 site-period observations are listed, except for 36 observations that were added from the Western Hemisphere Project (Steckel and Rose, 2002).

D.8.3 References for Data Sources

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D.8.4 European Settlements

Table D.10: First European settlement

Country	Admin 1 unit	First European settlement	Year
Belize	Cayo	Tipu	1544
El Salvador	Sonsonate	Sonsonate (Villa de la Santísima Trinidad)	1553
Guatemala	Escuintla	Escuintla (Dominican mission)	1538
Guatemala	Guatemala	Santiago de los Caballeros de Guatemala (Iximché)	1524
Guatemala	Huehuetenango	Huehuetenango (Zaculeu)	1525
Guatemala	Sololá	Panajachel	1567
Honduras	Colón	Trujillo	1525
Mexico	Chiapas	Villa Real de Chiapa/San Cristóbal de las Casas	1528
Mexico	Chihuahua	Santa Bárbara	1567
Mexico	Durango	Nombre de Dios	1562
Mexico	Guerrero	Taxco	1529
Mexico	Hidalgo	Pachuca	1553
Mexico	Jalisco	Guadalajara	1542
Mexico	Michoacán	Pátzcuaro	1538
Mexico	México	Toluca	1522
Mexico	Nayarit	Compostela	1530
Mexico	Oaxaca	Antequera (Oaxaca City)	1529
Mexico	Puebla	Puebla de los Ángeles	1531
Mexico	Quintana Roo	Bacalar	1544
Mexico	Sonora	Nuestra Señora de los Dolores	1687
Mexico	Tlaxcala	Ciudad de Tlaxcala	1525
Mexico	Veracruz	Villa Rica de la Vera Cruz	1519
Mexico	Yucatán	Mérida	1542
Nicaragua	Carazo	Diriamba	1548
Canada	British Columbia	Santa Cruz de Nuca	1789
Canada	Nunavut	Frobisher Bay base (Iqaluit)	1942
USA	California	San Diego	1769
USA	Georgia	San Miguel de Gualdape	1526
USA	Kentucky	Harrodsburg	1774
USA	Louisiana	Natchitoches	1714
USA	Massachusetts	Plymouth	1620
USA	Minnesota	Mendota	1812
USA	Mississippi	Fort Maurepas (Old Biloxi)	1699
USA	Montana	St. Mary's Mission (Stevensville)	1841
USA	Nebraska	Bellevue	1823
USA	New Mexico	San Juan de los Caballeros (Ohkay Owingeh)	1598

Table D.10 (continued)

USA	North Dakota	Pembina trading post	1801
USA	Oregon	Astoria (Fort Astoria)	1811
USA	Pennsylvania	Tinicum	1643
USA	South Carolina	Charlesfort (Port Royal)	1562
USA	South Dakota	Fort Pierre	1817
USA	Tennessee	Watauga settlements	1769
USA	Utah	Salt Lake City	1847
USA	Washington	Fort Vancouver	1825
USA	Wisconsin	Green Bay (fur-trade post)	1634
Argentina	Mendoza	Mendoza (Ciudad de Mendoza)	1561
Peru	Cusco	Cusco	1533
Peru	Lambayeque	San Pedro de Lambayeque	1553
Peru	Lima	Ciudad de los Reyes (Lima)	1535

Notes: Some settlements predated European arrival and already existed as Indigenous settlements under the same name. In these cases, the year refers to the conquest or onset of European control, not the original foundation.

E Conclusion

Despite decades of international commitments, progress in gender equality remains slow and uneven. This matters not only for idealistic reasons, but also because gender inequality generates substantial costs by lowering labor market opportunities, reducing productivity, and undermining economic development. Yet the long-run evolution of gender equality is still poorly understood because most standard indicators are only available for the recent past. One dimension that captures particularly deep-rooted gender inequalities, such as the preferential treatment of boys, is gender equality in health.

In this dissertation, I introduce and validate an anthropometric indicator of gender equality in health, using adult stature as a proxy that can be applied at the population level in contexts where conventional statistics are absent. Because adult stature reflects cumulative net nutrition and disease burdens during growth, gender equality in height captures gender differences in early-life investments and intra-household resource allocation. Across three empirical chapters, I apply this indicator to three distinct historical settings: twentieth-century Europe and Asia (Chapter B), precolonial Indigenous societies in the Americas (Chapter C), and Indigenous populations during and after European settlement (Chapter D). Taken together, the chapters show how institutional regimes, economic organization, and colonial shocks are associated with systematic variation in gender equality in health across multiple contexts and periods.

A central methodological contribution is the validation of a gender equality in health index derived from adult male and female stature while accounting for the biological inflation of the sex gap as average height rises. The index is validated by comparison with established indicators, including sex differences in life expectancy and the Gender Development Index (GDI), supporting its use for long-run analysis and enabling comparisons over centuries and millennia that would otherwise be impossible.

Chapter B shows that state socialist rule improved gender equality in health in twentieth-century Europe and Asia. Using country and birth-decade fixed effects, instrumental-variable

approaches (distance to Moscow), and staggered difference-in-differences designs, the analysis finds higher gender equality in height under socialism and corresponding improvements in gender equality in education, indicating that institutional and ideological change can produce substantial gains within a few decades. The chapter argues that socialism operated through two mutually reinforcing channels: institutional and policy changes (e.g., expanded schooling, public health and child care provision) that lowered the opportunity costs of investing in girls; and cultural and informational channels (e.g., curricula and media) that shifted expectations and gender norms. However, the cross-country macro-level design limits the ability to test specific mechanisms directly, and the results do not capture subjective well-being or the double burden many women faced from balancing paid work with domestic responsibilities.

Chapter C shifts the focus to the deep past and documents long-run patterns of gender equality in health among precolonial Indigenous societies in the Americas, relating them to subsistence systems. Drawing on a newly compiled sample of femur-based stature estimates, the chapter shows substantial spatial and temporal heterogeneity in gender equality in health over several millennia. Most notably, it finds that maize cultivation is positively associated with gender equality early on, but that this relationship turns negative in later periods, consistent with increasing population pressure and intensified competition for resources within households. Overall, the results are consistent with the view that women's relative economic contribution within different subsistence systems mattered for the long-run evolution of gender roles and norms. However, despite careful data plausibility checks for potential selection bias, concerns about representativeness remain because preservation, excavation, and publication practices shape the available bioarchaeological evidence.

Chapter D extends the analysis to the post-contact period by examining how European settlement exposure is associated with changes in gender equality in health. Using a two-way fixed effects regression and defining exposure as the presence of at least one European settlement near the archaeological site, the chapter finds a significant negative relationship between settlement exposure and gender equality in height relative to pre-contact baselines. The relationship is heterogeneous across colonial activity types and institutional environments but remains negative overall. The results suggest that colonial disruptions—particularly where they involved land alienation and forced relocation—altered access to resources and disrupted

livelihoods in ways that disproportionately affected female early-life health. While Chapters C and D do not make strong causal claims given limited plausibly exogenous variation, the empirical patterns are stable and consistent with the proposed mechanisms.

Taken together, the three chapters converge on a central finding: gender equality in health is shaped by both persistent structural conditions and discrete institutional change. Subsistence systems, the gender division of labor, and demographic pressure contributed to the emergence of gender inequalities in early-life health. At the same time, institutional environments and external shocks can produce faster changes in gender equality in health. This evidence cautions against viewing gender inequality as either fully predetermined by long-run norms or easily changed through short-run interventions. Instead, the findings suggest that lasting progress requires addressing both the structural foundations of gender inequality and the institutional environments that can either reinforce or counteract them.

The findings have important implications for policy measures aimed at reducing gender inequality. First, they suggest that such measures are most likely to be effective when they address the institutional and material basis of gender differences in early childhood investments. This can involve expanding access to nutrition, health care, and schooling, as well as strengthening legal and economic protections that improve women's and girls' access to resources within households and the labor market. Second, the evidence suggests that improvements in gender equality can occur relatively quickly when institutional reforms are accompanied by changes in culture and social norms. Third, the long-run perspective highlights that major disruptions that restructure access to land, labor, and livelihoods can have consequences for gender equality in health, underscoring the importance of gender-sensitive approaches in development policy, particularly in post-colonial contexts.

This dissertation provides new long-run evidence on gender equality in early-life health and demonstrates that both economic organization and institutional change play a role in shaping gender norms and gender roles. While the gender equality in height index has been validated against established measures, it captures only one dimension of gender inequality; future research should therefore complement the height-based measure with additional archaeological and historical proxies of gender relations and extend the approach to other world regions to assess the generalizability of the patterns documented here. Understanding these long-run roots helps

clarify why progress can be slow and how interventions can be made more effective, thereby bringing us a step closer to the United Nations' Sustainable Development Goal 5: achieving gender equality and empowering all women and girls.