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DISCUSSION PAPER SERIES

IZA DP No. 18046

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ABSTRACT

Stunted Adolescence: The Anomalous Growth Pattern of Americans Born After Mid-Century*

The secular trend of growth in height suddenly slowed for Americans born after the middle of the 20th century, and the health and human capital of these cohorts as adults appears to have declined, or at least stagnated, more broadly. This paper presents evidence that the physical growth of these unhealthy cohorts was particularly stunted during adolescence. Using data from NHANES and its predecessors, I show that males born in the 1960s were the same height in childhood as those born a decade earlier, but then fell behind and were half an inch shorter in adolescence. By adulthood, the heights of the two cohorts were nearly identical. This suggests that males born in the 1960s had a later or smaller adolescent growth spurt than those born a decade earlier. Similar patterns are not evident in the height of females; however, females born in the 1960s experienced menarche later than those born a decade earlier. The delayed puberty of cohorts born in the 1960s appears to be a short-term blip in a long-run trend towards earlier puberty. Later-born cohorts were taller in adolescence but approximately the same height in adulthood as those born in the 1950s and 1960s. The findings strongly suggest that something had already gone wrong by at least adolescence for American cohorts born after mid-century.

JEL Classification: I140, J130, N32

Keywords: height, health, human capital, cohorts, early-life

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1 Introduction

The secular trend of growing adult height suddenly slowed for Americans born after the middle of the 20th century, while the height of Europeans continued to grow rapidly (Komlos and Lauderdale, 2007a,b; Komlos, 2010). I have recently presented evidence of a broader decline in the health and human capital of Americans, beginning with those born after 1947 and continuing until at least those born in the mid-1960s (Reynolds, 2024, 2025). This decline represents a sudden stop after decades of improvement across cohorts born in the first half of the twentieth century. Growth in childhood height also appears to have stagnated for cohorts born after mid-century, at least among white boys. Though not widely reported, surprisingly, this was already noted in the 1970s in a National Center for Health Statistics report (Hamill et al., 1977), which described a "marked diminution and near cessation of the trend to constantly increasing size of successive generations of American children," and called it their "most dramatic and significant finding relating to human biology and human growth in general."

This paper presents new evidence on cross-cohort changes in the growth pattern of Americans from childhood through adolescence and into adulthood, and discusses their implications for understanding the broader decline in health and human capital. While, economic historians and development economists often study anthropometric measures in childhood and adolescence, such as height-for-age, these have been surprisingly understudied for recent American cohorts.[1] Additionally, while adult height is often viewed as a proxy for childhood nutritional status (Tanner, 1990; Floud et al., 2011), recent research emphasizes that it is not a sufficient statistic and that examining the pattern of growth from birth to adulthood can provide additional insights (Schneider, 2017, 2023; Aurino et al., 2023).

The most striking finding is that males born in the 1960s appear to have had a later or smaller adolescent growth spurt than those born a decade earlier. Combining the NHANES surveys and their precursors, I show that males born in the 1960s were the same height in childhood as those born a decade earlier, but then fell behind and were around half an inch shorter in adolescence. By adulthood, the heights of the two cohorts were nearly identical. These patterns are consistent with the 1960s cohort experiencing a slower growth tempo in adolescence through either a later or smaller adolescent growth spurt, followed by catch-up growth by growing longer into early adulthood (later "age at final height"). Similar patterns are not evident in the height of females; however, females born in the 1960s experienced menarche (first menstrual period) later than those born a decade earlier.

[1] Komlos and Breitfelder (2008) study changing heights of American children and adolescents, but use a very different methodology and do not focus on the adolescent growth spurt as I do here.

The trend towards delayed puberty in the 1960s appears to be a short-term blip in a long-run trend towards earlier puberty. Adolescent height more than rebounded for later-born cohorts. Boys born in the 1970s, 1980s, and 1990s were all more than an inch taller than those born in the 1960s (and therefore were around half an inch taller than those born in the 1950s). The 1970s cohorts were not surveyed in early childhood, but interestingly the 1980s and 1990s cohorts were already more than half an inch taller than the 1950s and 1960s cohorts at ages 6 to 11. Age at menarche also began to decline again for girls born after the 1970s. Completed height in adulthood has been approximately constant across post-1970 cohorts of both men and women. Thus, another substantive finding of this paper is that growth tempo grew substantially between the 1950-1960s cohorts and the 1970-1990s cohorts, even as final height was approximately constant.

However, the trends of increased height and delayed puberty appear to have been much slower for the 1950–2000 cohorts than they had been across cohorts born in the preceding at least 80 years. To summarize the long-run patterns in height in childhood, adolescence, and adulthood, I combine scattered historical studies of white boys compiled in Meredith (1964), white male adult height trends based on military samples (Costa, 2015), and national surveys. The NHES in the 1960s was the first national survey that measured childhood height; therefore, the evidence for pre-1950s cohorts has more potential for bias.[2] With these caveats in mind, the American pattern of growth for pre-1950 cohorts appears to have followed the classic "secular growth" pattern described in Cole (2003): steady increases in height at all ages, with the fastest growth at adolescence consistent with accelerated adolescent growth tempo, and reductions in age at menarche. All of these trends slowed substantially for post-1950s cohorts. As described above, some even temporarily reversed trend for the 1970s cohorts. However, even for the 1970 to 2000 cohort the trend towards faster growth and taller heights has been much slower than in the first half of the 20th century.

The findings in this paper provide further evidence that the declines in adult outcomes for Americans born after midcentury documented in Reynolds (2025) have their roots in adolescence, or earlier. While the exact biological mechanisms determining the age of puberty and the adolescent growth spurt are not fully understood, the trend over time and differences by income are thought to be driven by differences in nutritional status and disease exposure (e.g. Cole, 2003). Recent findings suggest that caloric deprivation in childhood activates particular receptors in the brain that delay the onset of puberty and the adolescent growth spurt, but also lead to a period of leg growth longer into early adulthood (Lam et al., 2021). More research is needed, but it appears likely that these cohorts had a hormone or nutrient deficiency of some kind in adolescence — either due to a shock occurring during adolescence or an earlier shock that particularly affected

[2]See Schneider (2020) for an extensive discussion of the potential impact of sample-selection bias. He suggests that selectivity into secondary school leads many samples from the late nineteenth and early twentieth century to overstate height in adolescence.

biological processes related to puberty.

One intriguing way to view the findings is through the adaptive framework summarized in Schneider (2017).[3] Broadly, the idea is that many of the effects of responses to environmental shocks on human growth are adaptive, in the sense that they increase the chances of survival to reproductive age and of producing viable offspring. The growth patterns found in this study for the 1960s cohort are the predicted response to a *postnatal* shock in this framework, the delayed adolescent growth spurt, and then catch-up growth leading to a similar final height in adulthood. Additionally, the growth pattern of cohorts from the 1970s to the 1990s is approximately consistent with the predicted adaptive response to a *prenatal* shock in the adaptive framework. The argument is that plasticity is greater in utero, and the fetus's adaptive response to a predicted bad environment is to speed up maturation to increase the probability of reaching reproductive age, but to reach a shorter adult height that will require fewer calories to maintain. This described pattern is similar to that found in the 1970s to 1990s cohorts: growth tempo sped up and age at menarche decreased, but adult height was unchanged — and may have declined for the cohort born in the 1990s. Plausibly, the cause of this decline in the prenatal environment could simply have been the worsened maternal health of cohorts born in the 1950s and 1960s, who were giving birth in the 1970s-1980s.

2 Background and motivation

Komlos and Lauderdale (2007a,b) present evidence of a sudden slowing of the cross-cohort "secular trend" of growing adult height of Americans. They use repeated rounds of the NHES and NHANES surveys collected between 1959 and 2004, and study trends in the height of native-born, non-Hispanic white and black Americans by birth cohort. Their findings for cohorts between 1910 and the early 1950s replicate the well-known pattern, found in many countries, of secular growth in height across generations. For all four race-sex groups, this trend slowed to a crawl around the 1950 birth cohorts. For example, white men's height grew 4.4 centimeters, or 1.73 inches, between the 1910-14 and the 1950-54 cohorts: a rate of about .43 inches per decade. It then grew only .4 centimeters, or .16 inches, between the 1950-54 and 1970-74 cohorts: a rate of only 0.078 inches per decade. The growth rate slowed by a factor of more than five. There is some evidence of a rebound in height for the post-1975 cohorts of white men, but as the authors' note, the sample sizes are small for these groups. This stagnation for cohorts born after mid-century is in sharp contrast to the continued growth experienced in European countries (Hatton and Bray, 2010).

The rapid growth in adult height across American cohorts in the first half of the twentieth century is viewed as a key piece of evidence that there were large gains in health and human

[3]This framework is based on work by human biologists (Gluckman et al., 2005; Gluckman and Hanson, 2006a,b), and outlined and applied to findings from the anthropometric history literature in Schneider (2017).

capital across these cohorts. As height is thought to be primarily determined by nutritional status in childhood (Tanner, 1990; Cole, 2003), the height growth is also a key piece of evidence in the argument that the main driver of these improvements have been gains in health in early life (eg Floud et al., 2011).[4] Therefore, Komlos and Lauderdale (2007a,b) describe the sudden stagnation in height during a period of rapid economic growth as a puzzle, and suggest that it may reflect evidence of a slowing in growth in the US "standard of living," and evidence that the US has started to lag behind Europe in some general sense of well-being even as American income has remained higher.

In Reynolds (2025), I presented evidence of a cross-cohort decline in the health and human capital of Americans, beginning with those born after 1947 and continuing until those born in the mid-1960s. I showed that educational attainment, men's wages, women's maternal health (proxied by their infants' birthweight), and mortality all exhibited trend breaks near the 1947 cohort, such that each outcome worsened for subsequent cohorts relative to the prior trend. The decline is large enough to drive: i) educational declines in the 1960s, ii) increases in low birthweight in the 1980s, iii) mortality increases since 1999, and to contribute substantially to iv) wage stagnation since the 1970s.

As an example, Figure 1 shows cohort trends of native-born Americans in adult height and educational attainment. The height trends are based on the NHES and NHANES data as in Komlos and Lauderdale (2007a,b); Komlos (2010), but include 12 more years of data than Komlos (2010), bringing the data up to 2018. Panel A shows a binned scatter plot based on data from the NHES and NHANES survey data, the height of men and women aged 23 to 40 years, with optimally chosen equally spaced bins (Cattaneo et al., 2024). I estimate trends in educational attainment based on decennial census and American Community Survey microdata, similar to the data and approach used in Card and Lemieux (2001); Goldin and Katz (2007)[5]. Panel B plots the age-adjusted educational attainment of native-born Americans, calculated from a regression with cohort fixed effects and a full set of age fixed effects.

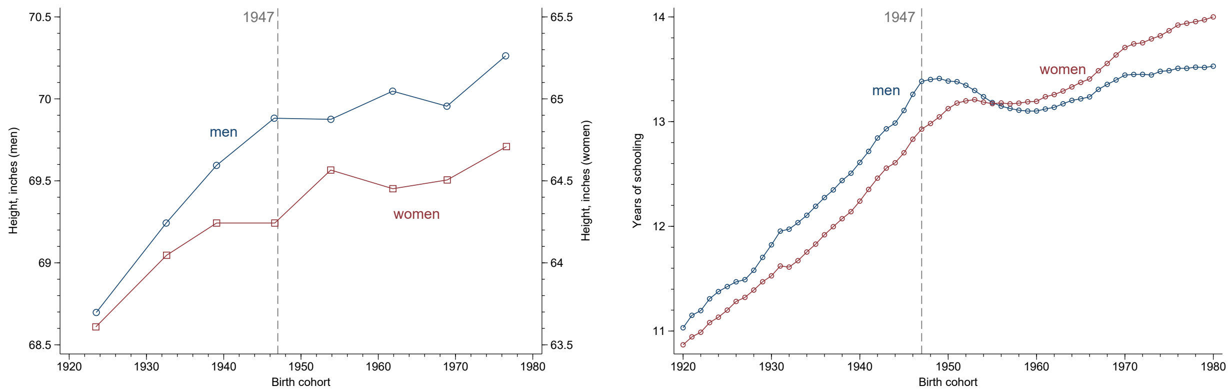
Both educational attainment and height grew across cohorts born between 1920 and midcentury, and then around 1950, that growth slowed. My previous paper emphasized the sharp timing of the trend break at the 1947 cohort for a number of different outcomes. This can be seen in the educational attainment trends for men, but notably, the trend break for women is a few cohorts later. Unfortunately, the NHES/NHANES samples are too small to precisely date the timing of the

[4] See also Fogel (1986); Fogel and Costa (1997); Costa and Steckel (1997); Fogel (2012); Costa (2015).

[5] This data likely understate the magnitude of the trend break for two reasons. First, Goldin (1998) found that older adults born in the first half of the twentieth century overreported their high school graduation rates. Second, GED holders are counted as having completed twelve years of schooling, and the rate of GED-holders increased for cohorts born after mid-century (Heckman and LaFontaine, 2010).

Figure 1: Stagnating height and human capital of Americans born after mid-century

(a) Height of native-born Americans **(b)** Educational attainment of native-born Americans



Panel A is binned scatter plot based on data from NHES and NHANES survey data, height of men and women ages 23 to 40, with optimally chosen equally-space bins (Cattaneo et al., 2024). Panel B shows years of schooling based on Decennial Census and American Community Survey microdata from 1960 to 2018, men and women ages 25 to 65, age-adjusted from a regression on a full set of age fixed effects.

stagnation in adult height. For example, the structural break methods I used in **?** yield point estimates for the timing of the trend break in men's and women's height at 1947 and 1957 respectively — but the confidence intervals both include more than 20 birth years between 1935 and 1965. Therefore, while certainly not definitive, the approximately shared timing, particularly between men's height and other measures of men's human capital, makes it seem quite plausible that the stagnation in height growth is another symptom of the broad health and human capital decline.

If one viewed cohort adult height as a sufficient statistic for cohort health and nutritional status in childhood (Tanner, 1990; Floud et al., 2011), this would have important implications. It would suggest that growth in cohort health in childhood suddenly slowed after midcentury. This could then suggest that the roots of the cohort health and human capital decline date to childhood as well. However, a tension exists because adult height does not decline in absolute terms — while educational attainment does. Additionally, calibration exercises in **?** suggest that human capital more broadly likely declined in absolute terms across cohorts born between 1947 and 1965. Should we conclude that there was a stagnation in childhood health for cohorts born after 1947, but then some subsequent shock to the same cohorts led to a decline in adult health and human capital in absolute terms?

I argue that such a conclusion would be premature because adult height is a useful, but imperfect, proxy for childhood health. Two adults who are the same height may have reached it via very different growth patterns. The factors that led to these different growth patterns may have also left lasting differences in the health and cognitive development of the two adults. For example, individuals who are malnourished as young children but then properly nourished thereafter may initially fall behind in height but then experience faster "catch-up growth" at later ages Tanner (1990). In some cases, catch-up growth is rapid enough that the individual achieves a 'normal' height in adulthood. However, there is some evidence that they would still bear the deleterious costs of childhood malnutrition, such as cognitive or other health effects.[6] Therefore, this paper uses height data from childhood, adolescence, and adulthood to provide a fuller picture of changes in the growth patterns of Americans born around the middle of the twentieth century.

Schneider (2023) provides a useful review of the growth pattern of human height, and it's changes over the long-run and across the world. He describes four characteristics of the growth pattern of human height: size at birth, height in adulthood, the timing of the adolescent growth spurt, and the speed of maturation (sometimes called "growth tempo"). These characteristics are interrelated but far from perfectly correlated across individuals and groups. While the biological determinants of each characteristic are not completely understood, they are thought to be determined by a combination of genetic variability and adverse health shocks, such as those caused by nutrition or infection (Tanner, 1990; Schneider, 2023).

Understanding the adolescent growth spurt will be particularly important for interpreting the results below. Humans experience a marked acceleration in the rate of growth at some point in their adolescence, approximately coinciding with other biological processes of puberty (Tanner, 1986). The spurt is later and more pronounced for boys, for whom the velocity of growth can be twice as fast during the growth spurt as it was a few years before (Schneider, 2023). Both the velocity and timing of the growth spurt (often measured as age at "peak height velocity") can vary substantially across individuals and groups.

Variation in either the timing or growth velocity during the spurt can lead to very large height differences in adolescence, which may be closed by adulthood. For example, if one teenage boy has their growth spurt at age 14 and another at 15, the earlier developing teen could be temporarily more than an inch taller than his peer. It is then common for individuals or populations who have a later growth spurt in adolescence to then continue growing for longer into their early twenties, at least partially catching up in adult height (Tanner, 1986; Lleras-Muney et al., 2022).[7]

While the exact biological mechanisms determining the age of puberty and the adolescent growth spurt are not fully understood, the trend over time and differences by income are thought to be driven by differences in nutritional status and disease exposure (e.g. Cole, 2003). Recent findings suggest that caloric deprivations in childhood activate particular receptors in the brain

[6] Schneider (2023) describes the literature on this question is underdeveloped. The balance of evidence seems to show that catch-up growth in height leads to at least partial catch-up growth in cognitive development as well.

[7] Note this phenomenon is distinct from the usual definition of "catch-up growth" when children who are temporarily malnourished are able to "catch-up" partially or completely if they receive good nutrition later in childhood.

which delay the onset of puberty and the adolescent growth spurt, but also lead to a period of leg growth longer into early adulthood (Lam et al., 2021).

This paper is relevant to the large literature studying the so-called "secular trend" in human growth. In many countries around the world trends have been observed towards: taller completed height in adulthood, faster growth tempo, earlier occurrence of puberty and the adolescent growth spurt, and an earlier age at which growth stops.[8] Consistent with a long-run trend towards an earlier or larger adolescent growth spurt, long-run changes in height-for-age are generally largest in the teenage years for males (Meredith, 1964; Cole, 2003). There is some evidence in a number of other high-income countries that the trend towards earlier menarche slowed or stopped for girls born around the middle of the twentieth century (see Cole 2000 and the citations therein). . However, the growth in adult height continued in other countries, at least until cohorts born around 1980 (Cole, 2003; Hatton and Bray, 2010; NCD-RisC, 2016).

Komlos and Breitfelder (2008) also study changing heights of American children and adolescents. However, they only reported results from a model in which age-effects and cohort effects are additively separable. By construction, this model cannot reveal changes between cohorts which are different at different ages. Such differential changes at different ages will be a key focus of the results below, and reveal important changes in the growth pattern.

3 Data

I combine data from the second and third National Health Examination Surveys (NHES II and III), and numerous rounds of the National Health and Nutrition Examination Survey (NHANES I to III, and the "continuous NHANES" from 1999 to 2018) to study changes in height in childhood, adolescence, and adulthood.

The NHES and NHANES surveys are cross-sectional and were designed to be representative of the US population at the time of the survey (or of select age groups). [9] However, the samples are relatively small, and the early surveys occurred irregularly and each survey focused on a different age group. However, (by lucky coincidence) it is possible to observe the heights of the cohorts born between 1951-1957 and 1961-1967 at multiple ages from 5 to adulthood, and therefore compare their growth patterns.

Panel A of Figure 2 shows the childhood component of this sampling in a Lexis diagram. The NHES II was carried out in 1963-1965 and only sampled 6-11 year olds, and NHES III was carried

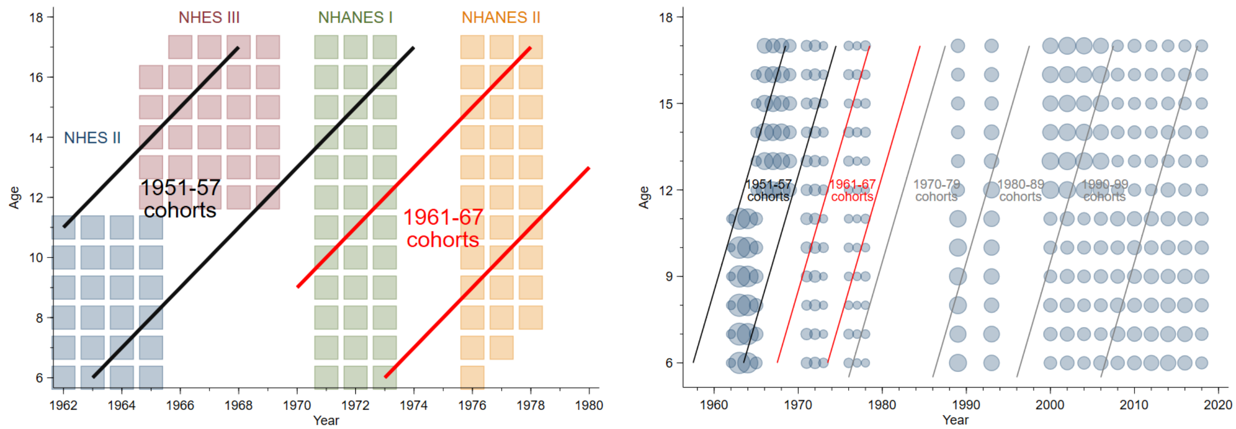
[8] See for example Wyshak and Frisch (1982); Hauspie et al. (1997); Cole (2003); Schneider (2023); Lleras-Muney et al. (2022) and the citations therein.

[9] Some respondents were interviewed in both NHES II and III, but the panel created from this sampling yields a very small sample and few cohorts. Hence, I do not use this panel component in this paper.

Figure 2: Lexis diagram of NHES and NHANES coverage of children by age, year, birth cohort

(a) NHES II-III, NHANES I-II cover 1951-57 and 1961-67 cohorts

(b) Later NHANES cover additional cohorts



Shows in which years and at which ages, between 6 and 17, were sampled in various NHES and NHANES surveys. In panel A, each square shows an age-year cell with a sample size of at least 50 in the listed survey. In panel B circles are included if the relevant age-year cell has sample size of at least 50, and the size of the circles are proportional to the sample size.

out in 1966-1970 and sampled 12-17 year olds. This allows me to observe the 1951-1957 cohorts once between the ages of 6 and 11, and again between the ages of 12 and 17. The NHANES I and NHANES II sampled ages 1 (or zero) to 74 and were carried out in 1971-74 and 1976-80. This allows me to observe some members of the 1951-1957 cohort a third time as teenagers. More importantly, it allows me to observe the 1961-1967 cohort twice, at similar ages to the earlier-born cohort.

I then use the NHANES I to III, and the Continuous NHANES from 1999 to 2018 to observe adult heights for both the 1951-57 and 1961-67 cohorts. I follow Komlos (2010) and focus on adults aged 23 to 40, ages at which height is approximately constant. I use sampling weights in all analyses and focus on individuals born in the US. For the NHES surveys this is defined based on a linkage to birth certificates and for the later surveys is self-reported.

Even when pooling data in this way, the sample sizes are not enormous but prove large enough to detect differences in adolescent height between the two groups. For the 1951-1957 birth cohorts, there are approximately 3000 observations of males with non-missing height at ages 6 to 11, a similar number at ages 12-17, and approximately 1300 observations in adulthood. For the 1961-1967 birth cohorts, there are only around 1200 and 900 observations at age 6-11 and 12-17, respectively, and 1200 in adulthood. See Appendix Table 1.

In Section 5, I extend the analysis to later birth cohorts, again using the NHANES I to III, and the Continuous NHANES from 1999 to 2018. Panel B of Figure 2 shows the extended sampling scheme in a lexis diagram. Appendix Table 1 shows the sample sizes for these cohorts as well, which range from approximately 500 to 2500 per age-group-birth-cohort cell.

Year of birth is not directly recorded in some of the later surveys; therefore, I impute it with some error based on age and the (approximate) year of the survey. For NHANES III, I define year of birth as 1990 minus age for those surveyed in Phase 1 (October 18, 1988, through October 24, 1991) and 1993 minus age for those surveyed in Phase 2 (September 20, 1991, through October 15, 1994). The continuous NHANES is organized into two-year waves, and the exact year of the survey within the wave is not recorded. For these surveys, I define year of birth as the later of the two survey years minus age. Native-born is not reported in NHES I; therefore, I include all individuals.

4 Comparing growth patterns of 1950s and 1960s cohorts

This section uses the NHES and NHANES data to compare the growth patterns of the 1951-57 and the 1961-1967 cohorts, from childhood through adolescence and into adulthood.

A Growth patterns of males

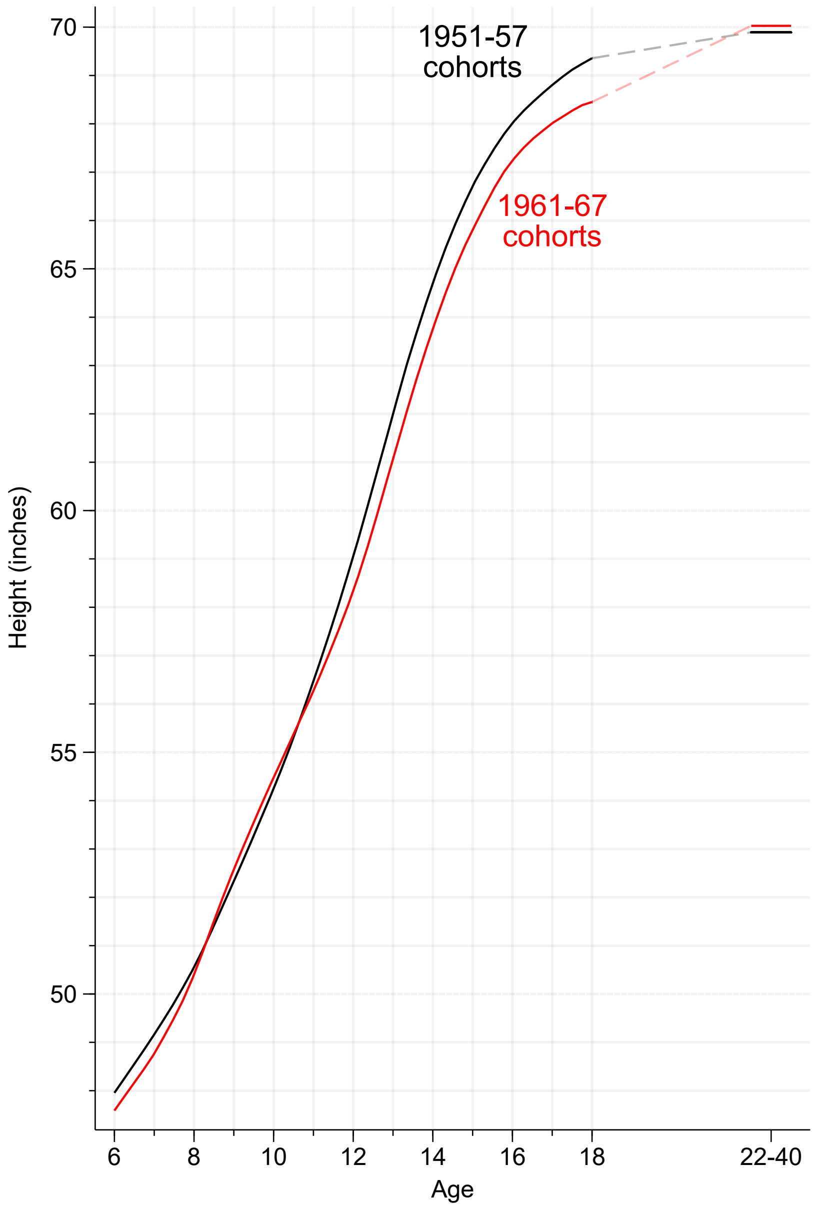
Figure 1 shows smoothed estimates of the average height of the 1951-57 and 1961-67 cohorts of American-born males from age 6 to 17, and then in adulthood. The lines for ages 6 through 17 come from separate kernel regressions of height on age in months, with an Epanechnikov kernel and a bandwidth of 12 months. These cohorts were barely sampled by national surveys at ages 18–20, but we can catch up with them by age 22. I pool ages 22 to 40 to measure approximately "completed" adult height, which is plotted at the top right corner of the figure.

The estimates suggest that the two cohorts were nearly identical in height from ages 6 to 11. After age 11, a gap starts to open up such that by ages 16 and 17, the later-born cohort was more than half an inch shorter. However, once they reach adulthood (ages 22–40), they are again nearly identical in height. This pattern is consistent with the later-born cohorts having a later or smaller adolescent growth spurt — temporarily falling behind the earlier-born cohort — and then either catching up once they have their later growth spurt or by growing longer into early adulthood.

I estimate regression models to assess the statistical significance of the height differences shown in Figure 3. For statistical power I pool ages into larger groupings, while flexibly controlling for more detailed age. In particular, I estimate models of the following form:

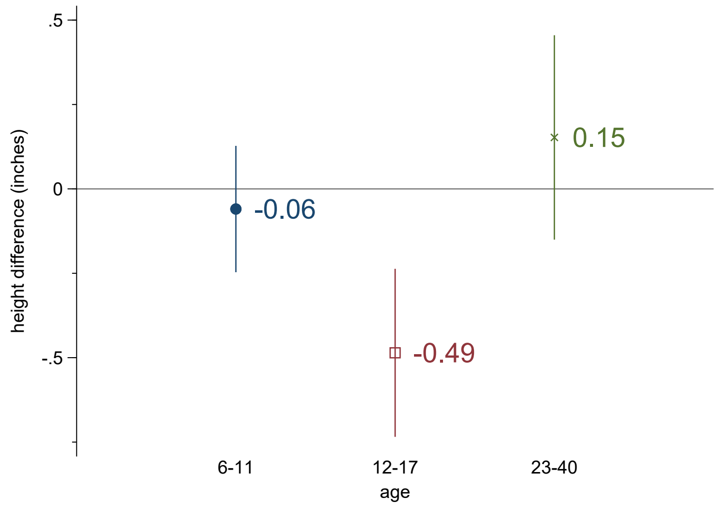
$$Y_{i,ac} = \gamma_{c=1960-66} + \mu + f(a) + \epsilon_{i,ac} \quad (1)$$

Figure 3: Smoothed height-by-age of American-born males: 1951-1957 vs. 1961-67 cohorts



Estimated on data on height and age-in-months from multiple rounds of the NHES and NHANES surveys. Smoothed profiles for ages 6 through 17 were estimated for each cohort group by a kernel smoother with an Epanechnikov kernel and a bandwidth of 12 months. The lines at age 22-40 report the pooled mean height across ages 22 to 40.

Figure 4: Regression estimates of height differences, American-born males: 1951-1957 vs. 1961-67 cohorts



Uses data from multiple rounds of NHES and NHANES surveys. Shows estimates of the height differences between the listed cohorts at different ages. All estimates comes from regression described in Section 2 which, for those aged 6 to 17, control for fixed-effects for single-year-of-age and a quadratic in age-in-months.

where $Y_{i,ac}$ denotes the height of individual i at age a in cohort c. I run the above regression separately for different age groups: 6–11, 12–17, and 23–40. In each regression $\hat{\gamma}_{c=1960-66}$ estimates the height differences between cohorts, and $f(a)$ controls for small differences in the distribution of ages when the cohorts are observed in the different surveys. For ages 6 to 11 and 12 to 17, I include dummies for age in years and a quadratic in age in months. I restrict to the native-born population and use sampling weights in all analyses.

Figure 4 shows the estimated differences in height, $\hat{\gamma}_{c=1960-66}$ between native-born males in the 1951-1957 and the 1961-1967 cohorts, for each of the three age groups. The results suggest that the two cohort groups had nearly identical average heights as children at ages 6 to 11. The point estimate would imply that the average height of the 1960s cohort was less than a tenth of an inch below that of the earlier-born cohort at these ages. The difference is statistically indistinguishable from zero, and the 95 percent confidence intervals would rule out differences larger than a quarter inch in either direction.

However, the point estimate in adolescence implies that the average height of the 1960s cohort group was *nearly half an inch* shorter in adolescence (ages 12 to 17) than the 1950s cohort group. This difference is significantly different from zero, and the 95 percent confidence interval would rule out cross-cohort declines smaller in magnitude than .24 inches.

Strikingly, the estimates suggest that the later-born cohort then caught back up in height in adulthood. The point estimate actually implies that the 1960s cohort group was .15 inches *taller* than the 1950s cohort group as adults, although the confidence interval includes values consistent with anything from an approximately .15 inch cross-cohort decline in height to a .45 inch cross-cohort improvement in height. Importantly, the estimates imply with a high degree of confidence that the gap in adulthood was much smaller than it had been in adolescence.

I use additional models to directly estimate and gauge the statistical significance of the differential growth in height implied by these patterns. For the sample of 6-to-17-year-olds I estimate:

$$Y_{i,ac} = \delta^{a=12-17}_{c=1960-66} + \gamma_{c=1960-66} + \mu + f(a) + \epsilon_{i,ac} \tag{2}$$

where $\delta^{a=12-17}_{c=1960-66}$ estimates how much larger the between-cohort height difference at ages 12-17 is than it had been at ages 6-11.

For the sample of 12-to-17- and 23-to-40-year-olds, I estimate:

$$Y_{i,ac} = \delta^{a=23-40}_{c=1960-66} + \gamma_{c=1960-66} + \mu + f(a) + \epsilon_{i,ac} \tag{3}$$

where $\delta^{a=23-40}_{c=1960-66}$ estimates how much larger the between-cohort height difference at ages 23-40 is than it had been at ages 12 to 17. I again include a flexible controls for age, $f(a)$, — I include an adult dummy variable and for ages 6 to 11 and 12 to 17 I include dummies for age in years and a quadratic in age in months.

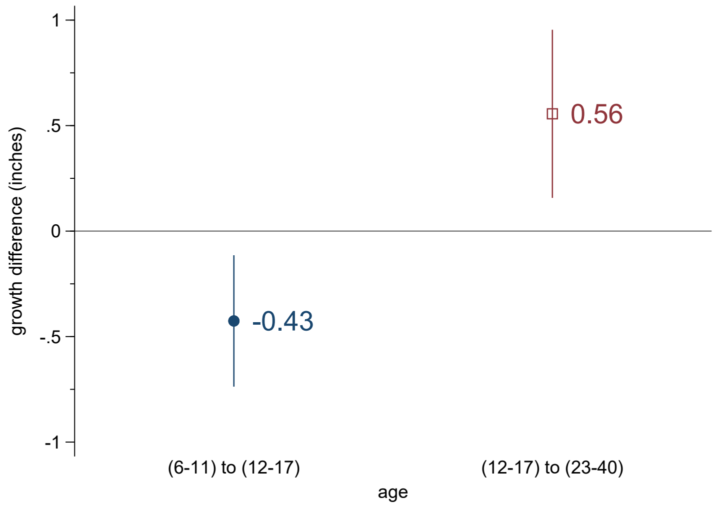
Figure 5 shows the resulting estimated growth differences, $\delta^{a=12-17}_{c=1960-66}$ and $\delta^{a=23-40}_{c=1960-66}$. The point estimates would that the later-born cohort grew .43 inches less between ages 6-11 and ages 12-17 than the earlier-born cohort. However, this reversed between ages 12-17 and adulthood, when the later-born cohort then grew .56 inches *more* than the earlier-born cohort. The differences in growth are statistically significant.

The estimates strongly suggest that the 1960s cohort grew more slowly in adolescence, either because of a later or a smaller adolescent growth spurt, and then was able to catch up in height by subsequently growing faster or for a longer period into early adulthood.[10]

Unfortunately, the relatively small sample sizes do not allow me to distinguish the precise age at which the gap in height first opened and when it began to close. This makes it unclear whether the height differences are due to differences in the timing of the adolescent growth spurt or differences in the growth velocity achieved during (or around) the adolescent growth spurt. Historically, in South Korea and Japan, these two processes, timing and peak height velocity, moved in tandem.

[10]Note that this is a catch-up in absolute terms, not just catch-up relative to a growth reference, which can be more difficult to interpret Schneider (2023).

Figure 5: Regression estimates of growth differences, American-born males: 1951-1957 vs. 1961-67 cohorts



Uses data from multiple rounds of NHES and NHANES surveys. The figure shows estimates of the differences between the listed cohorts in implied growth at different ages.. All estimates comes from regression described in Section 2 which, for those aged 6 to 17, control for fixed-effects for single-year-of-age and a quadratic in age-in-months.

That is, the enormous cross-cohort changes in growth in South Korea and Japan involved a move towards both an earlier growth spurt and a faster peak height velocity during the spurt (Cole and Mori, 2018). Therefore, it could be plausible that a similar change occurred between the 1950s and 1960s cohorts in the United States, but in reverse: that the 1960s cohort had both a later and smaller adolescent growth spurt on average than those born a decade earlier. However, note that the East Asian changes coincided with changes in final attained height, which are not seen for the American cohorts studied here.[11]

Without individual panel data, even larger sample sizes would not provide a complete picture of the cross-cohort changes in the growth pattern. As explained clearly by Tanner (1990), growth and velocity curves at the cohort level look very different from those at the individual level because of within-cohort variability in the timing of the growth spurt. For example, a reduction in the within-cohort variability of the age at peak height velocity can lead to an apparent increase in peak height velocity in adolescence when measured at the population level — even if individual level peak height velocities remain unchanged.[12]

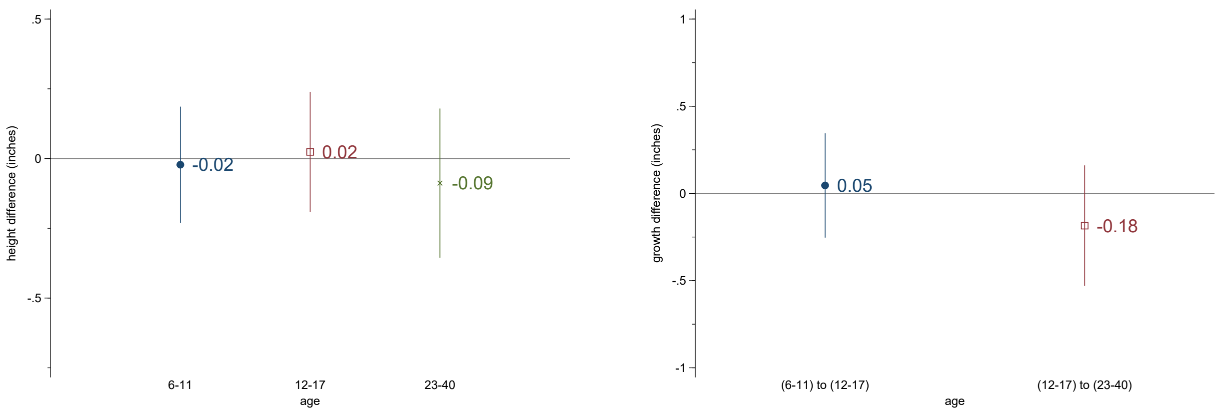
Appendix Figure 1 replicates the above analysis separately for non-Hispanic white and non-Hispanic black American-born males. Qualitatively, the patterns are very similar for both racial groups to those shown above for the full sample of native-born males. For example, the point

[11] Interestingly, studies of the individual level variation between timing and peak velocity in a single cohort have found the opposite association, with boys entering puberty later having a larger peak velocity (Cole et al., 2010).

[12] For an extended discussion of related issues see also Gao and Schneider (2021).

Figure 6: Regression estimates of height and growth differences, American-born females 1951-1957 vs. 1960-66 cohorts

(a) Height difference **(b)** Growth difference



All panels use data from multiple rounds of NHES and NHANES surveys. Panel A shows estimates of the height differences between the listed cohorts at different ages. Panel B shows the estimates of the difference between the listed cohorts in implied growth at different ages. All estimates comes from regression described in Section 2 which, for thoses ages 6 to 17, control for fixed-effects for single-year-of-age and a quadratic in age-in-months.

estimates suggest that in adolescence (ages 12 to 17), whites and blacks born in the 1960s cohort are .4 and .44 inches shorter than the cohort born a decade earlier. Of course, the confidence intervals widen with the decrease in sample size, and some previously significant differences lose statistical significance.

Appendix Figure 2 uses quantile regressions to assess whether the height decline is driven by declines at particular parts of the distribution. The results suggest that the decline in mean height is driven by shifts across the distribution of height. The decline in height is estimated to be quite similar across different quantiles, with slightly smaller declines at the 10th to 40th percentiles of approximately .4 inches, and slightly larger declines of .5 to .7 inches at higher percentiles.

B Growth patterns of females

Surprisingly, there is no evidence that the growth pattern of American-born females changed similarly across cohorts.

Figure 5 shows the differential height and growth results for females. The specifications are the same as those for Figures 3 and 4, again following Equations 1 to 3. These specifications show no evidence of a similar pattern of differential growth for females born in 1960-66 versus those born in 1951-1957. The point estimates for the differences in height at all three ages are small in magnitude and not statistically different from zero, although differences of .2 to .35 inches cannot be ruled out at standard levels.

The adolescent growth spurt for women occurs approximately 2 years earlier for girls than for boys. Therefore, I reran the above analysis, shifting the child and adolescent age groupings down by two years. I now use the following age groups: 6–9, 11–15, and 22–40. Appendix Figure 1 shows that the results are very similar qualitatively to those in Figure 6 — with again all height and growth differences not significantly different from 0 at conventional levels.

Why might the results for girls differ so significantly? Girls have slightly smaller adolescent growth spurts than boys. In the three years including peak height velocity, boys tend to grow about 9 inches in total, while girls tend to grow slightly less than 8 inches (Tanner, 1990). It is of course possible that there were small changes in the growth pattern of girls that were not detectable in the NHES and NHANES samples. Puberty also differs substantially between biological males and females. It is a rapid period of sex differentiation, and the hormonal processes driving the adolescent growth spurt in males and females differ (Tanner, 1990). Below, I show evidence that a different measure of pubertal development, menarche, age at first menstrual period, did change dramatically between the 1950s and 1960s cohorts of females.

5 Changes in growth patterns after the 1960s cohorts

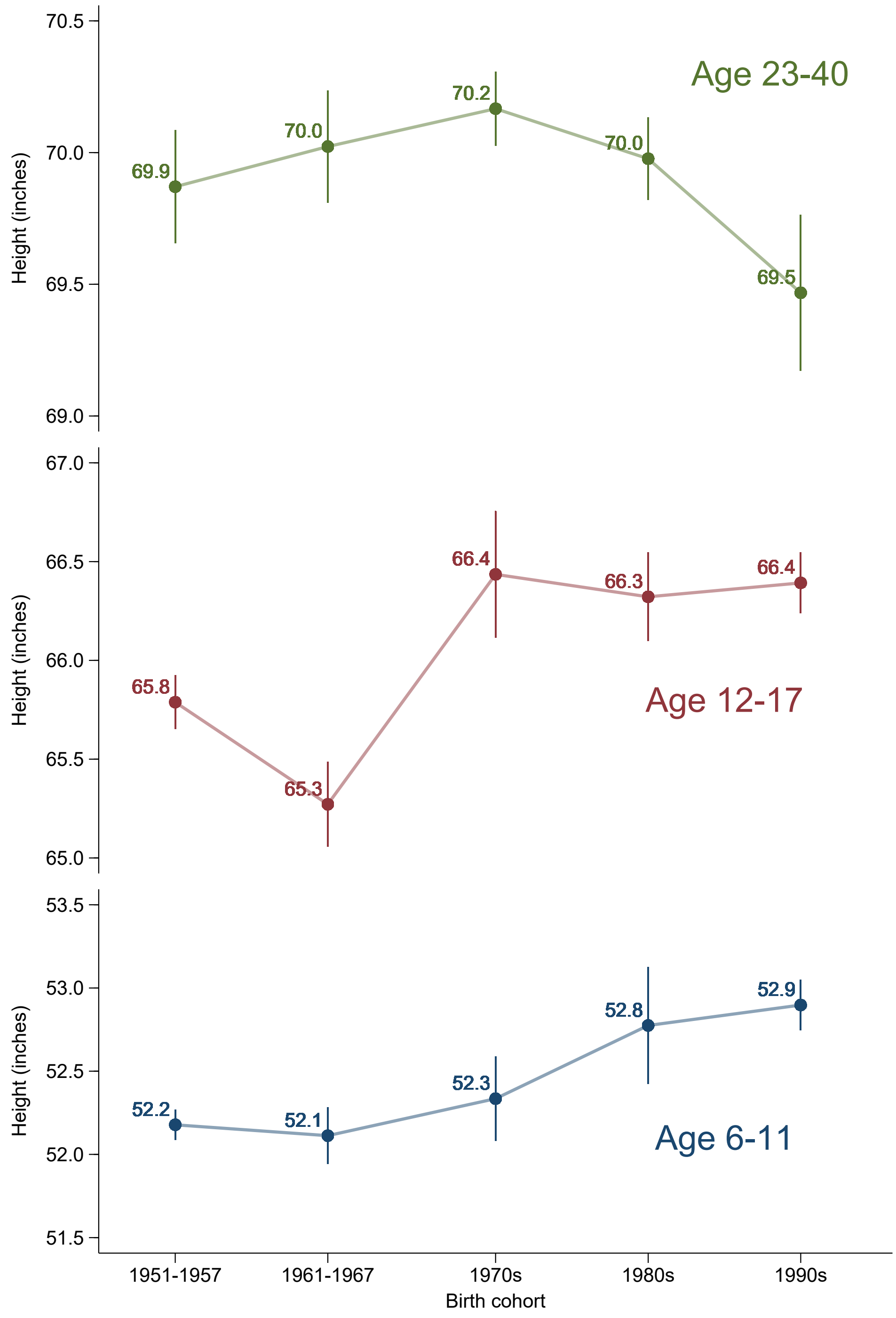
In this section, I use later NHANES surveys to extend the trends in height-by-age to later-born cohorts.

I compare heights at ages 6-11, 12-17, and 23-40 of cohorts born in 1951-1957, 1961-1967, 1970-79, 1980-89, and 1990-99. Within each age group and cohort, I calculate means by individual ages using sample weights. I then take the average of these means across single-year ages. I calculate standard errors of these "means of means" by the delta method and taking into account the sampling weights.

Figure 5 shows the results. As described above, there is little change in boys' height during childhood (ages 6-11) between the 1950s and 1960s cohorts. The point estimate for the 1970s cohorts suggests that they were just .2 inches taller. Then the 1980s and 1990s cohorts were approximately .5-.8 inches taller than the 1950s-1960s cohorts at these ages. Appendix Figures 4 and 5 show that similar patterns of change, though different levels, are evident separately for non-Hispanic whites and non-Hispanic blacks.

The adolescent series (ages 12-17) shows a large rebound for the 1970s and all later-born adolescent boys — such that those cohorts are around 1.2 inches taller than the 1960s cohort and therefore around .7 inches taller than the 1950 cohorts at these ages. The pattern for non-Hispanic whites, shown in Appendix Figure 4, is nearly identical to that for the full population. The pattern for non-Hispanic blacks shown in Appendix Figure 5 is also very similar, although the

Figure 7: Cross-cohort trends in height of males born in the US after 1950, by age, national, survey-based estimates



Uses data from multiple rounds of NHES and NHANES surveys. For each listed cohort group, I first calculated the means by single year of age. For each listed age group, I then take the simple average of these means across single-year ages. These age group means are plotted for each listed cohort group. The 95 percent confidence intervals for the age group means are also shown. They were calculated by the delta method and take into account the sampling weights and survey design.

point estimates suggest less growth in height for the 1970s cohort and larger growth for the 1980s and 1990s cohorts, although the estimates are of course less precise.

The adult series is approximately flat from the 1950s to the 1980s cohorts, before falling for the 1990s cohort. Just as the adolescent drop in height for the 1970s cohorts was no longer evident in adult heights, the rebound for post-1970s cohorts has also disappeared by adulthood. It appears that the 1970s and 1980s cohorts attained a faster growth tempo in adolescence than both the 1950s and 1960s cohorts — but these cohorts then caught up to them by growing longer into early adulthood. The drop in adult height of cohorts born in the 1990s is surprising — although the standard error is somewhat larger than those for other cohorts/ages. There is also little evidence of growth in adult height separately for either non-Hispanic whites or blacks, as shown in Appendix Figures 5 and 6.

While not the primary focus of this paper, the changes in height-by-age for American males are surprising and, to my knowledge, have not been shown in full previously. It appears that growth tempo grew substantially between the 1950-1960s cohorts and the 1970-1990s cohorts, both in childhood and in adolescence. However, attained final height in adulthood was approximately constant. This suggests that the age at cessation of growth fell between the 1950s-1960 cohorts and the 1970-1990s cohorts. In other words, cohorts born after 1970 grew faster but stopped growing at a younger age and at the same adult height as earlier-born cohorts. [13]

Interestingly, this increase in growth tempo also appears to have occurred for females in the same cohorts. Appendix Figure 6 shows that females in the 1970s-1990s cohorts were .3 to .5 inches taller in childhood and adolescence than the 1950s-1960s cohorts. However, as for males, all cohorts reached approximately the same height by adulthood.

6 Growth patterns in the longer-run

This section places the "stunted adolesence" of cohorts born in the 1960s in perspective. I combine the NHES and NHANES surveys with earlier historical estimates of childhood height compiled in Meredith (1964) and adult height series from (Bleakley et al., 2014) to provide a long-run perspective on the growth pattern of white American males.

To my knowledge, the NHES II was the first nationally representative study which measured childhood height. Meredith (1964) compiled results from a large number of historical studies of childhood height. Although they do not come from nationally representative samples, the studies

[13] Komlos and Breitfelder (2008) showed that heights of children and aodolescents were increasing for post-1970s cohort. But they did not make a direct comparison as here between cohorts heights in childhood and adolescents and in adulthood (they focused on height-for-age Z-scores), and hence their findings did not reveal evidence of the slowing of growth tempo.

did not explicitly target children with high or low socioeconomic status. He was also focused on trends for "North American boys" — so while his estimates are primarily based on American samples, they do include some Canadian studies. I use the series he constructs based on these studies of the height of white boys aged 10 and 15.[14] The childhood height series for these cohorts has more potential to be biased; for example, if children in school were more likely to be sampled, the selection bias may worsen in adolescence. This age-varying selection bias could also conceivably change over time as school enrollment rates change (Schneider, 2020).

The pre-1950 adult series is based on various military samples and comes from Costa (2015) and Bleakley et al. (2014), which updates Costa and Steckel (1997) and Fogel (1986). These series may also be biased if the factors affecting selection into the military change over time. The debate in the literature mainly focuses on the decline in height for earlier cohorts in the nineteenth century, with Bodenhorn et al. (2017) arguing that the decline is entirely an artifact of sample selection and Zimran (2019); Komlos and A'Hearn (2019) arguing that it is a much smaller issue.

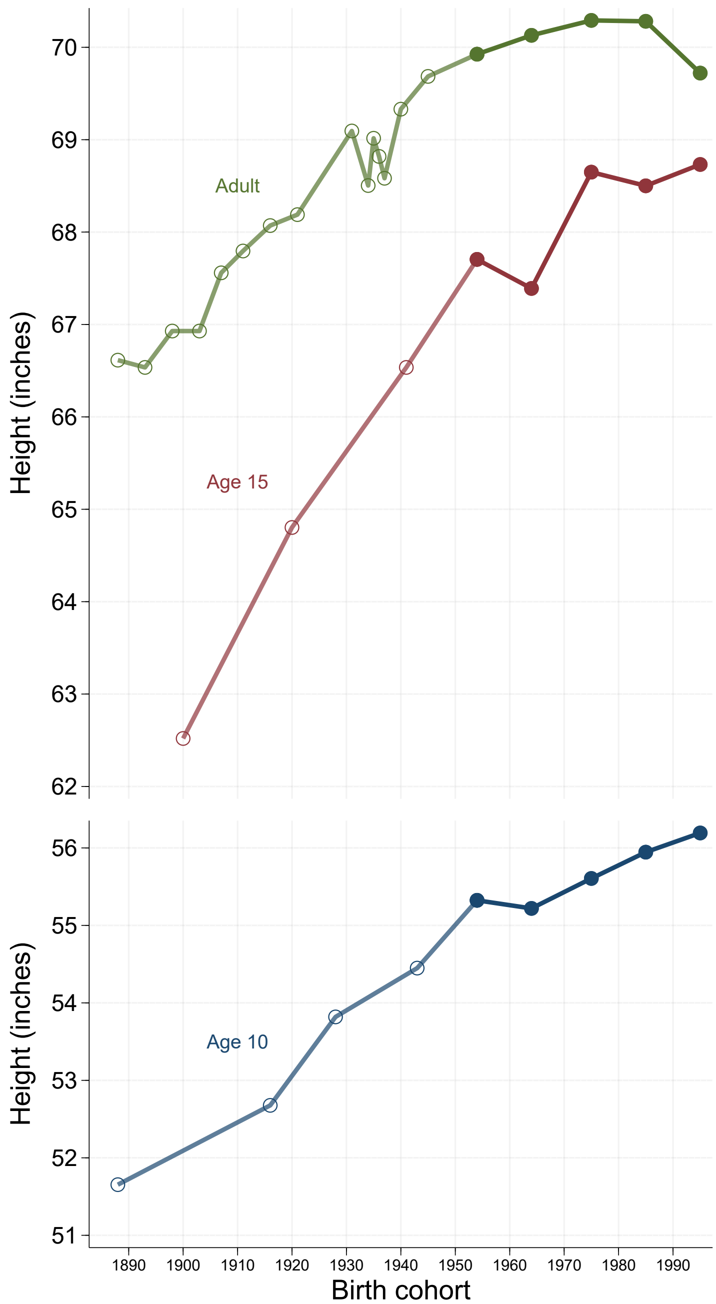
For post-1950 cohorts, I use the NHES and NHANES surveys and the same cohort groups as in the previous section. I restrict the sample to non-Hispanic native-born white males. To improve precision, I pool ages 6-11 and use a regression controlling for age-in-years fixed effects and a quadratic in age in months to predict height at age 10 for the cohort groups used in Section 3. Analogously, I pool ages 12-17 and use a similar regression to predict height at age 15. The adult series is the sample mean of 23-to-40-year-olds by cohort group.

Figure 6 shows these long-run height trends. Visually, it is clear that for all series the trend of growth was noticeably faster for the 1885 to 1950 cohorts than it has been for post-1950 cohorts. An important caveat of course is that 1950 is also the year in which the data sources change for each series, and there are particular potential sources of bias in the pre-1950 data. However, taking the series at face value, another noticeable pattern is that growth at age 15 before 1950 was faster than at either age 10 or in adulthood. Panel A of Appendix Figure 7 shows simple OLS trend estimates, which put growth from 1885 to 1950 cohorts at about .52 inches per decade at both age 10 and in adulthood, and much faster at .81 inches per decade at age 15. Put differently, comparing the average white American male born around 1950 to that born 50 years earlier: the later-born male would be about 2.6 inches taller at age 10, nearly 5.5 inches taller at age 15, and then only about 2.6 inches taller again in adulthood. This is the familiar "secular trend" pattern described in Cole (2003); **?**, and is consistent with an accelerating growth tempo in adolescence in particular over this period, in addition to growth in final height. However, this growth suddenly stagnates and for the next 50 years there is much slower cross-cohort growth in heights at all ages. The estimated

[14] Specifically, I use the mean heights reported in the left panels of Table XII and XIII of Meredith (1964). I calculate the midpoint of each time period, then subtract the relevant age to calculate the midpoint of the birth cohort group which is represented.

Figure 8: Longer-run trends in height of white non-Hispanic (North) American males, by age

historical estimates from various sources, pre-1950,
national, survey-based estimates post-1950



Points plotted with open circles for pre-1950 cohorts are based on various historical sources that are not random samples of the US population. The age 10 and age 15 series are the average heights from the various historical studies complied in Meredith (1964). The adult series is based on various military samples and comes from Costa (2015) and Bleakley et al. (2014), which updates Costa and Steckel (1997) and Fogel (1986). Points plotted with solid circles for post-1950 cohorts are based on data from multiple rounds of NHES and NHANES surveys, which are designed to be random samples of the US population. The age 10 series shows predicted values from a regression that pools boys aged 6 to 11 and controls for age-in-years fixed effects and a quadratic in age in months. The age 15 series comes from an analogous regression that pools boys aged 12 to 17. The adult series shows the sample mean of men aged 23–40 years by cohort group.

trend in height, shown in Panel B of Appendix Figure 7, for the post-1950 cohorts are .22 and .26 inches per decade at ages 10 and 15, and only .053 inches per decade in adulthood.

7 Menarche

As described above, I do not find evidence of an anomalous adolescent growth pattern for females born in the 1960s versus those born in the 1950s. In this section, I show evidence that a different measure of pubertal development, menarche, did change dramatically between the 1950s and 1960s cohorts. In particular, girls born in the 1960s had their first menstrual period later than those born in the 1950s.

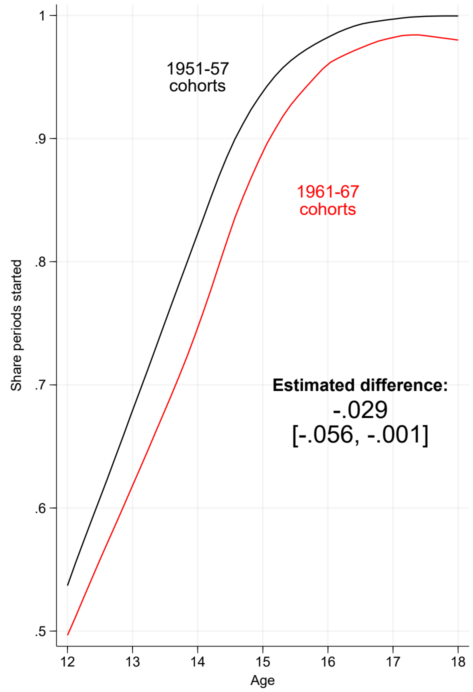
I first show evidence of these changes based on contemporaneous survey responses when these cohorts were still adolescents. Both the NHES II and NHANES I and II asked girls between the ages of 12 and 17 whether they had had their first menstrual period yet. Panel A of Figure 5 shows smoothed estimates of the share of native-born girls reporting having had their first menstrual period by age for the 1951-57 and 1961-57 cohorts of American-born females between ages 12 and 17. The lines come from separate kernel regressions of a menarche dummy on age in months, with an Epanechnikov kernel and a bandwidth of 12 months. At all ages from 12 to 17, the estimated share of girls in the 1960s cohort group who have had their period is approximately three percentage points lower than for those born a decade earlier.

I also estimate a regression of the form in Equation 1 to estimate the difference between the two cohorts in the probability of menarche occurring. I pool all girls aged 12 to 17 in the two cohort groups and control for dummies for age in years and a quadratic in age in months. The estimated between-cohort difference in the share of girls who had experienced menarche by a given age is -.029, with a 95 percent confidence interval of -.056 to -.001. The p-value for the null hypothesis of no difference is 0.039. This point estimate would imply a 2.9 percentage point lower share of girls had experienced menarche at any given age in the 1960s cohort than in the 1950s cohort.

I also use a retrospective question on age at menarche asked of adult women to construct a longer run cohort trend. I pool native-born women in NHANES I to III and the continuous NHANES, ages 20 to 75 and from the 1920 to 1985 cohorts. Panel B of Figure 5 shows binned scatter plots of average reported age at menarche by cohort.[15] A clear visual trend is of declining age at menarche is evident between the 1920 and mid-1940s cohorts, from nearly 13 to below 12.6. Around midcentury this trend reverses and age at menarche increases until mid-1960s cohorts, reaching at peak of around 12.75. After mid-1960s cohorts the declining trend restarts, and cohorts born around 1980 have an average age at menarche of 12.5. Appendix Figure 8 shows the smoothed

[15] I use the optimal equal-spaced bins and construct confidence intervals following Cattaneo et al. (2024).

Figure 9: Share of American-born girls who have had first menstrual period, smoothed estimates by age, contemporaneous reports:



Uses data from multiple rounds of NHES and NHANES surveys, on current age in months and whether girls report having had their first menstrual period. It shows smoothed profiles for ages 12 through 17 for the 1951-57 and 1961-57 cohorts of American-born females. between ages 12 and 17 for the 19 by a kernel smoother with an Epanechnikov kernel and a bandwidth of 12 months. The lines come separate kernel regressions of a menarche dummy on age in months, with a Epanechnikov kernel and a bandwidth of 12 months.

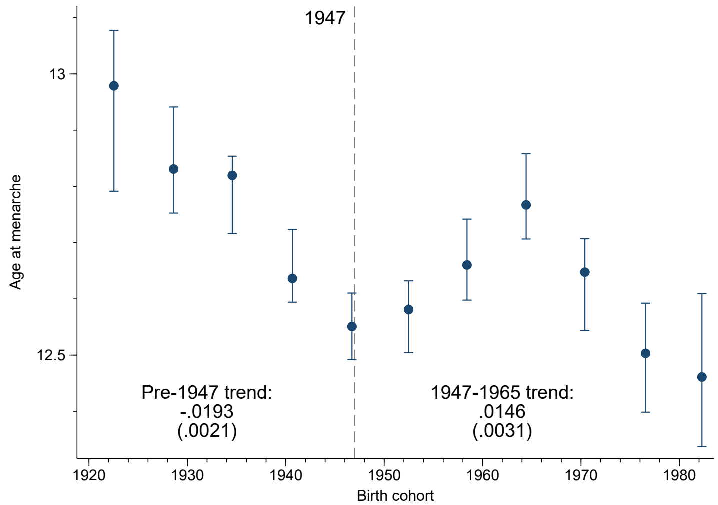
age profiles based on contemporaneous survey responses, similar to Figure 9, for additional cohort groups using subsequent NHANES surveys. The qualitative finding of a resumption of the trend towards earlier menarche for cohorts born in the 1970s through the 1990s is evident in this data as well.

8 Discussion

The findings of this paper provide additional evidence that the declines in adult outcomes for Americans born after midcentury have their roots in adolescence, or earlier. The relatively delayed puberty of cohorts born soon after midcentury strongly suggests that something had already gone wrong for these cohorts by adolescence. Puberty generally occurs later for individuals of lower socioeconomic status, and there has been a secular trend towards earlier puberty over the last 200 years in many high-income countries.[16] For example, Lleras-Muney et al. (2022) find that the

[16]See for example Lleras-Muney et al. (2022); Wyshak and Frisch (1982); Hauspie et al. (1997); Cole (2003) and the citations therein. Long run changes in height-for-age are also generally largest in the teenage years for boys,

Figure 10: Average age at menarche by cohort



Each point shows the average age at menarche for women in a given birth cohort bin, based on retrospective questions asked to women about the age when their periods first began. The sample includes native-born women aged 20 to 75, born between 1920 and 1985, pooled across NHANES I to III and the continuous NHANES up to 2018. Optimally chosen equally spaced bins and 95% confidence intervals were constructed following (Cattaneo et al., 2024). Estimated cross-cohort trends in average age at menarche, each come from a seperate regression on a linear cohort (year-of-birth) trend for women born 1920-1947 and those born 1947-1965.

timing of the adolescent growth spurt and age at menarche are both negatively associated with socioeconomic status in a large sample of low-income countries. While the exact biological mechanisms determining the age of puberty and the adolescent growth spurt are not fully understood, the trend over time and differences by income are thought to be driven by differences in nutritional status and disease exposure (e.g. Cole, 2003). Recent findings suggest that caloric deprivations in childhood activate particular receptors in the brain which delay the onset of puberty and the adolescent growth spurt, but also lead to a period of leg growth longer into early adulthood (Lam et al., 2021). Broadly, it seems likely that these cohorts had some kind of hormone or nutrient deficiency in adolescence — either due to a shock occurring during adolescence or an earlier shock that particularly affected biological processes related to puberty.

One intriguing way to view the findings is through an adaptive framework. This framework is based on work by human biologists (Gluckman et al., 2005; Gluckman and Hanson, 2006a,b), and outlined and applied to findings from the anthropometric history literature in Schneider (2017). Broadly, the idea is that many of the effects of responses to environmental shocks on human growth are adaptive, in the sense that they increase the chances of survival to reproductive age and of producing viable offspring. For example, the delayed adolescent growth spurt and subsequent

consistent with a long-run trend towards an earlier growth spurt Meredith (1964); Cole (2003).

catch-up growth leading to a similar final height in adulthood, observed for the 1960s cohorts, is the predicted adaptive response to a postnatal shock in this framework.

Interestingly, the pattern of growth for 1970s to 1990s and cohorts is approximately consistent with the predicted adaptive response to a prenatal shock in the adaptive framework. The logic here is that a negative shock in the prenatal period suggests that conditions are likely to be bad in the future. Therefore, an adaptive response is to speed up maturation to increase the probability of reaching reproductive age, but to reach a shorter adult height that will require fewer calories to maintain. This described pattern is similar to that found in the 1970s to 1990s cohorts: growth tempo sped up and age at menarche decreased, but adult height was unchanged — and may have declined for the cohort born in the 1990s. In addition to these adaptive responses to a prenatal shock, there is (debated) evidence that exposure to prenatal shocks also increase the risk of cardiovascular disease and other conditions (Barker and Osmond, 1986; Almond and Currie, 2011).

While much more research is needed, this interpretation paints a coherent and troubling story of health trends across American cohorts born since mid-century. It would suggest that a postnatal shock negatively affected cohorts born in the first approximately two decades after midcentury. These cohorts would then start to give birth themselves, and I have shown previously that they gave birth to lower birthweight infants (Reynolds, 2025); therefore, their depressed health could plausibly have led to a worsening of the prenatal health environment for cohorts born between the 1970s and the 1990s.

What could have been the underlying postnatal shock that negatively affected cohorts born in the first two decades after midcentury? In previous work, I presented evidence against a number of ex ante plausible causes of the broader cohort health decline but was unable to find a smoking gun (Reynolds, 2023, 2024, 2025). I suggested that two remaining broad candidate hypotheses were the most plausible. The first broad hypothesis is that the complex demographic process of the baby boom led to the cohort decline — for example, through "cohort crowding" (eg. Freeman, 1979; Easterlin, 1987; Bound and Turner, 2007; Macunovich, 2002) and birth order effects. The second candidate hypothesis is prenatal exposure to lead pollution from motor vehicle exhaust, discussed in detail in Reynolds (2024).

Do the new findings in this paper, that the adolescent growth spurt and puberty were particularly affected, shift the weight of evidence for or against either of these hypotheses?

In my view the new findings provide additional evidence against traditional cohort crowding mechanisms. The key cohort crowding mechanisms discussed in the above literature — such as decreased educational investment due to crowding and worsened labor market outcomes due to "oversupply" — appear unlikely to affect adolescent height.

However, baby-boom-related causes more focused on family size and birth order come out looking stronger. For example, the idea that increased birth rates and larger family sizes led to a worse infectious disease environment appears worth exploring. The average birth order, or "parity," across cohorts changed sharply with the baby boom, and, as I have discussed in previous work, could be a plausible contributor to the cohort health decline. There is a large body of literature documenting the effects of birth order on adult height. A common finding is that later-born children are shorter than their earlier-born siblings, with the comparison made within-family to control for other family specific factors correlated with family size (e.g. Hermanussen et al., 1988; Hatton and Martin, 2010; Myrskylä et al., 2013). There is a smaller literature on the effect of birth order on the adolescent growth spurt. I found two studies which find that first-born children are taller in adolescence and further along in pubertal development than later-born children, but they do not contain sibling samples and therefore cannot control for unobserved family specific factors (Wells et al., 2011; Kwok et al., 2016). Two prominent mechanisms have been suggested as driving birth-order effects on other outcomes, respiratory disease spillovers within the family (Daysal et al., 2021) and decreased parental health investment (Pruckner et al., 2021), seem to quite plausibly have the potential to affect adolescent growth and development as well.

This paper's new findings on adolescent height and delayed puberty also seem to strengthen the argument for lead pollution as a potential cause of the cohort health decline. Motor vehicle use began to increase rapidly after 1945, and lead additives were ubiquitous in gasoline. By the 1960s children across the US had blood lead levels well above those now considered safe. For example, McFarland et al. (2022) estimate that the share of children with blood lead levels above the 2015 threshold for "clinical concern" was 50 percent for the 1940-45 cohorts and reached 100 percent by the 1966-75 cohorts — meaning every single child's blood lead content was above this threshold. Prenatal and early life lead exposure is thought to have broad and lasting negative health effects, impacting for example the development of multiple organ systems, cognitive ability and emotional regulation, and cardiovascular disease.[17]

Importantly, lead exposure has also been linked to delayed puberty and slower adolescent growth. Lead is thought to be an endocrine disruptor that can affect the hormones that control puberty and the adolescent growth spurt. therefore affect the . A large number of studies have shown that adolescenct boys and girls with higher blood lead levels, measured either contemporaneously or in early childhood, are shorter and have delayed pubertal development.[18]

Additionally, the lead phaseout appears to coincide with gains in childhood and adolescence.

[17] See for example McMichael et al. (1986); Needleman (2004); McFarland et al. (2022); Hollingsworth et al. (2022); Aizer et al. (2018) on the health and cognitive effects of prenatal and childhood lead exposure.

[18] See for example Selevan et al. (2003); Wu et al. (2003); Hauser et al. (2008); Naicker et al. (2010); Sergeyev et al. (2017); Liu et al. (2019).

Lead additives were phased out of gasoline beginning in the 1970s, and blood lead levels of children fell rapidly. The results of this paper show that childhood growth and adolescent growth and development also improved for these cohorts. However, as noted above, completed adult height remained stagnant, and many other measures of health and human capital were stagnant or falling. As described above in the context of the adaptive framework, perhaps the mechanism driving outcomes for the 1960s cohorts was different than those which drove subsequent cohorts: lead exposure drove delayed puberty and poor outcomes in adulthood for the 1960s cohort; 1970s to 1990s cohorts were less exposed to lead, allowing their pubertal development to rebound, but the underlying prenatal shock of being *born to* lead-exposed cohorts led to stagnant final height and other poor outcomes in adulthood.

9 Conclusion

Previous research has shown that growth in adult height stagnated in the US for cohorts after midcentury, and that health and human capital declined more broadly for the same cohorts. This paper has shown that beginning with approximately the same cohorts the long-run trend towards earlier puberty suddenly reversed, as evidenced by boys adolescent heights and girls age at menarche. However, this reversal was only temporary, and adolescent height and age at menarche have rebounded for cohorts born since 1970. Perhaps surprisingly, adult heights did not increase for these cohorts. These findings have important implications for our understanding of the broader decline in health and human capital.

I argue that the findings in this paper strongly suggest that the declines in adult outcomes for Americans born after mid-century have their roots in adolescence, or earlier. More speculatively, viewing the results of this paper and my past work through the lens of the adaptive framework of human growth would suggest that: i) there was a progressively worsening negative factor affecting the *postnatal* environment between roughly 1950 and the 1960s, and ii) the postnatal environment may have improved, but the *prenatal* environment worsened for the 1970s, 1980s, and the 1990s cohorts. Plausibly the cause of the worsening of the prenatal environment could have been simply driven by the fact that post-1950 cohorts were now giving birth and had worse maternal health than earlier-born cohorts.

Further research is needed to falsify, substantiate, or complicate this specific narrative. For example, it would be useful to compile data allowing one to analyze the growth patterns of children born in the 1970s through 1990s separately based on when and where their parents were born. Additionally, searching for the particular negative exposure that could have caused the unusual cross-cohort patterns documented in this paper and past work, remains paramount.

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Appendix Table 1: Sample sizes by birth cohort and age group, males with recorded height

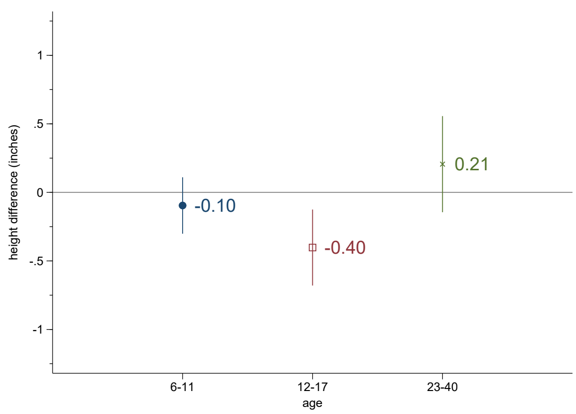
	Age Group		
Birth Cohort	**6-11**	**12-17**	**22-40**
1951-1957	3045	3337	1339
1961-1967	1186	863	1235
1970-1979	565	807	2282
1980-1989	1338	2066	1979
1990-1999	2182	2628	530

Reports the number of male observations with a recorded height, by age group and birth cohort group from the combined sample based on multiple rounds of NHES and NHANES surveys.

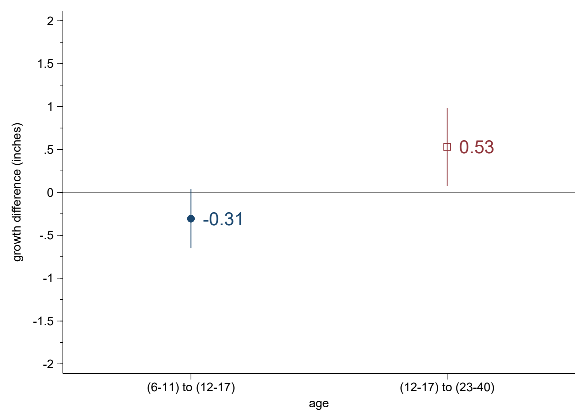
Appendix Figure 1: Regression estimates of height and growth differences, American-born males by race, 1951-1957 vs. 1960-66 cohorts

Non-hispanic whites

(a) Height difference

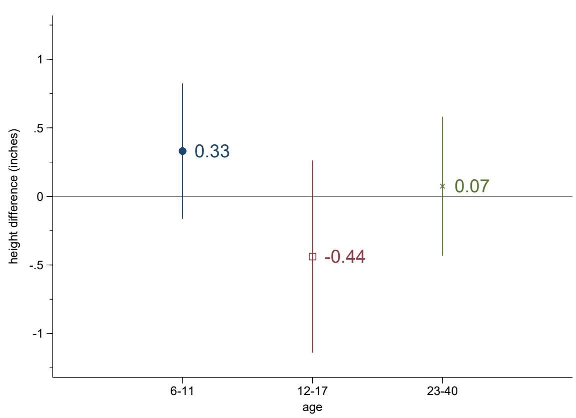


(b) Growth difference

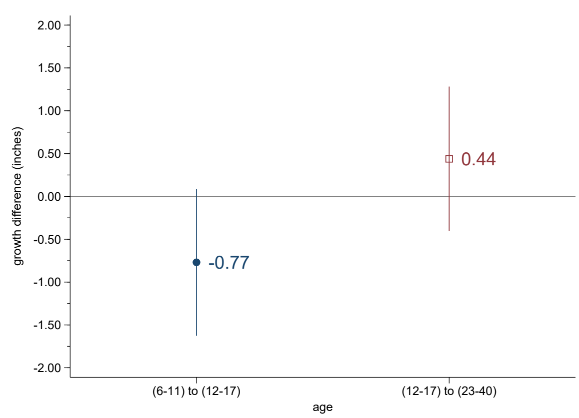


Non-hispanic blacks

(c) Height difference

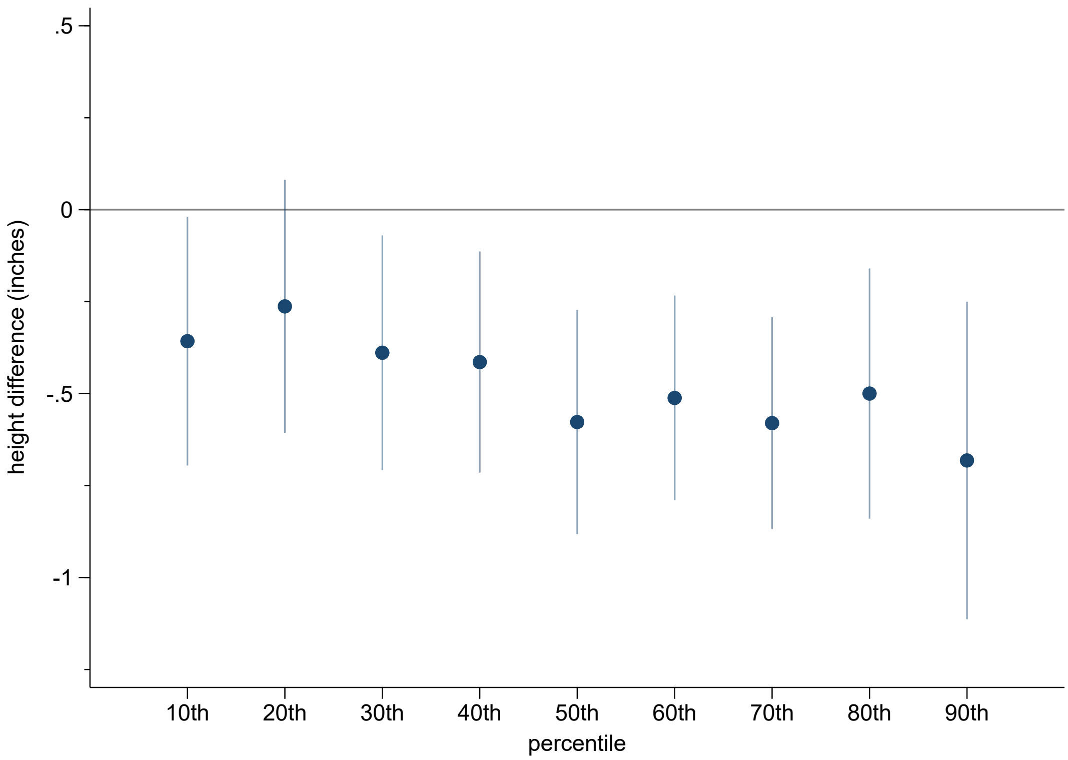


(d) Growth difference



All panels use data from multiple rounds of NHES and NHANES surveys. Panels A and C show estimates of the height difference of the listed cohorts at different ages. Panel B and D show estimates of the difference between the listed cohorts in implied growth between different ages. All estimates comes from regression described in Section 2 which, for those ages 6 to 17, control for fixed-effects for single-year-of-age and a quadratic in age-in-months.

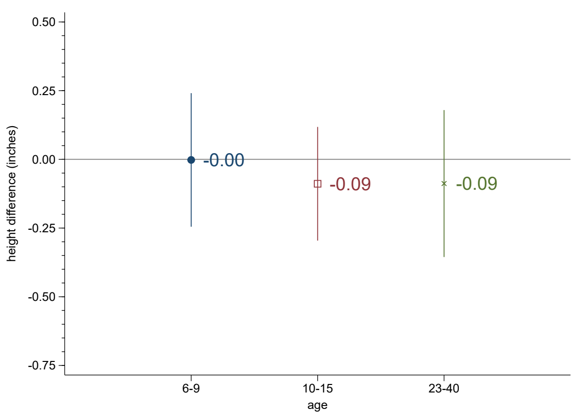
Appendix Figure 2: Quantile regression estimates of adolescent height differences, American-born males, 1951-1957 vs. 1960-66 cohorts



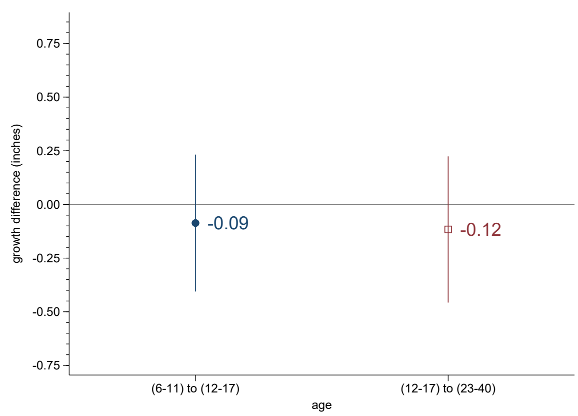
All panels use data from multiple rounds of NHES and NHANES surveys. Each point show estimates of the height difference of the listed cohorts at ages 12 to 17, at the listed percentile. Each estimate comes from a separate quantile regression, following the specification described in Section 2 which controls for fixed-effects for single-year-of-age and a quadratic in age-in-months.

Appendix Figure 3: Alternate age categories, regression estimates of height and growth differences, American-born females, 1951-1957 vs. 1960-66 cohorts

(a) Height difference

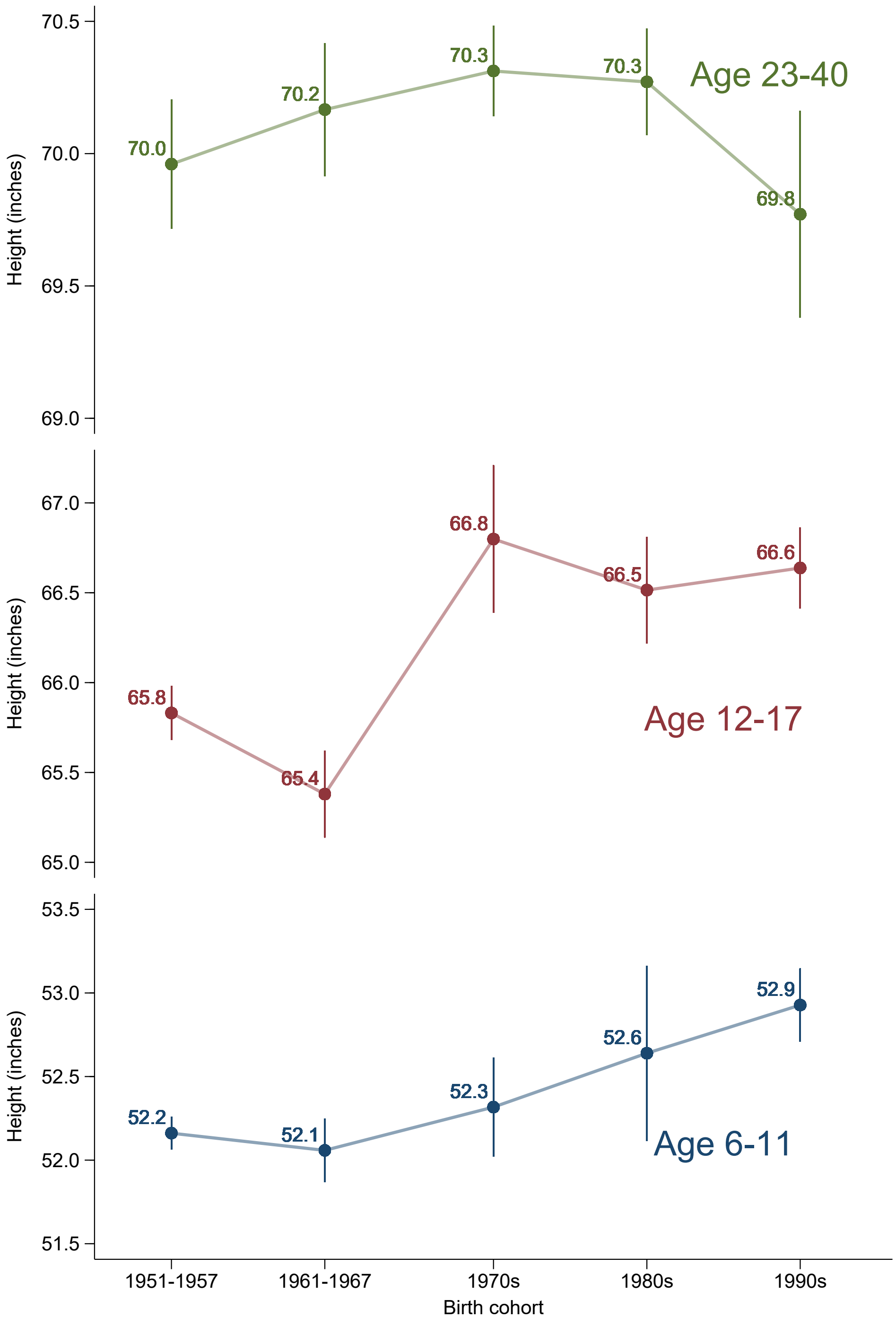


(b) Growth difference



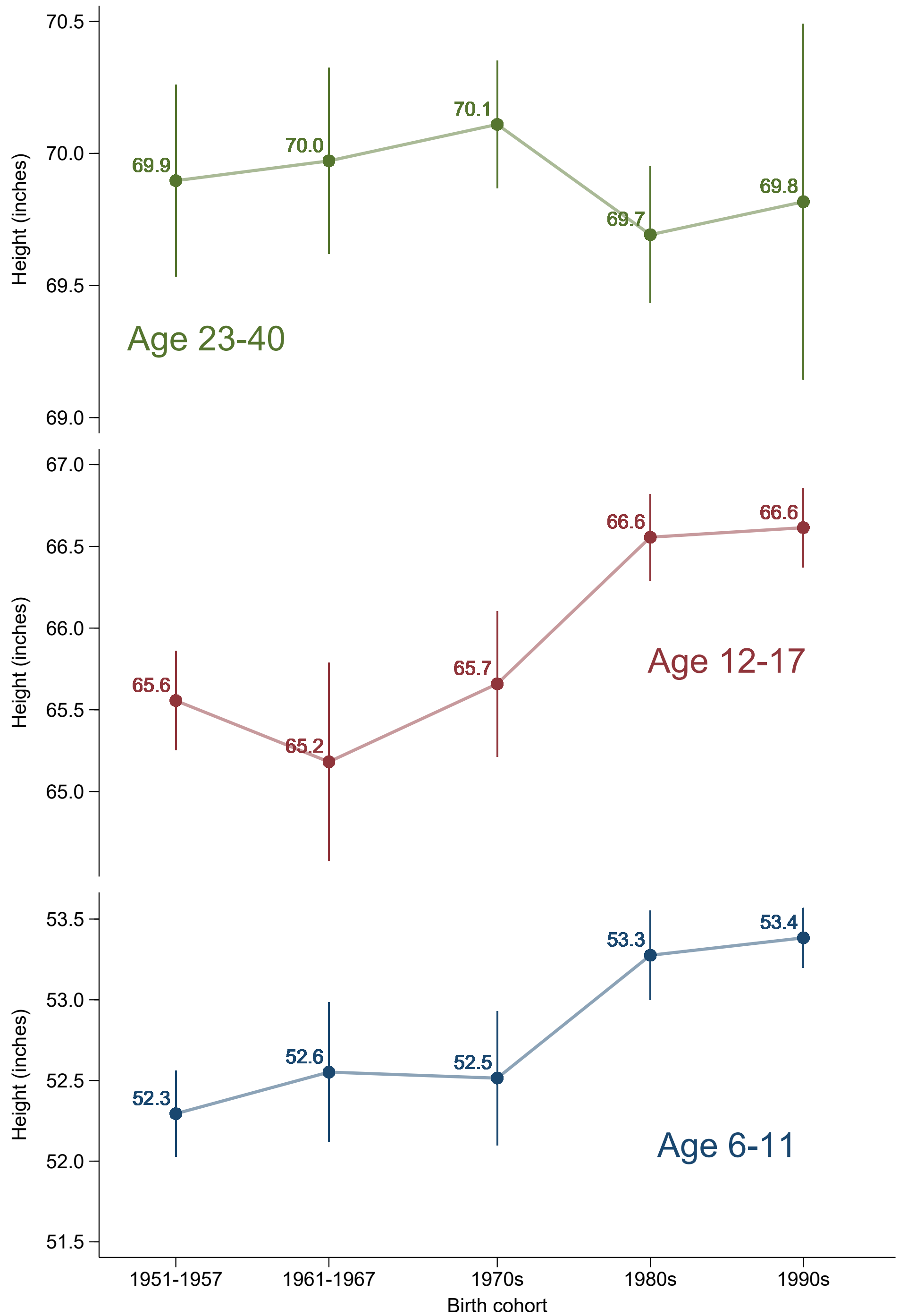
All panels use data from multiple rounds of NHES and NHANES surveys. Panel A show estimates of the height difference of the listed cohorts at different ages. Panel B shows estimates of the difference between the listed cohorts in implied growth between different ages. All estimates comes from regression described in Section 2 which, for those ages 6 to 17, control for fixed-effects for single-year-of-age and a quadratic in age-in-months.

Appendix Figure 4: Cross-cohort trends in height of non-Hispanic white males born in the US after 1950, by age



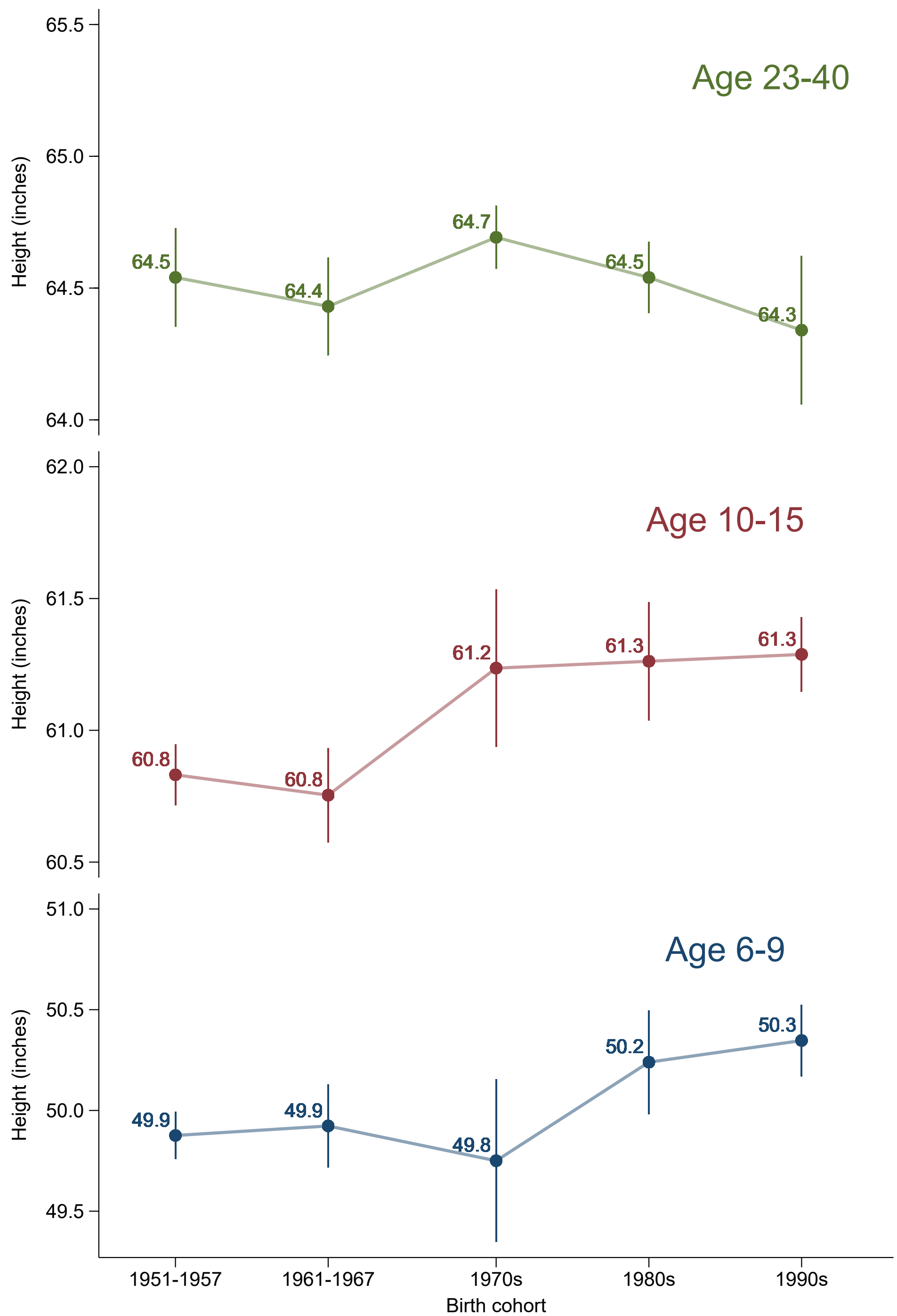
Uses data from multiple rounds of NHES and NHANES surveys. For each listed cohort group I first calculate means by single-year-of-age. For each listed age-group, I then take the simple average of these means across single-year ages. These age-group means are plotted for each listed cohort group. 95 percent confidence intervals for the age-group means are also shown. They were calculated by the delta method and take into account the sampling weights and survey design.

Appendix Figure 5: Cross-cohort trends in height of non-Hispanic black males born in the US after 1950, by age



Uses data from multiple rounds of NHES and NHANES surveys. For each listed cohort group I first calculate means by single-year-of-age. For each listed age-group, I then take the simple average of these means across single-year ages. These age-group means are plotted for each listed cohort group. 95 percent confidence intervals for the age-group means are also shown. They were calculated by the delta method and take into account the sampling weights and survey design.

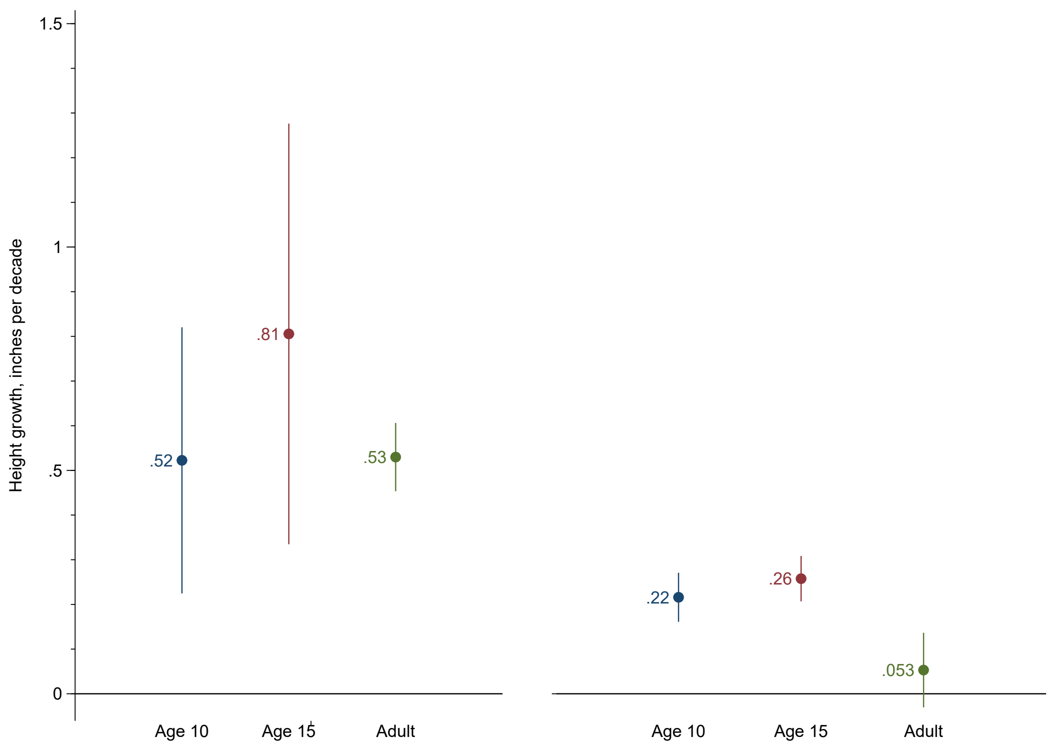
Appendix Figure 6: Cross-cohort trends in height of females born in the US after 1950, by age



Uses data from multiple rounds of NHES and NHANES surveys. For each listed cohort group I first calculate means by single-year-of-age. For each listed age-group, I then take the simple average of these means across single-year ages. These age-group means are plotted for each listed cohort group. 95 percent confidence intervals for the age-group means are also shown. They were calculated by the delta method and take into account the sampling weights and survey design.

Appendix Figure 7: Estimated cross-cohort trends in height of (North) American non-Hispanic white males born in the US, by age

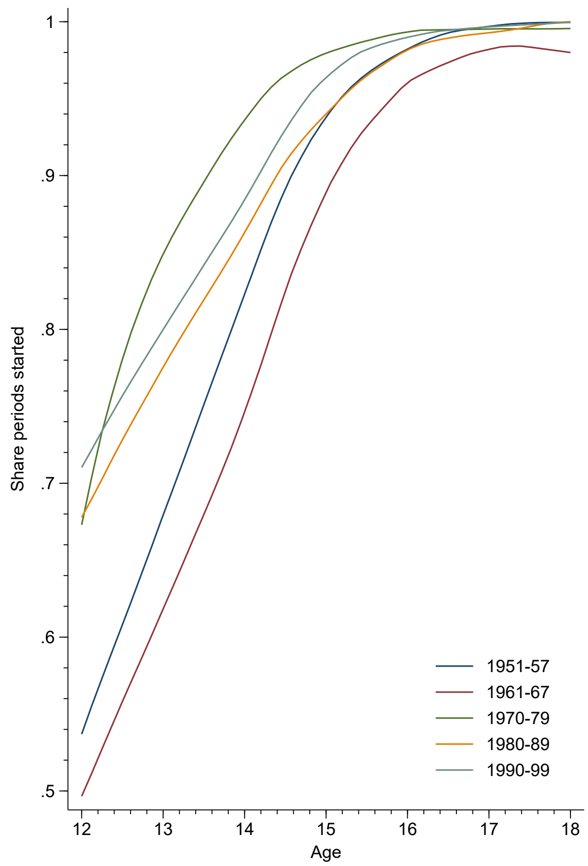
a) 1885-1950 cohorts **b)** 1950 to 2000 cohorts



Each point shows coefficient estimates of the cross-cohort trend in height for the listed age, associated 95% confidence intervals are shown with lines. The regressions in Panel A are based on various historical sources which are not random samples of the US population, described in more detail in Section 6. The age 10 and age 15 series are the average heights from the various historical studies complied in Meredith (1964). The adult series is based on various military samples, and comes from Costa (2015) and Bleakley et al. (2014), which updates Costa and Steckel (1997) and Fogel (1986). The regressions in Panel B are based on data from multiple rounds of NHES and NHANES surveys, which are designed to be random samples of the US population. The age 10 estimate reports the coefficient on year-of-birth in a regression which pools boys age 6 to 11, and controls for age-in-years fixed effects and a quadratic in age in months. The age 15 series comes from an analogous regression which pools boys age 12 to 17. The adult esimate reported comes from the sample of men aged 23 to 40.

Appendix Figure 8: Menarche, contemporaneous reports for additional cohorts

Share of girls whose periods have started, by age



Each line shows moothed estimates of the share of native-born girls reporting having had their first menstrual period by age for the listed cohorts of American-born females between ages 12 and 17. The lines come separate kernel regressions of a menarche dummy on age in months, with a Epanechnikov kernel and a bandwidth of 12 months.