Late Growth and Maturity Patterns at the turn of the 20th-Century Corrèze*

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Abstract

The height of conscripts around the age of 20 is widely used as a proxy for well-being in historical periods, under the assumption that it reflects nutritional and health conditions during growth years. This approach may be problematic if individuals are not yet fully grown at conscription age. This paper addresses this concern by constructing an individual-level panel of 2,916 men born in 1887 in Corrèze, using two nineteenth-century French conscription records. The data show that, for most men, height increases by only 0.3 to 0.4 cm in the year following their 20th birthday. However, the subset of the 20% of men identified as the most physically vulnerable continues to exhibit significant growth, gaining an additional 1.5 cm before reaching adult height around age 27. These findings suggest that relying on height at age 20, rather than adult stature, can lead to underestimation of available resources and an overstatement of inequality in their distribution.

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Résumé

La taille des conscrits autour de 20 ans est fréquemment utilisée comme indicateur du bien-être dans les périodes historiques, en supposant qu'elle reflète les conditions nutritionnelles et sanitaires durant la croisance du jeune homme. Cette approche peut poser problème si les hommes n'ont pas encore atteint leur taille adulte au moment de la conscription. Cet article discute ce point en construisant un panel individuel de 2,916 hommes nés en 1887 en Corrèze, à partir de deux sources de conscription françaises du XIXe siècle. Les données montrent qu'en moyenne, la croissance au cours de l'année suivant le vingtième anniversaire reste modeste, de l'ordre de 0.3 à 0.4 cm. La plupart des hommes seraient donc proches de leur maturité. Toutefois, les 20% identifiés comme les plus fragiles continuent de grandir, gagnant en moyenne 1,5 cm supplémentaires avant d'atteindre leur taille adulte, vers 27 ans. Ces résultats suggèrent que les inférences basées sur la taille à 20 ans, plutôt que la taille adulte, peuvent conduire à sous-estimer les ressources disponibles et à surestimer les inégalités dans leur répartition.

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Introduction

In the absence of reliable economic data, height is frequently employed as a proxy for well-being, as it reflects net nutrition, the balance between food intake and energy expenditure, following studies by Villermé (1829), Aron et al. (1972) or Fogel (1984). For historical periods, it is easily accessible in many countries through military statistics, which record the height of men around the age of 20 as part of military service. Nowadays these sources are commonly exploited with a cross-sectional methodology to infer changes in available resources from differences in the height of 20-year-old men born in different years.

A continuing process of late growth beyond age 20 would raise concerns for cross-sectional inferences, as two cohorts with the same height at age 20 but different adult statures could have experienced different living conditions. Height at age 20 would become even more difficult to interpret when accounting for the secular trend toward earlier maturity and greater adult height. As a snapshot of physical development, it is correlated with adult height but it is also influenced by the *tempo of growth*, leading to a lower signal-to-noise ratio compared to adult height.

Large-scale longitudinal (or panel) records on height, which follow the same individuals over time, only became available from World War I in the United States and World War II in Europe (Tanner, 1981). They usually locate growth cessation around the ages of 16 or 17 for males.[1] It is likely that growth beyond these ages was substantial prior to the twentieth century, as some contemporaries advocated postponing military service in order to reduce exemptions based on short stature. However, the high cost associated with collecting longitudinal data implies that we lack precise information on late growth and maturity for these earlier periods. Cross-sectional analysis suggests that maturity could have been reached beyond the age of 20 (Tanner, 1981). But it should be used cautiously as a substitute for longitudinal studies, as averaging heights of different individuals can be misleading, especially if the sample includes individuals selectively rather than randomly (Schneider, 2020). A more mixed picture emerges from the few identified longitudinal series for the nineteenth century. For instance, maturity was reached before age 20 in the sample used by Bowditch (1891), while Quetelet's son in Quetelet (1870) and Norwegian men in Kiil (1939) were still growing at that age.

The representativeness of these small longitudinal samples is questionable. Beekink and Kok (2016), Thompson et al. (2020) and Donald et al. (2023) are the only modern studies that inform us on late height growth in the nineteenth century using

[1] This is 17.5 years for the average boy in North America and north-west Europe, with a confidence interval of $\pm$ 2 years; see, e.g., Tanner (1978), Chapter 1, Post-adolescence growth.

substantial-sized longitudinal samples.[2] The first two find that Dutch conscripts grew by nearly 5 cm between the ages of 19 and 25. A 20-year-old conscript measured at 169 cm in 1900 would thus have reached 174 cm by age 25, which was the average height of a 20-year-old Dutch conscript measured 50 years later, in 1950 (Chamla, 1964). Donald et al. (2023) also report significant growth between age 20 and full maturity, possibly reached after age 26, for British and Irish male teenage convicts transported to to nineteenth-century Australia.

This article adopts an approach similar to that of the studies on Dutchmen to build an individual-level panel on the height of men born in 1887 in Corrèze, a poor rural area of France. This panel reveals late growth beyond age 20 that may challenge conclusions drawn from height-at-20 data when sources are analyzed separately within a cross-sectional framework.

This panel includes all men alive at age 20, provided they meet a residency criterion. Given infant mortality and rural exodus at that time, it is probably affected by endogenous sample selection that cannot be addressed using military data alone. One can, however, address another type of endogeneity, which relates to the timing of the last height measurement. In the French conscription process, this measurement was taken later for those deemed least fit for military service, who may have had the weakest growth potentials. The factors influencing aptitude assessments are partly unobserved by the researcher today, which gives rise to endogeneity. The paper deals with this issue by using an instrumental variables approach, leveraging heterogeneity in leniency assessments of military fitness, following the pioneering work of Kling (2006). This approach is complemented by a switching model à la Heckman (1976) to estimate quadratic growth curves from age 20 to maturity.

We find that approximately 80 percent of men would have experienced a moderate height gain of less than 1 cm before reaching their adult height, likely around ages 22 or 23. The others would have shown delayed growth until age 27, with an estimate of the average height gain of 1.5 cm before maturity, growing from 160.8 cm to 162.3 cm, thereby partially catching up with their more privileged peers. We argue that the resources available to the less privileged segment at age 20 might be better assessed by referring to the height of different 20-year-old men, who were actually measured at least 11 years later by the military and were taller than the Corréziens we consider. These estimated growth episodes extend actual curves of the shortest modern French

[2]The growing literature using individual-level longitudinal height data includes Gao and Schneider (2021), which documents the growth of British children aged 10 to 18 (thus younger than typical conscripts) over more than a century from the 1850s. See also Persaud (2023) for addressing measurement errors in height data on Indian laborers who migrated to Trinidad in the late 19th century.

men within the first decile of the height distribution. These findings imply that the resources available to these men may be underestimated when researchers rely on their height at age 20, and that inequality in their distribution may have been more equal than commonly assumed.

1 Longitudinal height data for conscripts

The Maurice Berteaux Law, passed on 21 March 1905, provides that a conscription board (*conseil de révision*) had to evaluate the military service eligibility of all men in the year following their 20th birthday. All men of a *canton* (a French administrative subdivision grouping several communes or municipalities) were examined sequentially during half a day session at the start of every year. A man was considered domiciled in the canton if his legal guardian (usually his father) lived there. Emigrants could be reviewed where they lived, but if domiciled in the canton, information had to be sent to this canton, which remained the sole decision-making authority.

A total of $2,916$ men were reviewed in 1908 in the 29 cantons of Corrèze, a rural *département* (a division roughly equivalent to a county), starting on February 18 with the canton of Ayen and ending on April 13 with that of Eygurande.[3] The statistics in the *Tables du Mouvement de la Population* give $4,541$ boys born in 1887 in Corrèze, so that $1,625$ men are missing in 1908. Attrition results from mortality before reaching age 20 or rural exodus migration. The Tables report that 532 out of the $4,541$ boys died before reaching age 1, and approximately 450 between ages 1 and 19, suggesting that mortality was the primary cause of attrition.

Poor conditions prevailed during this period. The price of rye, the main cereal produced, fell sharply following the Great Crisis at the end of the nineteenth century, and local markets were almost deserted in 1908. The Russian flu affected the region from 1890 to 1898, and typhoid fever remained endemic. All these factors may have reduced height due to scarring, whereas higher mortality risks among shorter men (Bozzoli et al., 2009) and shorter migrants would instead have implied a bias in favor of taller individuals. It is difficult to address these issues without individual data on local mortality and migration. Our results should accordingly be interpreted as applying to the presumably endogenous sample of men who were alive at age 20, considered by the military as domiciled in Corrèze, and who had likely faced adverse environmental conditions.

[3]Each canton typically includes around ten municipalities. It is part of an *arrondissement*, and several arrondissements form a département, a larger administrative division. By the late 19th century, the département of Corrèze had 289 municipalities, 29 cantons and 3 arrondissements (Brive, Tulle, and Ussel).

This sample is nearly comprehensive. Height was taken for almost all men during the review in 1908 and recorded in the recruitment table (*tableau de recrutement*). Those deemed fit were enlisted (*incorporés*) in the fall of that year. Others were either exempted (*exemptés*) or discharged (*ajournés*). A military Instruction dated 29 December 1905 orders that exemptions be applied to men who are 'truly incapable, without hope of improvement, of enduring the rigors of service.' In principle, those exempted were never to join the army, but the cohorts just before WWI were recalled, and many of them eventually enrolled during the war. Men discharged in 1908 instead were provisionally exempted pending re-examination in the following year. If deemed fit in 1909, they were enlisted in the fall of 1909. Otherwise, they were granted a permanent exemption, subject to the same recall caveat.

An individual registration form (*fiche matricule*) was created for every man not exempted in 1908, and for those exempted but recalled later. It was used to track men over a 25 year period of service. It contains socio-demographic and anthropometric information including height.

The recruitment table and registration forms pertain to different points in time, respectively before and after the selection into military service. Figure 1 shows that height information on men born in 1887 and reviewed in 1908 in Corrèze differ in these two sources. The differences are structured around a clear pattern, with a deficit of men in the registration forms compared to the recruitment table for every height below the peak at 163 cm, and an excess for heights above 163 cm.[4]

Height of men who did not appear before the board is missing in the recruitment table, while no registration form exists for men exempted in 1908 and never recalled. Nevertheless these coverage differences alone cannot fully explain the discrepancies, as there are still 20% of men with two height measurements that differ from each other.

Insert Figure 1

Measurement errors exist, but they are difficult to reconcile with the regular rightward shift shown in Figure 1. Such a pattern can be rationalized by considering height growth. To see this, suppose that every man experiences a 1 cm gain in height between the review board examination and the moment when his height is recorded in the registration form. Then, a number n_h of men measured at height h cm during their first examination translates into n_{h-1} men at height h cm in the forms (they

[4] There is no truncation at the bottom, as no minimum height was required since 1901 in France. Concentrations at 150 cm, 160 cm, and 170 cm may be due to rounding or manipulations to meet height requirements for certain army units. Figure 2 suggests that these anomalies lead to underestimated growth at 151 cm and 159 cm.

were $h - 1$ cm tall initially). A deficit of $n_h - n_{h-1}$ men for every height h below the peak of 163 cm follows from the single-peaked shape of the distribution from the recruitment table. In counterpart, the same argument leads to an excess of men for heights in the right tail of the distribution.

The date of the first measurement appears in the recruitment table. The height in the registration form may have been taken during two additional inspections conducted after the conscription board. Those deemed fit were first subjected to the departure examination (*visite de départ*) within the recruitment office (*bureau de recrutement*) that handled the allocation of men to military units. Then, in the following days, they were subjected to a new inspection, the enlistment examination (*visite d'incorporation*) within the assigned unit (Roynette, 2000).

The registration forms were issued by the recruitment office, suggesting that the height recorded may have been taken during the departure examination.[5] However, the exact status of this information remains unclear: while the military regulations appear to permit the recruitment office to simply copy the height recorded during the review board examination,[6] they can also be interpreted as requiring a new measurement to be taken within the recruitment office. The 'On Physical Aptitude to Military Service' military Instruction dated 22 October 1905 states that 'young men deemed fit are allocated by recruitment office commanders to the different military units according to their physical and professional abilities $(\cdots)$. The main physical requirements are: height, ability to walk, horse riding abilities and capacities to handle heavy loads. The first of these requirements $(\cdots)$ must be assessed using a graduation measuring rod' that the office was required to have.

In what follows, we will consider that the height recorded in the forms was taken during the departure examination.[7] Unfortunately, the data does not include the date of the departure examination. We will use the enlistment date, recorded in the form and closely following the examination, to approximate the second measurement date.

Combining data from the recruitment table and registration forms gives a longitudinal individual-level panel with two different height measurements after age 20,

[5]The register that compiles the registration forms states that the 'recruitment office commander must start the registration as soon as possible' after the selection of draftees by the review board.

[6]Article 17 of the military Instruction dated 29 December 1905 specifies that the commander is assisted during the review board by an officer 'responsible for recording the height $[\cdots]$ of the young men examined.' And Article 16 indicates that 'using this document [the recruitment table], which will later serve to establish the register compiling the registration forms $[\cdots]$, the recruitment office commander $[\cdots]$'

[7]Other practices may have been used elsewhere. For instance, Maurin (1982) suggests a single measurement in Hérault and Lozère.

one during the conscription board examination (reported in the recruitment table), and the other around the time of actual enrollment (in the registration form). Coverage differences leave us with $2,587$ out of $2,916$ men with recorded height in the two sources.

Almost all measurements were taken before leaving for military service, ensuring that changes in stature between the two points of measurement cannot be attributed to the military environment, such as better nutrition or improved hygiene conditions. The only exceptions are some men re-measured after enlistment, so that their form contains both the height recorded during the departure examination and a revised height (*taille corrigée*). To exploit this information, we created new observations that link the height taken during the review board examination and this revised height. This increases the sample size to $2,691$ observations with two measurements.

Individual height differences range from -15 cm to $+23$ cm in the $2,691$ observation sample. Our empirical analysis uses the subsample of $2,425$ observations that excludes the bottom and top 2.5% of the height growth distribution and all 149 volunteers. Extreme growth over a short period is due to measurement errors, while negative growth is inconsistent with our assumption that the height recorded on the forms was taken after the conscription board measurement, except possibly for volunteers, who should have been recorded as shorter at enlistment, as they joined before the call-up. However, the data show zero growth for most volunteers and an overall positive average height gain. It is possible that new registration forms were created for them in 1908, with their initial enlistment date but an updated height, though we have no information on the exact timing of this new measurement.

Insert Table 1

Table 1 provides summary statistics on the $2,425$ observation sample. Height differences now range from -2 cm to 9 cm. It is hoped that the remaining errors balance each other out. Men enlisted after 1908 appear shorter initially, but their total growth is greater than that of men enlisted in 1908. The opposite is observed annually, where the shortest men grow the least. This suggests that men enlisted later have lower growth potentials but continue to grow for several years after the conscription board to (partially) catch-up 1908 enlistees.

2 Height gains in late growth stages

In order to provide a quantitative assessment of growth following the review board examination, height h_{it} (in cm) of man i at time t is assumed to fit

$$h_{it} = \gamma_i + \beta a_{it} + \varepsilon_{it} \tag{1}$$

where a_{it} is the age (in year) of the man at time t, and γ_i captures all fixed characteristics of man i that are relevant for late growth, e.g., genetic factors, chronic illness, permanent disability, family traditions or wealth. The variable t takes value 0 when the man is reviewed in 1908 and value 1 at enlistment. The error term ε_{it} accounts for omitted variables that may be specific to individual i but vary over time. Examples could include income or health changes. The parameter of interest is β. It gives the average growth over one year from the review board examination.

Many characteristics in γ_i are not reported in the military data. One can get rid of them by time-differencing (1), which leads to

$$\Delta h_i = \beta \Delta a_i + u_i \tag{2}$$

where $\Delta h_i = h_{i1} - h_{i0}$ represents the height growth of man i over the $\Delta a_i = a_{i1} - a_{i0}$ time period that starts from the review board examination. The new error term u_i is the difference between ε_{i1} and ε_{i0}.

The specification (1) is clearly restrictive. In particular, it does not allow for variations in growth based on initial height. It also assumes a constant maintained growth, which may be accurate over a short period but not over a longer period when growth has to gradually slow down. These limitations are addressed in Sections 2.2 and 2.3.

2.1 Short-run growth after age 20

Table 2 reports an Ordinary Least Squares (OLS) growth estimate of β based on (2) that is 0.21 cm, with a $[0.177, 0.241]$ cm confidence interval. Men enlisted in 1908 are assessed with a 0.44 cm growth over one year, while those discharged in 1908 and enrolled in 1909 experience a growth of 0.30 cm only. Those initially exempted but recalled during the war show an even lower height gain that depresses the global estimate.

Insert Table 2

The reliability of OLS depends on the exogeneity of the Δa duration. Exogeneity holds if $\mathbb{E}[u \mid \Delta a]$ in (2) remains constant as Δa varies. Otherwise, the effect on growth of a one-year increase in age does not solely reflect β but also includes an impact through the disturbance term u. The OLS estimate, which accounts for both effects, is then biased: it either over- or under-estimates the true causal effect β of aging on height.

In our context, endogeneity concerns arise because Δa is determined by the decision of the conscription board to either enroll men in the fall or discharge or exempt them. This decision was based on an assessment of fitness for military service. Those deemed temporarily unfit were re-examined the following year. Therefore, if a temporarily weakened state of health, omitted in (2), both increases the likelihood of discharge (leading to a higher Δa) and reduces growth (resulting in a lower u), the OLS estimate, which does not account for this correlation, suffers from downward bias. The true causal effect of aging on height would then be greater than the OLS estimate suggests.

Cross-sectional analysis based on (1) with γ_i replaced with a constant term independent of individual characteristics can be used to illustrate this concern. Regressing height h_{i0} at the first measurement on age a_{i0} at that moment yields a growth of 1.03 cm per year. In this regression, initial age thus can be considered exogenous, i.e., $\mathbb{E}[\varepsilon_0 \mid a_0]$ does not vary with a_0 in (1) at $t = 0$, since the military administration scheduled review sessions based on minimizing transportation costs between cantons, independently of the individual characteristics of the men being examined. However, a similar cross-sectional regression of h_{i1} on a_{i1} at the second measurement yields an implausible negative growth estimate of -0.41 cm per year. We regard this result as a consequence of the legal recommendation to discharge men in poor but recoverable health, while exempting those deemed permanently unfit for service. Namely, if men with weaker growth potentials were more often deferred, then $\mathbb{E}[\varepsilon_1 \mid a_1]$ decreases with a_1 in (1) at $t = 1$, leading to shorter heights among those measured later.

This points to a final age that is not exogenous, with ε_1 and a_1 negatively correlated in (1). Health status and recovery potentials, which are only partially observed by the researcher today, thus enter the disturbance term u and render Δa endogenous in (2).

We first deal with endogeneity of Δa using an instrumental variable (IV) strategy. The idea is to find a variable (referred to as the instrument) that explains the decision to postpone enrollment without relying on factors that influence growth and are omitted in (2), thus contributing to u disturbance. The part of the time interval Δa between the two measurements that is explained by the instrument is presumably exogenous (it is independent of u). Height growth attributable to this part can then be considered unbiased.

Our main instrument derives from the Berteaux Law, which stipulates that the Chairperson of the conscription board must be the Prefect (*préfet*), the representative of the central government overseeing the administration of the département. In 1908, the Prefect was Georges Calmès, a short man in frail health who had previously been exempted from military service. If unable to attend a session, the chairmanship was delegated to the Secretary (*secrétaire général*), Charles Filhoulaud in 1908. Table 3 shows that Calmès was more inclined to postpone decisions than Filhoulaud. In the full sample considered in Column (1), the time between the two measurements is extended by nearly 5 months when Calmès chairs the conscription board. Additional checks in Appendix A suggest no obvious reason why the presence or absence of the Prefect would relate to individual growth potentials. Formally, the identity of the Chairperson is correlated with Δa while presumably uncorrelated with unobserved factors contributing to height growth embodied in the disturbance term u.

The sample of 2,425 observations includes both men enlisted in 1908 and those enlisted beginning in the autumn of 1909. Those deferred in 1908 may have been enlisted in 1909 or during the WWI recall waves of 1914, 1915, and 1917. Results in Column (4) of Table 3 show that Calmès influences the time between measurements for men recalled during the war but has no effect within the subsample of men enlisted by 1909.

Column (5) suggests that initial age can be used as instrument in the subsample of men enlisted in 1908 or 1909, following the approach of Angrist and Krueger (1991). The argument relies on the fact that the scheduling of review sessions can be considered exogenous, and that these sessions took place over a short period at the beginning of the year. It follows that, for presumably exogenous reasons, men born early in 1887 were older at the time of the initial 1908 review. Column (5) indicates that older men at the time of the initial 1908 review were less likely to have their examination postponed to the following year.

To summarize, the presence of the Prefect primarily influences the outcome of whether men are enlisted before or after 1909, whereas initial age affects the deferral decision for men who will be enlisted in 1909. This distinction should not hide the fact that it does not correspond to a precise categorization of men deferred in 1908. Indeed, when the discharge decision is made in 1908, it remains uncertain whether the man will be enlisted or exempted in 1909, as that decision will be made by the board the following year.

Insert Table 4

Table 4 reports IV growth estimates when Δa is instrumented using the Chairperson and/or initial age. Annual growth is revised upward to 0.303 cm, with a $[0.249, 0.357]$ confidence interval in the full sample. The higher 0.414 cm growth in men enlisted in 1908 or 1909 reported in Column (5) shows that the review board effectively identified and excluded the weakest men from the Army. These excluded men would not have been re-measured were it not for WWI. Thus, under normal circumstances, they would not have appeared in the database, and their small annual growth would have gone unnoticed. However, as discussed in Section 2.3, it is possible they experienced a greater total growth between 1908 and the war, making their recall and incorporation feasible.

Our estimates are consistent with those reported in Donald et al. (2023), which show that British and Irish convicts transported to Australia in the late nineteenth century have grown by $2.21/5 \simeq 0.44$ cm per year between the ages of 20 and 26. They are much smaller than those in Beekink and Kok (2016) and Thompson et al. (2020), which measured Dutchmen at ages 19 and 25 in the early nineteenth century. The Dutch, with a similar average height at 19 (163.4 cm *versus* 163.79 cm in Table 1), grew 4.3 cm over six years, which is about 0.7 cm per year. The next sections explore richer specifications that could account for higher growth in specific population segments in Corrèze.

2.2 Catching-up of late maturers

The literature indicates that children in the twentieth century who were exposed to developmental delays resulting from adverse environmental conditions frequently exhibited catch-up growth, eventually narrowing the gap with their more privileged peers (see, e.g., Case and Paxson, 2010 or Schneider et al., 2021). In our context, the fact that results from the cross-sectional methodology applied at the time of initial measurement differ from the longitudinal estimates suggests that height does not change linearly with age at the same rate for all individuals. Our first departure from Equation (2) relaxes the assumption of a fixed uniform growth regardless of initial height. We consider the variant of specification (2),

$$\Delta h_i = \sum_d \beta_d \Delta a_i \times \mathbb{1}_{id} + u_i \tag{3}$$

where $\mathbb{1}_{id}$ equals 1 if conscript i is d cm tall in the recruitment table, and 0 otherwise. The β_d coefficient represents the annual height growth of men who were d cm tall at the time of the first examination.

Insert Figure 2

Figure 2 depicts IV growth estimation results using the Chairperson instrument in the $2,425$ observation sample. All men continue to grow after the 1908 review, except those over 170 cm. We conclude that most zero-growth observations in the sample are likely part of incomplete growth sequences, either because growth is too small to be measured accurately or because the sequence is taken from a short observation period, rather than due to a lack of growth.

Catch-up growth follows from shorter individuals exhibiting greater growth. Men measured below the peak of 163 cm grow by 0.437 cm over a year. The shortest men below 152 cm grow by 0.576 cm, with a confidence interval $[0.255, 0.896]$. The 0.7 cm annual growth found in Dutch men by Beekink and Kok (2016) and Thompson et al. (2020) aligns with this interval, pointing to a late growth pattern similar to that of the shortest men from Corrèze at the turn of the twentieth century.

2.3 Growth to adult maturity

In order to account for growth exhaustion as maturity approaches, we now include the squared age into (1),

$$h_{it} = \gamma_i + \mu_t + \beta_1 a_{it} + \beta_2 a_{it}^2 + \varepsilon_{it}. \tag{4}$$

This formulation implies an annual growth equal to $\beta_1 + 2\beta_2 a$ at age a. A dampening of growth is accordingly driven by a negative β_2 coefficient, and men stop growing up at age $a_{\mathrm{m}} = -\beta_1/2\beta_2$ years. Although many men were observed over at most two years, a_{m} can be found beyond this range, as inferred from the height-for-age initial curvature following the conscription board.

We again address conscript fixed effects γ_i by applying time-differencing to (4). This yields

$$\Delta h_i = \mu + \beta_1 \Delta a_i + \beta_2 \Delta a_i^2 + u_i \tag{5}$$

where Δa_i^2 denotes the squared-age difference $a_{i1}^2 - a_{i0}^2$ of man i. The constant term μ is the difference between the time fixed effects μ_1 and μ_0 in (4). It captures changes in variables that uniformly affect height of all men but differ between measurement points, causing a shift in the entire growth curve between these moments. Assuming no shift after the last measurement, the predicted height of man i at maturity is

$$h_i^{\mathrm{m}} = h_{i1} + \beta_1 \left(a_{\mathrm{m}} - a_{i1}\right) + \beta_2 \left(a_{\mathrm{m}}^2 - a_{i1}^2\right) + \left(\varepsilon_{i\mathrm{m}} - \varepsilon_{i1}\right). \tag{6}$$

The inclusion of the squared age term presents an additional challenge for the estimation. Since the two explanatory variables Δa_i and Δa_i^2 are susceptible to endogeneity, IV estimation would require an instrument that complements the Chairperson. Initial age is a natural candidate but it is identified as weak in the full sample. This difficulty can be overcome by exploiting the fact that these two durations relate to the decision to incorporate men in 1908 or at a later time. This makes an endogenous switching (Tobit-5) model appropriate for the situation. Such a model consists of three equations: one represents the selection stage that allocates men into two groups, early *versus* late enlistees, while the other two describe growth within each group. Endogeneity is addressed by allowing the error terms of all three equations to be correlated.

To represent the selection stage, we assume that man i is discarded by the review board in 1908 if the latent variable

$$s_i^* = \mu^{\text{sel}} + \lambda z_i + \zeta' \mathbf{x}_i + v_i \tag{7}$$

is positive. He is otherwise enlisted in the fall of 1908. A lower value of the constant term μ^{sel} in (7) favors an early enlistment. The Chairperson z_i is introduced to meet the exclusion restriction, which allows for distinguishing between the factors influencing selection and those affecting growth. The vector $\mathbf{x}_i$ includes characteristics of man i that the board can use for its decision at time $t = 0$. It consists of his height at the first measurement, his education and occupation, and a dummy for whether he was actually examined in Corrèze or abroad (given the domiciliation criterion used by the military, those examined abroad were mostly emigrants whose parents still resided in the département). All these variables likely relate to unobserved growth potentials and are accordingly controlled for in the height-for-age curves (5). The v_i term is a Gaussian disturbance.

This representation simplifies the decisions the board had to make, as the late enlistees group aggregates men subject to a finer distinction between temporary and permanent deferral. The binary representation is partly justified by the possibility that an exemption in 1909 may follow a discharge decision made in 1908. In addition, as discussed by Chyn et al. (2024), it matches the number of different examiners, Calmès versus Filhoulaud, a feature that facilitates identification.

The two remaining equations in the switching model consist of the two growth curves, one for each group of men, both of which follow the specification in (5). A nice by-product of this approach is that it can accommodate different growth processes by allowing for different vectors of coefficients (μ, β_1, β_2) for the two groups. There are then two regimes, one for 1908 enlistees and another for those discarded, each with its own idiosyncratic slowdown in late growth.

Estimation details and results are provided in Appendix B. One main finding is that substantial catch-up growth continues to be observed among shorter individuals, even when accounting for growth exhaustion. Late enlistees appear to have reached maturity around age 27, experiencing a height gain of approximately 1.5 cm, from 160.84 cm in 1908 to 162.36 cm at maturity. When the estimation is replicated on the subsample of men enlisted in 1908 or 1909, we find little growth in men enlisted in 1909, which suggests that the growth of late enlistees may be driven by those who were recalled during the war. In contrast, the growth trajectory for the 1908 enlistees appears nearly flat, likely reflecting that these individuals were close to full maturity at the time of the initial 1908 conscription assessment. They may have attained a final height of 164.9 cm at 22.8 years of age, representing a modest increase of just 0.36 cm from their initial height of 164.54 cm recorded during the conscription examination.

An implication of these findings is the reduction in height disparity between the two groups upon reaching maturity. The height difference of 3.70 cm observed in 1908 (164.54 cm *versus* 160.84 cm) represents a 45% inflation relative to the 2.55 cm difference measured at full maturity (164.91 cm *versus* 162.36 cm). Reliance solely on conscription board data would hide this convergence and lead to an overestimation of height inequality. Assuming a positive correlation between economic resources and stature, height measured at age 20 likely underestimates lifetime resource availability and may also exaggerate inequality in its distribution.

Insert Figure 3

Despite catch-up growth, the height levels remain low by contemporary standards. This is illustrated in the top panel of Figure 3, which displays the growth curves of modern French boys (solid circles), as used in individual health records (*carnets de santé*) up to 2018 (Sempé et al., 1979). The late growth episodes predicted by the switching model (hollow circles) are shown beginning at age 19. The growth trajectory of the 1908 enlistees aligns closely with the modern reference curve for boys at the 6th height percentile.[8]

The curve for men enlisted after 1908 is located around the 1st or 2nd percentile of the modern distribution, but the matching of velocities is not entirely convincing. Following the type of adjustments underlying the SITAR model in Cole et al. (2010), the bottom panel of Figure 3 shifts backward their growth curve by attributing their predicted height at age a to the previous year, $a-1$. This leads to a better extension, suggesting that these men resembled at age $a-1$ modern boys in the 2nd percentile at age a. Similar results are seen with WHO curves (plain black diamonds), which align more closely with the revised French growth charts since 2018 (Scherdel et al., 2015).

A premise of these exercises is to assume prolonged growth episodes, with projected growth curves derived from the switching model extending beyond the actual curves observed in modern boys. However, estimation results show a positive value for the constant term μ in (5) that is consistent with an upward shift between the

[8] This finding aligns with Donald et al. (2023), who observed that late growth among British and Irish convict boys transported to Australia corresponded to the 5th–10th percentile height trajectories in the contemporary United States.

two measurement points for late enlistees. This shift may reflect a sudden catch-up phase following delayed growth, which would in turn trigger with a new phase of growth toward maturity. In this case, the growth curve of late enlistees before age 20 would lie below that of the shortest 2% of modern boys.

3 Discussion and concluding comments

Height, which reflects net nutrition, is frequently used by historians as a proxy for material living standards. Fogel (1994) actually argues that nutritional deficiencies have historically been a major impediment to economic growth, although the direction of causality may also run from economic conditions to nutritional intake. This article shows that most men born in 1887 in Corrèze likely experienced a modest height gain of 0.4 cm before reaching adulthood, around ages 22 or 23. In contrast, late maturers, who represented approximately one-fifth of the cohort, are estimated to have reached full maturity only around age 27, during which they achieved a significant additional height increase of 1.5 cm. This gives an average height gain until maturity of $0.8 \times 0.4 + 0.2 \times 1.5 \simeq 0.6$ cm in the whole cohort. This section examines the potential implications of these findings for living standards in Corrèze at the turn of the 20th century. Specifically, it compares the inferences about living conditions that can be drawn from height at age 20 with those that would be derived from adult height.

To implement such a comparison, we let y_t denote the resources available to men who turn 20 in year t, and we assume that these resources relate to their adult height h_t^m via $y_t = F(h_t^m)$, F being an increasing function. The researcher observes the actual height h_t in year t from military data, but both the resources and the adult height h_t^m remain unknown. The error in predicted resources is $F(h_t^m) - F(h_t) \geq 0$ when h_t is used instead of h_t^m. The error vanishes if one refers to the observed height h_{t+k} of 20-year-old men in year $t + k$, where k satisfies $h_t^m = h_{t+k}$. That is, the researcher should prefer the height of 20-year-old men in year $t + k$ to infer resources available to 20-year-old men in year t. The k-year shift serves as a time measure for the error on the resources.

To put this argument into practice, we exploit statistics from recruitment table in (Chamla, 1964). They show a nearly constant height increase among 20-year-old conscripts during the first half of the 20th century. The average height of conscripts in Corrèze in 1960 was 170.8 cm, implying an annual gain of 0.14 cm from the 1908 average of 163.8 cm. Adding the 0.6 cm average needed for maturity gives an adult height of 164.4 cm for 1908 conscripts. This matches the average height of 20-year-old conscripts $0.6/0.14 \simeq 4$ years later, i.e., in 1912. Thus, k should be set to 4 years if 1910 conscripts reached maturity in 1910, and above 4 years if they were still growing. In this sense, economic resources in 1908 are underestimated by at least 4 years when based on the 1908 height of 163.8 cm.

The underestimation would be more severe among less well-off men. Following Case and Paxson (2010), these boys may have experienced significant adverse shocks during childhood, such as food shortages or illnesses in a poor hygiene environment, which have been identified as leading to slower maturation. Schneider et al. (2021) points to shocks occurred in late childhood and early adolescence, thus shortly before 1908. The estimate of 1.5 cm gain experienced by the shortest men is consistent with a delay of $1.5/0.14 \simeq 11$ years. If, again, these men had not yet reached their adult height by age 20 in the early 1920s, the underestimation exceeds 11 years.

One consequence of catch-up growth, characterized by greater height gains among shorter men following the initial examination, is that economic conditions may have been more favorable and more evenly distributed than what military height statistics at age 20 would suggest. Nonetheless, it remains likely that these men were initially exposed to particularly poor environmental conditions. The data allow us to draw a profile of the men who were re-measured after 1909, that is, those who experienced the most substantial final growth. Compared to others, these men were shorter and younger at the time of the 1908 review. They were also predominantly farmers and had low levels of education. The cantons with the highest proportions of such men are geographically concentrated in a central band of Corrèze, oriented from northwest to southeast. This includes all cantons in the Tulle arrondissement, except Tulle-Nord and Tulle-Sud, as well as all neighboring cantons in the Brive arrondissement. The canton of Uzerche recorded the lowest proportion of men enlisted in 1908 (66%) and the highest proportion re-measured after 1909 (20%). In contrast, in the cantons of Bugeat, Eygurande, and Bort, all located in the Ussel arrondissement, nearly 90% of men were enlisted in 1908.

In principle, it is possible to extend the analysis to whole France during the nineteenth century. As a caveat, given the ambiguities left open by military regulations, the implementation of the conscription law may have varied across regions and time periods. Moreover, our analysis relies on a cohort reviewed shortly before WWI, and exploits the particular inclination of the Prefect to postpone enlistment.

In a climate of war preparation, France decided in 1913 to increase military service from 2 years to 3 years, implying a call during the year following the 19th rather than 20th birthday. Cohorts were called even younger during the war. Exploiting the younger age when examined by the review board should provide a more precise picture of the final growth episode.

A more speculative direction for further research relies on the interplay between height level and growth to quantify the contributions of the environment and genetic factors in human development (Silventoinen et al., 2012). If individuals with the same adult height possess similar height-related genetic traits, prolonged growth may indicate penalties from a less favorable environment. This approach is especially relevant in contexts like those described by Alter and Oris (2008), where height at age 20 may not fully reflect environmental effects—particularly in privileged settings, where wealthier families can shield children from adversity, masking early-life impacts.

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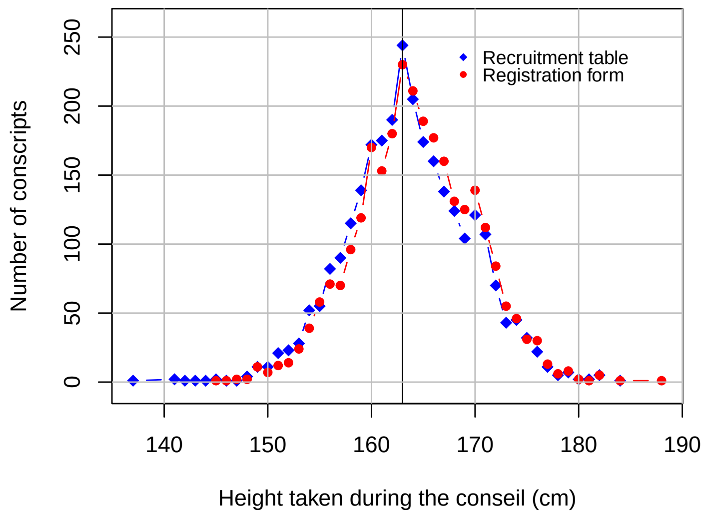

Figure 1: Height distributions in the two sources

The blue distribution gives the number of men (in the vertical axis) for every height in cm (in the horizontal axis) in the recruitment table (this height was taken during the review board examination). The red distribution is from the registration forms.

Source: Author's calculations and construction.

Table 1: Summary statistics

	Full sample	Enrolled in 1908	Enrolled in 1909	Enrolled after 1908	Enrolled after 1909
	(1)	(2)	(3)	(4)	(5)
Review board					
Height (cm)	163.79	164.55	161.18	160.84	160.48
Age (year)	20.70	20.71	20.65	20.66	20.68
Enlistment					
Height (cm)	164.19	164.80	161.65	161.81	161.96
Age (year)	22.02	21.27	22.22	24.94	27.76
Height growth (cm)					
Average	0.40	0.26	0.48	0.96	1.47
Standard error	1.49	1.27	1.60	2.06	2.32
Time difference (year)					
Average	1.32	0.56	1.57	4.27	7.08
Standard error	1.99	0.06	0.04	2.91	1.33
Observations	2,425	1,927	254	498	244

All columns use the 2,425 observation subsample that excludes volunteers and the top and bottom 2.5% of the height growth distribution from the original data of 2,691 observations with two recorded heights, one from the recruitment table and one from the registration form. The enlistment date is provided in the registration form. The annual height growth is calculated as the population average of ratios of individual growth over the time difference, which is the duration between the draft board examination in 1908 and enlistment. The population will be divided into two groups in Section 2.3, those enlisted in 1908, shown in Column (2), and those whose enlistment was postponed until after 1908, shown in Column (4). Men enlisted after 1909 in Column (5) are primarily those recalled during the war.

Source: Author's calculations.

Table 2: OLS height growth estimates

	Height growth Δh_i (cm)				
	Full sample	Enrolled in 1908	Enrolled in 1909	Enrolled in 1908 or 1909	Enrolled after 1909
	(1)	(2)	(3)	(4)	(5)
Age difference (year)	0.209***	0.443***	0.302***	0.372***	0.194***
	(0.016)	(0.063)	(0.069)	(0.043)	(0.017)
Observations	2,425	1,927	254	2,181	244
r^2	0.105	0.037	0.081	0.043	0.257

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. The $2,425$ observation subsample excludes the top and bottom 2.5% of the height growth distribution and volunteers. Men were examined by canton and robust standard errors are clustered at this level.

Reading: The difference between the height in the registration forms and the height in the recruitment table is 0.443 cm over one year for men enlisted in 1908. Over the actual average time of 0.56 year between the two measurements, these men would thus have grown by 0.258 cm.

Source: Author's calculations.

Table 3: Instrumenting the age difference

	Explained variable: Age difference Δa_i (year)					
	Full sample			Enrolled in 1908 or 1909		
	(1)	(2)	(3)	(4)	(5)	(6)
Constant	1.429***	8.119***	7.536***	0.685***	2.652***	2.625 ***
	(0.055)	(2.745)	(2.702)	(0.016)	(0.584)	(0.575)
Absent Prefect	−0.394***		−0.383***	−0.021		−0.017
	(0.088)		(0.087)	(-0.031)		(0.029)
Initial age a_{i0}		−0.328**	−0.295**		−0.095***	−0.094***
		(0.133)	(0.131)		(0.028)	(0.028)
F statistics	20.03	6.11	17.94	0.45	11.34	5.77
Observations	2,425	2,425	2,425	2,181	2,181	2,181

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. The $2,425$ observation subsample excludes the top and bottom 2.5% of the height growth distribution and volunteers. Men were examined by canton and robust standard errors are clustered at this level.

Reading: The time between the two height measurements on a given man is reduced by 0.394 year (nearly 5 months) if the Prefect is absent, i.e., if Filhoulaud, rather than Calmès, chairs the conscription board. It is reduced by 0.328 year (nearly 4 months) if the man was born on January 1, 1887, rather than December 31, 1887.

The low F-statistic indicates that initial age is a weak instrument in Column (2). The Chairperson identity is also weak in the subsample of men enrolled in 1908 or 1909 used in Column (4), making their combination weak as well in Column (6).

Source: Author's calculations.

Table 4: IV HEIGHT GROWTH ESTIMATES

	Explained variable: Height growth Δh_i (cm)		
	Full sample		Enrolled in 1908 or 1909
	(1)	(3)	(5)
Age difference	0.303***	0.302***	0.414***
	(0.027)	(0.028)	(0.051)
Instruments	Absent Prefect	Absent Prefect & initial age	Initial age
Observations	2,425	2,425	2,181
Weak instrument test (p-value)	$< 2.2\text{e} - 16$	$< 2.2\text{e} - 16$	$< 2.2\text{e} - 16$
Wu-Hausman test (p-value)	3.77e-07	4.13e-07	0.019
Sargan		0.912	

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. The $2,425$ observation sample excludes the top and bottom 2.5% of the height growth distribution and volunteers. Men were examined by canton and robust standard errors are clustered at this level. The column numbering corresponds to the specifications reported in Table 3.

Reading: Men are estimated to gain 0.303 cm in height over the course of one year when the age difference is instrumented using a binary variable indicating whether the conscription board was chaired by Calmès or Filhoulaud. The weak instruments hypothesis is consistently rejected, and the Wu-Hausman test indicates that the age difference is endogenous, thereby rendering OLS estimates biased and inconsistent. The specification in Column (3) employs both the Chairperson variable and initial age as instruments to address the single endogenous regressor. This results in an overidentified model, permitting the use of a Sargan test, which does not reject the null hypothesis of instrument validity. The remaining specifications use the instruments that most effectively explain variation in the age difference, i.e., those with the highest F-statistics reported in Table 3.

Source: Author's calculations.

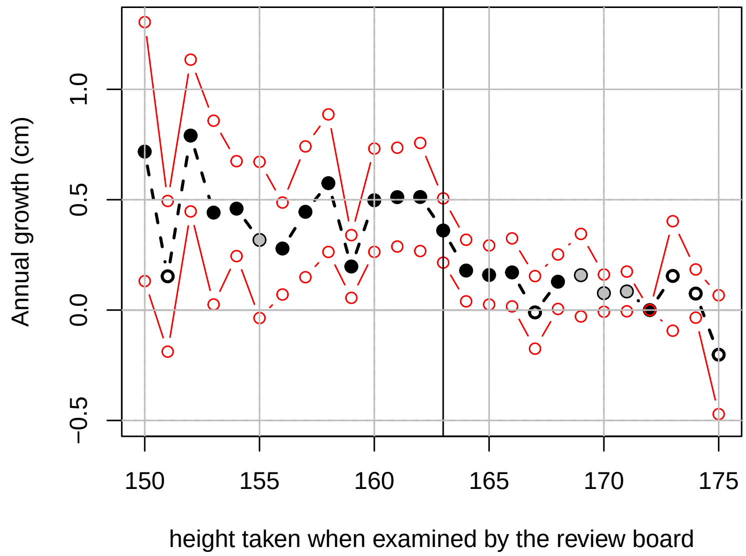

Figure 2: Catching-up in late growth

The vertical axis represents the estimated one-year height gain (in cm) for men whose height, measured during the 1908 conscription board examination, is plotted on the horizontal axis. The age difference, defined as the time elapsed between enlistment and the 1908 examination, is instrumented using the identity of the Chairperson. Solid black dots denote estimates statistically significant at the 5 percent level, while grey dots indicate significance at the 10 percent level. Hollow black circles correspond to estimates that are not statistically significant at either threshold. Hollow red circles indicate the upper and lower bounds of the 95 percent confidence intervals.

Source: Author's calculations and construction.

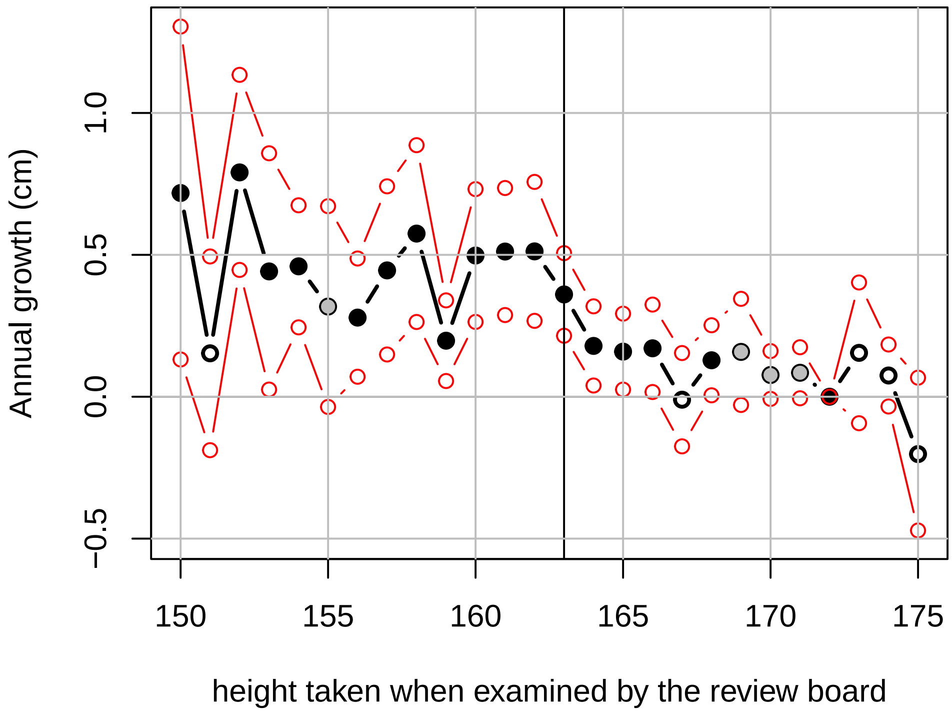

Figure 3: Prolonging modern growth curves

The filled circles represent height (vertical axis) by age (horizontal axis), based on data for modern French boys from Sempé et al. (1979). The figure displays height-for-age curves corresponding to the 2nd (blue), 6th (red), median, and top 1% percentiles (grey). Hollow black circles indicate predicted heights from age 19 to maturity, derived from the robust estimation of the specification in Column (4) of Table 6. The growth trajectory for the 1908 recruits aligns with and extends the 6th percentile Sempé curve, while the trajectory for those enlisted after 1908 follows the 2nd percentile curve. In the bottom panel, filled black diamonds represent WHO reference heights, and hollow black circles correspond to men enlisted after 1908, with height at age a imputed from measurements at age a_1.

Sources: Sempé et al. (1979), World Health Organization Height-for-age child growth standards (boys percentiles: expanded tables) available at `www.who.int/tools/child-growth-standards`, and author's calculations.

Appendix

A Validity of the chairperson instrument

The personal file of Georges Calmès suggests a special relationship with the Army.[9] His mother came from a prestigious military family, with some members' names still engraved on a pillar of the Napoleonic Arc de Triomphe in Paris. Following France's defeat in the war with Prussia, in a context of strong revanchism, the young Calmès entered the high-level military school of Saint-Cyr, which trains future officers for the armed forces. However, he resigned (a relatively rare occurrence) and was later exempted from military service.

Described in the Archives Nationales files as a short man, Calmès was noted over 30 years for his poor health, which was consistently cited as a significant constraint on his occupation options. A representative report dated March 26, 1888, states: 'Calmès is a civil servant of great merit [$\cdots$] Health is the only thing he really lacks. This is why he decided to enter the conseils de préfecture, having been forced to leave his position as inspecteur de l'enregistrement due to the travels it required.'

Table 5 provides suggestive evidence of his idiosyncratic propensity to discharge or exempt men during the review board examination in 1908.

Table 5: Chairperson and delayed enlistment

	Age difference[1] (year)			Height taken during the board	Time between January 1st, 1908 and the board
	Enlisted in 1908	Enlisted in 1909	Enlisted after 1909		
	(1)	(2)	(3)	(4)	(5)
Absent Prefect[2]	−0.012	−0.003	−0.305	0.448	0.013
	(0.018)	(0.018)	(0.263)	(0.421)	(0.019)
Constant	0.565***	1.574***	7.135***	163.666***	0.197***
	(0.010)	(0.011)	(0.089)	(0.238)	(0.011)

***$p < 0.01$; **$p < 0.05$; *$p < 0.1$. The 2,425 observation sample excludes the top and bottom 2.5% of the height growth distribution and volunteers.
1. The explained variable is the time between the review board examination and enlistment.
2. The head of the review board is Filhoulaud rather than Calmès.
Source: Author's calculations.

[9] Archives nationales, reference F/1bI/450.

Columns (1) to (3) indicate that the correlation between the age difference and the identity of the Chairperson (Calmès *versus* Filhoulaud) vanishes when one restricts attention to the separate subsamples of men enlisted in 1908, in 1909, or those enlisted after 1909. That is, the impact of the Chairperson goes through the binary decision made in 1908 about an enlistment in 1908 or later rather than the precise moment at which men are enlisted within a year. The date of enlistment was actually set by the military administration.

The last two columns serve as robustness checks for the validity of the chairperson instrument. Column (4) shows that the presence of the Prefect is not based on the height taken during the review board, e.g., because the Prefect would choose to be present in poor cantons where men are short and more likely to be discharged or exempted. Column (5) tests for the mechanical effect that in 1908 the Prefect would have been present during the first sessions only, implying a longer period of time elapsed between the review board and the enlistment. Here the explained variable is the duration (in year) between January 1, 1908 and the session of the review board. This duration is not correlated with the presence/absence of the Prefect.

B Endogenous switching model

The endogenous switching model is formed by the selection stage decribed by (7) and the two growth curves (5). Estimation presents two main difficulties:

1. The two groups are not random samples of the population. That is, the enlistment decision represented by the group s (early *versus* late enlistment) depends on unobserved characteristics that influence Δh through the u disturbance in (5). If z is independent of v given $\mathbf{x}$, endogenous sampling happens if u and v given $\mathbf{x}$ are correlated.

2. The age at final measurement depends on unobserved individual characteristics related to growth potential. Unlike standard versions of this model, the durations Δa and Δa^2 that explain growth are likely endogenous.

These two difficulties are closely tied since the final age a_1 is partially determined by the allocation decision s between an enlistment in 1908 or later. Following Heckman (1976), endogenous sampling issues are resolved by controlling for unobserved sources of height growth specific to each group. For normal disturbances, the growth curves in (5) should include the inverse Mills ratio as an additional regressor. Endogeneity matters if the coefficient of this ratio (which itself is proportional to the group-specific correlation between u and v) is statistically significant, making the OLS estimator biased if the ratio were omitted in (5).

The additional problem of endogeneity in the duration covariates disappears if the ε_1 disturbance is mean-independent of a_1, given s and the observable characteristics $\mathbf{x}$. Intuitively, a_1 becomes exogenous once s is controlled for, if the endogeneity of a_1 is solely due to s. Exogeneity of Δa and Δa^2 given s and $\mathbf{x}$ is credible for men enlisted in 1908 since the date of the second measurement mostly depends on military administration procedures. This is more debatable for the group of late enlistees, as men incorporated in 1909 differ from those re-measured later. However, accounting for the $\mathbf{x}$ variables in (5) and (7) could capture part of this heterogeneity.[10]

Insert Table 6

Estimation results are reported in Table 6 for various specifications. Columns (1) to (3) assume trivariate normal disturbances (u, v). Robust estimates that allow for small deviations from normality are presented in Columns (4) and (5).

The allocation stage in (7) is estimated using a probit model. Filhoulaud is confirmed as more likely to opt for enlistment in 1908 compared to Calmès. We also find that the 1908 enlistees are taller and older, so small growth in the data may reflect near-adult maturity or a short 6-month observation period, where slight growth is rounded to zero. As before, initial age is only used in the subsample of men enlisted in 1908 or 1909 in Column (5).

The probit gives the Mills ratios omitted in the outcome equations (5). Accounting for the Mills ratio in the growth curve of late enlistees points to OLS biases from the endogenous composition of the groups. The positive sign of the inverse Mills ratio coefficient indicates a negative correlation between u and v for late enlistees $s = 1$. This supports the view that a temporary poor health increases the likelihood of deferral and negatively impacts growth.

The estimate of the growth curve for the 1908 enlistees lacks precision. The point estimates in Columns (1) to (3) fall below age a_0 when individuals were first examined (note however that the upper bound of the confidence intervals are greater than a_0). If evaluated at these point estimates, the quadratic specification is consistent with negative growth, which seems unrealistic at age 20. Robust estimates in Column (4)

[10] A formal argument proceeds as follows. Let $s = 0$ for early enlistees, and $s = 1$ for lates enlistees. Let also $\beta^1 = \beta^0 + s\delta$, with δ being the annual growth increment if $s = 1$. In the simple case where the Chairperson is the only explanatory variable of selection, and the height-for-age relation includes neither time fixed effects nor squared-age, $\mathbb{E}[\Delta h \mid \Delta a, s, z] = (\beta^0 + s\delta)\Delta a + \mathbb{E}[u \mid \Delta a, s]$, where we have used u independent of z. The assumption $\Delta a \perp u \mid s$ implies $\mathbb{E}[\Delta h \mid \Delta a, s, z] = (\beta^0 + s\delta)\Delta a + \mathbb{E}[u \mid s]$, which coincides with standard versions of the endogenous switching model.

suggest that these results may stem from outliers that violate normality assumptions. These robust estimates are those used in the main text.

The small magnitude of growth estimated for 1908 enlistees aligns with the expected daily shrinkage due to cartilage compression while standing. Estimates could accordingly reflect the within-day timing of measurements. For instance, growth overestimates would follow from initial measurements taken late in the day and final ones early. The timing of the first measurement within the day given age is found to not significantly affect height growth, suggesting that the measurements were taken randomly and, therefore, the growth of the 1908 enlistees in Column (4) can be considered effective.

The results in Column (5) apply to the subsample of men enlisted in 1908 or 1909, thus excluding observations on men recalled during the war. The shorter time interval of 6 to 18 months addresses the concern that increasing the time between measurements mechanically allows for greater height growth. The robust estimation of the quadratic specification predicts no significant growth. Evaluated at the point estimate of adult age, those discharged in 1908 could reach maturity one year after the examination, thus 6 months before enlistment.

Table 6: Adult maturity

	Heckit			Robust	
	Full sample (2,425 observations)				Enlisted in 1908-09 (2,181 observations)
	(1)	(2)	(3)	(4)	(5)
Selection equation (Probit model)					
Explained variable: The second height is taken after *versus* in 1908					
Constant term μ^{sel}	-0.769^{***}	12.426^{***}	12.426^{***}	12.426^{***}	17.691^{***}
	(0.033)	(1.043)	(1.043)	(1.043)	(3.223)
Absent Prefect	-0.211^{***}	-0.230^{***}	-0.230^{***}	-0.231^{***}	
	(0.070)	(0.077)	(0.077)	(0.077)	
Initial age a_{i0}					-0.334^{**}
					(0.141)
Initial height h_{i0}		-0.081^{***}	-0.081^{***}	-0.081^{***}	-0.073^{***}
		(0.006)	(0.006)	(0.006)	(0.008)
Examined abroad		-0.456^{***}	-0.456^{***}	-0.456^{***}	-0.437^{***}
		(0.098)	(0.098)	(0.098)	(0.129)
Education & occupation	N	Y	Y	Y	Y
Outcome equations					
Explained variable: Height growth from the board Δh_i (cm)					
Group $s = 0$**.** The second height measurement is taken in 1908 (1,927 observations)					
Constant μ^0			7.156^{***}	2.184	2.734^{*}
			(2.482)	(1.358)	(2.634)
Age difference β_1^0 (year)	2.903	2.984	2.983	2.123^{*}	3.127
	(3.923)	(3.863)	(3.874)	(1.200)	(2.051)
Squared age difference β_2^0 (year)	-0.078	-0.075	-0.075	-0.047	-0.070
	(0.094)	(0.092)	(0.092)	(0.029)	(0.049)
Initial height h_{i0}		-0.041^{***}	-0.041^{***}	-0.013^{*}	-0.016^{*}
		(0.014)	(0.014)	(0.008)	(0.009)
Examined abroad		0.559^{***}	0.558^{***}	0.159^{***}	0.132^{**}
		(0.119)	(0.119)	(0.052)	(0.112)
Inverse Mills ratio	-1.280^{**}	0.072	-0.072	0.098	0.343
	(0.624)	(0.522)	(0.522)	(0.267)	(0.472)
Adult age (year)	18.7	19.9	19.9	22.8	22.2
	[11.6,25.8]	[12.8,26.9]	[12.8,26.9]	[17.7,27.8]	[19.1, 25.5]
Adult height (cm)	165.34	164.95	164.95	164.91	164.87
Growth to maturity (cm)	-0.79	-0.41	-0.41	0.36	0.33
Group $s = 1$**.** The second height measurement is taken after 1908					
Constant term μ^1			31.176^{**}	31.176^{**}	122.11
			(13.083)	(13.083)	(114.42)
Age difference β_1^1 (year)	2.110^{**}	2.223^{***}	2.223^{***}	2.223^{***}	56.986
	(0.842)	(0.843)	(0.833)	(0.833)	(57.208)
Squared age difference β_2^1 (year)	-0.039^{**}	-0.041^{**}	-0.041^{**}	-0.041^{**}	-1.262
	(0.016)	(0.016)	(0.016)	(0.016)	(1.283)
Initial height h_{i0}		-0.216^{**}	-0.216^{**}	-0.216^{**}	-0.924
		(0.092)	(0.092)	(0.092)	(0.863)
Examined abroad		0.222	0.222	0.222	-4.618
		(0.619)	(0.619)	(0.619)	(5.586)
Inverse Mills ratio	-0.119	2.578^{*}	2.578^{*}	2.578^{*}	14.618
	(0.184)	(1.398)	(1.398)	(1.398)	(14.264)
Adult age (year)	27.2	27.1	27.1	27.1	22.6
	[25.6,28.8]	[25.6,28.6]	[25.6,28.6]	[25.7,28.6]	[20.8,24.3]
Adult height (cm)	162.34	162.36	162.36	162.36	161.91
Growth to maturity (cm)	1.50	1.52	1.52	1.52	0.73
Observations	498	498	498	498	254
Education & occupation	N	Y	Y	Y	Y

$^{***}p < 0.01$; $^{**}p < 0.05$; $^{*}p < 0.1$. The 2,425 observation sample excludes the top and bottom 2.5% of the height growth distribution and volunteers. The adult age is $\beta_1^s/2\beta_2^s$ for group s (its 95% confidence interval obtains using the Delta method). The (estimated) adult height is computed from (6). Growth to maturity is the difference between adult height and height when examined by the board, e.g., between 162.36 and 160.84 cm for men remeasured after 1908 in Column (4) (see Table 1). Robust estimation in Columns (4) and (5) use the `ssmrob` `R` package with Huber tuning `t.c` set to 10.

Source: Author's calculations.