Late Growth and Adult Maturity from Historical Panel Data*

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Abstract

Combining height data from two 19th-century French conscription sources yields a quasi-exhaustive individual-level longitudinal dataset for men from their 21st year, allowing for an assessment of late height growth and age of maturity. Among 2,923 men born in 1887 in Corrèze, annual growth ranges from 0.29 cm to 0.39 cm. Most men mature around ages 21-22, but the shortest in the first quintile grow 1.6 cm, reaching 162.7 cm at ages 26-27.

JEL classification numbers: N33, O15, J11.

Keywords: Height, growth, rural development, historical demography, military data, secular trend.

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Extended abstract

Adult height commonly serves as a proxy for well-being and economic prosperity when other reliable data is lacking. Height often obtain from conscription records which give the height of men around the age of 20 taken once at a single point in time. Such sources are therefore misleading if there is significant growth beyond age 20. This is less of a concern in the twentieth century, as adult height is generally attained before the age of 20. However, because of the lack of identified longitudinal sources, little is known on the height-for-age dynamics after age 20 for periods preceding the twentieth century. This study introduces a methodology to assess growth dynamics near maturity during the nineteenth century. The methodology combines height data from two French conscription sources, resulting in an almost comprehensive individual-level longitudinal panel of men from their 21st year. The *tableau de recrutement cantonal* applies to men when considered for military service, while the *fiches matricules* pertain to men from 6 to 22 months later. An illustration on the 2,923 men born in 1887 in the Corrèze department shows an average annual growth ranging from 0.29 cm to 0.39 cm. Most men reach maturity around ages 21 and 22, but the first quintile shortest men continue growing by 1.6 cm until ages 26 and 27. Delayed growth beyond 20 years suggests that height at age 20 underestimates economic well-being in historical periods.

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Significance statement

Life history theories refer to the secular trend hypothesis that men mature earlier and attain greater height. 20th-century support comes from large-scale longitudinal data recording individual height changes over time. Longitudinal data identified for periods before the 20th-century are typically small-scale and concern children before they reach adult maturity. This study merges French conscription data to create a comprehensive 19th-century longitudinal dataset allowing for addressing late growth and maturity. An illustration on the rural backward department of Corrèze shows significant post-21st-year height gains that are consistent with the secular trend hypothesis. The 20 percent shortest men born in 1887 continue growing by 1.6 cm, reaching an adult height of 162.7 cm by ages 26-27.

1 Introduction

In situations where economic data is limited or unreliable, adult height is often used as a proxy for the underlying state of well-being, following Villermé [38] and Fogel [15].[1] Height, as a key military requirement, is readily available for males from the early nineteenth century through conscription records in many countries. This source typically reports individual height taken once around the age of 20 during the process of evaluation of physical aptitude for military service. Nowadays it is commonly used following a cross-sectional methodology by inferring changes in economic resources from differences in average height among 20-year-old men born in different years.

Although most men in developed economies currently have reached adult height by the age of 20, there is strong suspicion that they experienced continued growth beyond that age prior to the twentieth century. Delayed growth beyond the age of 20 raises concerns with standard cross-sectional analysis, as two cohorts with the same average height at age 20 did not necessarily share similar living conditions. Reliability of the height at 20 becomes even more questionable when considering the secular trend toward earlier maturity and increased adult height. The height recorded by the military, as a snapshot of human physical development, is plausibly correlated with adult height but it is also influenced by the *tempo* of growth, implying a high signal-to-noise ratio if referring to age-20 height.

We have little information about the volume of individuals experiencing late growth, the magnitude of late growth, and the age of maturity prior to the twentieth century. Late growth was significant enough, however, for some to propose postponing military service to limit exemptions for short height (Rampal [28]). The lack of information is due to the high cost associated with collecting longitudinal or panel data that record the height of the same individual over time. Most longitudinal studies conducted in the nineteenth century were therefore on school-aged children, a population easy to monitor but under 20 years old.[2] Large-scale longitudinal data sources only exist for periods after World War I in the United States and World War II in Europe (Tanner [33]). They usually locate growth cessation around the ages of 16 or 17 for males, which might suggest that extending the analysis beyond the age of 20 would yield limited additional insights for periods before the twentieth

[1] See also Deaton [13] for limits to this approach.

[2] See, *e.g.*, Boas [5], Carlier [11], Godin [16] or Pagliani [24]. See also Gao and Schneider [14] for a longitudinal study on children over more than one century.

century.

Cross-sectional analysis point to a maturity reached well beyond the age of 20 during the nineteenth century, though information is of low precision.[3] Still such analysis, which entail averaging the heights of different individuals of the same age may obscure sudden breaks in the individual growth pattern (Tanner [32]) and yield biased estimates if there is differential selection of individuals into the sample (Schneider [30]). A more mixed picture emerges from the few identified historical longitudinal series that can provide information on late growth. Then, however, representativeness is a concern since we have to rely on very small sample size data, sometimes on just one individual. In the eighteenth century the children raised in privileged environments of Montbeillard [9] and Wiener [39] reached adulthood before the age of 20 while those attending Carlschule in Stuttgart continued to grow between the ages of 20 and 21 (Theopold [34]). In the nineteenth century maturity was reached well before 20 in the longitudinal sample used by Bowditch [7], but the son of Quetelet [26] and the Norwegian men in Kiil [20] were still experiencing late growth in height after 20.

Beekink and Kok [2] and Thompson, Quanjer, and Murkens [35] provide the only available estimates of the magnitude of late height growth in the first half of the nineteenth century from substantial-sized samples. Both rely on self-selected Dutch conscripts measured twice, first at 19 and then at 25 when they decided to apply to the civic guard. Growth during this six-year period is found to reach up to 5 cm. A 20-year-old Dutch conscript measured 169 cm in 1900 would therefore have reached 174 cm at the age of 25, which was the average height of a 19-year-old Dutch conscript 50 years later in 1950 (Chamla [12]). Such magnitudes call into question the cross-sectional methodology to recover available economic resources from height at 20.

This article shows how to build a quasi-exhaustive individual-level panel dataset on the height of men after they reach 20 years old for France. It exploits a methodology similar to the one used by Beekink and Kok [2] and Thompson, Quanjer, and Murkens [35] based on the timing of conscription. However, it is almost immune to endogenous sample selection issues. The

[3] Anthropometric studies from the nineteenth century range the age at maturity between 25 and 40 years. For instance, Bertillon [4] estimated maturity to be reached 'at 25 years or sometimes earlier', while Quetelet [27] and Lelut [21] proposed 30 years. Vaerveck [37] suggested a range of 32 to 38 years, and Topinard [36] and Pfitzner [25] placed it at 34 and 40 years, respectively. Gould [17] found that American soldiers in the Northern army reached maturity at around 30 years, and Baxter [1] sets it at 35 years.

methodology is illustrated on men born in 1887 in the department of Corrèze, an economically disadvantaged rural area of France. Many men are found to register a moderate height gain of 0.4 cm before they reach their maximal height (which we use as characterizing maturity), going from 164.4 cm to 164.8 cm, plausibly achieved around the age of 21 and a half, but definitely before the age of 23. Still 20 percent of men show delayed growth until the ages of 26 or 27, experiencing a height gain of 1.6 cm, growing from 161.1 cm to 162.7 cm, thus only partially catching up with their well-off peers. This could represent an underestimation of the economic resources accessible to the less privileged segment of the population by over 11 years.

2 Building longitudinal data

Following the Maurice Berteaux Law [22] of 21 March 1905, the review board (*conseil de révision*) held at the beginning of every year $t+1$ was reviewing all men born in $t-20$ to select those fit for military service. Most men were reviewed in their birth county; those who had migrated could be granted for an examination where they lived, but information had to be passed on where they were born. Height was taken for every man during the examination and recorded in the recruitment table (*tableau de recrutement*).

Men deemed fit were enrolled (*incorporés*) in the fall of $t+1$. Those who did not meet the criteria were either exempted (*exemptés*) from service or discharged (*ajournés*). In principle, exempted men were never to join the army, but those from pre-Great War cohorts were recalled during the war and many of them eventually joined. Men discharged in $t+1$ were provisionally exempted pending re-examination in year $t+2$. If deemed fit in $t+2$, they were enrolled in the fall of $t+2$; otherwise they were granted a permanent exemption, subject to the same caveat involving recall.

An individual registration form (*fiche matricule*) exists for every man deemed fit.[4] The form was used by the military administration to track men over a 25 year period of service. It contains socio-demographic and anthropometric information including a height.

The recruitment table and the registration forms pertain to different points in time, respectively pre and post-enlistment. So far this observation

[4]Unlike the recruitment table, which can only be found through archival work, digitalized copies of the registration forms are available from the Archives websites for every department of France. Information is handwritten in both sources.

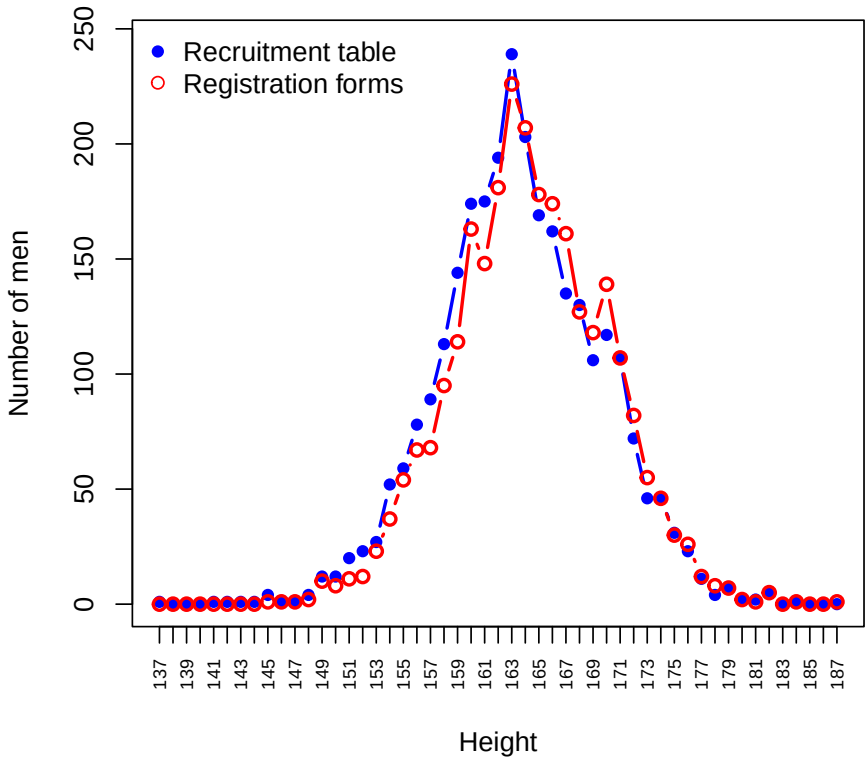
has not been exploited. There exists no systematic individual-by-individual comparison of the height information in the two sources.[5] Information differs in the case of the cohort of the 2,923 men born in 1887 in Corrèze, a small backward rural department of France. Figure 1 depicts the height distributions from the recruitment table (in blue) and the registration forms (in red). It shows a deficit of men in the registration forms for every height below the peak at 163 cm, and an excess of men taller than 163 cm.

The recruitment table does not include height of men who did not appear before the review board, while no registration form exists for men deemed unfit by the review board. Height therefore is missing is one source for some men. But these differences in coverage cannot completely account for the discrepancies observed between the two distributions, as the subsample of men with two completed heights still contains 498 observations with two different heights.

Measurement and/or transcription errors contribute to the discrepancies, but they are difficult to reconcile with the regular pattern observed in Figure 1. Instead this pattern can be easily rationalized building on a continuing process of late height growth. To see this, suppose that every man experiences a 1 cm height gain from the review board examination and that his final height is recorded in the registration form. A number n_h of men with height h when examined by the review board then translates into n_{h-1} men with height h in the registration forms (their height was $h-1$ when initially examined). A deficit of $n_h - n_{h-1}$ men follows from the single-peaked shape of the height distribution from the recruitment table for every height h below the peak of 163 cm. In counterpart there is an excess of $n_{h-1} - n_h$ men for heights above the peak. Section 3.2 shows that the height gain is actually decreasing with the initial height, rather than being constant. This explains why the two distributions nearly coincide in Figure 1 for tall men.

The height recorded in the registration form may have been taken during two additional inspections made after the review board examination. Men were first subjected to the departure examination (*visite de départ*) made within the recruitment office (*bureau de recrutement*) to assign them to different army units. Then, in the following days, men underwent the enlistment examination (*visite d'incorporation*) conducted within their assigned

[5] An exception is the study by Maurin [23] on two departments of France, Hérault and Lozère, which suggests that in these cases the height in the registration form may be a transcript of the height taken during the examination by the review board, recorded in the recruitment table. This may be why the two sources are considered as about identical.



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 is taken during the review board examination), with 2,793 observations. The red distributions is from the 2,699 registration forms.

Figure 1: HEIGHT DISTRIBUTIONS IN THE TWO SOURCES

unit. The 'On Physical Aptitude to Military Service' legal *Instruction* [3] of 22 October 1905 explicitly rules that a new height measurement had to be taken during the departure examination within the recruiting office.[6] As this same office was also responsible for the creation of the registration forms, one may set that the height in the registration form was taken during the departure examination.[7]

The date of the first height measurement, made during the review board examination, is reported in the recruitment table. The data does not give the date of the departure examination but the date of enlistment, which closely follows this examination (Roynette [29]), is known from the registration form. In the sequel, the enlistment date will be used as a proxy for the date of the second height measurement.

The combination of the recruitment table and the registration forms yields a longitudinal individual-level panel with two different measurements on men after age 20. The panel is quasi-exhaustive for cohorts concerned by recall during World War I. The height is definitively lost for men absent from the review board, and for those first exempted and never recalled. There still remains $2,707$ observations out of the $2,923$ men born in 1887 in Corrèze with an individual height recorded in the two data sources.[8]

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[6]There was no minimum height requirement for army recruits since 1901 in France. But men had to meet certain height standards to enter specific units, hence a second height measurement in a context where many men may continue growing after the review board examination. The *Instruction* states that

> 'young men deemed fit [by the review board] are allocated by recruitment office commanders to the different military units according to their physical and professional abilities (...). The main physical requirements are: height, ability to walk, horse riding abilities and capacities to handle heavy loads. The first of these requirements (...) can be assessed using a graduation measuring rod; the determination of others is more complex and falls within the specific competence and sphere of responsibility of the military physician.'

The requirements were actually ranked in a previous version of this same text published in 1891: 'first height and then ability to walk' (see Section V page 76 of the *Instruction* [19] of 1891). Note that recruitment office was part of the review board and so aware of the height taken during the review board examination.

[7]It appears at the beginning of the registers compiling individual registration forms that the 'register (...) is (...) held by the commander of the recruitment office' and that the 'recruitment office commanders must start the register as soon as possible,' after the selection of draftees by the review board.

[8]Actually there are only $2,612$ men with at least two height measurements. We also find cases of three available heights for the same man. A typical case is one where the man was

In the 2,707 observation subsample men are (in average) 20.7 years old in the recruitment table, and their height is 163.71 cm. They gain 0.60 cm over approximately one year between the two height measurements. The one-year average mixes 6 to 8 months for the 2,025 men enlisted in the fall of 1908, and 18 months for those enlisted in 1909. More marginal cases are volunteers who self-select before the call and men recalled several years later during the war.

Men enlisted in 1908 are initially 164.4 cm tall. They are taller than men exempted or discharged in 1908 and experience a 0.35 cm growth over the 6-month period. Still they end-up taller. Instead the height of those discharged goes from 161.1 cm to 161.66 cm.

Figure 2a plots height against age at the review board examination (plain circles) and enlistment (bold circles), both for men enlisted either in 1908 (in black) and 1909 (in red). The upward trend of height of men enlisted in 1908 slows down between the spring and the fall of 1908. The data from the first examination indicates that men born early in 1887 and enlisted after 1908 were slightly shorter than those born later in the year, following the lean season of 1887. The trend picks up an increasing pace one year and a half later. It is then stronger than the upward trend found on early enlisted.

Figure 2b shows that the average height growth (rather than the level) increases with the time between the two height measurements. It is weaker and more dispersed among those enlisted after 1908.

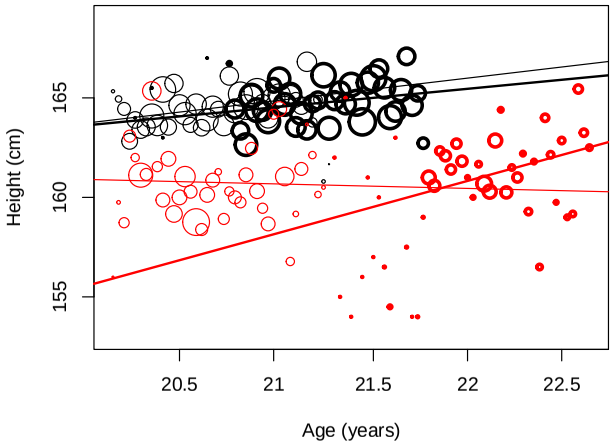
3 Measuring late height growth

In order to estimate the height gain during the year following the examination by the review board, height h_{it} (in cm) of man i at time t is first assumed to fit

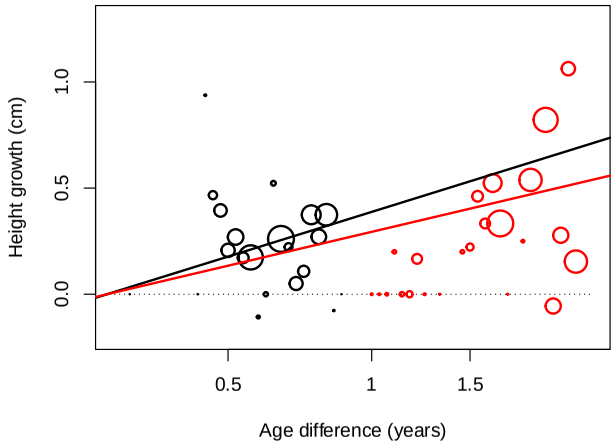
$$h_{it} = \beta a_{it} + \gamma_i + \varepsilon_{it} \tag{1}$$

where a_{it} is the age (in year) of the man at time t, and γ_i captures characteristics of the man fixed over time that may be relevant for growth, *e.g.*,

initially deemed fit by the review board (thus not exempted) but later rejected (*réformés*) from the army at the outcome of either the departure or enlistment examination, and eventually recalled during the war. Then the registration form reports the height taken when subject to the departure examination, and also a revised or 'corrected' height (*taille rectifiée*) when recalled. In such cases two observations are carried out, both starting from the review board examination and concerning the same man.



(a) Age and height level



(b) Age difference and height growth

Figure 2 uses the 2,707 observation sample. It focuses on the standard case of men enlisted either in 1908 or 1909 to enhance readability. Every point in Figure 2a gives the average height (in the vertical axis) of all men whose age when measured (in the horizontal axis) falls within every 10-day interval. Age heterogeneity mixes heterogeneity in the distribution of births during the year 1887, and heterogeneity in the timing of height measurements. The representation thus loses the longitudinal dimension. Plain circles apply to the examination made by the review board, and bold circles to the examination at enlistment. Black is used for men enlisted in 1908, and red for those enlisted in 1909. The figure does not account for volunteers, and data corresponding to men recalled during the war is not depicted. The size of a circle is proportional to ratio of the number of men involved to the total number of men in the same category, *i.e.*, either men enlisted in 1908 or those enlisted later (the size of black circles thus cannot be compared to the size of red circles). For instance, the average height is 165.33 cm for the 9 men enlisted in 1908, whose age was between 20.15 and 20.17 years when subjected to the review board examination. The weighted regression lines are represented using the same color and thickness conventions.

Figure 2b keeps with the longitudinal dimension. Height growth (in the vertical axis) is the difference between height at enlistment and height taken during the review board examination. It is expressed in cm. The age difference (in the horizontal axis) is the time between the two height measurements. The same conventions as those used in Figure 2a apply (the distinction between plain and bold circles now is irrelevant).

Figure 2: Age and height

some genetic factors, chronic illness, frailness or disability, family traditions or wealth. The variable t takes value 0 when the man is examined by the review board in 1908 and value 1 at enlistment. A zero-mean residual ε_{it} is needed for the right-hand side of (1) to match the h_{it} level of height for all i and t. The β coefficient is the parameter of interest. It gives the average height growth over one year from the review board examination.

The formulation (1) does not allow growth to vary with initial height; this is relaxed in Section 3.2. In addition the linear shape in (1) is plausible over a short time window, but not over a longer period where growth gradually slows down; Section 3.3 deals with growth exhaustion and age at maturity.

Many relevant characteristics in γ_i are likely unobserved in the data. We 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 (in cm) over the $\Delta a_i = a_{i1} - a_{i0}$ time period (in years) starting from the review board examination.

3.1 Short-run growth after 20

Column (1) of Table 1 reports an Ordinary Least Squares (OLS) growth estimate of 0.31 cm over one year in the full 2,707 observation sample, starting from the review board examination. The top and bottom 2.5 per cent of the height growth distribution mostly involve men examined outside Corrèze and/or men recalled during the war with negative or implausibly large growth which are likely measurement errors. Height growth falls to 0.24 cm when they are excluded from the sample in Column (2). Since men were examined by county, standard errors are clustered at this level in Columns (3) to (5).

Columns (4) and (5) apply to the subgroups of men enlisted in 1908 or 1909, thus excluding most volunteers and all recalled men. Men enlisted in 1908 are assessed with a 0.45 cm growth over one year, while those first discharged in 1908 and enrolled later experience a growth of 0.29 cm only. The lower 0.24 cm estimate in Column (3) implies that volunteers and recalled men display weaker annual growth.

The OLS estimate relies on the exogeneity of the time Δa_i elapsed between the two height measurements. In the present context, this is a potential issue since this time depends on the evaluation made by the review board

Table 1: HEIGHT GROWTH – OLS ESTIMATES

	Height growth Δh_i (cm)				
			Robust county-clustered standard error		
	(1)	(2)	(3)	(4)	(5)
	Initial sample	95% subsample[a]		Enlisted in 1908 in the 95% subsample	Enlisted in 1909 in the 95% subsample
Age difference Δa_i (years)	0.306***	0.237***	0.237***	0.454***	0.291***
	(0.022)	(0.013)	(0.019)	(0.062)	(0.067)
Number of observations	2,707	2,596	2,596	1,965	293
r^2	0.064	0.11	0.11	0.034	0.083

Notes: ***Significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level.
a. The 2,596 observation subsample excludes the top and bottom 2.5% of the height growth distribution.
Reading: In the 2,596 observation sample, the OLS estimate of yearly individual growth is 0.237 cm.

about individual aptitude. The legal recommendation was to postpone to the following year the decision on men in poor health but assessed as able to recover. Health status and height growth potential are likely correlated; the OLS results suggest that men showing the lowest potential measured over a longer period of time. That is, men discharged/exempted in 1908 and measured in 1909 or later, in the fictitious situation where they would have been enlisted in 1908, would have registered a weaker growth than those actually enlisted in 1908. The endogenous enlistment/discharge decision, which determines the individual age difference in (2), would therefore make the OLS under-estimate the true growth.

We deal with endogeneity using an instrumental variable (IV) strategy. The general idea is to find a variable (referred to as the instrument) that explains the decision to postpone without relying on the unobserved growth potential of the individual. Then, in a second stage, height growth is regressed on the part of the time between the two measurements explained by the instrument; this part is presumably exogenous.

In order to find a suitable instrument, we exploit Article 16 of the Berteaux Law which provides that the Chairperson of the review board had to be the Prefect (*préfet*) of Corrèze. In 1908, the Prefect was Georges Calmès, a short man with a frail health who had previously been exempted from military ser-

vice. In the case where the Prefect was unable to attend a session for some county, the chair was given to the Prefecture Secretary (*secrétaire général*) Charles Filhoulaud. The first stage results in Table 2 show that Calmès was much more willing to postpone decisions than Filhoulaud. A man experiences a time gap of 0.3 year between the two height measurements if Filhoulaud rather than Calmès chairs the review board. We view the presence/absence of the Prefect as providing us with a relevant exogenous source of variation in the deferral decision. Additional biographical information from personal files of Calmès and Filhoulaud held by the Archives Nationales as well econometric robustness checks in Appendix B suggest no obvious reason why the presence/absence of the Prefect in a county would relate to the height growth potential of a particular man examined in this county.

The second stage results in Table 2 report the IV growth estimates when the age difference is instrumented by the Chairperson, either Calmès or Filhoulaud. The OLS annual growth is revised upward by 0.1 cm to 0.34 cm in Column (2), with a $[0.29, 0.39]$ confidence interval. Appendix D reports similar estimates from the larger sample formed by the three cohorts reviewed while Calmès was Prefect of Corrèze. The few absentees in Appendix E would neither impact estimates.

Beekink and Kok [2] and Thompson, Quanjer and Murkens [35] report estimates of late height growth from panel data based on self-selected samples of Dutchmen born in the first half of the nineteenth century. These men were measured twice, first at the age of 19 as part of conscription, and when they decided to enter the civic guard at the age of 25. The average height gain over these 6 years ranges from 4.3 and 4.8 cm; it is 5.5 cm among poor farmers. This gives a gain around $0.7-0.9$ cm per year, well above the figures in Table 2. The next Section allows for a correlation between growth and initial height to discuss whether Dutchmen who have chosen to enter the civic guard may look more like specific men from Corrèze who would display a higher growth.

3.2 Late maturers and catching-up

In the twentieth century poor economic conditions are found to delay growth, but short children eventually experience partial catch-up with their well-off peers (Case and Paxson [10]). An assessment of this process for nineteenth century obtains from a variant of (2),

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

Table 2: Height growth – Absent Prefect IV estimates

	(1)	(2)	(3)
	Initial sample	95% subsample	95% subsample net of volunteers
First stage	Age difference[a] (year)		
Absent Prefect[b]	-0.290^{***}	-0.278^{***}	-0.315^{***}
	(0.081)	(0.084)	(0.087)
Constant	1.371^{***}	1.363^{***}	1.345^{***}
	(0.064)	(0.065)	(0.068)
F statistic	11.1	11.1	12.96
Second stage	Height growth (cm)		
Age difference (year)	0.464^{***}	0.340^{***}	0.329^{***}
	(0.052)	(0.027)	(0.024)
Instrument	Absent Prefect	Absent Prefect	Absent Prefect
Weak instrument test (p-value)	< 2.2e-16	< 2.2e-16	< 2.2e-16
Hausman test p-value	1.3e-06	1.15e-07	2.14e-06
Number of observations	2,707	2,596	2,463

Notes: ***Significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level. Robust standard errors (into brackets) are clustered at the county level.

a. The explained variable is the time between the review board examination and enlistment.

b. The Chairperson is Charles Filhoulaud rather than the Prefect Georges Calmès.

Reading: In the 2,707 observation sample, the time between the review board of 1908 and the enlistment decreases by 0.29 year if the review board is chaired by Charles Filhoulaud. Individual growth in height over 1 year is 0.464 cm, once the Chairperson is used as an instrument for the age difference.

where $\mathbb{1}_{id}$ equals 1 if conscript i is d cm tall in the recruitment table, and 0 otherwise. The β_d coefficient gives the average annual height growth of men who were d cm tall when examined by the review board in 1908.

Figure 3 depicts the estimation results using the Chairperson (Calmès or Filhoulaud) as an instrument for the age difference. It uses bold plain dots for growth estimates significant at the 5 per cent level (the 95 per cent confidence interval is in red). The height gain is decreasing with initial height. Tall men over 170 cm, who represent 15 per cent of the cohort, already reached adult maturity when examined by the review board. All remaining men grow in height. Most zero-growth observations in this cohort would thus be part of incomplete growth sequences rather than lack of growth. Short men below 160 cm grow by 0.6 cm over a year, a figure close to the $0.7 - 0.9$ cm annual growth estimates found on Dutch conscripts.

3.3 Adult maturity

The assumption of a maintained growth of β or β_d cm every year is not plausible after 20, when growth gradually slows to zero as adult maturity approaches. One can account for growth exhaustion by including the squared-age into (1),

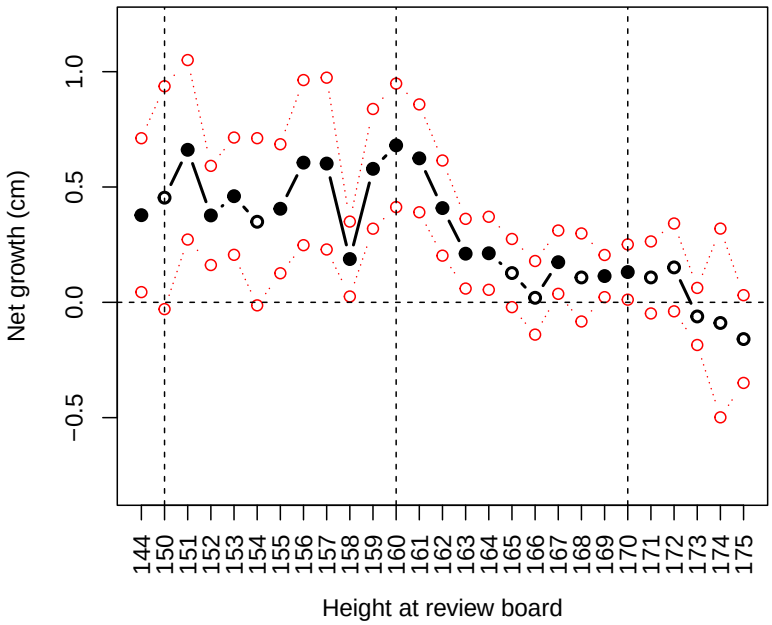
$$h_{it} = \alpha_t + \gamma_i + \beta_1 a_{it} + \beta_2 a_{it}^2 + \varepsilon_{it}.$$

After time-differencing this yields

$$\Delta h_i = \alpha^{\text{out}} + \beta_1 \Delta a_i + \beta_2 \Delta a_i^2 + u_i, \tag{4}$$

where Δa_i^2 denotes the age-squared difference of man i. The specification accounts for a constant term α^{out} which captures changes in variables that affect every man uniformly but vary between the two points of measurements, *e.g.*, the state of the total harvest. Growth now equals $\beta_1 + 2\beta_2 a$ at age a so that some dampening is driven by a negative β_2 coefficient. Figure 4 reproduces height velocity of modern boys using WHO data. The linear shape of velocity implied by the quadratic specification appears as a plausible, though crude approximation of the growth episode following the peak in adolescence.

The age a_{m} of adult maturity is when men stop growing up, which is $a_{\text{m}} = -\beta_1/2\beta_2$ in this specification. The vast majority of men is observed over at most two years from the review board examination. The assumed quadratic formulation in (4) however possibly yields an age of maturity beyond the



Black dots have in the vertical axis the estimated height growth over one year of the men whose height taken during the examination by the review board of 1908 is reported in the horizontal axis. Height growth estimates are given in Table 7 in Appendix C. They rely on IV estimation, with the age difference (the time between the examination by the review board and the enlistment) instrumented by the identity of the head of the review board. Plain black dots apply to estimates significant at the 5 per cent level; black circles correspond to estimates not significant at this level. The red dots are the upper and lower bounds of the 95 per cent confidence intervals. Negative growth from the review board examination may concern volunteers if enrolled before the call, or are due to measurement errors.

Figure 3: Within-cohort norm of reaction

range of observed ages in the data, as inferred from the curvature of the height-for-age relation over the few years following the initial examination.

The selection by the review board relies on the Chairperson z_i ruling the examination of man i as well as individual observed characteristics X_i of the man. Man i is exempted or discharged in 1908 when

$$y_i = \alpha^{\text{sel}} + \delta z_i + \gamma' X_i + \varepsilon_i^{\text{sel}} \tag{5}$$

is positive. He is otherwise enlisted in 1908. The coefficients (β_1, β_2) in (4) are set to $(\beta_1^{\text{enl}}, \beta_2^{\text{enl}})$ for men enlisted in 1908, and $(\beta_1^{\text{dis}}, \beta_2^{\text{dis}})$ for the remaining men. The model thus accommodates for two regimes, one for men entering service in 1908 and another for those discarded in 1908, and each regime incorporates a slowdown in late growth.

Results in Table 3 use the Heckman [18] two-step estimation procedure in the subsample without volunteers, as these men decide for themselves to perform military service. They confirm Filhoulaud as being more prone to draft men early in 1908 than Calmès. Men deemed fit in 1908 grow by 0.13 cm over 6 months, or 0.26 cm on a yearly basis.[9] But estimates lack precision, probably because many men are reported with no growth over such a short period. This uncertainty translates into a wide range of possible values of the age of maturity, between 19 years and a half and 23 years approximately. An age closer to the upper bound would be more in line with the results in Table 2; in fact, in view of the magnitude of growth reported in Table 1 for men enlisted in 1908, they could achieve maturity around the time of enlistment, at 21.3 years.

The loss of significance of the coefficient of the Mills ratio from Column (1) to (2) puts forward individual age, education and occupation at the moment of the first measurement as good proxies for unobserved characteristics that make an early enlistment more likely.

The uncertainty about the age a_{m} of maturity contaminates the estimate of adult height. A side-by-side difference between (4) evaluated at a_{m} and a_{i0} gives a height $h_{i\text{m}}$ reached by man i at maturity equal to

$$h_{i\text{m}} = h_{i0} + \beta_1 \left(a_{i\text{m}} - a_{i0}\right) + \beta_2 \left(a_{\text{m}}^2 - a_{i0}^2\right).$$

[9] This is, using the results in Column (2), half of $4.111 - 2 \times 0.093 \times 20.7$ over 6 months (where 20.7 is the average age at which men undergo the review board examination, regardless of whether they are enlisted in 1908 or later).

Table 3: Adult maturity

	(1)	(2)	(3)
Selection equation			
Constant (α)	-0.764^{***}	4.795^{**}	4.795^{**}
	(0.033)	(2.096)	(2.096)
Absent Prefect (δ)	-0.215^{***}	-0.186^{***}	-0.186^{***}
	(0.065)	(0.067)	(0.067)
Age at review board examination		-0.253^{**}	-0.253^{**}
		(0.101)	(0.101)
Education and occupation controls	No	Yes	Yes
Outcome equation 1: Men enlisted in 1908[a] (1957 observations)			
Constant			0.509
			(0.325)
Age difference ($\hat{\beta}_1^{\text{enl}}$)	4.918	4.111	4.076
	(3.915)	(4.348)	(4.321)
Age squared difference ($\hat{\beta}_2^{\text{enl}}$)	-0.128	-0.093	-0.112
	(0.094)	(0.102)	(0.103)
Inverse Mills ratio	-0.146^{**}	0.0404	-0.311
	(0.640)	(0.303)	(0.308)
Age at maturity ($-\hat{\beta}_1^{\text{enl}}/(2\hat{\beta}_2^{\text{enl}})$)			
Average	19.172	22.08	18.159
Delta method standard error	(1.932)	(1.257)	(3.495)
95 per cent confidence interval	[15.385, 22.959]	[19.618, 24.547]	[11.309, 25.009]
Average height at maturity (cm)	165.358	164.849	165.879
Outcome equation 2: Men exempted or discharged in 1908[a] (506 observations)			
Constant			0.503
			(0.739)
Age difference ($\hat{\beta}_1^{\text{dis}}$)	3.726^{***}	3.858^{***}	3.578^{***}
	(0.830)	(0.788)	(0.849)
Age squared difference ($\hat{\beta}_2^{\text{dis}}$)	-0.069^{***}	-0.072^{***}	-0.067^{***}
	(0.016)	(0.015)	(0.016)
Inverse Mills ratio	-0.458^{***}	-0.499^{***}	-0.793^{*}
	(0.165)	(0.154)	(0.481)
Age at maturity ($-\hat{\beta}_1^{\text{dis}}/(2\hat{\beta}_2^{\text{dis}})$)			
Average	26.728	26.669	26.708
Delta method standard error	(0.327)	(0.304)	(0.336)
95 per cent confidence interval	[26.087, 27.368]	[26.073, 27.265]	[26.049, 27.366]
Average height at maturity (cm)	162.68	162.70	162.64
Number of observations[a]	2,463	2,463	2,463

Notes: ***Significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level.
a. The model in estimated on the 2,463 observation subsample that excludes the top and bottom 2.5% of the height growth distribution and all volunteers.

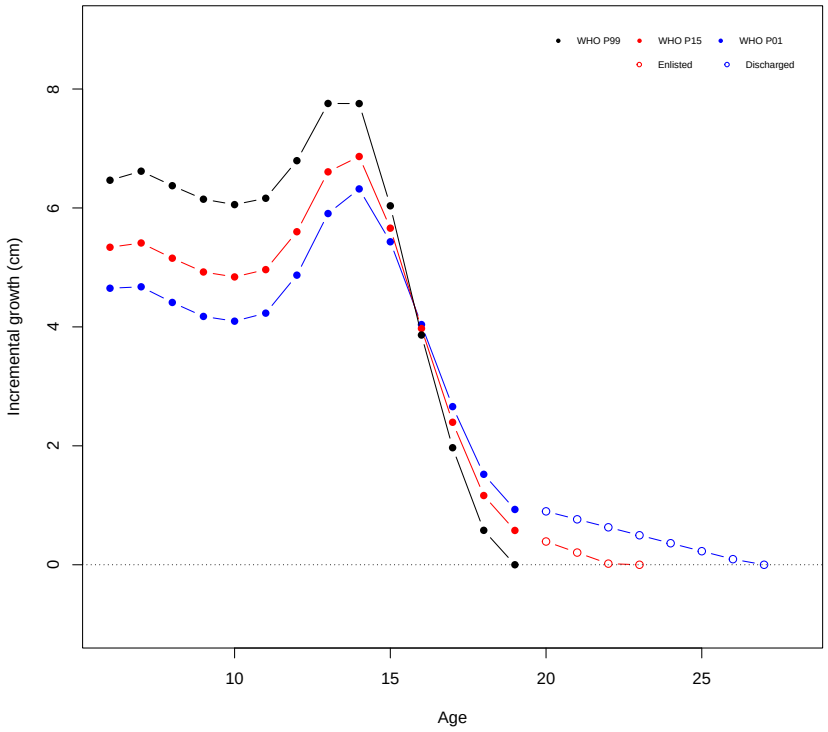
If computed at the mean age of maturity of 22.08 years obtained in Column (2), height at maturity is 164.8 cm. This corresponds to a gain in height of 0.4 cm from their 164.4 cm initial height.

Information on men exempted or discharged in 1908 is more precise. They are predicted to grow over several years, attaining maturity between 26 and 27 years. This long process still results in a short adult height of 162.7 cm, yielding a height gain of 1.6 cm from their 161.1 cm height at the review board examination. The initial selection would thus succeed to identify late maturers and postpone their enlistment. The magnitude of the coefficient of the Mills ratio in every specification in Table 3 confirms the presence of selection issues. Its lower precision in Column (3) when introducing time fixed effects is consistent with a postponement decision that takes into account predictable components of the environment driving the potential for late maturers to recover in the following year. The state of the 1908 harvest could serve as a plausible candidate.

The predicted episode of late growth for the two groups of men is depicted from age 20 in Figure 4 referring to the estimates in Column (2). For the sake of comparison Figure 4 also reports WHO velocity growth curves of modern boys for the bottom 1 percent shortest boys, the 15 percentile and the top 1 percent of the height distribution. The velocity at age a is computed as the difference between heights attained at age a and $a-1$, for every age from 6 to 19 (the WHO curves stop at 19). The extensions of the WHO curves does not seem to be beyond the realm of possibility. The men enlisted in 1908, who were assessed as healthy around age 20 in 1908, may resemble boys in the 15 percentile nowadays. Those discharged in 1908 would be closer, and more likely shorter, than the 1 percent shortest modern boys.

4 Discussion and concluding comments

This article documents height growth in males after 20 from quasi-exhaustive historical longitudinal individual-level data. The panel obtains from the combination of two widely used anthropometric sources from military conscription in France. A product from this combination is illustrated on the cohort of men born in 1887 in the department of Corrèze. Men continue to grow in height after age 20. Many reach adulthood between the ages of 21 and a half and 23. Late maturers, who are a fifth of the cohort, only reach maturity at age 26/27, a figure that echoes the *crementus corporis* age in Ancient Greece



At age a (in years) in the horizontal axis, the vertical axis gives the height velocity (computed as the difference in cm between height at age a and height at age $a-1$). Plain dots apply to WHO data while circles obtain from the estimates in Column (2) of Table 3. WHO data stop at age 19. The velocity for men enlisted in 1908 is represented by red circles with $4.111-2\times0.093\times a$ in the y-axis for age a in the x-axis. The blue circles also obtain from Column (2), using estimates found for men exempted or discharged in 1908. Both are assumed to be valid from age 20.

Figure 4: Fitting the growth curves of modern boys

(Tanner [33]). They still experience a significant gain in height of 1.6 cm before reaching height maturity.

The results reported in Column (2) of Table 3 yield a 164.4 cm average adult height, 0.7 cm above the 163.7 cm height in the recruitment table.[10]

Perhaps a way to put the 0.7 cm growth in height into perspective is to discuss how much the height at 20 provides us with a reliable proxy of the underlying economic prosperity.[11] Chamla [12] computes a 170.8 cm average height from the 1960 recruitment table in Corrèze. Her data from this source suggests that in this department men may have experienced a nearly constant increase of the average height over the first part of the twentieth century. The corresponding constant annual gain would be 0.14 cm from the average height of 163.7 cm in 1908. The 0.7 cm needed to attain adult height at 20 in 1908 starting from an observed height of 163.7 cm would therefore correspond to an underestimate of economic prosperity in 1908 by $0.7/0.14 = 5$ years. Equivalently, the (unobserved) adult height in 1908 would coincide with the (observed) average height of 164.4 cm computed from the recruitment table 5 years later in 1913. It is likely that adult height was not reached at age 20 when men were subjected 5 years later to the 1913 review board examination. In this case, the public statistics from the review board examination underestimate economic resources by more than 5 years.

The underestimation would be more severe among the less well-off men. Applying a similar calculation to the 1.6 cm height gain experienced by the shortest men yields a delay of 11 years (1.6 divided by 0.14). If those measured in the early 1920s in Corrèze have not yet reached their adult height by age 20, the underestimation would exceed 11 years in this part of the population, suggesting much lower economic inequalities than what would be inferred from data of the sole recruitment table.

The underestimated level of adult height is associated with a dampened increase in adult height over time if one supposes that in 1960 men in Corrèze

[10] The average adult height is $1,957 \times 164.85 + 506 \times 162.64$ divided by the total sample size, $2,463$. The results in Column (3) of Table 3 yield a greater point estimate of the height gain of 1.5 cm between the examination by the review board and maturity, but the estimated age at maturity lacks of precision.

[11] This relies on the link between height and net nutrition. However, in specific historical periods or parts of the world, such as past Ireland or certain regions of Africa, poor economic conditions may have contributed to improvements in height. Bozzoli, Deaton and Quintana-Domeque [8] consider both selection and scarring to address such cases. Tough economic conditions could lead to a taller population if they are associated with the mortality of the shortest individuals.

achieved maturity when subjected to the review board examination. A cross-sectional analysis applied to adult height would then yield a constant annual increase in adult height equal to 0.1 cm. This is 30 per cent revision below the observed 0.14 cm increase of the average height at age 20. Supposing a strict proportionality between growth in adult height and growth in available economic resources is arguably questionable. But, if assumed to be correct, this would result in an impressive overestimate of annual economic growth by 30 percent when relying solely on data from the recruitment table.

In conclusion, our findings on adult height suggest that aggregate economic conditions may have been more favorable and much less dispersed among families in Corrèze than typically inferred from military data on height.

In principle, it is possible to extend the analysis to cover whole France during the nineteenth century. In practice, however, the examples in Maurin [23] in footnote 5 show that the actual implementation of the military law may have varied across regions. Moreover, the present analysis closely relies on the specific features: the men from the 1887 cohort were examined shortly before the Great War, and their selection was ruled by a Prefect who exhibited a particular inclination to postpone enlistment. The quasi-exhaustiveness of the sample is achieved through the implementation of recall waves during the war. The distinctive attributes of the Prefect allow us to address endogeneity concerns in the time difference between the two height measurements.

In a climate of war preparation, France decided to extend the duration of military service from 2 to 3 years in 1913. This implied a one-year anticipated call of men born in 1893, during the year following their 19th rather than 20th birthday. The war even called for cohorts in the year following 18. Exploiting the younger age of the last cohorts when examined by the review board should allow us to sketch a final growth episode, and possibly observe in the military data the precise age of adult maturity of the tallest men.[12]

There are two other possible, and more speculative, directions for further research relying on both height level and height growth. A first line participates in the widespread effort to quantify the relative importance of the environment and genetic factors on human development; a standard rule of

[12]The strategy cannot be implemented on Corrèze, however, as the height taken during the review board is rarely recorded in the recruitment table for this department during the war.

thumb imputes 80 per cent of adult height to genetic factors and 20 to the environment (Barry Bogin [6]). If individuals with the same adult height share similar enough height-related genetic capital, so that one such individual who continues to grow after 20 has a genetic capital similar to that of a taller individual whose growth is completed at 20, a prolonged growth episode of the former suggests he was penalized by an unfavorable economic environment. In this regard, it could be meaningful that growth beyond the age of 20 pertains to approximately one-fifth of the 1887 cohort in Corrèze.

Height growth of the man, used on top of the height level, may also provide additional information in the assessment of long-run economic performance. In line with the analysis of β-convergence, the heterogeneity in per capita income growth rates is often exploited to get insights on the long run of economies with similar current per capita income levels: in the presence of decreasing returns, a higher growth rate signals that the economy still stands far from its long-run steady-state equilibrium. The present analysis suggests a way to go beyond the correlation between the height level and the actual state of the economy, with a higher height growth rate proxying long-run economic possibilities.

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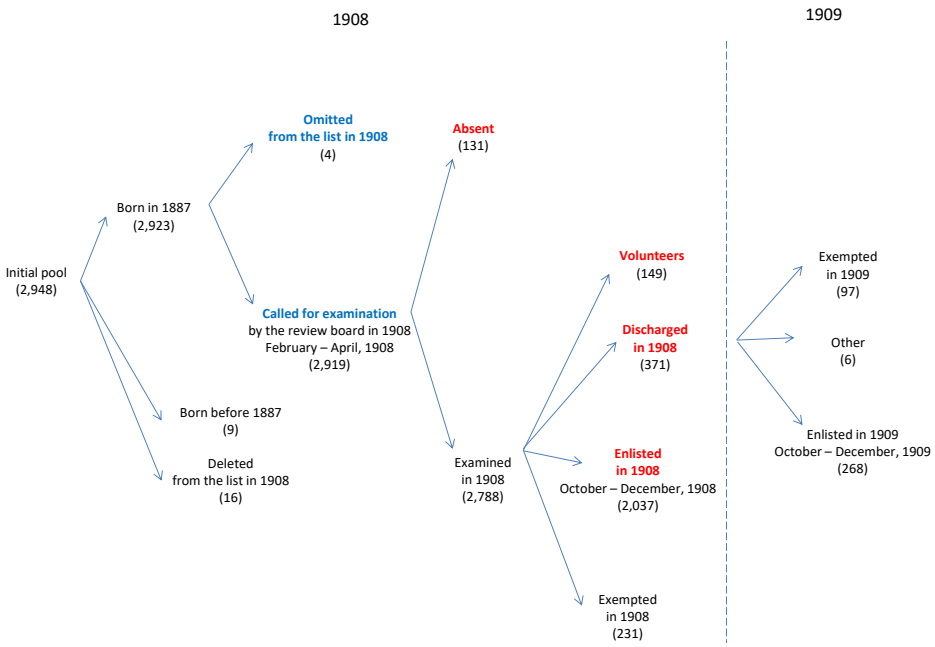
Appendix – Not to be published

A Data preparation

Data from the review board examination is depicted in blue in the sequence of events summarized in Figure 5. Data from the registration forms is in red.



The men measured during the examination by the review board (with a height reported in the recruitment table) appear in bold blue. Those who should theoretically be subject to a registration form appear in bold red. The number of men concerned by conscription in Corrèze in 1908 are in brackets. For instance there were 2,919 men born in Corrèze in 1887 called for an examination by the review board in 1908. They all appear in the recruitment table, including 131 men who did not respond to the summons. In principle, a registration form exists for each of these men, except 231 men exempted from military service in 1908. In fact, the data contain registration forms for some exemptees (see Table 4).

Figure 5: Enlistment timeline

Data from the recruitment table can only be found from archival work. A scanned sample of all the registration forms was prepared as part of the

Mémoire des Hommes national project to celebrate the hundredth anniversary of World War I. It is freely available for each department of France from the *Archives départementales* websites. Each individual form is fully identified by the (military) recruitment office (Brive or Tulle) in charge of the man and his unique registration number. Entering these two pieces of information on the *Archives de la Corrèze* website allows the reader to access every form used for illustration purpose in this appendix. The project sometimes includes digitized individual registration form information about civil status, occupation and literacy. The *Archives départementales de la Corrèze* provided me with the digitized file of all men born in Corrèze between 1863 and 1901. I completed this file with information from the recruitment table on men born in Corrèze in 1887 and examined by the review board in 1908. For every observation in the resulting exhaustive sample of all the men born in Corrèze in 1887 and reaching 20 years old in 1907, I entered additional (handwritten) information from the recruitment table: the height, the review board that actually examined the man, and the exemption/discharge/enlistment decisions made by the review board in 1908 and 1909. In addition, for every man with a registration form, I entered his (handwritten) enlistment date, his height and, if available, his corrected height.

Figure 5 also reports in brackets the numbers of men born in Correze in 1887 involved in the various steps of the enlistment process in 1908 and 1909. The initial $2,948$ pool includes a few men born before 1887 but omitted from the initial census made by mayors and gathered at the county level. It also includes some men who do not fall within the competence of the review board of Correze. The analysis in the main text starts with the $2,923$ men born in 1887 and falling within the competence of the review board of Correze. Most of them were examined in 1908 (only 4 were omitted from the census made at the end of 1907 and examined later). They all appear in the recruitment table.

In principle, an individual registration form had to be created for each men called for an examination by the review board in 1908, except 231 men who were exempted from military service in 1908. Its theoretical scope covers men enlisted in the fall of 1908, and those discharged in 1908, regardless of the outcome of the examination by the review board in 1909 was. It also includes 149 volunteers, who decided to enlist before being called, and 131 men absent from the review board of 1908 (absentees were automatically classified as suitable to serve). This theoretical scope is subject to the proviso that many men exempted in 1908 were actually reexamined throughout the

Table 4: Height completion

	Number of men	Number of men with a missing height in the recruitment table	Number of men with a missing height in the registration form	Number of men with a height entered in both sources
Initial sample	2,948	141	238	2,623
Men removed from the list	16	14	15	1
Men born before 1887	9	1	3	6
Men born in 1887	2,923	126	220	2,616
Men omitted from the list in 1908	4	0	0	4
Men called in 1908	2,919	126	220	2,612
Absentees in 1908	131	124	42	3
Examined by the review board in 1908	2,788	2	178	2,609
Volunteers	149	0	2	147
Enlisted in 1908	2,037	0	12	2,025
Exempted in 1908	231	1	142	89
Discharged in 1908	371	1	22	348
Enlisted in 1909	268	1	9	258
Exempted in 1909	97	0	13	84
Other	6	0	0	6

Reading: There are 2,025 out of 2,037 men enlisted in 1908 with a height completed in both the recruitment table and the registration form. The height of each of the 2,037 men is always completed in the recruitment table (filled out during the review board). It is missing for 12 men in the registration forms.

war: men from Correze were involved in three consecutive waves of recall occurring in 1914, 1915 and 1917. Some men exempted in 1908 eventually entered the army, and in this way they were subject to a late registration form.

Table 4 adds to the timeline of Figure 5 some information about the number of completed/missing individual heights in the recruitment table and the registration forms. Height may be missing either because the man does not appear in the source or because his height is left blank or not legible. Table 4 shows that there are two cases where height information is more likely to be missing: height is missing in the recruitment table for men who are listed in the municipality census but did not obey the review board summons, and men exempted in 1908 and never recalled during the Great War do not appear in the registration forms (many of them actually died before the war). The anthropometric literature often deals with truncation issues, as samples drawn from records of enlisted soldiers frequently display truncation from below due to minimum height requirements. Such selection criteria were abolished by the Law of 2 April 1901 [**?**] in France. Table 4 highlights the impact of recall procedures, as height is known in $231 - 142 = 89$ men exempted in 1908.

The enlistment date serves as a proxy for the date of the second measurement. It is typically unambiguous. The following rule was followed to assign

an enlistment date to every man.

1. The height of enlisted men is their height at enlistment.

   This covers men enlisted in 1908, men discharged in 1908 and deemed fit in 1909, as well as the men exempted in 1908 or 1909 but enlisted following recall waves during World War I.

   Pierre Gautherie was 161cm tall during the review board. He is discharged in 1908 because of eczema. A form is created in 1908 following the discharge decision, with registration number 1049 from the recruitment office of Brive. He is not subject to the departure examination in 1908. He is exempted in 1909 and so he is neither subject to the departure examination in 1909. He is reexamined by the Army in the course of the first recall wave occurring in December 1914 and eventually enlisted. The height of 163 cm reported in his registration form is set as taken in 1914.

Item 1 covers the most common cases as most men born in 1887 end up enlisted in 1908, 1909 or during the Great War. More specific situations are considered in the following Items.

2. The height of men discharged in 1908 and exempted in 1909 is taken during the 1909 examination by the review board.

   A registration form is created following a discharge decision in 1908. The man is not subject to the departure and enlistment examinations in 1908. The last measurement is assumed to be taken during the examination by the review board in 1909. If recalled during the war, see Item 4 below.

   François Dupuy (registration number 17 from the recruitment office of Tulle) is discharged in 1908 and exempted in 1909 for 'overall weakness.' The height of 163 cm reported in his registration form is set as taken on 26 April, 1909 when the review board examines the men born in 1888 in the county of Argentat. The observation corresponding to this man associates a height of 163 cm taken during the review board on 14 March 1908 (the initial date of 6 March 1908 that appears in the *Bulletin* was modified after the publication) with the same height of 163 cm taken in 1909.

3. The height of men exempted in 1908 or 1909 and once again exempted at the outcome of all recall waves is their height measured during the first recall in December 1914.

   There are 47 registration forms on men exempted in 1908 and rejected at the outcome of recall waves; see, e.g., Antoine Bouilhac (registration number 134 from the recruitment office of Brive). I set that the form is created following the first wave of recall in 1914. This should be seen as a conservative choice since the height coincides in the recruitment table and the registration forms for 45 men, i.e., this amounts to setting no individual height growth over a long period of time.

4. Corrected height is the height of the man at the moment of his last enlistment.

   Men may be measured several times following enlistment, e.g., when assigned to a new military unit or following a novel enlistment during the Great War several years after the 1908/1909 examinations. The Army then needs to update the height reported in the registration form according to item 1 or 2. This is done using the corrected height field of the form. The data only includes 104 corrected heights.

   René Aupetit (registration number 1633 from the recruitment office of Tulle) is discharged in 1908 with a short height of 154 cm and a low weight of 48 kg, but deemed fit by the review board in 1909 and enlisted on 7 October 1909. His height in the registration form, taken in 1909, is still equal to 154 cm. He is nevertheless rejected for 'insufficient weight' as of 12 October 1909, presumably at the outcome of the sequence of departure and enlistment examinations. When reexamined during the 1914 recall wave, he is considered as able and enlisted. The corrected height field is filled out in his registration form, with a height of 158 cm.

   Antoine Nauche (registration number 208 from the recruitment office of Tulle) is discharged in 1908 (with height 150 cm in the recruitment table) and absent from the examination by the review board in 1909, but enlisted in October 1909. His height set according to Item 1 as taken when enlisted in 1909 is still 150 cm. He is re-examined and enlisted in August 1914 (the corrected height field reports a height of 152 cm). There are two observations for this man in the sample, one with a height pair $(150, 150)$ associated with an age difference of

Table 5: Height differences between the two sources

	Number of men with height completed in the two sources	identical in the two sources	different in the two sources
Initial sample	2,623	2,125	498
Men removed from the list	1	1	0
Men born before 1887	6	6	0
Men born in 1887	2,616	2,118	498
Men omitted from the list	4	2	2
Men called in 1908	2,612	2,116	496
Absentees	3	1	2
Examined by the review board	2,609	2,115	494
Volunteers	147	104	43
Enlisted in 1908	2,025	1,714	311
Exempted in 1908	89	41	48
Discharged in 1908	348	256	92
Enlisted in 1909	258	183	75
Exempted in 1909	84	69	15
Other	6	4	2

Reading: Out of $2,025$ men enlisted in 1908 with a height completed in both the recruitment table and the registration form, height differs in the two sources for 311 men (so $2,025 - 311 = 1,714$ display equal height in the two sources).

about 1 year (from 1908 to 1909), and another observation with a pair $(150, 152)$ associated with an age difference of about 6 years (from 1908 to 1914).

Table 5 gives information on height information in the two sources. The initial $2,623$ observation subsample consists of men with a height recorded in both the recruitment table and the registration form. It excludes absentees and exempted men with only one height measurement. There are 498 men among those born in 1887 who display different heights in the two sources. Height is more likely to differ in the two sources if there is a long time period elapsed between the selection by the review board in 1908 and the departure examination within the recruitment office: there are 30 per cent $(75/257)$ of men enlisted in 1909 who display a different height in the two sources, against 15 per cent $(311/2,025)$ among those enlisted in 1908.

B Chairperson as an instrument

The personal file of Georges Calmès, the Prefect of Corrèze in 1908, suggests a special relationship with the Army.[13] His mother was from a military

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

family, the names of some members still stood out etched into a pillar of the Napoleonic *Arc de Triomphe* in Paris. Following the defeat of France in the 1870 war with Prussia, in a context of strong revanchism, the young Calmès succeeded in entering in 1872 the high-level military school of Saint-Cyr training future officers for the armed forces. But he decided to resign, which seems to be a quite rare occurrence. Later he was exempted from military service; he is described in the files as a short man, and during 30 years every internal administrative document emphasizes his poor health status as a strong constraint on the place where he can be employed. A representative report[14] on Calmès dated from 26 March 1888 states that 'Calmès is a civil servant of great merit [...]. Health is the only thing he really lacks. This is why he decided to enter the *conseils de préfecture*, forced to leave his position as *inspecteur de l'enregistrement* because of travels and trips that the position involves.'

Table 6: Review board chair and delayed enlistment

	Age difference[a] (year)		Review board	
			height[b] (cm)	time[c] (year)
	(1)	(2)	(3)	(4)
	Enlisted in 1908 in the 95% subsample	Enlisted in 1909 in the 95% subsample	95% subsample	
Absent Prefect[d]	−0.020	0.021	0.348	0.019
	(0.018)	(0.030)	(0.425)	(0.018)
Constant	0.566***	1.483***	163.729***	0.195***
	(0.010)	(0.020)	(0.218)	(0.011)
Number of observations	1,965	293	2,596	2,596
r^2	0.019	0.002	0.001	0.033
F statistic	1.3	0.5	0.674	1.032

Notes: *** significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level. Robust standard errors (into brackets) are clustered at the county level. The 95% subsample excludes the top and bottom 2.5% of the height growth distribution.

a. The explained variable is the time between the review board examination and enlistment.

b. The explained variable is the height taken during the review board examination.

c. The explained variable is the time between 1 January 1908 and the review board examination.

d. The head of the review board is the Secretary Charles Filhoulaud rather than the Prefect Georges Calmès.

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

Columns (1) and (2) in Table 6 indicate that the correlation between the age difference and the identity of the Chairperson of the review board (either the Prefect Georges Calmès or the Secretary Charles Filhoulaud) vanishes when one restricts attention to the separate subsamples of men enlisted in 1908 or those enlisted in 1909. This shows that the impact of the Chairperson goes through the binary enlistment/discharge decision made in 1908 rather than the precise moment at which men are enlisted within a year. Indeed the time when the man is enlisted actually depends on the management of human resources left to the military administration.

The last two columns in Table 6 serve as robustness checks for the validity of the chairperson instrument. Column (3) shows that the presence of the Prefect is not based on the height taken during the review board, e.g., because the Prefect would especially choose to be present in poor counties where men are short and more likely to be discharged. Column (4) serves as a test for the mechanical effect that in 1908 the Prefect would have been present during the first sessions of the review board 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 date of the session of the review board. This duration is not correlated with the presence/absence of the Prefect. Additional tests are performed in Table 3 in the main text.

C Late Catch-up

Table 7: Late catch-up

	Height growth (cm)	Standard error	Number of men
(144,150]	0.378**	(0.170)	27
(150,151]	0.454*	(0.246)	13
(151,152]	0.661***	(0.198)	14
(152,153]	0.377***	(0.110)	23
(153,154]	0.460***	(0.130)	52
(154,155]	0.349*	(0.185)	52
(155,156]	0.406***	(0.143)	68
(156,157]	0.606***	(0.183)	76
(157,158]	0.602***	(0.190)	100
(158,159]	0.188**	(0.083)	119
(159,160]	0.579***	(0.132)	166
(160,161]	0.681***	(0.137)	164
(161,162]	0.624***	(0.119)	196
(162,163]	0.409***	(0.105)	225
(163,164]	0.211***	(0.077)	187
(164,165]	0.213***	(0.081)	160
(165,166]	0.127*	(0.075)	155
(166,167]	0.020	(0.081)	130
(167,168]	0.174**	(0.070)	122
(168,169]	0.108	(0.097)	100
(169,170]	0.114**	(0.047)	111
(170,171]	0.131**	(0.061)	107
(171,172]	0.108	(0.08)	66
(172,173]	0.151	(0.097)	44
(173,174]	−0.061	(0.063)	41
(174,175]	−0.089	(0.209)	27
(175,184]	−0.159	(0.097)	51
Instrument	Absent Prefect		
Observations	2,596		
r^2	0.084		

Note: ***Significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level. All robust standard errors are clustered by county.

D Cohort-specific growth

The Berteaux Law was implemented from the review board examinations in 1906. Georges Calmès has remained in Correze from March 1905 to November 1908, when appointed Prefect of Hérault. Charles Filhoulaud remained Secretary in Correze from 1900 until his retirement in 1923. Hence they shared the chair of the review board under the Law of 1905 for the three cohorts of men born between 1885 and 1887.

The sample of men born in 1886 (examined in 1907) differs in two respects from the other cohorts. First, nearly half of the observations are missing as the recruitment table has not been preserved for twelve counties in the subdivision (*arrondissement*) of Tulle. In addition, the review of the seven counties in the subdivision of Ussel was carried out exceptionally late in May 1907, implying a very short period of time between the two height measurements for men enlisted in the fall of 1907.

The full sample of the three cohorts contains 6,573 observations with completed age difference and height growth episodes. As before, I discard the bottom and top 2.5 per cent of the (three-cohort) height growth distribution to deal with outliers. This yields a 6,182 observation sample.

An important point for the instrumental methodology concerns the replacement of Calmès as Chairperson. At the moment of the review made in 1908 considered in the main text, Calmès was on the way out and Filhoulaud replaced him in one-third of the counties (9 out of 29 counties in Correze). In the two previous years, however, the newly arrived Prefect was replaced far less often: Filhoulaud ruled the selection of men from the 1885 and 1886 birth cohorts in only four counties out of a total of $2 \times 29 = 58$ counties. Column (1) of Table 9 shows that the lower variability in the presence/absence of the Prefect in the three-cohort sample makes this instrument no longer suitable for dealing with the endogenous age difference between the two height measurements.

The presence/absence of the Prefect instrument can be strengthened by exploiting small provisions on the timing of the review board in a context of high transportation costs. The schedules reproduced in Table 8 show that at most one meeting per day was held and that the examination of all the men from a county was programmed on-site within a half-day. Two sessions set up on two consecutive days often concern neighboring counties, while breaks with at least one day off entail more distant counties. The minimization of transportation costs rationale for the schedule of the review board,

Table 8: Annual schedules of the review board

County	Men born in 1885	Men born in 1886	Men born in 1887
Argentat	1906-03-15, Thursday, 10:00		1908-03-14, Saturday, 10:00
Ayen	1906-03-01, Thursday, 9:30	1907-03-11, Monday, 9:30	1908-02-18, Tuesday, 10:00
Beaulieu	1906-03-13, Tuesday, 13:45	1907-03-22, Friday, 13:45	1908-02-26, Wednedsay, 13:45
Beynat	1906-03-14, Wednedsay, 10:30	1907-03-28, Thursday, 10:30	1908-02-28, Friday, 10:30
Bort	1906-04-10, Tuesday, 13:15	1907-05-16, Thursday, 10:15	1908-04-02, Thursday, 13:15
Brive	1906-03-07, Wednedsay, 13:00	1907-03-26, Tuesday, 13:00	1908-02-29, Saturday, 13:00
Bugeat	1906-04-04, Wednedsay, 10:15	1907-05-13, Monday, 10:15	1908-04-09, Thursday, 10:15
Correze	1906-03-29, Thursday, 13:30		1908-03-10, Tuesday, 13:30
Donzenac	1906-03-02, Friday, 13:45	1907-03-12, Tuesday, 13:45	1908-02-21, Friday, 13:45
Egletons	1906-03-19, Monday, 13:15		1908-03-24, Tuesday, 10:45
Eygurande	1906-04-06, Friday, 10:15	1907-05-10, Friday, 10:15	1908-04-13, Monday, 10:15
Juillac	1906-03-06, Tuesday, 9:15	1907-03-15, Friday, 9:15	1908-02-20, Thursday, 9:15
Lapleau	1906-03-20, Tuesday, 9:30		1908-03-09, Monday, 9:30
Larche	1906-03-12, Monday, 13:15	1907-03-23, Saturday, 13:15	1908-02-27, Thursday, 13:15
La Roche Canillac	1906-03-21, Wednedsay, 10:00		1908-03-25, Wednedsay, 10:00
Lubersac	1906-03-03, Saturday, 9:00	1907-03-18, Monday, 9:00	1908-02-22, Saturday, 9:00
Mercoeur	1906-03-17, Saturday, 10:00		1908-03-07, Saturday, 10:00
Meymac	1906-04-09, Monday, 9:00	1907-05-11, Saturday, 9:00	1908-04-04, Saturday, 13:00
Meyssac	1906-03-08, Thursday, 9:30	1907-03-25, Monday, 9:30	1908-03-04, Wednedsay, 9:30
Neuvic	1906-04-07, Saturday, 10:15	1907-05-14, Tuesday, 10:15	1908-04-11, Saturday, 10:15
Saint-Privat	1906-03-16, Friday, 14:00		1908-03-06, Friday, 11:15
Seilhac	1906-03-24, Saturday, 13:30		1908-03-12, Thursday, 13:30
Sornac	1906-04-03, Tuesday, 9:30	1907-05-08, Wednedsay, 9:15	1908-04-07, Tuesday, 9:30
Treignac	1906-03-28, Wednedsay, 9:30		1908-03-28, Saturday, 9:30
Tulle-Nord	1906-03-26, Monday, 9:00		1908-03-26, Thursday, 9:00
Tulle-Sud	1906-03-23, Friday, 9:00		1908-03-13, Friday, 9:00
Ussel	1906-04-02, Monday, 9:15	1907-05-07, Tuesday, 9:15	1908-04-06, Monday, 9:15
Uzerche	1906-03-27, Tuesday, 13:00		1908-03-30, Monday, 14:00
Vigeois	1906-03-05, Monday, 14:00	1907-03-14, Thursday, 14:00	1908-02-19, Wednedsay, 14:00

combined with the observation of sequences of consecutive examinations of neighboring counties, suggests that some members of the committee sometimes had to spend the night within the reviewed counties. The fact that a star-shaped network designed around the Prefecture in Tulle was considered as too costly presumably indicates that the chosen schedule makes a return to Tulle difficult between an afternoon session followed by a session in the next morning.[15]

Georges Calmès, portrayed as a frail man, was nearly 60 years old when reviewing these three cohorts in Corrèze, and he had just married on 6 September 1905 Victorine Bédache. Suppose then that Calmès, who lives in the city center of Tulle, prefers not to spend the night away from home. An examination late in the afternoon following a day with no session enables him to leave Tulle in the morning on the day of examination: he should therefore prefer this option to an examination early in the morning. Symmetrically, an early examination in the morning allows him to return to Tulle in the evening if no session is scheduled the following day, which should suit him better than an examination scheduled in the afternoon.

Column (2) of Table 9 accounts for the impact of a new Night in Tulle dummy variable on the enlistment decision. The dummy takes value 1 if the session of the review board is consistent with a night spent in Tulle before or after the examination. Namely, it is 1 if the examination either starts after 1:30 p.m. if no session is scheduled the day before, or before 10:00 a.m. if no session is scheduled the day after. Otherwise the variable takes value 0. It appears that Calmès and Filhoulaud make similar enlistment/discharge decisions when it is difficult to depart from or return to Tulle the day of the examination (the Night in Tulle dummy is 0). However the Prefect is much more willing to discharge or exempt men than the Secretary in the case where he does not have to spend the night in the countryside away from Tulle (the Night in Tulle dummy is 1).

In Column (3) the instrument for the age difference is a dummy that takes value 1 if Calmès chairs a session starting either after 1:30 p.m. if no session

[15]The *Archives de la Corrèze* hold a rich documentation on the itineraries followed by the review board for the costing of the examination sequences (reference R27). In 1908, travel was either by train or car. A departure by car from Brive was scheduled at 11:30 a.m. for an arrival in Donzenac, located 10 km away, at 1:30 p.m. on 21 February. On 7 March 1908, the 12 km travel from Argentat to Mercoeur took nearly 3 hours. The same R27 reference material also contains individual financial compensation requests showing that some members of the board were not following the planned route.

Table 9: A night in Tulle

	Age difference (cm)			
	(1)	(2)	(3)	(4)
	Sample of men born in 1885, 1886 or 1887			Sample of men born in 1885 or 1887
Reference: Calmès chairs the board				
Absent Prefect (Filhoulaud chairs the board)	−0.126			
	(0.080)			
Reference: Calmès chairs the board × Night in Tulle is 0				
Calmès chairs the board × Night in Tulle is 1		0.373***		
		(0.118)		
Filhoulaud chairs the board × Night in Tulle is 0		0.022		
		(0.085)		
Filhoulaud chairs the board × Night in Tulle is 1		−0.080		
		(0.098)		
Reference: Calmès chairs the board × Night in Tulle is 1				
Either (Filhoulaud chairs the board)			−0.378***	−0.489***
or (Calmès chairs the board × Night in Tulle is 0)			(0.115)	(0.104)
Constant	0.899***	0.800***	1.172***	1.341***
	(0.053)	(0.049)	(0.108)	(0.094)
Number of observations	6,182	6,182	6,182	4,909
r^2	0.001	0.01	0.009	0.013
F statistic	2.5	4	10.8	22.08

Notes: ***Significant at the 1 per cent level. ** 5 per cent level; ∗ 10 percent level. Robust standard errors are clustered by county and year of birth.

Night in Tulle is 1 if the session of a review board is scheduled so that one can spend the night in Tulle before and/or after the session. It is 0 otherwise.

is scheduled the day before, or before 10:00 a.m. if no session is scheduled the day after. In every other alternative, i.e., either Calmès chairs a session while Night In Tulle is 0 or Filhoulaud replaces Calmès, the variable takes value 0. Nearly a quarter of men (1,367 over 6,182) are associated with a dummy of 1. This refined binary Night in Tulle × Calmès instrument is strong enough to deal with the endogenous age difference. It is even more powerful in Column (4) that excludes the incomplete 1886 birth cohort.

Table 10 reproduces the same robustness tests as in Table 6. The Night in Tulle × Calmès instrument is neither correlated with age at the moment of the examination by the review board nor the individual height taken during this examination. There is no specific pattern in the schedule where, say, the instrument would mostly take value 1 at the beginning or the end of the whole set of sessions, thus implying a mechanical spurious impact on the age difference.

Table 10: Robustness for Night in Tulle × Calmès instrument

	Height in the recruitment table	Age	Time from January, 1st to the review board
	(1)	(2)	(3)
Reference: Calmès chairs the board × Night in Tulle			
Either (Filhoulaud chairs the board)	0.376	0.024	0.014
or (Calmès chairs the board × Night away from Tulle)	(0.317)	(0.021)	(0.016)
Constant	163.601***	20.716***	0.210***
	(0.291)	(0.019)	(0.014)
Number of observations	6,182	6,182	6,182
r^2	0.001	0.001	0.011
F statistic	1.4	1.3	0.7

Notes: ***Significant at the 1 percent level; ** at the 5 percent level; * at the 10 percent level.
All robust standard errors (into brackets) are clustered by county and year of birth.

Table 11 reports IV estimation results on height growth using the Night in Tulle × Calmès instrument for the age difference. Column (1) shows that the average growth over one year from the review board equals 0.43 cm in the three-cohort sample, a figure that does not significantly differ from the one found for the men born in 1887 using the single absence/presence of the Prefect as instrument. Column (2) shows that height growth of the different cohorts do not differ either, which may be viewed as a further indication of

the validity of the approach. The point estimate of growth in the incomplete sample of men born in 1886 is slightly lower, possibly following the short period of time elapsed between the two measurements for many of these men. Column (3) restricts to the subsample excluding the men born in 1886 and reports an unaffected growth in the two remaining cohorts.

Table 11: Quantifying height growth

	Height growth (cm)		
	(1)	(2)	(3)
	Sample of men[a] born in 1885, 1886 or 1887		Sample of men[a] born in 1885 or 1887
Age difference (year)	0.433***		
	(0.040)		
Age difference (year) × born in 1885		0.543***	0.543***
		(0.110)	(0.110)
Age difference (year) × born in 1886		0.253***	
		(0.059)	
Age difference (year) × born in 1887		0.411***	0.411***
		(0.032)	(0.032)
Instrument[b]	Night in Tulle × Calmès	Night in Tulle × Calmès × Birth year	Night in Tulle × Calmès × Birth year
Weak instrument test (p-value)	0	0	< 2.2e-16
Hausman test p-value	< 2.2e-16	< 2.2e-16	< 2.2e-16
Number of observations	6,182	6,182	4,909

Notes: ***Significant at the 1 percent level; ** at the 5 percent level; * at the 10 percent level. Robust standard errors clustered by county and year of birth.

Reading: The average height growth in the three-cohort sample is 0.433 cm over one year following the examination of the review board.

a. This excludes the bottom and top 2.5 percentiles of the three-cohort height growth distribution.

b. Night in Tulle × Calmès is 1 if Calmès chairs a session of the review board scheduled so that he can spend the night in Tulle before and/or after the session. It is 0 otherwise. The variable is interacted with the year of birth in the case where cohort-specific growth rates are estimated.

E Accounting for absentees

There were 131 men absent from the examination by the review board in 1908. They are not included into our final data set since their initial height

is missing and definitively lost. Many absentees were eventually retrieved by the Army and enlisted, often in 1908: Table 4 shows that the registration forms report the height of 89 absentees. Their average height is 164 cm in the registration forms. It stands below the height of the men present at the review board. The norm of reaction pattern in Section 3.2 suggests that our assessment of the height growth of the man could consequently be underestimated. To get a quantitative evaluation of the possible bias due to these men, I have matched every absentee with the man present at the review board with the nearest propensity score. The score is computed referring to the age of the man when examined by the review board in 1908, his height at enlistment and his county of birth. Once matched, absentees are imputed the height at the review board of their nearest neighbor.

The imputed height of absentees is 163.11 cm, with half of absentees' heights between 160 and 165 cm. Reintroducing the absentees with their imputed height into the sample, one gets an augmented initial sample of $2,785$ observations with a filled height in the two sources (rather than $2,707$ in the main text).

Table 12 reports estimation results from the model (2) on this augmented sample. It shows that the small number of absentees does not have much of an effect on estimated growth. Growth tends to be magnified if one discards extreme height growth observations in the tails of the distribution, yielding an additional height gain of 0.1 cm. In view of their short imputed height and the fact that many absentees were enlisted in 1908, the height gain is even more pronounced when restricting to the standard case where enlistment occurs in 1908 or 1909, reaching 0.2 cm.

Table 12: Height growth of absentees– Absent Prefect IV estimates

	Height growth (cm)		
	(1)	(2)	(3)
	Augmented initial sample	95% subsample	Enlisted in 1908 or 1909 in the 95% subsample
Age difference (year)	0.487***	0.434***	0.608***
	(0.058)	(0.033)	(0.063)
Number of observations	2,785	2,667	2,325
Instrument	Absent Prefect	Absent Prefect	Absent Prefect
Weak instrument test (p-value)	< 2.2e-16	< 2.2e-16	< 2.2e-16
Hausman test p-value	5.59e-07	8.7e-14	1.1e-4

Note: ***Significant at the 1 per cent level; ** 5 per cent level; * 10 per cent level. All robust standard errors (into brackets) are clustered at the county level.