

# ***Remapping Italy's Path to the XIX<sup>th</sup> Century: Anthropometric Signposts\****

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*Mean stature is estimated for late eighteenth-century Northern Italy on the basis of archival records from the armies of the Napoleonic-era Kingdom of Italy. The principal finding is that average heights for the birth cohort of the 1780s were lower than for earlier generations, but still quite respectable by European standards. There is evidence that pronounced inequality in living standards was present – across provinces and between social groups – that nutritional stress which prolonged the growth process into the mid-20s, and that urban places had not yet become less healthy environments than the countryside. The paper also explores refinements to the truncated maximum likelihood estimator for dealing with 'heaped' [i.e. mal-distributed] and rounded data. The results corroborate tentative previous findings based on alternative data sources. They suggest that in Northern Italy's economic decline from Renaissance leadership to nineteenth-century backwardness, the real crisis was not the collapse of traditional export industries in the seventeenth-century but the buildup of Malthusian pressure in the eighteenth. Prior to this period any decline was not absolute, but relative to the region's own past and industrializing Northwest Europe*

## **1. Leader to laggard in three centuries**

The secular decline of Northern Italy is potentially rich in historical lessons. Renaissance Europe's undisputed leader in commerce, finance and industry in the Middle Ages, the region was highly urbanised, prosperous and integrated into international markets through the mid-

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sixteenth century.<sup>1</sup> On the eve of Italian unification in the mid-nineteenth century, it had slipped well down the continental scale of economic development and prosperity. Commonly cited estimates of per capita GDP circa 1820 put the region in the middle of the European pack, far behind the leading economies of Britain and the Netherlands. This position deteriorated further by 1870.<sup>2</sup> Other measures such as real wages, industrialisation, productivity, exports or mortality rates concur in relegating Risorgimento Northern Italy to the relatively underdeveloped periphery.<sup>3</sup>

Traditional accounts of the decline focused on the collapse of the region's export base in the seventeenth century, which was attributed to institutional rigidity in the face of exogenous shocks.<sup>4</sup> The shocks included the reorientation of trade toward the Atlantic, disruption of the most important export markets, and mid-century population losses due to plague. The first of these shocks, gradually but cumulatively, gave English and Dutch

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<sup>1</sup> Northern Italy refers here to that part of the peninsula north of (and excluding) Rome: the regions of Lombardy, Veneto, Emilia-Romagna, the Marches, Piedmont, Tuscany, and Umbria. The area can equivalently be called North-Central Italy. The new evidence presented in the paper concerns the first four of these regions, with the discussion focused primarily on the first three.

<sup>2</sup> Maddison, *World Economy*, Table A1-c, p. 185, assuming a 15 percent advantage over the national average for the North; see Cohen and Federico, *Growth*, p. 15.

<sup>3</sup> While Allen's recent estimates indicate that real wages for labourers in Milan and Florence were the lowest in Europe in the late eighteenth and the nineteenth centuries, most indicators do not suggest such extremes. (Allen, *Great Divergence*, Tabs. 5-6.) This is true of infant mortality and life expectancy at birth, for example. Galloway's annual estimates for Northern Italy average 23 percent and 33 years, respectively, from 1750 to 1850. Neither measure shows any clear improvement over the period, and both are clearly worse than figures for England or Scandinavia. The Netherlands and France improve and move ahead of Northern Italy over time, while the region retains a slight advantage over countries like Spain and Russia. (Galloway, *Reconstruction*; Livi-Bacci, *Population*, Tabs. 5.3, 6.4, pp. 113, 135; Maddison, *World Economy*, Tab. 1-5a, p. 30; Del Punta, *Dalla metà*, p. 148 for region-specific Italian data). The story is similar for urbanisation; Northern Italy remains more urban than much of Europe, but is clearly behind the United Kingdom or the Low Countries by the nineteenth century. (De Vries, *European Urbanization*, Tab. 3.7, p. 39). Employment shares in industry in the first census of unified Italy further show an economy lagging far behind Northwest Europe. Italy's 1871 share of male employment in agriculture is 61%, well above figures of around 50% for Austria, Belgium, Denmark or France from twenty years earlier, to say nothing of the Netherlands (45%) or UK (28%). The North's share would have been a few points below the Italian figure. (Mitchell, *European Historical Statistics*, Tab. C1.)

<sup>4</sup> An example of such a traditional account can be found in Cipolla, *Before the Industrial Revolution*, especially pp. 253-63. It is criticised in Malanima, *La fine*, and Fenoaltea, *Lo sviluppo*.

merchants the strength to wrest control of even Mediterranean trade from Italians. The second was caused by war in Germany and Turkey and the decline of precious metal flows into Spain from the Americas. The third was induced by a mid-century outbreak of plague and raised real wages. Institutional rigidity referred primarily to guild control of production, which kept real wages high and blocked innovation in both process and product, specifically the imitation of the cheaper northern textiles produced in rural areas under the putting-out system. The results were a collapse of exports and deindustrialisation (or, more strongly, "refeudalisation") as both nobility and the bourgeoisie withdrew capital from industry and commerce and invested it in the land or loans to the state. By the end of the century, Italy "had begun her career as an underdeveloped area within Europe."<sup>5</sup>

A weakness of this account is that it equates structural change with decline, without providing direct evidence of the latter. While it is clear that production and export of high-quality woollens collapsed in Venice and Florence, it is not at all clear by how much per capita output in Northern Italy – or even, more narrowly, industrial production – decreased. Though it is well established that foreign merchants increasingly dominated even intra-Mediterranean trade, the extent of any decline in living standards is not evident. Indeed, it is not certain that Northern Italy experienced an economic decline at all, in absolute terms.

In a series of publications, Malanima has synthesised fragmentary evidence and exploited continuous data on wages and prices to develop measures of real wages, agricultural and industrial production, and GDP per capita for the very long run.<sup>6</sup> While such estimates inevitably rely on strong assumptions to extrapolate from scarce evidence, the assumptions are clear, the indicators internally consistent and comparable over time. They suggest an interpretation rather different from the crisis scenario outlined above. The seventeenth century was a period of conversion, rather than crisis. And Northern Italy experienced an absolute decline only later, in the latter half of the eighteenth century.

Urban populations did not collapse over the seventeenth century.

<sup>5</sup> Cipolla, *Before the Industrial Revolution*, p. 263.

<sup>6</sup> Many of these results are summarised in Malanima, *L'economia*.

Despite a devastating mid-century outbreak of plague, by 1700 they had recovered to within a few percent of their levels in 1600. As the countryside was less severely struck, urbanisation rates fell slightly, but this continued a trend already underway before 1600.<sup>7</sup> And the region remained one of the most urbanised in Europe, falling behind only the smaller Netherlands and Belgium. Urban real wages show neither a precipitous rise that might have caused a collapse of export industry nor a dramatic fall that might have resulted from it. Rather, having descended from extraordinary highs in the century or so following the appearance of the plague, they fluctuate around a fairly stable trend (gently rising in the best-documented case of Florence) from the early 1500s through the early 1700s. Decline comes only from the mid-eighteenth century, when it is quite substantial. Real wages then stagnate at low levels through the mid-nineteenth century.<sup>8</sup> Malanima argues that even the narrowly defined industrial sector did not experience a decline, as the decline of wool was matched by the rise of silk. As most silk-producing operations took place in the countryside, however, they eluded the kind of attention given to traditional metropolitan crafts.<sup>9</sup> Fenoaltea argues that the decline of wool can even be interpreted as *caused by* the rise of silk.<sup>10</sup> And Sella has presented new evidence contesting the received wisdom that by the late seventeenth century Northern Italian imports had switched from raw materials to manufactures.<sup>11</sup>

Nor do things appear to have gone differently in agriculture. Real wages in the sector were stable or gently rising through the seventeenth and up until the middle of the eighteenth century. Federico and Malanima have circumvented the problem of missing data on agricultural supply by estimating output from the demand side, using data on wages and prices for agricultural and non-agricultural goods in the framework of an assumed demand function with plausible parameter values.<sup>12</sup> Their

<sup>7</sup> Malanima, *L'economia*, p. 371-84.

<sup>8</sup> Malanima, *L'economia*, pp. 240-47, 417-26.

<sup>9</sup> Malanima, *La fine*, pp. 168-90.

<sup>10</sup> The idea is that strong export performance in silk products produced a balance of payments surplus, specie inflow, and rising wages and prices that made traditional exports uncompetitive – an early example of the Dutch Disease. Fenoaltea, *Lo sviluppo*.

<sup>11</sup> Sella, *Industrial Raw Materials*.

<sup>12</sup> Federico and Malanima, *Progress*.

estimates indicate that output per capita and per worker increased through the seventeenth century (from a low point at its beginning), and fell in the second half of the eighteenth, stagnating at this level through the mid-nineteenth. While labour productivity in agriculture grew more slowly than elsewhere from 1600, it was only in the later period that France or England forged ahead. Finally, estimates of GDP per capita show that declines were in the sixteenth and in the later eighteenth century, not in the seventeenth. If these estimates are correct, it is clear that the traditional account of Italy's decline will have to be rethought.

Wage and price data lie at the heart of the estimates just described. Evidence from an entirely different source corroborates their account of declining living standards in the eighteenth century; mean heights declined over the same period. Mean height is a reliable indicator of average living conditions, for it accurately reflects cumulative net nutrition, meaning the balance between intake of nutrients and the demands of basal metabolism, workload and disease. Positive net nutrition is fuel for growth. The body can react to brief or mild periods of deprivation by delaying and lengthening the growth process, which can continue into the mid-20s. Prolonged or severe stress, especially during infancy and early childhood, has permanent effects on final stature. As an indicator of real incomes, height is not always unambiguous and must be interpreted with care. It is possible for groups to be poor and tall, for example, if environmental conditions are propitious or the situation makes a favourable diet possible.<sup>13</sup> Nonetheless, incomes generally constrain both dietary choice – in particular the ability to buy protein-rich foods important for growth such as meat and dairy products, and access to health care and salubrious living conditions.

*Figure 1* (see Appendix) plots estimated mean heights of 21-year-

<sup>13</sup> Among dairy farmers of Southern Bavarian "milk regions" in the eighteenth century, low population density created a favourable epidemiological environment, while the export of butter but not cheese left a surplus of high-protein skimmed milk available for consumption at low or zero opportunity cost. Baten, *Ernährung*. A similar argument has been made for Ireland, where potatoes and skimmed milk (a non-tradable by-product of butter production) made for a protein-rich diet in a poor country. Mokyr and O'Grada, *Heights*.

old Lombard soldiers born from 1740 to 1840, who served in the armies of Habsburg Austria (of which Lombardy was a possession). As indicated by the two standard error bands, the estimates are relatively imprecise, and short-run fluctuations not always meaningful. Yet the three-centimeter decline over the course of the century is unambiguous and statistically significant. As with other measures of economic performance or living conditions, the level of heights at the end of the period is clearly behind England and Scandinavia, but on a par with other peripheral regions. For this limited period of overlap, then, the anthropometric evidence offers a precious independent corroboration of the revisionist view that the decline of Northern Italy in absolute terms was limited and late.

For several reasons, these conclusions must remain tentative. The sample from the Vienna *Kriegsarchiv* on which they are based was small, relative to the long interval of time covered. Analysis of the data presented several technical challenges, because recruiting practices changed over time and the high minimum height requirement enforced during the early decades eliminated the entire lower half of the height distribution. Finally, there was a gap in coverage for recruitment during the Napoleonic era, when the region was no longer under Habsburg control.<sup>14</sup> This paper fills that gap. It also explores refinements to the statistical techniques available for analysing historical height samples.

## 2. New data from a new army

In 1796 French troops arrived in Italy, making common cause with local revolutionary forces to depose *anciens régimes* and establish republics through most of the peninsula. The Cisalpine Republic (1797-99) and its successor states, the Italian Republic (1802-05) and Kingdom of Italy (1805-14), united a large area of Northern Italy under a single government for the first time. At its greatest extent, the Kingdom encompassed the modern regions of Lombardy, Trentino-Alto Adige,

<sup>14</sup> This corresponds to births in the 1770s, 1780s, and early 1790s, which are less well represented than births in the periods 1745-60, 1798, and 1820-40. There is an even more severe shortfall in the *Kriegsarchiv* data of births in the 1800s and 1810s.

Veneto, Friuli, Emilia-Romagna, and the Marches, and had a population of over six million.<sup>15</sup>

Though the "legions" of the early Cisalpine Republic were at first volunteer units, the new nation never succeeded in kindling enthusiasm for military service, which offered low pay, abusive treatment by officers, garrison living conditions miserable to the point of endangering health, service far from home, and high casualty rates on combat duty.<sup>16</sup> Instead, the sizeable armed forces of the state would be based on mass conscription. Under legislation of 1802, young men were conscripted (enrolled on a list of those liable to be called up for military service) for a period of five years beginning on 1 January after their twentieth birthday.<sup>17</sup> In their first year, this newly-conscripted group were referred to as Class I. Men already in their second year on the lists, aged 21 at the beginning of the year, were Class II, and so on through Class V. Ordinarily, the army requisitioned recruits from Class I only, to serve a term of four years in peacetime, or indefinitely in wartime. The extraordinary levy of 1802, however, was a case in which the Ministry of War drew from all five classes.

The machinery of conscription operations was locally based. Town mayors were responsible for maintaining the register of men reaching conscription age each year, examining them, and making a preliminary assignment to one of five lists: Lists 1 and 2 for those claiming an exception or exemption based on physical defects, specific family situations or religious status; List 3 for those who had evaded previous drafts and were designated "first to march"; List 4 for men without any

<sup>15</sup> Bonaparte maintained direct control, first as President, later as King and through Viceroy Eugene Beauharnais. But the government and bureaucracy were almost exclusively Italian. The new state was organised along French lines, with centrally-appointed prefects governing some 20 *dipartimenti*. Those parts of Northern and Central Italy not part of the Kingdom were mostly annexed directly to France. For an accessible, brief summary of events in the period, see Grab, *French Revolution*.

<sup>16</sup> Of 21,500 Italian soldiers who fought in Spain, only 8,900 ever returned to Italy. Of the 27,400 who participated in Napoleon's tragic Russian campaign, only about 1,000 survived. Ilari, *Storia*, p. 231.

<sup>17</sup> The discussion of conscription regulations draws primarily on the Ministry of War's *Istruzioni* of 1811, as well as on Ilari, *Storia*, Grab, *Army*, Schneid, *Soldiers*, and Della Peruta, *Esercito*, and describes the system towards the end of its development.

special circumstances; and List 5 for those designated "last to march" by virtue of specific family situations.<sup>18</sup> No exemptions or preferences were granted for social status, occupation or residence. During the physical examination, height was measured and recorded as an identifying characteristic, along with details such as hair and eye colour, shape of the nose, scars, and so on. Measurement of stature also ensured that the conscript satisfied the army's minimum height requirement.

Local decisions were reviewed and ratified at higher levels, with compilation of the definitive lists the responsibility of the departmental prefect and draft council. After conscription, the men's movement was restricted to impede flight, travel documents being mandatory even within the Kingdom. The quota of recruits requisitioned by the Ministry of War was filled by first exhausting List 3, and then selecting conscripts by lottery from List 4.<sup>19</sup> In the event that an individual was requisitioned, it was possible to avoid service by providing a physically-fit substitute under the age of thirty and paying a fine to the state. Added to the payment made to the substitute himself, this expense made recourse to substitutes a privilege of the wealthy.<sup>20</sup> The sons of wealthy families had the further option of joining elite guards units.<sup>21</sup>

<sup>18</sup> Individuals granted exemption or exceptions included those suffering from any of a long list of specific physical disabilities and maladies, priests and seminarians, widowers with children, and men married before the 1802 law was enacted. Examples of those granted preferential "last to march" status include only sons of aged parents, those with a brother already serving, and those married after 1802.

<sup>19</sup> Local quotas were shares of national recruitment targets proportional to local population. They were sometimes assigned at the municipal, sometimes at the district level. Technically, it was the order on the list that was randomly selected, with conscription officials then simply going down the list until the quota was filled. In the early years of the system, the lists were ordered by birth date, youngest first. In this early version, those benefiting from a preference were included at the end of the list of eligibles, while they later were kept on an entirely separate list.

<sup>20</sup> Ilari (*Storia*, p. 220) explains that the fine was proportional to income and was not to exceed 1,000 lire, according to the 1802 conscription law. He cites average payments to substitutes in the range of 1,000-1,400 lire around 1807, rising to 5,000-6,000 lire in 1813 after the Russian campaign (p. 228), without mentioning the fine. See also Grab, *Army*, p. 33. For comparison, the annual income of a mason was roughly 420 lire in the years 1800-10. (Malanima, *L'economia*, p. 422)

<sup>21</sup> These units were the *guardia reale d'onore* and, for less prominent families, the *veliti*. Military authorities eventually despaired of filling guards units with volunteers and resorted to conscription.

The population resisted the new institutions of mass conscription and military service with tenacity. Despite increasingly draconian penalties, young men departed for remote regions before being conscripted, assaulted officials and were pursued by the *gendarmérie*, inspired violent uprisings, bribed doctors to be declared physically unfit for service, and even went so far as to mutilate themselves (the trigger finger typically being amputated) or pay elderly women to marry them to obtain preferential placing on List 5. (This was later declared grounds for inclusion on List 3 instead.) Once requisitioned, many fled while being escorted to the military depot, or deserted at the earliest opportunity. In 1810, Viccroy Beauharnais reported that, over the previous three years, some 40,000 men had either deserted or failed to report after being requisitioned.<sup>22</sup> Still, the system ultimately enlisted upwards of 150,000 men for Napoleon's European campaigns.<sup>23</sup> These men were a representative cross-section of Northern Italian society, excluding only the wealthy.

Army personnel records have been preserved among the documents of the Ministry of War, 1797-1815, at the *Archivio di Stato* of Milan (ASM), as well as in local archives. Unfortunately allied bombing during the Second World War completely destroyed the ASM's collection of registers (*matricole*) of enlisted soldiers, documents which contained information regarding heights. Nor do conscription lists survive there. However, a large number of other personnel records with height data do survive. As might be inferred from the foregoing discussion, the largest number pertain to desertion. Other sources include registers of officers and non-commissioned officers, promotion requests, transfers from one unit to another, records of physical examinations to determine fitness for service, and pension requests.

A sample of approximately 1,500 was drawn from documents dating from 1798 to 1813. The most common source documents (covering

<sup>22</sup> Della Peruta, *Esercito*, p. 27. Also see Grab, *Army*. Repeated amnesties for evaders of previous drafts undermined the system.

<sup>23</sup> Ilari (*Storia*, p. 230) cites a figure of 163,000 Italians being successfully conscripted and beginning their service between 1797 and 1814. Grab (*Army*, p. 26) gives a figure of 155,000. Schneid (*Soldiers*, p. 24) reports 200,000.

roughly 60 percent of the sampled individuals) are lists of deserters being sought, convicts being transferred to prisons or penal units, or former deserters taking advantage of amnesties to rejoin their units. In addition to height, the documents provide the individual's age, military rank and unit, birth region, and in some cases occupation.<sup>24</sup> A smaller sample of roughly 350 was drawn from records at the *Archivio di Stato di Modena* (ASMod). The source documents are lists of conscripts requisitioned from various districts of the Panaro Department. The lists date from 1804 to 1812, and provide the height, occupation, places of birth and residence, birth date or age, and, in some cases, literacy of the conscripts.

### 3. Heights and other sample data

The sample is composed overwhelmingly of ordinary soldiers, conscripts, and deserters from infantry units. They were born from the late 1760s to the early 1790s – two thirds of them in the 1780s. Their recorded ages ranged from the late teens to the mid-30s, concentrated in the early 20s (*Table 4*). Birthplace was typically specified as *dipartimento* of origin only, which made it impossible to remap birthplaces to later Italian provinces. (I shall refer to the departments by their capitals, rather than the sometimes obscure or ambiguous rivers after which they are named, and use the words department and province interchangeably.) In those cases where a specific town was listed, individual place names were mapped to departments on a case-by-case basis. For such cases, urban birth can be identified, but only with some uncertainty, as the place of origin was never listed unambiguously as the city, rather than the general region. All parts of the Republic/Kingdom are represented in the sample, with roughly 650 from Emilia-Romagna, 450 from Lombardy, 350 from Veneto, and smaller numbers from Marche, Piedmont, and other Italian regions outside the

<sup>24</sup> Data were extracted from the following files of the ASM, *Archivio napoleonico, Ministero della Guerra: cartelle* 15, 299, 391, 399, 401/2, 410, 412, 421, 456, 460/2, 785, 803. Data from the ASMod are from the *Archivio napoleonico, serie 27, rubbrica 25 (coscrizione), buste* 5622 and 5625. Photocopies of the records of 20 individuals were provided to me directly by the *Archivio Storico Comunale di Vignola* without more detailed archival information.

state (*Table 2*). Because of small sample sizes, some contiguous and geographically similar departments were aggregated in the analysis. These include: the low-lying plains of the Po Valley; the Southeast Coast; the Alps; the Northeast; and the Emilian departments other than Modena.<sup>25</sup> Occupations were given for only about one third of the sample. Of these, 60 percent were agricultural professions such as "peasant," "labourer," or "farmer," which are aggregated into a single occupational group for statistical analysis. The remainder were divided over a large number of professions, with almost every conceivable trade represented. Small numbers made it difficult to construct meaningful aggregates, however, so that these occupations were all combined into an "other crafts" group.

Heights were measured in feet, inches, and "lines" (*pedi, pollici, and linee*) based on the French foot, or *piede di Parigi*, whose inch measured 2.707 cm. There were twelve inches to the foot, twelve lines to the inch. Accuracy of measurement was important to the military, and improved over time in the sample. Prior to 1804, measurements display a high degree of rounding to whole inches.<sup>26</sup> From 1804 on, the proportion of whole-inch heights falls from 73 percent to 43 percent. 'Heaping', discussed at length below, also diminishes at this point. A similar improvement in quality is evident in the data on ages. Prior to 1805, 70 percent of recorded ages (rather than the expected 50 percent) are even numbers. This seems to reflect a switch from self-reporting of age, and possibly height, to systematic maintenance of conscription lists. An 1811 manual of instructions for applying the law on military conscription is insistent in calling for accuracy in the measurement of stature, describing in detail the measuring device each municipality was obliged to procure and the procedure to be followed.<sup>27</sup> Repeated measurements were mandated for questionable cases near the minimum height requirement.

<sup>25</sup> The aggregated areas are: Po Plains (Padova, Ferrara, Mantua, Cremona), Southeast Coast (Ancona, Ascoli, Forlì, Macerata), Alps (Sondrio, Trento, Belluno), Northeast (Venice, Treviso, Udine), and Other Emilia (Bologna, Reggio).

<sup>26</sup> Rounding in these early years was also asymmetric. There is only one case of a height with more than six lines, or half an inch, meaning that heights were rounded up more frequently than down.

<sup>27</sup> Ministero della Guerra, *Istruzioni*, p. 15.

By 1811, the minimum had been lowered successively from 5'0" to 4'9".<sup>28</sup> Conscripts measuring between 4'7½" and 4'9" were to be re-examined first by the vice-prefect, then by the departmental prefect and draft council, who made the final decision on such individuals. Those exempted due to insufficient stature had to pay a substantial tax. Individual branches of the military had different height requirements. For the artillery, 5'3½" was required in 1811, for the dragoons 5'4", for example. In some cases *maximum* heights were also in place, as for the cavalry. When requisitioned conscripts arrived at the military depot, a new list was drawn up, ordered by height, and units of the several military branches drew their quota in a specified order, "first come, first served" as far as stature was concerned.

The sample distribution of heights is depicted in *Figure 2*. Panel (a) reveals that the data suffer from heaping and rounding. Heaping is evident in the enormous frequency of observations at 60", or just five feet. The peak at 63" is also a bit taller than might have been expected. Rounding is seen in the high frequencies of heights at whole inches. To a lesser extent, rounding to the half- and quarter-inch is also visible in Panel (a). The superimposition of a normal curve on the histogram in Panel (b) helps make clear that while the upper tail of the distribution fits well, frequencies drop off too sharply on the left, where there is no proper tail. It also suggests that the peak at 60" is likely to exert a confounding influence on attempts to estimate sample moments.<sup>29</sup>

A clearer picture emerges when the data are disaggregated according to date, branch of the military, apparent minimum height, importance of heaping, and the presence or absence of an age-height relationship. Six distinct groups can be identified on this basis, as enumerated in *Table 1*. Regarding the last criterion, all documents give the year of birth and are

<sup>28</sup> According to Della Peruta (*Esercito*, pp. 62, 86, 107, 136, 221, 223) the minimum height requirement was lowered from 5'0" to 4'11" in 1804, then to 4'9" by 1811. Minima were higher for some branches of the military, such as the gendarmes and Presidential (later Royal) Guards. The 1811 requirements are given in the *Istruzioni*, p. 64.

<sup>29</sup> The raw data exhibit *negative* skewing, despite being truncated from below, and extreme excess kurtosis. Both phenomena seem to be caused by heaping on 60". A kernel density estimate of the underlying distribution does display positive skewing and greatly reduced excess kurtosis, but is still clearly affected by the 60" peak.

themselves dated, allowing us to infer age. In some sources, heights appear to have been up-to-date, measured and recorded, along with age, at the time the document was written. This would be the case for conscription documents, or records of physical examinations of soldiers suffering sickness or injury. In other cases, heights seem instead to have been transcribed from earlier documents and to be out-of-date, though age is correct. This might be expected for lists of deserters, whose current age would have been known, but whose height had not been measured since the time of conscription. A reliable age-height relationship is apparent in all the cavalry data and in the early infantry data. In the remainder of the sample, no such relation is apparent; it will have to be assumed that reported heights were measured at the time of conscription, on average in the early 20s. As for heaping, the peak in the overall distribution at 60" derives almost entirely from the "Early Infantry" and "Bad60 Infantry" groups. Apparent height minima perceptible by visual inspection range from 58" to 62", not always corresponding to official requirements. Distributions for the individual groups are given in *Figure 3*.

#### **4. Statistical problems and solutions**

Heaping, rounding, and deficient or missing lower tails are common problems in historical height distributions. Researchers have developed a variety of techniques for dealing with them, an arsenal that will be both used and expanded here, through a minor refinement and a speculative extension.

Models of the determinants of height are based on the normal distribution, which is known to describe accurately variation in human stature due to random genetic differences. Average height in a group, hence the expected value of the height of a randomly drawn individual ( $\mu$ ), is determined by average net nutrition in the group, as described in Section I. This cannot be measured directly, but is assumed to be a linear function of variables describing social, economic and epidemiological conditions during childhood and adolescence. In the present case, these variables include birth cohort, rank, place of birth, and, for subsets of the sample, occupation or literacy. These data have been coded as 0-1

“dummy” variables. Mean height is also a function of age, of course. Controlling for the effect of age is important in samples from historical eras when poor nutrition and health induced a prolongation of the growth phase into the early 20s. Equation [1], which for simplicity abbreviates the full list of cohort, age, and departmental dummies and entirely omits occupation and literacy, expresses this relationship.

$$\mu_i = \beta_0 + \beta_1 D_i^{rec19} \dots + \beta_k D_i^{cohort1} + \beta_p D_i^{depr1} \dots + \beta_m D_i^{officer} + \beta_g D_i^{urban} \quad [1]$$

Individual height  $b_i$  is assumed to be randomly distributed around this mean according to the normal distribution due to genetic and other unobserved variation. This can be thought of as adding a normally-distributed error term to [1], or modelled directly as in Equation [2], where  $\sigma^2$  is the variance of the distribution and another parameter to be estimated. The maximum likelihood (ML) estimator chooses values of the betas and of sigma to maximize (the average of the logarithm of) Equation [2] for the sample.

$$f(b_i) = (1/\sigma) \phi \left( \frac{b_i - m_i}{\sigma} \right); \phi(\cdot) \text{ is the standard normal density.} \quad [2]$$

A first complication is caused by truncation of the data. Truncation refers to the absence from the sample of observations below a certain threshold, and its effects are well understood. Consider the problem of comparing the mean heights of two groups, one with characteristics implying a low mean stature (e.g. 17 year-old conscripted day-labourers born in a famine year in an impoverished, malaria-ridden region), the other with characteristics implying tall average stature (e.g. 24 year-old officers from landowning families in a prosperous province). A minimum height requirement truncates the data from below. Only the tallest individuals from the first group will exceed this threshold, while even below-average members of the second group make it into the sample. Comparing truncated-sample means would be like comparing the basketball team from the first group with a random sample from the second; the difference in mean heights would be understated. To

understand more formally why both ordinary least squares (OLS) and ML estimation based on [2] are biased when the data are truncated, think of adding a normally distributed random error to [1]. The individuals from the first group who are observed in our sample are those with a positive and large realisation of the error; individuals whose characteristics (for whom the values of explanatory variables) are associated with short stature have positive errors. Those whose mean stature is very tall are observed with the full range of errors, positive and negative, hence zero on average. In this way, although the error is truly random and independent in the population, it is correlated with the explanatory variables of interest in the sample.

The solution is to modify the likelihood function [2] so that it gives the probability of height taking on certain values *conditional on its exceeding the truncation point*, as in Equation [3]. The denominator in [3] is the probability that the individual's height satisfies the minimum height requirement (is greater than or equal to the truncation point). The estimator that results is called the truncated maximum likelihood (TML) estimator.

$$f(b_i | b_i > \tau) = \frac{(1/\sigma)\phi((b_i - \mu)/\sigma)}{1 - \Phi((\tau - \mu)/\sigma)}; \Phi(\cdot) \text{ is the cumulative standard } [3]$$

normal distribution and  $\tau$  is the minimum height requirement or truncation point.

A second problematic feature of the data is rounding. Rounding itself does not bias the ML estimator based on [2]; intuitively, positive and negative rounding errors cancel each other out on average. And, in practice, explicit models of rounded data fail to deliver advantages in terms of precision that justify their complexity.<sup>30</sup> The *truncated* ML

<sup>30</sup> An explicit model of rounding derives the probabilities of heights falling in each one-inch (or other unit) bin, as a function of the unknown parameters of an underlying truncated-normal distribution. The probability of observing a particular set of frequencies being observed is then derived from the multinomial distribution with these probabilities. Heintel, *Statistical Models*.

estimator based on [3] does require adjustment in the presence of rounding, however. The problem is that the *apparent* truncation point, which is the minimum observed sample height, no longer corresponds to the *effective* truncation point. Suppose the apparent truncation point is 60", and that rounding is to the nearest whole-inch. Then the *effective* truncation point is actually  $59\frac{1}{2}$ "; heights above this level are rounded up to and reported as 60", and are included in the sample. Similarly, if rounding had been to the nearest half-inch, the effective truncation point would have been  $59\frac{3}{4}$ ". In general, the rule is that the effective truncation point equals the apparent truncation point minus one-half the rounding interval. Subject to this simple modification, the TML estimator has been shown to be unbiased with rounded data.

The effective truncation point adjustment is intuitively obvious for "pure" rounding schemes, in which all measurements are rounded to the same degree of accuracy. Less clear is how to deal with *mixed rounding schemes*, a common problem in historical data that has not been addressed in the literature. As is evident in *Figure 2a*, the data under analysis are the product of mixed rounding. They can be shown, under some simplifying assumptions, to be approximately consistent with the following rounding scheme: 30 percent of heights rounded to the nearest inch, 10 percent each to the nearest half and nearest quarter, and 50 percent rounded to the nearest twelfth (the official standard).<sup>31</sup> In such a case, there is no single rounding interval from which to derive

<sup>31</sup> The main simplifying assumption is that the probability of rounding is independent of height itself. In fact, as noted previously, the relative paucity of heights with a fractional part exceeding six lines (greater than half an inch) indicates that they were more likely to be rounded up to a whole inch than down. Heaping is also assumed away. In order to avoid the confounding effect of heaping on 60", the figures reported in the text analysed only heights of 61" and greater. The calculation assumes that heights measured to the nearest twelfth-inch would be uniformly distributed over 0-11 lines. The observed frequencies at 1, 2, 4, 5, 7, 8, 10, and 11 lines (which must have been measured to the nearest twelfth, as they are *not* possible results of rounding to full, half or quarter inches) should therefore be 8/12s of the total number of heights measured to the nearest twelfth. That total is then estimated by multiplying the observed number of cases at these measures by 12/8. Consider next quarter-inch rounding. Observed heights ending with  $\frac{1}{4}$ , or  $\frac{3}{4}$ , partly reflect individuals measured to the nearest twelfth whose height happened to be 3 or 9 lines above a whole-inch. The remainder were rounded to the quarter inch, and represent  $\frac{2}{3}$ s of all those rounded to this interval (the other  $\frac{1}{3}$ s ending up as whole or half inches). In similar fashion, the share rounded to the half and whole inch can be recovered.

the effective truncation point adjustment. Some insight can be gained from simulation studies, however. *Table 6* presents the results of a study, in which random samples were generated from a normal population with a mean of 63" and a standard deviation of 2.3", subjected to a mixed rounding scheme, and then truncated at various levels (the apparent truncation points). TML estimation with a variety of guesses for the effective truncation point adjustment was then employed.<sup>52</sup> The table reports the average bias of mean estimates in 100 repetitions; a similar pattern characterizes the associated estimates of the error standard deviation.

For apparent truncation points in whole-inches, below the mean, bias is minimised with an adjustment of -0.25", and would be zero with a deduction of between 0.20" and 0.25" in four of six cases. This result has a very intuitive interpretation, for it is closely approximated by a weighted average of the relevant "pure" adjustments of  $\frac{1}{2}$ ,  $\frac{1}{4}$ ,  $\frac{1}{8}$  and  $\frac{1}{24}$ ". Weighting those figures by the corresponding rounding shares yields an average of 0.235". The usefulness of this rule of thumb has been confirmed for several rounding schemes. A second result of the simulation study is that for schemes with a non-trivial share rounded to whole-inches, the researcher should always work with a whole-inch apparent truncation point. For apparent truncation points with a fractional component in the interval from one half to a full inch it is possible to find appropriate adjustments, but they are close to zero and no longer have an intuitive interpretation. For truncation points with a fractional part below a half-inch, the effective truncation point would have to be modelled as *exceeding* the apparent (i.e. a *positive* adjustment) to render the TML estimator unbiased.

The last feature of the data requiring special attention is 'heaping' on 60". One problem this creates is difficulty identifying the appropriate truncation point. The model summarised in Equation [3] describes, and is only appropriate for use with, a cleanly-truncated normal distribution. The discussion of effective truncation point adjustment similarly assumed

<sup>52</sup> The scheme underlying *Table 3* results is 35, 8, 20, and 36% shares rounded to the nearest whole,  $\frac{1}{2}$ ,  $\frac{1}{4}$ , and  $\frac{1}{12}$ ", respectively.

a clear apparent truncation point. Unfortunately, this is not what is suggested by *Figure 2*. It is typical of historical military samples like this one that minimum height requirements varied over time, between units, or across regions, and that enforcement of official requirements was equally variable. In pooled samples, the lower tail of the distribution is, therefore, increasingly deficient, rather than clearly missing, below a certain point. It is then necessary to select and impose a truncation point, discarding observations below it. Heintel's truncation point estimator, which is based on examination of a smoothed estimate of the underlying density function, was designed for such situations. Unfortunately, the peak at 60" so distorts kernel density estimates that the method cannot be employed here.<sup>33</sup> This forces us to consider separately the sub-groups identified in *Table 1*, for which truncation points can be identified with a combination of knowledge of official minimum height requirements, visual inspection of the distribution, and use of Heintel's estimator where applicable. As indicated in *Table 1*, the truncation points chosen for each sub-group vary from 58 to 61 inches, not always coinciding with official height minima. For the "Early" and "Bad60" infantry groups, a truncation point exceeding the apparent minimum (namely 61") was chosen to eliminate heaping.

Having identified the group-specific truncation points underlying the pooled sample, one can proceed in two ways. One possibility is to apply the highest truncation point of any subgroup (62" here) to the entire sample. This ensures a complete distribution above the truncation point, but has the disadvantage of diminishing the sample size – dramatically so, in the present case. And while the TML estimator is unbiased for any truncation point, its variability increases markedly as the truncation point

<sup>33</sup> The truncation point estimator examines the absolute value of the first differences of the estimated density, seeking the point of maximum ascent. The intuition is that if the distribution is deficient below a certain point, complete above it, then the estimated density will have to rise steeply to connect the lower, deficient portion and the higher complete portion. Thus, the point of maximally steep ascent identifies the point below which the distribution is damaged. In the present sample, heaping on 60" causes the point of maximum ascent in the lower half of the distribution always to be found at 60" itself. The distortion due to heaping is such that the *global* maximum is in the *upper* tail, however, which is just the opposite of the pattern expected. Heintel, *Historical Height Samples*.

approaches the mean.<sup>34</sup> Alternatively, the model described in Equations [1] and [3] can be modified to handle multiple truncation points – one for each group. Each group is assigned a unique likelihood function [3] with its own truncation point  $\tau$ , but with sigma and the betas in [1] held constant across equations.<sup>35</sup> This permits as much as possible of the data to be retained, and is the basic regression specification preferred in the paper.

Solving the heaping problem by truncating above 60" in the relevant groups has the disadvantage of discarding useful information. Accurately measured heights below the heaping point are lost; some of the heaped observations were, in fact, accurately measured to that height; and the rest can be expected to be rounded from true heights drawn from an area around 60" (rather than being completely random). Heaping resulted from errors and approximations of convenience made by local municipal officials when compiling conscription lists.<sup>36</sup> Because local authorities were legally responsible for the accuracy of the lists, because height had consequences that both families and the military cared about, and because the lists were reviewed and conscripts re-examined by the vice-prefect and later the prefect and departmental draft council, egregious misrepresentations of an individual's height would have been avoided.

I propose to model heaping as a form of heteroskedasticity. Heaped measurements should not be regarded as entirely lacking real informational content, but as simply less reliable than the rest, subject to an additional source of random variation. This can be modelled by allowing the error standard deviation ( $\sigma$ ) to vary between observations with heaped height

<sup>34</sup> Intuitively, without at least a partial left tail of the distribution, it can be difficult in some random samples to distinguish between, for example, the upper 60 percent of a normal distribution with a given mean and standard deviation, and the upper 40 percent of a distribution with a lower mean and higher standard deviation. A'Hearn, *Restricted Estimator*.

<sup>35</sup> The effective truncation point adjustment can of course vary as well, but rounding schemes are sufficiently similar across groups that a common offset was used in the results described here.

<sup>36</sup> In cases of individuals failing to report for examination and conscription, for example, one can imagine local officials seeking and recording secondhand information about their height and other identifying characteristics. Or, under time pressure or in the absence of a proper measuring device, some clerks may have simply satisfied themselves by a quick visual appraisal of whether an individual satisfied the minimum height requirement.

measurements and the rest. (Alternatively, weighted ML estimation can be employed.) This technique is applicable to more general cases in which heaping does not coincide with or lie close to the truncation point.<sup>37</sup> Freely estimating  $\sigma$  for the two groups of heaped and non-heaped observations seems an attractive principle, but cannot be implemented; by construction there is no variation in the dependent variable in the 60"-only group. A feasible approach is to *impose* a different value of sigma based on non-sample information, or to impose a ratio of  $\sigma_{60}$  to  $\sigma$ . In this paper, the ratio  $\sigma_{60}/\sigma$  is chosen on the basis of simulation results. Random samples from a normal population with a mean of 63" and standard deviation of 2.3" were generated, and subjected to a mixed rounding scheme. A percentage of observations randomly chosen from an interval around 60" were then converted to 60" exactly, and the sample truncated.<sup>38</sup> This yielded a distribution similar to that observed in the data under study: not suffering a visually obvious departure from normality except in having a large excess above the expected number of observations at 60".

*Table 7* presents results of TML estimation with the simulated data, for two truncation points, two heaping intervals, and a variety of ratios of error standard deviations. The table gives the bias and standard deviation of mean estimates in 100 repetitions; a similar pattern characterises estimates of the error standard deviation. When the heaping interval is narrow and symmetric, and when the truncation point and heaping point do not coincide, the bias induced by heaping is minimal and the standard deviation of the estimates low. In this case, heaping is just another form of rounding, where positive errors of rounding up are cancelled on average by negative errors of rounding down. A ratio of  $\sigma_{60}$  to  $\sigma$  not far from one eliminates bias in this case, and brings with it a slight improvement in precision. At the other extreme, when the heaping interval is wide and asymmetric, and when the truncation and heaping points coincide, the bias in mean estimates is substantial at -0.56". The variability of mean estimates is also high in this case, more than double the value of the opposite extreme. Imposition of the optimal  $\sigma_{60}/\sigma$  ratio not only eliminates bias, but quite substantially

<sup>37</sup> Heaping typically occurs on measures that end in even numbers, zero or five. In later Italian data, 165 and 170 cm are unduly frequent observations, for example.

<sup>38</sup> The percentages were 10% over the interval 57-63" and 6% for the 57-66" interval.

reduces variability here. Across the cases considered, the optimal  $\sigma_{\theta_0}/\sigma$  varies between 1.20 and 1.60, but performance of the estimator is fairly robust to small changes in the ratio. An intermediate value of 1.35 is adopted for the regression results reported below.

## **5. New estimates of mean height**

The determinants of height were estimated by TML under a variety of specifications. *Table 2* presents estimates for the baseline regression, which has multiple, group-specific truncation points (see *Table 1*), and includes all explanatory variables. *Table 8* gives results for four alternative specifications: the heteroskedasticity-corrected specification described in Section IV; a "relaxed" specification that ignores heaping altogether in choosing truncation points and uses the apparent minimum height requirements of *Table 1*; and two "strict" specifications that employ a uniform, high truncation point for all groups. The latter are provided for reference and will not be discussed at any length for the reasons elaborated in Section IV. All results presented include the full list of explanatory variables because robustness testing revealed the inclusion or exclusion of each set of measures to have limited impact on the estimated effects of others. All specifications used the same effective truncation point adjustment (0.225") to address mixed rounding. In both tables, coefficient estimates and standard errors have been converted to centimeters for comparability with other studies.

In general, results are similar across specifications. Results for the heaping-corrected TML estimator are quite close to the baseline regression, but with uniformly smaller standard errors. The "relaxed" specification also yields results not too far from the baseline. Because the sample size remains small even in these specifications, and perhaps because of the quality of the data, most individual coefficient estimates are not statistically different from zero (though they are jointly highly significant). Nonetheless, a number of plausible and interesting patterns in the results merit discussion. Overall, the estimates corroborate earlier findings regarding heights in northern Italy.

Estimated age effects are plausible and lend credibility to the model.

They show a nearly monotonic annual increase in height from age 18 through the mid 20s, with total growth on the order of 7 cm. This basic pattern is robust to specification choice and similar to previous results based on the Habsburg army data described above. The results clearly support the interpretation that poor nutrition caused the growth phase to be prolonged well into the 20s in late-eighteenth-century Italy. Age effects were estimated based only on the three sub-groups in which an age-height profile was separately evident – about half the sample. For the remainder, all age dummies were zero but the group mean was allowed to differ from that of the reference group (age 21) by means of a “no-age-height group” dummy. The small but positive estimated effect makes sense, since this group included soldiers measured at a variety of ages, on average probably exceeding 21.<sup>39</sup>

Birth cohort effects, though statistically insignificant, indicate a gentle, unsteady upward trend in heights over the last decades of the eighteenth century. This effect is weaker in the heaping-corrected specification, considerably stronger and statistically significant in the “strict” specifications. A rising trend is consistent with earlier findings from the Habsburg army sample, but the timing of the low point in the late 1760s and early 1770s better fits with historical events such as the famine of 1764–67. In any case, the general interpretation of a period of recovery from those particularly difficult years is sustained. The magnitude of increase in the baseline regression, about 1.6 cm to the early 1790s peak, is also similar to earlier findings.

Estimation of birthplace effects is difficult due to a sample that is too small and units of observation (the *dipartimenti*) that are too big. For only two departments (Milan and Modena) are as many as 100 observations recorded (*Table 5*). The departments, moreover, often combine geographically and economically diverse areas. Modena's department extended from the Po valley plains in the north right across

<sup>39</sup> The deserters are all in the no-age-height group, so the no-age-height dummy effectively conflates two effects. When a separate deserter variable is added, its effect is estimated to be large and negative, while the no-age-height estimate becomes large and positive. The two cancel each other out, except for a small number of non-deserter no-age-height soldiers.

the Apennines and into modern Tuscany in the south. For these reasons, departmental effects are not always plausible and generally not statistically significant. The analysis does, however, yield one new finding that is robust and statistically significant: the relatively short stature of young men from the southeast coast (the modern Marche region plus Forlì). This finding fits well with later data on conscripts for the Italian army born in the 1840s and 1850s. More generally, the new estimates are broadly plausible and supportive of earlier results from the Habsburg army sample. In particular they show the Northeastern departments of the Veneto region to be tall, and the province of Milan to enjoy an advantage over many neighbouring areas. The small stature of Modena, the other Emilian departments, and the low-lying departments of the Po plains (Cremona, Mantova, Ferrara, Padova) relative to Milan matches previous findings, for example. So do the disadvantages estimated for Como (slight) and Bergamo (more substantial). Two anomalous notes disrupt the harmony: Vicenza and Brescia. Both have rather substantial (though not statistically significant) estimated effects of the opposite sign from what would be expected on the basis of other data sources.

Urban birth is associated with taller stature in the data, the effect being almost 2 cm (though not statistically significant) for big cities. This finding makes Northern Italy seem more like agricultural Bavaria than relatively urban and industrial America.<sup>40</sup> It contrasts with the result from the Habsburg army data that found an advantage for small cities but a disadvantage for large cities. It should be borne in mind that the number of large city soldiers in the sample is quite small and mostly from Milan.

A robust and statistically significant height disadvantage of just over 2 cm is estimated for individuals reporting agricultural occupations.<sup>41</sup> Speculatively, one might note that this would fit with the height advantage of the urban-born to suggest poverty was greater in the countryside than in the cities. As described above, small sample size made it necessary to include all other reported professions in a single

<sup>40</sup> Baten, *Ernährung*, p. 94; A'Hearn, *Antebellum Puzzle*.

<sup>41</sup> The category also includes a few unskilled labouring jobs and a handful of beggars.

category. This group turned out not to have statistically different heights from the large group for which no occupational data is provided. Another indicator of socio-economic position is rank. The army inherited a few officers of aristocratic background who had served in *ancien régime* forces, but the Italian nobility lacked a strong tradition of military service, and the army was in any case meritocratic. One of the merits it most rewarded was education, whether at a military academy or at a private institution.<sup>42</sup> As a result, the officer corps came disproportionately from the urban, bourgeois or petty-bourgeois social stratum that had access to education.<sup>43</sup> The robust and statistically significant 4.6 cm height advantage for officers exceeds that found in the Habsburg army data for members of the same social class, and reinforces the conclusion that inequality was pronounced in this period, and may have had an urban-rural dimension.

The regression constant refers to an infantryman, conscript or deserter, known to have been 21 at the time of measurement, born in a rural (or unknown) part of Milan province between 1785 and 1789, reporting no occupation. The average height for this group is estimated to have been 166.1 cm, with a rather wide 95 percent confidence interval of +/- approximately 4 cm. The point estimate is quite close to the corresponding estimate from the Habsburg army data of 166.5 cm, well within the latter's narrower confidence interval of +/- roughly 1.4 cm.<sup>44</sup> The difference shrinks slightly when average figures for all of Northern Italy are calculated (165.9 and 166.3; see Section VI). In view of the different data sources and methods employed and the small sample sizes, this has to be

<sup>42</sup> Literacy was required even for non-commissioned officers, who could receive battlefield promotions to positions of command, in which event they would need to be able to read orders and correspond with superiors. The lack of a height advantage for this group in Table 2 is not a robust result. When occupational variables are excluded, for example, noncoms are consistently estimated to have been taller than average.

<sup>43</sup> Schneid, *Soldiers*, p. 45. A *direct* effect of education (literacy, more precisely) can be estimated for a small sub-sample of 195 conscripts from Modena's department. Truncated-sample mean heights were 1.57 cm greater for literate individuals than for the rest. The corresponding difference in population means would be greater.

<sup>44</sup> The constant from the baseline Habsburg data regression (165.4 cm) relates to the same reference group, except for the birth cohort. Adding the estimated effect for 1785-89 birth (+1.1 cm) yields 166.5.

considered a rather good match. The heaping-corrected specification yields an only slightly smaller constant of 165.7 cm.<sup>45</sup> The estimated standard deviation of the error is 7.3 cm in the baseline case, 7.1 cm in the heaping-corrected specification, both plausible values. As a slightly smaller value (6.86 cm) has been suggested as an average baseline value based on modern data, the regression in *Table 2* was also estimated subject to the restriction that  $\sigma = 2.53$ ".<sup>46</sup> This has almost no effect on the estimates of covariate effects, but raises the constant by approximately 0.8 cm, to slightly above the earlier Habsburg army data estimate. The same technique applied in the heaping-corrected specification produces an increase of 0.3 cm in the estimated constant.

## 6. Conclusions and corroborations

Analysis of the Napoleonic era data provides an independent corroboration of tentative conclusions advanced in the only previous anthropometric study of eighteenth- and nineteenth-century Northern Italy. Individually, both the earlier Habsburg army sample and the present data suffer from weaknesses that limit their ability to yield decisive statistical results. Together, their accordance on a number of points justifies increased confidence in the findings.

It is clear in both samples that young men continued growing into their mid-20s, indicating net nutritional deprivation relative to today's

<sup>45</sup> Estimated constants from the other specifications vary widely, but should be discounted due to probable negative bias, the unreliability of TML estimation with high truncation points, and small sample sizes. With the truncation point set at 62", only a handful of soldiers constitute the group to which the constant refers. While this small group has a substantially higher estimated mean, most other groups are estimated to have means well below it, so that the overall sample mean is about the same. This is evident for the estimated effects of an agricultural occupation (-5.9 vs. -2.1 cm), birth before 1775 (-3.8 vs -1.3 cm), or age 18 (-7.9 vs. -4.1 cm). The constant accommodates an unusual, small group.

<sup>46</sup> Cole, *Galton's Midparent Height*. The same restricted TML technique was employed in the earlier Habsburg army data study. In that case, it was impossible to estimate accurately the variance of the distribution for the eighteenth-century data because the truncation point and distribution mode coincided. A lower value of 5.9 cm, estimated from a nineteenth-century subsample of the dataset, was instead imposed. If a higher standard deviation such as 6.86 had been imposed in that dataset, the estimated constant would have fallen.

standards. Between ages 18 and 25, heights increased by 4.5 cm in the Habsburg army data, and by as much as 7 cm, according to the new estimates in *Table 2* (or 5 cm in the heaping-corrected specification). This growth is comparable to, if perhaps a bit greater than, that observed in other European countries in the late eighteenth century: 4 cm in Britain, 1.5 to 5 cm in Southern Germany, and 3 to 6.3 cm in Hungary.<sup>47</sup> Both studies similarly document a striking degree of inequality. In the present study, officers are estimated to be 4.6 cm taller than the reference group of enlisted men reporting no occupation, while soldiers reporting an agricultural occupation are 2.1 cm shorter. The Habsburg army sample lacks officers, but has better occupational data; in that study, occupational effects range from a +2.9 cm advantage for property owners, merchants and the learned professions to a -1.6 cm disadvantage for barbers, domestic servants and similar service trades. These disparities appear broadly similar to those in other countries in the eighteenth century, such as France, where soldiers from an upper-class background were 3.6 cm taller than textile workers.<sup>48</sup> They exceed the gap found by Ridolfo Livi for soldiers of post-unification Italy: a smaller 2.6 cm advantage for students relative to peasants.<sup>49</sup>

<sup>47</sup> The lower of the Hungarian figures is the only one based on longitudinal data and is taken from Komlos, *Nutrition*, p. 81 ("Variant A") for soldiers born 1750-69 and 1780-99; the Hungarian upper limit is from a TML regression of height on age dummies, analogous to the present study; British data from Mokyr and O'Grada, *Heights of the British*, p. 47, simple mean heights by age of men recruited into the East India Army in the years 1800-1814; South German data from Baten, *Erndbrung*, pp. 177-179, TML estimates for samples recruited 1760-87 and 1805-11 in three regions.

<sup>48</sup> Komlos, *Anthropometric History*, p. 7. The data on which the estimates are based are primarily from the first half of the XVIII<sup>th</sup> century. Baten, *loc. cit.*, estimates officers to have been from 2.5 to 7.8 cm taller than enlisted men born in late eighteenth-century South Germany. The same author (*op. cit.*, pp. 161-64) reports differences between the lower and middle/upper classes ranging from 0.8 cm in proto-industrial districts to 2.3 cm in the cities for soldiers born in a slightly later period (1815-39). It is common to find occupational differences favouring those occupations associated with education or status. Mokyr and O'Grada (*op. cit.*), for example, report that literate workers averaged roughly 2.5 cm taller than labourers.

<sup>49</sup> Livi, *Antropometria Militare* Parte II, p. 49. The reported gap is based on enlisted soldiers, hence on truncated distributions, and is therefore biased downward. Livi's data are for the whole of Italy.

Perhaps most importantly, the two studies yield nearly the same estimates of the reference group mean. A difference of less than half a centimetre has to be considered small when derived from two independent samples differing in units of measure, extent of heaping and rounding, minimum height requirements, and underlying recruiting practices. And this suggests that the earlier study may have got things about right in spite of the difficulties presented by the data. The new mean estimate for the 1780s indirectly confirms the negative trend found in the earlier study, since (new) accurate estimates of mean heights in the region during the 1840s are a centimetre and a half lower.<sup>50</sup> More confidence is, therefore, justified in that study's conclusions that heights experienced a pronounced fall starting in the mid-eighteenth century, stagnated at low levels through the mid-nineteenth, but remained respectable in international comparison as late as the 1830s. The level of heights for births in the 1830s was average for Europe: clearly behind England or Scandinavia, close behind France and the Netherlands, just above several regions of Central and Eastern Europe.<sup>51</sup> This decade was chosen for comparison because the Habsburg army sample had a large number of observations and a low truncation point in these years, making the corresponding height estimates the most reliable. In light of the present study's corroboration of the estimates for a half-century earlier, a comparison for the 1780s now seems warranted.

Table 3 presents mean heights in several countries, newly estimated from the original data or drawn from published sources. In most cases the figures refer to 21 year-old rural-born soldiers born in the 1780s, and were estimated by TML. For the two Northern Italy estimates, a population-

<sup>50</sup> The estimate for the 1840s is 164.4 cm, which can be compared to 165.9 for the 1780s in Table 3. The 1840s estimate is based on conscription data for the army of unified Italy in the 1860s. It concerns birth-year 1847, one of the first for which data are available from Veneto, and in which the mean age at the time of measurement was coincidentally 21.6 years. Annual reports by the Ministry of War (Italy, Ministero della Guerra, *Della leva*) gave frequency distributions of heights of all young men examined for conscription. Maximum likelihood estimates of the mean were calculated from these data, and averaged for the regions Lombardy, Emilia-Romagna and Veneto, with weights equal to the number of young men registered for conscription in 1847 (some 73,000 in total). Details of the estimation technique available from the author.

<sup>51</sup> A'Hearn, *Anthropometric Evidence*, p. 370.

weighted regional average was constructed, using only provinces found in both samples and having at least 50 observations.<sup>52</sup> Given the diversity of the underlying data sources, variation in truncation points, heaping and rounding problems, and in some cases differences in age groups, birth cohort, or method of estimation, caution is called for in drawing any conclusions from *Table 3*. Nonetheless, it does seem reasonable to conclude that Northern Italy in the 1780s fared a bit better in international comparison than in the 1830s. Italian heights in *Table 3* are clearly below only the estimates for Württemberg and Sweden – both of which include soldiers over 21 in the reference group. Habsburg sample estimates rank immediately after these leaders, while the new estimates of the present study lie just a bit further back: very close behind France, Bavaria and England, on a par with Saxony, and clearly ahead of the Low Countries and Eastern Europe.

It bears reiteration that heights are not always well correlated with other measures of well-being, it being possible to be poor but tall. In *Table 3*, for example, the relatively agrarian and “backward” provinces of Galicia and Hungary are the tallest of the Habsburg domains in Central and Eastern Europe. Ireland and parts of Bavaria are well-known examples of poor regions that enjoyed a protein-rich (height-favouring) diet due to specialisation in dairy exports that left non-tradable skimmed milk as a by-product available for local consumption.<sup>53</sup> But we know that Northern Italy did not have a dairy-based diet.<sup>54</sup> Even less was it the case that respectable heights in the 1780s resulted from frontier-like environmental conditions of low population density and abundant natural resources. The region’s population density was nearly triple the European

<sup>52</sup> This definition excludes the provinces of Piedmont as well as Parma from the Habsburg army sample, and the provinces of Marche region from the present sample. For the Kingdom of Italy sample, aggregates such as the Po Plains region, for which at least 50 observations were available, were included in calculating the overall average, weighted by the sum of populations in their constituent provinces. The population weights are for 1810, and taken from Zangheri, *Popolazione italiana*, app. IV, p. xxi. Also added to the constant was the (simple) average birth-cohort effect for the 1780s: zero by definition for 1785-89, -0.17 cm for 1780-84 in the present sample.

<sup>53</sup> See footnote 13.

<sup>54</sup> Parts of Lombardy did in fact specialize in dairy production, but exported cheese rather than butter, leaving behind no surplus of skimmed milk for local consumption. See A'Hearn, *Anthropometric Evidence*, p. 367.

average in 1700, clearly exceeding that of England, Belgium, or even the Netherlands.<sup>55</sup> By 1800, population had increased by 25% and North Italy retained its status as the most densely populated large area in Europe. In this light, and bearing in mind the lack of evidence of a severe urban penalty, it is hard to accept Allen's recent estimates of urban real wages, according to which Northern Italy ranks lowest in Europe in the eighteenth and nineteenth centuries.<sup>56</sup>

It was not the gifts of nature but the industry of man that safeguarded through the 1780s a biological standard of living comparable to that in the leading economies. North Italian agriculture responded to growing resource scarcity on both the extensive and intensive margins, enlarging the area under cultivation and adopting new crops requiring more labour and less land than wheat. Rice permitted the cultivation of otherwise marginal wet areas, and offered higher yields per hectare by value or in calories. Maize, which did not exhaust the soil, permitted a reduction of fallow that greatly increased calories produced per hectare.<sup>57</sup> Silk production expanded rapidly in response to the growth of export markets elsewhere in Europe. Malanima estimates raw silk output to have more than tripled between 1600 and the late eighteenth century.<sup>58</sup> Mulberry tree cultivation and silkworm rearing effectively exploited labour and land with low opportunity costs: peasant household labour in the off-season, and land on hillsides or the margins of the arable. The first phase of processing the raw, reeling the filament from the cocoon, similarly took advantage of rural labour with a low opportunity cost. In this way, land productivity not only maintained a high level (in part a legacy of medieval and early-modern irrigation, drainage and reclamation work) but rose steadily in the seventeenth and eighteenth centuries.<sup>59</sup>

The falling trend in heights already underway by the 1780s demonstrates the limits of a model based on intensification of cultivation and export-

<sup>55</sup> Malanima, *L'economia italiana*, Tab. 1.6, p. 30 and Tabs. A.7 and A.9, pp. 368-9.

<sup>56</sup> Allen, *Great Divergence*, Tabs. 5-6.

<sup>57</sup> Malanima (*Fine del primato*, Tab. 9, p. 163), presents data showing rice produced 22% more calories per hectare than wheat, while maize yielded 62% more. See also Malanima, *L'economia italiana*, pp. 125-29.

<sup>58</sup> Malanima, *Fine del primato*, pp. 168-185.

<sup>59</sup> Federico and Malanima, *Progress*, Tabs. 6-7, pp. 456-7.

driven growth in the absence of fundamental structural, organisational or technological change. As there is no evidence of an exogenous deterioration of the disease environment over the period, declining heights are evidence of a fall in income (relative to the prices of protein-rich foods). This is reflected in the steady shift to a diet dominated entirely by maize, most tragically documented by the spread of pellagra through the region beginning in the later eighteenth century.<sup>60</sup> Declining heights parallel Malanima's recent estimates of declining output per worker in agriculture, falling real wages in both city and country, and a drop of more than 10 percent in GDP per capita between the mid-1700s and the early 1800s.<sup>61</sup>

Both the level and the trend of mean heights thus support an emerging consensus on Italy's path from Renaissance leadership to nineteenth-century peripheral and underdeveloped status. The seventeenth and early eighteenth centuries were a period of change rather than crisis, of relative rather than absolute decline. The anthropometric evidence identifies the later period from the mid-eighteenth to the mid-nineteenth centuries, with the economy's failure to keep ahead of Malthusian pressure on natural resources, as the real moment of crisis for Northern Italy.

## REFERENCES

- A'HEARN B., "The Antebellum Puzzle Revisited: A New Look at the Physical Stature of Union Army Recruits during the Civil War," in John Komlos and Jörg Baten (eds), *Studies on the Biological Standard of Living in Comparative Perspective*, (Franz Steiner Verlag: Stuttgart 1998), pp. 250–67.
- , 'Anthropometric Evidence on Living Standards in Northern Italy, 1730-1860', *Journal of Economic History* 63 (June 2003), pp. 351–381.
- , 'A Restricted Maximum Likelihood Estimator for Truncated Height Samples', *Economics and Human Biology* 2 (March 2004), pp. 5–19.
- ALLEN R., 'The Great Divergence in European Prices and Wages from the Middle Ages to the First World War', *Explorations in Economic History* 38 (October 2001), pp. 411–447.

<sup>60</sup> On dietary composition and pellagra, see A'Hearn, *Anthropometric Evidence*.

<sup>61</sup> Federico and Malanima, *Progress*, Figs. 3,4,6, pp. 442–44; GDP per capita in Malanima, *L'economia italiana*, Tab. A.63, p. 440.

- ALTER G., 'Stature in transition: a microlevel study from nineteenth Belgium', *Indiana University Early-life Conditions, Social Mobility, and Longevity*, Working Paper, (6), August 2002.
- BATEN J., *Ernährung und wirtschaftliche Entwicklung in Bayern (1730-1880)*, (Franz Steiner Verlag: Stuttgart 1999).
- CIPOLLA C., *Before the Industrial Revolution: European Society and Economy, 1000-1700*, 2nd edition, (W.W. Norton: New York 1980).
- COHEN J. and FEDERICO G., *The Growth of the Italian Economy 1820-1960*, (Cambridge University Press: Cambridge 2001).
- COLE T., 'Galton's Midparent Height Revisited', *Annals of Human Biology* 27 (2000), pp. 401-405.
- DAVIS J., 'Remapping Italy's Path to the Twentieth Century', *Journal of Modern History* 66 (1994), pp. 291-320.
- , "Mutamenti di prospettiva sul cammino dell'Italia verso il XX secolo", in Pierluigi Ciocca and Gianni Toniolo (eds), *Storia Economica d'Italia: 1. Interpretazioni*, (Laterza, Roma-Bari 1999), pp. 197-259.
- DE VRIES J., *The Economy of Europe in an Age of Crisis, 1600-1750*, (Cambridge University Press: Cambridge 1976).
- , *European Urbanization 1500-1800*, (Harvard University Press: Cambridge Mass. 1984).
- DEL PANTA L., "Dalla metà del settecento ai nostri giorni," in Lorenzo del Panta, Massimo Livi-Bacci, Giuliano Pinto and Eugenio Sonnino (eds), *La popolazione italiana dal medioevo a oggi*, (Laterza: Roma-Bari 1996), pp. 133-212.
- DELLA PERUTA F., *Esercito e società nell'Italia napoleonica*, (Franco Angeli; Milan 1988).
- DRUKKER J.W. and TASSENAAR V., "Paradoxes of modernization and material well-being in the Netherlands during the Nineteenth century", in R. Steckel and R. Floud (eds), *Health and Welfare during Industrialization*, (University of Chicago Press 1997), pp. 331-337.
- EWERT U.C., 'The biological standard of living on the decline: episodes from Germany during early industrialization', *European Review of Economic History*, 10 (1), pp. 51-88, April 2006.
- FEDERICO G. and MALANIMA P., 'Progress, Decline, Growth: Product and Productivity in Italian Agriculture, 1000-2000', *Economic History Review* LVII (August 2004), pp. 437-464.
- FENOALTEA S., "Lo sviluppo economico dell'Italia nel lungo periodo: riflessioni su tre fallimenti," in Pierluigi Ciocca and Gianni Toniolo (eds), *Storia Economica d'Italia: 1. Interpretazioni*, (Laterza: Roma-Bari 1999), pp. 3-41.
- GALLOWAY P., 'A Reconstruction of the Population of North Italy from 1650 to

- 1881 using Annual Inverse Projection with Comparisons to England, France, and Sweden', *European Journal of Population* 10 (1994), pp.223–274.
- GRAB A., 'Army, State, and Society: Conscription and Desertion in Napoleonic Italy', *Journal of Modern History* 67 (March 1995), pp. 25–54.
- , "From the French Revolution to Napoleon," in John Davis (ed.), *Italy in the Nineteenth Century*, (Oxford University Press: Oxford 2000), pp. 25–50.
- HEINTEL M., 'Historical Height Samples with Shortfall: A Computational Approach', *History and Computing* 8 (1996), pp. 24–37.
- , "Statistical Models for Truncated and Rounded Normal Data." Technical report, (University of Munich 1997).
- HEINTEL M., SANDBERG L. and STECKEL R. 'Swedish historical revisited. New estimation techniques and results', in J. Komlos and J. Baten (eds), *The Biological Standard of Living in Comparative Perspective*, (Stuttgart: Franz Steiner Verlag 1998).
- ILARI V., *Storia del Servizio Militare in Italia. Vol. 1 1506-1870*, (Centro Militare di Studi Strategici / Rivista Militare 1989).
- KOMLOS J., *Nutrition and Economic Development in the Eighteenth-Century Habsburg Monarchy*, (Princeton University Press: Princeton 1989).
- , 'The Secular Trend in the Biological Standard of Living in the United Kingdom, 1730-1860', *Economic History Review* XLVI (1993), pp. 115–144.
- , 'An Anthropometric History of Early-Modern France', *European Review of Economic History* 7 (August 2003), pp. 159–189.
- LIVI R., *Antropometria militare*, (Tipografia E. Voghera: Roma 1896 [Parte I], 1905 [Parte II]).
- LIVI BACCI M., *The Population of Europe*, (Blackwell: Oxford 2000).
- MADDISON A., *The World Economy: A Millennial Perspective*, (Organisation for Economic Cooperation and Development: Paris 2001).
- MALANIMA P., *La fine del primato: crisi e riconversione nell'Italia del seicento*, (Mondadori: Milan 1998).
- , *L'economia italiana: dalla crescita medievale alla crescita contemporanea*, (Il Mulino: Bologna 2002).
- MINISTERO DELLA GUERRA (Direzione Generale delle Leve e della Truppa), *Della leva sui giovani nati nell'anno ..., Relazione del Tenente Generale Federico Torre a S.E. il Ministro della Guerra*, (Tipografia Bencini: Roma), various years.
- MINISTERO DELLA GUERRA E DELLA MARINA, *Istituzioni sull'esecuzione della legge della coscrizione militare*, (Unpublished: Milan 1811).
- MITCHELL B., *European Historical Statistics*, 1st edition, (Macmillan: London, 1975).
- MOKYR J. and CORMAC O'GRADA, "The Heights of the British and the Irish c. 1800-

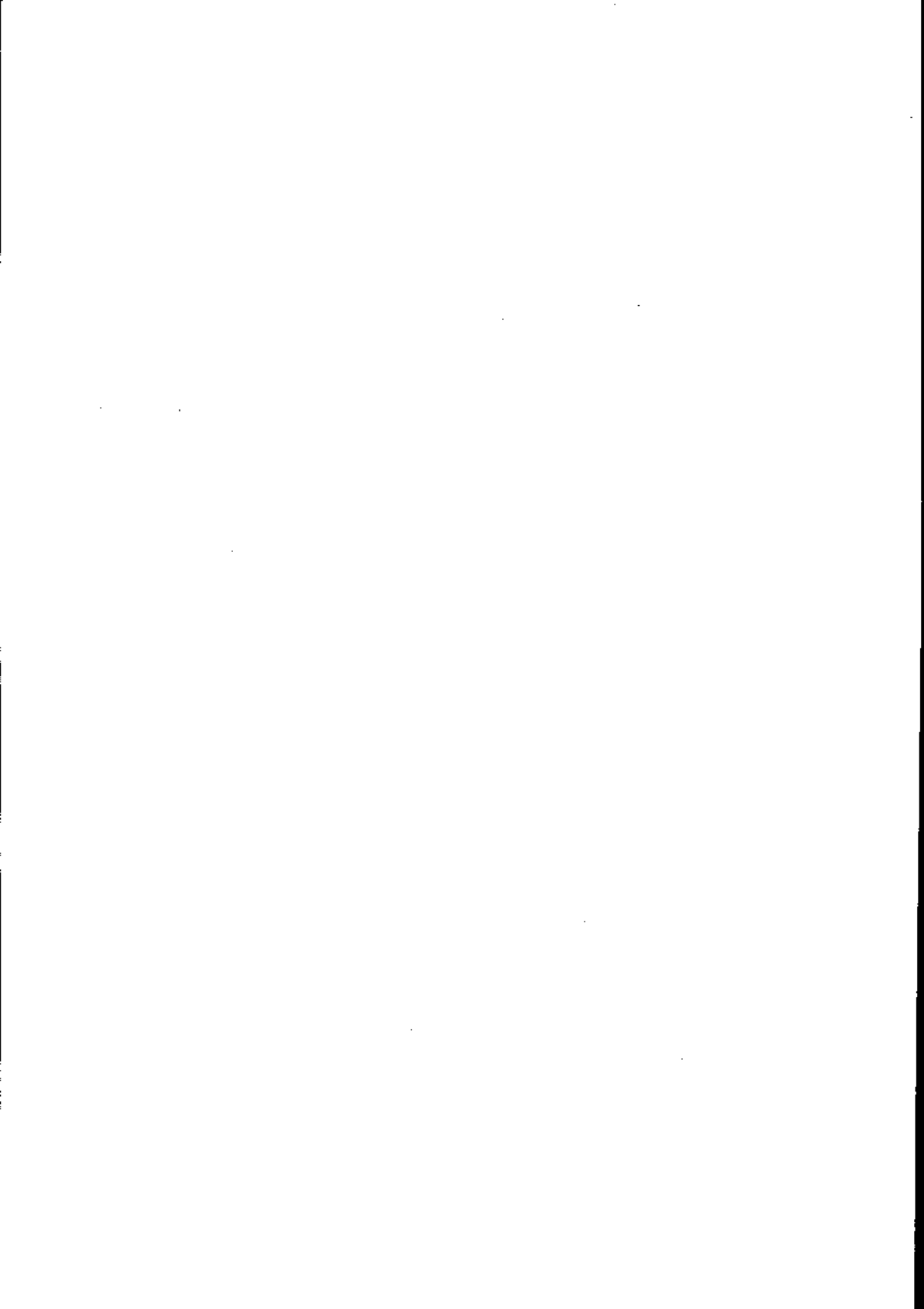
1815: Evidence from Recruits to the East India Company's Army," in John Komlos (ed.), *Stature, Living Standards, and Economic Development*, (University of Chicago Press: Chicago 1994), pp. 39–59.

SCHNEID F., *Soldiers of Napoleon's Kingdom of Italy*, (Westview Press: Boulder 1995).

SELLA D., 'Industrial Raw Materials in the Import Trade of Northern and Central Italy during the XVIIIth Century', *Journal of European Economic History* 33 (Spring 2004), pp. 59–70.

WEIR D., "Economic Welfare and Physical Well-Being in France, 1750-1990," in Richard Steckel and Roderick Floud (eds), *Health and Welfare During Industrialization*, (University of Chicago Press / NBER: Chicago 1997), pp. 161–200.

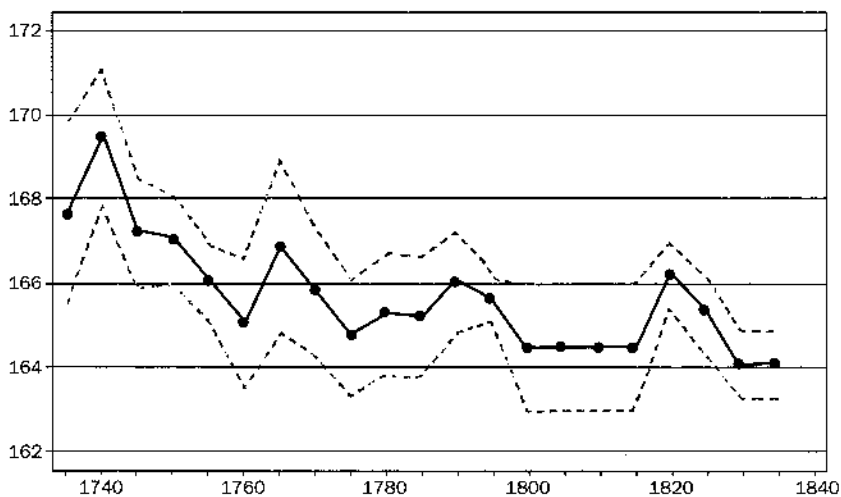
ZANGHERI R., 'La popolazione italiana in età napoleonica', *Bollettino del Museo del Risorgimento*, VIII, (1963), pp. 3-21.



## *Appendix*

Remapping Italy's Path to the XIXth Century:  
Anthropometric Signposts

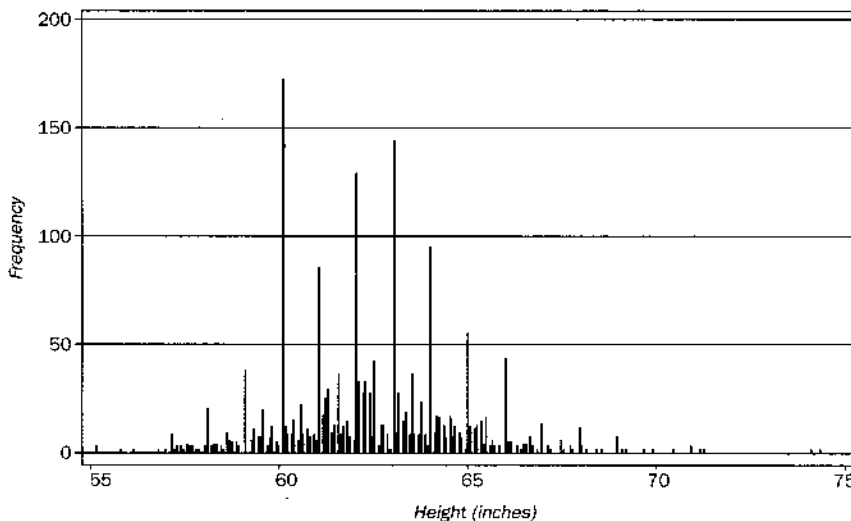
**FIGURE 1. Mean heights in Lombardy: Habsburg army data**

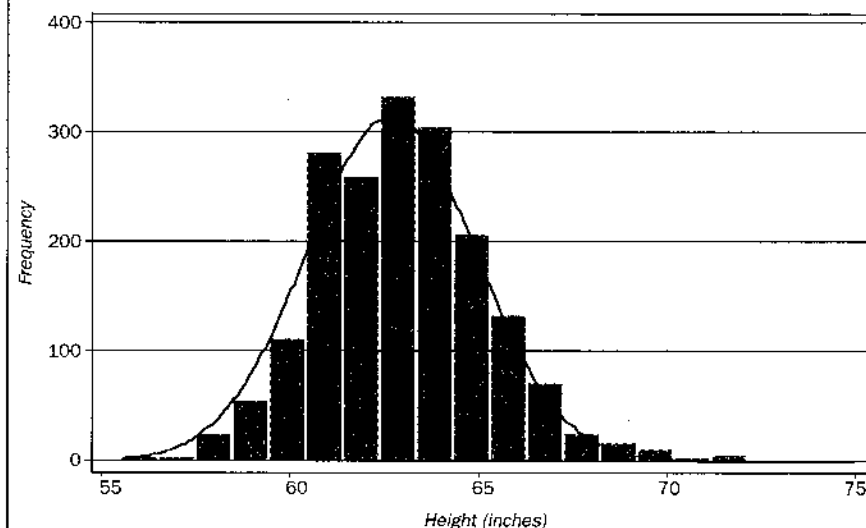


Notes: TML estimates of the mean height of a 21-year-old, rural-born infantryman reporting no occupation, weighted average over Lombard provinces in sample. Two standard error band indicated by the dashed lines.

Source: A'Hearn. *Anthropometric Evidence*.

**FIGURE 2a. Distribution of sample heights, raw data**



**FIGURE 2b. Distribution of sample heights, one-inch bin histogram with normal curve**

**TABLE 1. Sample subgroups and their characteristics**

Group	MHR	TP	Heaping	Age-height	Dates	N	Main Sources
Early infantry	60	61	60	Yes	1798-1808 Mona Dept.	582	LC I, II, IV, V; conscript lists; GR. C, E, N, O, D, I, T.
Early cavalry	60	60	No	Yes	1804-05	84	RD "Napoleone", unspecified RD. C, V, I, T.
Late cavalry	62	62	No	Yes	1805-13	286	RD "Regina", 2 <sup>nd</sup> RU, 1 <sup>st</sup> RC, RC "Principe Reale", C, E, N, O, I, T, P.
Deserters I	59	60	(62?)	No	1810-13	201	2 <sup>nd</sup> RIL, unspecified units. D.
'Bad60' infantry	58	61	60, (63?)	No	1811	250	3 <sup>rd</sup> , 6 <sup>th</sup> , and 7 <sup>th</sup> RIL, GR. C, D, T, P.
Deserters II	58	58	No	No	1811-12	475	Units unspecified. D (amnestied).

Columns: MHR = apparent minimum height requirement in sample; TP = truncation point chosen for later statistical analysis; Heaping = excessive frequencies at particular heights; Age-height = presence or absence of an age-height relationship; Dates = dates of source documents; N = number of observations; Main sources = military unit, service branch, document type, or condition of individuals.

Abbreviations for units: LC - Cisalpine legion, RIL - line infantry regiment, RD - dragoon regiment, RU - hussars regiment, RC - cacciatori regiment, GR - Royal Guards.

Abbreviations for record type: C - conscripts, D - deserters, E - enlisted soldiers, I - invalids, N - noncommissioned officers, O - officers, P - applications/recommendations for promotion, T - transfers from/to other units, V - volunteers.

Early infantry group: members of GR were grooms assigned to a cavalry unit of the guards: 21 records from later years (after 1808) also included in this group.

TABLE 2. TML estimates of determinants of height

Variable	coeff. est.	s.e. of est.	p-value
<b>AGES</b>			
age 18	-4.14	3.78	0.27
age 19	-0.95	3.28	0.77
age 20	-0.10	1.80	0.96
age 21	<i>reference group</i>		
age 22	0.51	1.84	0.78
age 23	1.04	2.01	0.60
age 24	3.08	1.91	0.11
age over 24	2.84	1.63	<b>0.08</b>
no-age-height group	0.77	1.63	0.64
<b>BIRTH COHORTS</b>			
pre-1775	-1.29	1.59	0.42
1775-79	0.02	1.20	0.98
1780-84	-0.17	0.75	0.82
1785-89	<i>reference group</i>		
post-1789	0.34	0.82	0.67
<b>BIRTHPLACE</b>			
Novara	-0.72	1.90	0.70
Bergamo	-2.14	2.00	0.29
Brescia	1.49	1.66	0.37
Como	-0.60	2.06	0.77
Milan	<i>reference group</i>		
Alps	2.74	1.88	0.14
Modena	-1.62	1.45	0.27
Other Emilian dipt.	-0.51	1.51	0.74
Po plains	-0.75	1.31	0.57
Verona	1.69	1.60	0.29
Vicenza	-1.37	1.57	0.38
Northeast	1.94	1.48	0.19
Southeast coast	-2.99	1.56	<b>0.06</b>
Other / unknown dipt.	0.88	1.35	0.51
Urban birth			
Big city	1.82	1.49	0.22
Small city	0.98	1.01	0.33
Unknown / rural area	<i>reference group</i>		
<b>OCCUPATION</b>			
No occ. reported	<i>reference group</i>		
Agricultural / Labourer / Poor	-2.10	0.92	<b>0.02</b>
Other Craft	-0.62	0.97	0.53
<b>RANK</b>			
Non-com. officer	-0.10	1.38	0.94
Officer	4.57	1.32	<b>0.00</b>
Special forces	4.50	2.68	<b>0.09</b>
Cavalry	-1.75	1.11	0.11
Infantry	<i>reference group</i>		
Constant	166.06	1.95	<b>0.00</b>
Error standard deviation	7.32	0.24	<b>0.00</b>
Wald Statistic, $\chi^2_{3df}$	89.78		<b>0.00</b>
Sample size	1,550		
Notes: Controls for ages less than 18 (each of which with less than 10 observations) included but not reported. TML estimation with multiple truncation points as indicated in Table 1. Effective truncation point adjustment 0.225*.			

**TABLE 3. Mean height estimates for the birth cohort of the 1780s**

Country	Age	Birth Years	Mean height
Württemberg	24+	1780s	166.8
Sweden	21+	1780s	166.6
Northern Italy 1	21	1780s	166.3
France 1	21	1760s	166.3
Bavaria	21	1780s	166.2
England	20-23	1780s	166.1
Northern Italy 2	21	1780s	165.9
Saxony	21	1780s	165.9
Poland (Galicia)	21	1780s	165.2
Netherlands	20	1795-1804	164.5
Hungary	21	1780s	164.1
France 2	20-21	1784-92	163.7
Belgium	21	1790s	163.7
Lower Austria	21	1780s	163.5
Moravia	21	1780s	163.3
Bohemia	21	1780s	162.5

*Notes:* Northern Italy 1 (Habsburg army) and 2 (Napoleonic data) estimated by TML as described in text, calculated as constant plus average 1780s birth effect plus average regional effect. Bavaria, Saxony, and Württemberg calculated from published regression coefficients as constant plus (average) 1780s birth effect, plus age-21 effect if relevant. Hungary, Bohemia, Moravia, and Galicia estimated by TML with age controls. A truncation point of 62 Austrian inches (A.i.) was used, with province-specific adjustments for rounding. Lower Austria estimated using a truncation point of 63 A.i., which yields similar results to published quantile bend estimates and restricted TMLE with the standard deviation forced to be 2.61 A.i. (6.86 cm). France 1 figures estimated using age controls by restricted TML, with a truncation point of 61 French inches (F.i.), appropriate rounding adjustment, and standard deviation forced to be 2.53 F.i. (6.86 cm). France 2 estimate is for of the median, rather than the mean, taken directly from the published source and averaged over the birth years 1784-92. Swedish figure estimated from published graph. England estimate calculated by applying published index number to the base of 167.6 cm. Netherlands mean is average for births during 1795-1804, taken from published source. Belgium figure is average of published figures for towns Limbourg and Sart for soldiers aged 20, born in the 1790s, adjusted to age 21 by adding 1.63 cm, the regression estimate of the effect of an additional year of age.

*Sources:* Bavaria – Baten, *Ernährung*, p. 179, Tab. B3; Northern Italy 1 – A'Hearn *Anthropometric evidence*, pp. 363/4, Tab. 2; Northern Italy 2 – present study; France 1 – dataset downloaded from the University of Tübingen data hub; see also Komlos, *Anthropometric history*; France 2 – Weir, *Economic welfare*, Table 5B.1, p. 191; England – Komlos, *Secular Trend*, Tab. 6, p. 136; Sweden – Heintel et al., *Swedish historical heights*, Fig. 3, p. 455; Netherlands – Drukker and Tassenaar, *Paradoxes*, Table 9A1; Saxony and Württemberg – Ewert, *Biological standard*, pp. 60-61, Tabs. 1-2, Cols. 1; Belgium – Alter, *Stature*, Tables 5-6, pp. 16/17. Bohemia, Galicia, Hungary, Lower Austria, Moravia – dataset downloaded from University of Tübingen data hub; see also Komlos, *Nutrition and Economic Development*.

**TABLE 4. Sample birth dates and ages**

Birth cohorts	Freq.	Ages	Freq.
Pre-1770	47	20	153
1770-74	81	21	250
1775-79	223	22	293
1780-84	520	23	263
1785-89	745	24	168
Post-1789	262	25	125
		26	120
		27	102
		28	85
		29	59
		30	54
		Over 30	128

**TABLE 5. Sample birthplaces**

Department	Capital	Region	Freq.
Adda	Sondrio	LO	15
Adige	Verona	VE	67
Adriatico	Venice	VE	23
Agogna	Novara	PM	59
Alto-Adige	Trento	AA	6
Alto-Po	Cremona	LO	91
Bacchiglione	Vicenza	VE	92
Basso-Po	Ferrara	ER	95
Brenta	Padua	VE	81
Crostolo	Reggio Emilia	ER	49
Lario	Como	LO	52
Mella	Brescia	LO	77
Metauro	Ancona	MA	39
Mincio	Mantua	LO	45
Musone	Macerata	MA	25
Olona	Milan	LO	130
Other or unknown			214
Panaro	Modena	ER	395
Passariano	Udine	FV	23
Piave	Belluno	VE	22
Reno	Bologna	ER	91
Rubicone	Forlì	ER	54
Serio	Bergamo	LO	52
Tagliamento	Treviso	VE	50
Tronto	Ascoli Piceno	MA	12

Notes: Regions refer to the modern political units, abbreviated as follows: AA = Trentino - Alto Adige, ER = Emilia-Romagna, LO = Lombardy, MA = Marche, PM = Piemonte, VE = Veneto, FV = Friuli - Venezia Giulia

**TABLE 6. Simulation results: TML bias of mean estimates under mixed rounding**

Apparent truncation points	Effective truncation point adjustment										
	0.025	1/24	0.05	1/12	0.1	1/8	0.15	0.2	1/4	0.3	0.35
59	-0.06	-0.06	-0.05	-0.04	-0.04	-0.03	-0.02	<b>-0.01</b>	<b>0.01</b>	0.02	0.03
59.25	0.04	0.05	0.05	0.06	0.07	0.08	0.08	0.10	0.11	0.12	0.13
59.5	<b>0.01</b>	0.02	0.02	0.03	0.04	0.05	0.06	0.08	0.10	0.11	0.13
59.75	-0.06	-0.05	-0.05	-0.03	-0.02	<b>0.00</b>	0.01	0.04	0.06	0.08	0.10
60	-0.17	-0.16	-0.15	-0.12	-0.11	-0.09	-0.07	-0.03	<b>0.00</b>	0.03	0.06
60.25	0.09	0.11	0.11	0.14	0.15	0.17	0.18	0.21	0.24	0.26	0.29
60.5	<b>0.01</b>	0.03	0.04	0.07	0.09	0.11	0.13	0.17	0.21	0.24	0.27
60.75	-0.14	-0.11	-0.10	-0.05	-0.03	<b>0.01</b>	0.04	0.09	0.14	0.19	0.23
61	-0.46	-0.41	-0.39	-0.32	-0.28	-0.23	-0.18	-0.09	<b>-0.02</b>	0.05	0.11
61.25	0.23	0.25	0.27	0.31	0.34	0.37	0.40	0.45	0.50	0.54	0.58
61.5	<b>0.00</b>	0.04	0.06	0.13	0.17	0.21	0.26	0.34	0.40	0.46	0.52
61.75	-0.27	-0.21	-0.18	-0.08	<b>-0.03</b>	0.04	0.10	0.22	0.31	0.39	0.47
62	-1.05	-0.94	-0.88	-0.68	-0.59	-0.47	-0.35	-0.16	<b>0.01</b>	0.14	0.26
62.25	0.42	0.47	0.49	0.58	0.61	0.67	0.72	0.80	0.88	0.94	1.00
62.5	<b>-0.03</b>	0.05	0.09	0.23	0.30	0.39	0.47	0.61	0.72	0.82	0.91
62.75	-0.50	-0.37	-0.31	-0.09	<b>0.00</b>	0.14	0.26	0.46	0.62	0.76	0.87
63	-2.60	-2.24	-2.08	-1.51	-1.28	-0.97	-0.70	-0.27	<b>0.05</b>	0.31	0.52
63.25	0.69	0.77	0.81	0.95	1.01	1.09	1.17	1.30	1.40	1.49	1.57
63.5	<b>-0.01</b>	0.14	0.22	0.47	0.58	0.72	0.85	1.07	1.24	1.37	1.49
63.75	-1.04	-0.75	-0.62	-0.16	<b>0.03</b>	0.27	0.48	0.82	1.07	1.27	1.43
64	-7.12	-5.59	-4.98	-3.17	-2.53	-1.76	-1.16	-0.31	<b>0.28</b>	0.70	1.01

*Notes:* The adjustment is a deduction of the amount specified from the apparent truncation point. Rounding scheme applied: 35, 8, 20, and 36 percent shares rounded to the nearest whole-, half-, quarter-, and twelfth-inch. Mean and standard deviation of underlying distribution: 63.0", 2.3". Repetitions: 100. Bias is the mean deviation from 63.0 in estimating the mean. Bold type indicates row minima in absolute value.

TABLE 7. Simulation results: bias of the heaping-corrected TML estimator

$\alpha_{60}/\sigma$	Heaping Interval 57-63"				Heaping Interval 57-66"			
	tp = 60		tp = 58		tp = 60		tp = 58	
	bias ( $\mu$ )	sd ( $\mu$ )	bias ( $\mu$ )	sd ( $\mu$ )	bias ( $\mu$ )	sd ( $\mu$ )	bias ( $\mu$ )	sd ( $\mu$ )
1.00	-0.31	0.130	-0.10	0.0754	-0.56	0.159	-0.18	0.0867
1.05	-0.23	0.123	-0.07	0.0748	-0.47	0.146	-0.15	0.0861
1.10	-0.17	0.116	-0.05	0.0742	-0.39	0.136	-0.13	0.0855
1.15	-0.11	0.112	-0.02	0.0738	-0.32	0.127	-0.11	0.0851
1.20	-0.06	0.108	-0.01	0.0734	-0.26	0.120	-0.09	0.0847
1.25	-0.02	0.104	0.01	0.0731	-0.21	0.114	-0.07	0.0844
1.30	0.01	0.102	0.03	0.0729	-0.17	0.109	-0.06	0.0842
1.35	0.05	0.100	0.04	0.0727	-0.13	0.105	-0.04	0.0840
1.40	0.07	0.098	0.05	0.0725	-0.10	0.102	-0.03	0.0838
1.45	0.10	0.096	0.06	0.0724	-0.07	0.099	-0.02	0.0836
1.50	0.12	0.095	0.07	0.0722	-0.04	0.096	-0.01	0.0835
1.55	0.14	0.094	0.08	0.0721	-0.02	0.094	0.00	0.0834
1.60	0.16	0.093	0.09	0.0720	0.00	0.092	0.01	0.0833
1.65	0.18	0.092	0.10	0.0719	0.02	0.090	0.01	0.0832
1.70	0.19	0.091	0.10	0.0719	0.04	0.089	0.02	0.0831
1.75	0.20	0.091	0.11	0.0718	0.06	0.087	0.03	0.0830
1.80	0.22	0.090	0.11	0.0717	0.07	0.086	0.03	0.0830
1.85	0.23	0.090	0.12	0.0717	0.08	0.085	0.04	0.0829
1.90	0.24	0.089	0.12	0.0716	0.10	0.084	0.04	0.0829
1.95	0.25	0.089	0.13	0.0716	0.11	0.083	0.05	0.0828
2.00	0.26	0.089	0.13	0.0715	0.12	0.082	0.05	0.0828

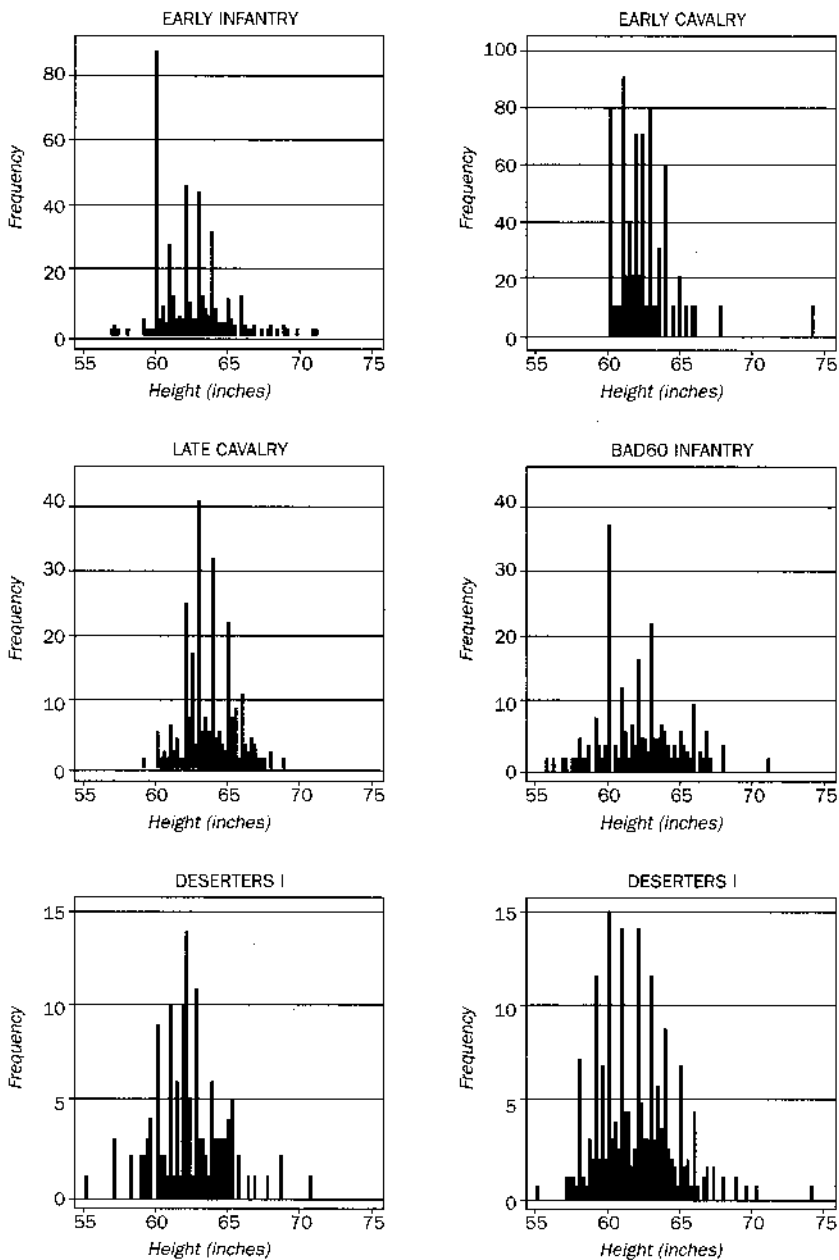
Notes: Rounding scheme: 35, 8, 20, and 36% shares rounded to the nearest whole-, half-, quarter-, and twelfth-inch. Underlying mean and standard deviation: 63.0" and 2.3". Repetitions: 100.  $\alpha_{60}/\sigma$  refers to the imposed ratio of the standard error of observations with a height of 60" (the heaping point) relative to the rest of the sample. A random 10% of the 57-63" interval were heaped on 60", 6% of the wider 57-66" interval. An effective truncation point adjustment of 0.225" was employed.

**TABLE 8. TML estimates of the determinants of height, alternative specifications**

Variable	Heaping-corrected multiple t.p.s			Heaping ignored multiple t.p.s			"Strict" truncation point 62"			"Less strict" truncation point 61"		
	coeff.	s.e.	p-val.	coeff.	s.e.	p-val.	coeff.	s.e.	p-val.	coeff.	s.e.	p-val.
Age 16	-0.32	6.33	0.96	-0.83	6.69	0.90	2.41	9.71	0.80	1.79	5.89	0.76
Age 17	-10.62	6.37	<b>0.10</b>	-11.76	6.62	<b>0.08</b>	9.13	10.92	0.40	0.41	6.37	0.95
Age 18	-1.57	3.02	0.60	-1.39	3.24	0.67	-7.89	5.98	0.19	-0.91	3.22	0.78
Age 19	-0.58	2.68	0.83	-0.88	2.83	0.76	5.08	5.06	0.32	-0.61	2.74	0.82
Age 20	0.28	1.49	0.85	0.45	1.59	0.78	-1.92	2.73	0.48	0.96	1.55	0.53
Age 21	reference group											
Age 22	2.21	1.53	0.15	2.69	1.63	<b>0.10</b>	1.00	2.61	0.70	0.50	1.49	0.74
Age 23	1.51	1.70	0.38	1.61	1.81	0.37	0.11	2.88	0.97	1.03	1.63	0.53
Age 24	3.51	1.64	<b>0.03</b>	4.05	1.76	<b>0.02</b>	2.87	2.66	0.28	3.28	1.57	<b>0.04</b>
Age over 24	3.62	1.39	<b>0.01</b>	4.12	1.49	<b>0.01</b>	3.18	2.29	0.17	3.09	1.34	<b>0.02</b>
No-age-height group.	1.43	1.35	0.29	2.32	1.45	0.11	-2.29	2.41	0.34	0.69	1.38	0.62
Born pre-1775	-1.14	1.42	0.42	-1.27	1.52	0.40	-3.77	2.25	<b>0.09</b>	-2.25	1.39	0.11
Born 1775-79	0.15	1.05	0.89	0.07	1.12	0.95	-2.84	1.77	0.11	-1.34	1.06	0.21
Born 1780-84	-0.15	0.65	0.81	-0.25	0.70	0.72	-2.98	1.29	<b>0.02</b>	-1.90	0.74	<b>0.01</b>
Born 1785-89	reference group											
Born post-1789	-0.18	0.71	0.80	-0.30	0.75	0.69	3.47	1.48	<b>0.02</b>	0.67	0.88	0.45
Novara	-0.21	1.66	0.90	-0.21	1.77	0.90	1.70	2.93	0.56	0.92	1.73	0.60
Bergamo	-1.22	1.63	0.45	-1.04	1.74	0.55	0.40	3.28	0.90	-0.53	1.97	0.79
Brescia	1.72	1.47	0.24	1.84	1.56	0.24	0.93	2.51	0.71	0.77	1.53	0.62
Como	-0.40	1.81	0.83	-0.47	1.94	0.81	-2.95	3.21	0.36	0.72	1.81	0.69
Milan	reference group											
Alps	2.56	1.63	0.12	2.79	1.74	0.11	6.49	2.97	<b>0.03</b>	3.98	1.85	<b>0.03</b>
Modena	-1.62	1.24	0.19	-1.68	1.32	0.20	0.27	2.22	0.90	0.41	1.32	0.76
Other Emilian dipt.	-1.02	1.32	0.44	-1.14	1.40	0.42	-1.18	2.46	0.63	-0.32	1.45	0.83
Po plains	-0.64	1.14	0.57	-0.59	1.21	0.63	-2.24	2.13	0.30	-0.68	1.25	0.59
Verona	1.74	1.43	0.22	1.88	1.52	0.22	1.39	2.60	0.59	1.22	1.59	0.44
Vicenza	-0.18	1.35	0.90	-0.03	1.44	0.98	-1.40	2.78	0.61	-0.87	1.65	0.60
Northeast	2.00	1.30	0.12	2.10	1.38	0.13	1.09	2.39	0.65	1.28	1.46	0.38
Southeast coast	-2.53	1.33	0.06	-2.53	1.42	<b>0.07</b>	-5.55	2.67	<b>0.04</b>	-3.25	1.52	<b>0.03</b>
Other / unknown dipt.	0.54	1.20	0.65	0.42	1.27	0.74	-0.49	1.98	0.80	0.30	1.20	0.80
Big city	1.68	1.34	0.21	1.60	1.43	0.26	1.64	2.01	0.41	1.93	1.25	0.12
Small city	0.72	0.90	0.42	0.64	0.96	0.51	1.16	1.42	0.42	1.38	0.87	0.12
No occupation	reference group											
Ag. / labour occ.	-2.11	0.83	<b>0.01</b>	-2.22	0.89	<b>0.01</b>	-5.86	1.66	<b>0.00</b>	-2.82	0.87	<b>0.00</b>
Other craft	-0.90	0.87	0.30	-1.04	0.93	0.26	-2.93	1.52	<b>0.05</b>	-1.01	0.87	0.24
Non-com. officer	0.22	1.22	0.86	0.13	1.31	0.92	-0.46	1.79	0.80	0.29	1.09	0.79
Officer	3.98	1.19	<b>0.00</b>	3.99	1.27	<b>0.00</b>	3.94	1.75	<b>0.03</b>	4.31	1.11	<b>0.00</b>
Special forces	4.84	2.33	<b>0.04</b>	5.63	2.49	<b>0.02</b>	7.14	3.50	<b>0.04</b>	4.88	2.31	<b>0.04</b>
Cavalry	-1.50	0.99	0.13	-1.16	1.06	0.28	-1.90	1.53	0.21	0.10	0.93	0.92
Constant	165.73	1.62	<b>0.00</b>	164.47	1.74	<b>0.00</b>	168.08	3.06	<b>0.00</b>	167.57	1.71	<b>0.00</b>
Sigma	7.09	0.21	<b>0.00</b>	7.45	0.23	<b>0.00</b>	7.82	0.53	<b>0.00</b>	6.61	0.27	<b>0.00</b>
Wald $\chi^2_{35}$	112.73		<b>0.00</b>	110.32		<b>0.00</b>	53.86		<b>0.02</b>	101.60		<b>0.00</b>
N	1756			1756			1106			1364		

Remapping Italy's Path to the XIXth Century: Anthropometric Signposts

**FIGURE 3. Height Distributions by sub-sample**



Note: see Table 1 for details on the six sub-samples.

