From left-skewness to symmetry: how body-height distribution among Swiss conscripts has changed shape since the late 19th century

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Abstract

Background: It is generally accepted that height distribution in modern populations is nearly symmetrical. However, it may deviate from symmetry when nutritional status is inadequate.

Aim and subjects: This study provides an analysis of changes in the shape of the height distributions among Swiss conscripts (n = 267,829) over the past 130 years based on a highly representative, standardized and unchanged data source.

Results: The analysed distributions from the 1870s–1890s conscription years are markedly left-skewed (~0.76 to ~0.82), with short and very short men significantly over-represented. Standard deviation is 7.7 cm. In particular, the left tails of the late-19th- and early-20th-century distributions are very heavy. In the first half of the 20th century the first signs of a diminution of the heavy left tail are observable, by the 1970s the phenomenon disappears and height distribution becomes symmetrical; standard deviation is now 6.5 cm.

Conclusion: The relatively strong left-skewness during the late 19th and early 20th centuries may have been due to the interaction of a number of causes, chiefly malnutrition, a wider range in physical development at age 19 and widespread iodine deficiency.

Keywords

Anthropometric history, distribution, iodine deficiency, malnutrition, stature

Background

It is generally agreed that height as a polygenetic additive metric trait is likely to be distributed very close to symmetry and normality (following a bell-shaped Gaussian function) (Terrenato & Ulizzi, 1983) and that standard deviation is ~6.5 cm in (male) populations of today’s well-nourished industrialized countries (Bogin, 1999; Eveleth & Tanner, 1990; Hermanussen et al., 1995; Jacobs et al., 2008). However, it is also known that height distribution may differ from symmetry when nutritional status is inadequate or unequally distributed, e.g. in pre-modern times and in developing countries today (A’Hearn et al., 2009; Hermanussen et al., 1995).

Height data offer insights into the well-being of populations in pre-modern eras (A’Hearn et al., 2009; Komlos, 2008). The average height of a given adult population serves as a measure of nutritional status and living conditions from birth through adolescence to adult height (including periods of deprivation and subsequent catch-up growth) (Bogin, 1999). Nutritional status is defined as the collective impact of epidemiological environment, nutrient intake and claims on nutrient intake made by leisure as well as work activities and is in turn partly a function of an individual’s metabolic rate. Whereas genes are largely responsible for an individual’s height potential (~80%), variation in average height over time and across sub-populations is driven by systematic differences in diet, disease environment, workload and healthcare, which in turn determine the extent to which individuals in these sub-populations reach their genetic potential (McEvoy & Visscher, 2009). Because human growth reflects economic conditions, it is a direct measure of health status (Steckel, 1995, 2009). Nutrition, infection and immunity are closely related and changes in one component affect the other two (Lunn, 1991). In the case of growing children who suffer from malnutrition, not only is immunity compromised and susceptibility to infections increased, but severe stunting may also result (Grantham-McGregor et al., 1989).

Adolphe Quetelet (1796–1874) and Edouard Mallet (1805–1856) first discussed the symmetry of height distribution, based on frequency tables of conscript height data recorded during the 1830s (Mallet, 1835; Quetelet, 1830, 1835; Staub et al., 2011a; Tanner, 1981). The concept of the normal curve was subsequently established more systematically by Galton (1889) and Pearson (1894) a few decades later and then applied to Italian conscripts by Livi in the 1880s (A’Hearn et al., 2009; Boldsen & Kronborg, 1984). The empirical data required in order to assess the shape and changes in the height distribution are derived, for the most part, from military-conscription registers. Recruitment data are well suited to quantitative diachronic comparisons because they are recurrent (yearly), height is measured in a standardized procedure and recruits are largely homogeneous in age (Jacobs et al., 2008; Staub et al., 2013b).
Recent anthropometric and auxological studies have focused on the changing shape of the height distribution of Danish (Boldsen & Kronborg, 1984), Italian (A’Hearn et al., 2009; Arcaleni, 2006; Hermanussen et al., 1995; Terrenato & Ulizzi, 1983), Dutch (Hermanussen et al., 1995; Jacobs et al., 2008), German (Hermanussen et al., 1995) and Portuguese (Padez, 2002) conscripts during the 19th and 20th centuries.

The anthropometric history of Switzerland has been increasingly explored during the past 11 years (Rühli et al., 2008; Schoch et al., 2012; Staub et al., 2010, 2011b, 2013a; Staub & Rühli, 2013). The positive secular height trend began in the 1870s (birth years, Figure 1): Average height of 19-year-old Swiss conscripts increased from 163.3 cm in 1878/1879 (years of birth 1859/1860) to 178.3 cm in 2011 (year of birth 1992) (Staub et al., 2011b). Vast improvements in living conditions (nutrition, disease environment and physical work loads) may be among the clustered co-factors contributing to the secular height trend (Staub, 2010). At the beginning of this period Swiss conscripts were on average as tall as Italian and Spanish conscripts. After World War I (birth years) they had reached similar average heights as Belgian and French conscripts (Hatton & Bray, 2010).

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The height-distribution analysis presented here is based on a representative, standardized and unchanged data source spanning the past 130 years. The present study aims to determine whether the changing shape of the height distribution of conscripts in Switzerland during the past 130 years reflects the country’s evolving standard of living from a relatively low level in the 19th century to one of the highest in the world today (Schoch et al., 2012; Studer, 2008).

Sample, data and methods

Anthropometric data from Swiss conscription examinations yield a year-by-year picture of the cumulative growth of young men at the prescribed age of 19 years (Staub et al., 2013b). Swiss conscription has been universal and standardized since 1875 and measurement procedures for height have not changed. Therefore, recruitment data are an ideal base for a detailed study of changes in the height of young men in Switzerland over the past 130 years (Kurz, 1985; Wolf, 1891). The records of the medical examination procedure include the height, measured by medical personnel, of every conscript, including those who subsequently received an exemption. Conscripts later declared unfit because they did not reach the minimum height requirement (1877–1911: 156 cm; 1912–1931: 155 cm; 1932–1952: 154 cm; 1952–today: no minimum height requirement) are therefore also included (Staub, 2010). The frequency tables in the Appendix show that even the shortest men have been measured. Stature has been recorded to the nearest centimetre. In addition, the age range within a given cohort is homogeneous; since 1874 conscription is conducted in the year in which the conscripts reach the age of 19. Since the start of the period under study the conscript subpopulation and the 19-years-old-male-resident census subpopulation have remained almost entirely congruent (Staub et al., 2010); for instance, the 2004–2012 Armed Forces census still represented more than 90% of the birth cohorts concerned (Panczak et al., 2014; Rühli et al., 2008). Because these data are based on virtually complete enumerations, not samples, there is no issue with truncation (A’Hearn, 2004; Komlos, 2004).

In this study we present all available height distribution data at the national level for Swiss conscripts (total n = 267,829) (vertical dashes in Figure 1). The data for distributions a (conscription years 1878/1879), b (conscription year 1884), c (conscription year 1891), d (conscription years 1909/1910) and f (conscription year 1972) come from reports published by the Swiss Federal Bureau of Statistics and the Swiss Army (Eidgenössisches Statistisches Amt, 1974; Schweiz. Figure 1. The secular trend in average height (cm) in Switzerland since the late 19th century, partially compared with average height of conscripts in Belgium, France, Italy and Spain (Hatton & Bray, 2010); (a–h) highlight the years for which distribution data are analysed in this study.
The mean heights of the eight analysed distributions reflect a positive secular trend among Swiss conscripts, making for a broader distribution among populations in which average height was lower than that of modern conscripts.

Second, evidence for the change in shape of the distributions is provided by comparisons between means and medians (Table 1): Whereas the mean of each of the two modern distributions, g and h, is slightly above the median (by 0.2–0.4 cm), the two measures of location are almost equal in the 1930s distribution, e. In contrast, in the three distributions a, b and c, from the 1870s–1890s, have a standard deviation of 7.7 cm, the distributions d and e, from the first half of the 20th century (SD = 7.0, 6.7, respectively), mark the transition towards the modern distributions f, g and h, with a standard deviation of 6.3–6.5 cm. The corresponding variation coefficients (standard deviation divided by the average) decreased over time, indicating a broader distribution among populations in which average height was lower than that of modern conscripts.

In terms of skewness and kurtosis (Table 1), the three distributions a–c, from the 1870s–1890s, were markedly left-skewed (~0.76 to ~0.82). Again, the distributions d and e, from 1909/1910 and 1927–1932, with their decreasing...
skewness (~0.60, ~0.20, respectively), mark the transition towards the modern distributions f, g and h, with scarcely any skewness (~0.03 to 0.07) (Figure 3). Accordingly, the distributions from the 19th century show hyper-kurtosis (2.17–2.44), in contrast with the modern distributions (0.04–0.91).

The interquartile ranges stayed stable, at ~8–9 cm, among all distributions (Table 1), indicating that diachronic changes in the shape of the distributions did not occur in the centre of the distributions. The Q–Q plots for each of the eight distributions, a–h, provide a precise illustration of this phenomenon (Figure 4). In 19th century Switzerland the average height of conscripts differed significantly from normal distribution. Not only the three distributions a–c, from the 1870s–1890s, but also distribution d, from 1909/1910 (birth year 1890/1991), show a heavy left/lower tail compared with the corresponding normal distribution (red line), whereas the upper ends of the distributions are close to the latter. Short and very short men have been markedly over-represented in the earlier populations (e.g. in 1884 5.1% out of 22 413 conscripts instead of the expected 2.3% based on the normal distribution, were under 150 cm in height). The 1927–1932 distribution (e) already shows signs of a lighter left tail and in f (1972) the heavy left tail has disappeared. The two most recent distributions, g and h (1993/1994 and 2008/2009), display an almost symmetrical normal distribution.

**Discussion and comment**

Since the start of the secular height increase, in the late 19th century, there has been a change not only in mean height and the position of the distribution but, also, more pronouncedly in the shape of the height distribution. In skewness and kurtosis, height distribution shows a clear trend towards
normal distribution. Until the mid-20th century the analysed height distributions were left-skewed; short and very short men were over-represented. While there was little deviation from symmetry at the upper end, the left tails of the late-19th- and early-20th-century distributions were abnormally heavy. Between 1909/1910 and 1927–1932 the first signs of a diminution in the weight of the heavy left tail are observable and between 1927–1932 and 1972 the heavy tail has disappeared and the distribution becomes symmetrical. Initial hyperkurtosis has diminished to values typical of the normal distribution in parallel.

The deviating and heavy left tail of the height distribution has also appeared in data on 19th-century conscripts in Denmark (Boldsen & Kronborg, 1984), the Netherlands (Hermanussen et al., 1995; Jacobs et al., 2008) and Italy (A’Hearn et al., 2009; Arcaleni, 2006; Terrenato & Ulizzi, 1983). The Italian conscription provides a data series comparable to that of the Swiss-conscripts (Terrenato & Ulizzi, 1983). The left-skewness among the Italian height distributions also disappears during the mid-20th-century. However, there are important differences: First, the left-skewness of the height distribution was markedly lower in Italy (−0.27 vs −0.82 in the birth cohorts 1874 and 1872, respectively). Second, the Italian height distributions show no change in standard deviation over time (constantly between 6.8–7.0 cm), whereas among the Swiss conscripts it decreased from 7.8 cm to 6.5 cm. The fact that the variation coefficient in the 19th-century Swiss-conscripts distribution was 4.7% (which in a normal distribution would be expected to be ~3.7%, Hermanussen et al., 1995) indicates that the left-

Figure 4. Q–Q-Plots comparing each of the eight distributions a–h from Table 1 and the Appendix to the corresponding normal distribution (straight line).
skewness and the over-representation of short and very short conscripts were particularly marked among Swiss conscripts.

There are several possible data-inherent explanations for the observed pattern. First, the fact that in the 19th century the heights of even the shortest young men below 150 cm have precisely been measured and recorded (which may not have been the case in other countries) could contribute to explain the comparatively strong degree of left-skewness during the late 19th century. Second, an absentee rate of 5% among the modern birth cohorts may partly explain that the modern height distributions are nearly symmetrical, since young men suffering from severe (chronic) diseases or disabilities are assessed unfit for military service in absentia, on the basis of medical certificates. However, such exemptions are not restricted to short young men and the two modern distributions still include single cases of young men under 150 cm who theoretically match the diagnosis criteria for short stature (Wales, 2013). According to the Swiss Army, the number of young men classified unfit for service in absentia due to small or tall stature during the recent years was restricted to less than 20. Since the left tail of the analysed modern distributions phases out smoothly (Appendix), legitimate exemptions as well as absenteeism among the modern cohorts cannot alone account for their tendency towards symmetry. Third, in the case of the Swiss data, age variations among conscripts can be ruled out due to strict procedure protocols (steady conscription age of 19 years). Fourth, Boldsen and Kronborg (1984) suggested that deviation from normal distribution on a national level can result from a mixture of normal distributions of two sub-populations. This may be the case in Switzerland, since throughout the 19th century regional variation in average height was significant (Staub et al., 2013a). Unfortunately, the question cannot be answered at present, since distribution data at the regional level are not yet available. Fifth, heaping and rounding may also affect comparison of height distributions. The red columns among the orange ones in the 1878/1979 histogram indicate a weak tendency of heaping towards numbers ending in 5 or 0 and also towards the minimum height requirement (156 cm at the time) (Figure 2). However, it has been shown that heaping on the numbers 5 or 0 does not significantly bias the results of height distribution analyses (Schneeweiss et al., 2010).

Since these data-inherent explanations are not able to fully explain the observed pattern, environmental aspects should also be considered, which can deform the stature distribution towards negative skewness and hyperkurtosis. These factors must be reduced, if not eliminated, in order that a given population achieve normal distribution. Once the majority of a given population (migration excluded) shares the benefits of favourable environmental conditions, required for full genetic growth potential, the stature distribution can reach normality (Terrenato & Ulizzi, 1983). In contradiction, deprivation, unequally distributed or inadequate net nutrition and a heavy disease load can have a disproportionately negative impact on individuals at the short end of the height range, negatively skewing the distribution (A’Hearn et al., 2009).

Both inadequate net nutrition and the disease environment are key explanations for the strong left-skewness of the height distribution in the 19th century. First, real wages in Switzerland at the end of the 19th century were lower than those of other European countries (Studer, 2008). Net nutrition was poor; Body Mass Index analyses of Swiss conscripts in 1875–1879 reveal that 12% were underweight by modern WHO standards (BMI <18.5 kg/m²), whereas cases of overweight and obesity were nearly non-existent (Staub et al., 2010). Widespread malnutrition therefore contributed to the over-representation of short and very short young men, despite almost doubled per capita milk consumption in Switzerland between 1850 and 1900 (Staub & Rühli, 2013). By extension, the phenomenon of delayed physical growth may also have been a factor. The physical-development gap between healthy young men whose final height has been achieved by the age of 19 and those who, on account of inadequate net nutrition, continued to grow after this age and did not achieve their final height until their mid-20s certainly was wider in the 19th century than it is today (Hermanussen et al., 1995). In addition, widespread vitamin D deficiency causing frequent cases of rickets during the crucial growth years of childhood may also be a contributing factor (Huh & Gordon, 2008; Staub & Rühli, 2013).

In addition, the most likely driving disease environmental factor behind the particularly strong left-skewness of the Swiss height distribution during the 19th century was widespread endemic iodine deficiency (Burgi et al., 1990; Papageorgopoulou et al., 2012)—a problem known to plague neighbouring Italy at the time (Arcaleni, 2006). Iodine deficiency is closely associated with somatic growth in general (Zimmermann et al., 2007), endemic ‘cretinism’ (mental impairment and/or delayed physical development among growing children) and is a cause of goitre (enlarged thyroid gland) and hypothyroidism at all ages (Hetzel et al., 1990; Zhou et al., 2013; Zimmermann et al., 2008). Prior to the introduction of the iodized salt programme, in 1922, cases of goitre and severe stunting were particularly widespread in the Swiss alpine areas and the foothills of the Alps. Some alpine districts had reported a prevalence of palpable goitres of all sizes among as many as 82% of their conscripts (with 29 of the 136 districts reporting a prevalence of over 50% in 1988) (Burgi et al., 1990; Papageorgopoulou et al., 2012). Research into regional variations in the extent of iodine deficiency in Switzerland at the end of the 19th century could provide further information on the causes of the strong left skewness, but such research pre-supposes the existence of regional height distribution data that have yet to be collected.

In conclusion, regional variations and endemic iodine deficiency aside, the strong left-skewness is—along with the low levels of income in real terms and average height in Switzerland at the time, relative to those recorded elsewhere in Western Europe—strong evidence of just how low living standards were 130 years ago in what is today one of the world’s wealthiest countries. In summary, the relatively strong left-skewness during the late 19th and early 20th centuries may have been due to the interaction of a number of causes, chiefly malnutrition, a wider range in physical development at age 19 and widespread iodine deficiency.

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The authors wish to thank the Swiss Army (Logistikbasis der Armee – Sanität) for providing the individual data 1993/1994 and 2008/2009. We also cordially thank Radoslav Panczak (University of Bern) for

DOI: 10.3109/03014460.2014.942366

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Supplementary material available online

**Appendix Table**