A tall order: Small area mapping and modelling of adult height among Swiss male conscripts

Radoslaw Panczak[a,b], André Moser[b,c], Leonhard Held[d], Philip A. Jones[e], Frank J. Rühli[a], Kaspar Staub[a,*]

[a] Institute of Evolutionary Medicine, University of Zurich, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland
[b] Institute of Social and Preventive Medicine, University of Bern, Finkenhubelweg 11, CH-3012 Bern, Switzerland
[c] Department of Geriatrics, Inselspital, Bern University Hospital, University of Bern, CH-3012 Bern, Switzerland
[d] Epidemiology, Biostatistics and Prevention Institute, University of Zurich, Hirschengraben 84, CH-8001 Zurich, Switzerland
[e] Department of Geography, Swansea University, Wallace Building, Singleton Park, Swansea SA2 8PP, UK

ARTICLE INFO

ABSTRACT

Adult height reflects an individual's socio-economic background and offers insights into the well-being of populations. Height is linked to various health outcomes such as morbidity and mortality and has consequences on the societal level. The aim of this study was to describe small-area variation of height and associated factors among young men in Switzerland.

Data from 175,916 conscripts (aged between 18.50 and 20.50 years) was collected between 2005 and 2011, which represented approximately 90% of the corresponding birth cohorts. These were analysed using Gaussian hierarchical models in a Bayesian framework to investigate the spatial pattern of mean height across postcodes. The models varied both in random effects and degree of adjustment (professional status, area-based socioeconomic position, and language region).

We found a strong spatial structure for mean height across postcodes. The range of height differences between mean postcode level estimates was 3.40 cm according to the best fitting model, with the shorter conscripts coming from the Italian and French speaking parts of Switzerland. There were positive socioeconomic gradients in height at both individual and area-based levels. Spatial patterns for height persisted after adjustment for individual factors, but not when language region was included. Socio-economic position and cultural/natural boundaries such as language borders and mountain passes are shaping patterns of height for Swiss conscripts. Small area mapping of height contributes to the understanding of its cofactors.

1. Introduction

The average height of a given adult population serves as a measure of nutritional status and living conditions across the first 20 years of life, capturing the influence of periods of deprivation and subsequent catch-up growth (Bogin, 1999). Whereas genes are largely responsible for an individual's height potential (c80%), variation in average height over time and across sub-populations can be driven by systematic differences in diet, disease environment, economic conditions, workload and healthcare, which in turn determine the extent to which individuals in these sub-populations realize their genetic potential (Grasgruber et al., 2016; McEvoy and Visscher, 2009; Steckel, 2009). Thus, adult height reflects an individual's socio-economic background and offers insights into the well-being of populations (A'Hearn et al., 2009; Akachi and Canning, 2015; Baten and Blum, 2014; Dalou, 2015; Komlos, 2008).

Height can also be linked to various health outcomes such as morbidity and mortality (Engeland et al., 2003). Overall, being taller seems to be negatively related to all-cause and cardiovascular disease (CVD) mortality, but positively related with cancer mortality (The Emerging Risk Factors Collaboration, 2012). However, the precise mechanisms underlying these associations have yet to be identified. Furthermore, height has consequences on a societal level: taller men evaluate their life as more favourable

* Corresponding author at: Kaspar Staub, Institute of Evolutionary Medicine, Winterthurerstrasse 190, CH-8057 Zurich, Switzerland.
E-mail address: kaspar.staub@iem.uzh.ch (K. Staub).

(Deaton and Arora, 2009), have greater success in the marriage market, and have greater career chances in the labour market compared to shorter men (Herpin, 2005; Magnusson et al., 2006). Similar to what is found in Germany, a height premium was also associated with 5 per mille additional salary per cm of stature (or 1.52 per mille per inch) in Switzerland in 2002 (Gautschi and Hangartner, 2006; Heineck, 2005; Hübler, 2009). The positive effect of height on labour market outcomes has been described for various countries (Case and Paxson, 2008; Gao and Smyth, 2010; Persico et al., 2004; Schultz, 2002; Vogl, 2014), and studies using twin data imply that in the case of men, cognitive ability could explain the effect of height on earnings (Böckerman and Vain-iomäki, 2013).

Adult height varies geographically between world regions (Deaton, 2007; Natale and Rajagopalan, 2014) and even between Northern and Southern Europe (McEvoy and Visscher, 2009). However, less is known about small-area differences within countries and to the best of our knowledge, there are only very few studies that have evaluated national height differences on the small-area level (Ayuda and Puche-Gil, 2014; Baten, 2009). Small-area analyses are able to describe clusters and geographic variations of a given outcome (Elliott and Wartenberg, 2004). In the case of height, this might be of particular interest because people with high socioeconomic position usually tend to live near others with high socioeconomic position, irrespective of administrative units such as districts or cantons (Panczak et al., 2016). Such spatially organized socioeconomic and/or demographic effects often continue to be observed after controlling for individual-level factors (Panczak et al., 2012).

Because average height continues to differ between socio-economic groups in modern Western societies (Hiermeyer, 2009; Huang et al., 2015; Rühli et al., 2008), such small-area studies could further point to genetic and socioeconomic associations with height. Switzerland serves as an ideal basis for such studies because of its cultural and demographic diversity and historical stability (four official language regions, and significant variation of geographical and socioeconomic environment). Studies of mortality and obesity have already shown the benefits of small-area analyses in Switzerland (Moser et al., 2014; Panczak et al., 2016, 2012). Moreover, military conscription provides a large, spatially referenced dataset of the anthropometric status of young men at a prescribed age. The data are collected yearly and, amongst other things, include standardized height measurements (Staub et al., 2013b).

Adult height in Switzerland and its historical development have been described in depth elsewhere (Staub et al., 2013a), but it is important to note that the positive height trend of Swiss conscripts has plateaued since the 1990s (1970s birth years) on a level of 178.2–178.3 cm for men (Staub et al., 2014, 2011). Previous studies documented large scale geographical differences in average height in modern Switzerland and found significant differences between *Grossregionen* based on Swiss Household Panel data (Kues, 2010) and between cantons or districts based on conscription data (Hermanussen et al., 2014; Rühli et al., 2008; Staub et al., 2013a).

The main goal of this study was to extend this research and explore spatial patterns of height with a higher spatial resolution. We hypothesised that there is a spatial pattern in height among young Swiss men and that this variation is partly explained by socioeconomic and cultural factors. In this paper we use spatial statistical methodology (Section 2), to gain area-based estimates of heights from differently specified models (Section 3) before discussing these results in the light of the current state of knowledge (Section 4) and reaching a conclusion (Section 5).

2. Materials and methods

2.1. Data sources

The recruitment process of the Swiss Armed Forces has been described in details elsewhere (Bruggisser et al., 2016; Panczak et al., 2016, 2014), in brief, all men are reviewed for recruitment during the year in which they turn 19. The military assessments include, among others, a standardized measurement of height (rounded to integers) of every conscript (without shoes and in light underwear), including those who get deferred or exempted (*Bundesgesetz über die Armee und die Militärverwaltung, Militärgesetz MG*, 510.10, *Art. 2; MG Art.* 9, *Verordnung über die Rekrutierung VREK*, 511.11, *Art. 3* and *Art. 9*) (Panczak et al., 2016, 2014). Swiss Armed Forces provided a complete set of anonymized conscript records from 1.1.2005 to 31.12.2011 which included date of birth, date of conscription, height, current occupation, postcode of place of residence (further referred to as 'postcode') and stage of conscription (first, regular visit versus reassessment). Information on the place of birth was not available. We obtained a dataset of postcode boundaries from the Federal Directorate of Cadastral Surveying ("Release 7–1. Mai 2013", boundaries as per 31st of March 2013) (Panczak et al., 2016, 2014).

2.2. Data availability and ethics statement

The data are available from the Swiss Armed Forces (Logistikbasis der Armee LBA San, 2014) upon submission and approval of a study protocol. According to Swiss federal law (*Bundesgesetz über die militärischen Informationssysteme MIG, BG* 510.91, *Art. 2*, 9, 24–29), the Swiss Armed Forces are authorized to make the data accessible in anonymous form for academic research. The Swiss Armed Forces fully anonymized the records by removing all names, social-security numbers, and exact residential addresses. Because Swiss conscription is mandatory and the anthropometric measurements used in this study are nonclinical, governmental data, informed consent was not required. When the analyses are based on anonymized, nonclinical governmental data additional ethical approval is not needed (Swiss data privacy act, SR 235.1; 19.6.1992 and Federal Act on Research involving Human Beings HRA, 810.30; 1.1.2014) (Bruggisser et al., 2016; Panczak et al., 2016, 2014).

2.3. Study population

We included all male conscripts appearing for the first, regular assessment, aged between 18.50 and 20.50 years. We excluded women, conscripts appearing for reassessment, conscripts below 18.5 and above 20.5 years old (who requested to undergo conscription either before or after the year in which they turned 19), those with missing or implausible postcode, those with height beyond a plausible range (below 130 cm or above 220 cm) and conscripts with missing or insufficient data on occupation (Panczak et al., 2014). The spatial resolution for the study was obtained by using place of residence at the time of conscription, and standardizing the postcodes from various years to that on 31.3.2013 to align them across datasets (Swiss Federal Statistical Office, 2014a).

2.4. Representativeness

Currently, no dataset exists that allows precise assessment of the representativeness of the conscript population compared to the total population of young men in Switzerland. However, an earlier study using similar sources (Panczak et al., 2014) estimated data to be of high coverage (>90%). Swiss Armed Forces declare that the medical causes of up to 10% of young men who were judged