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Early life undernutrition and adult height: The Dutch famine of 1944–45

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ABSTRACT

Current research shows strong associations between adult height and several positive outcomes such as higher cognitive skills, better earning capacity, increased chance of marriage and better health. It is therefore relevant to investigate the determinants of adult height. There is mixed evidence on the effects of undernutrition during early life on adult height. Therefore, our study aims at assessing the impact of undernutrition during gestation and at ages younger than 15 on adult height.

We used data from the Longitudinal Aging Study Amsterdam. Exposure to undernutrition was determined by place of residence during the Dutch famine during World War II. Included respondents were born between 15 May 1930 and 1 November 1945 and lived in the northern part of the Netherlands during the famine period (n = 1008). Exposure data was collected using interviews and questionnaires and adult height was measured. Exposed and non-exposed respondents were classified in the age categories pregnancy- age 1 (n = 85), age 1–5 (n = 323), age 6–10 (n = 326) or puberty (age 11–15, n = 274). Linear regression analyses were used to test the associations of adult height with exposure. The robustness of the regression results was tested with sensitivity analyses.

In the models adjusted for covariates (i.e., number of siblings, education level of parents, and year of birth) and stratified by gender, adult height was significantly shorter for females exposed at ages younger than 1 (−4.45 cm [−7.44–−1.47]) or at ages younger than 2 (−4.08 cm [−7.20–−0.94]). The results for males were only borderline significant for exposure under age 1 (−3.16 [−6.82–0.49]) and significant for exposure under age 2 (−4.09 cm [−7.20–−0.96]). Exposure to the Dutch famine at other ages was not consistently significantly associated with adult height.

In terms of public health relevance, the study's results further underpin the importance of supporting pregnant women and young parents exposed to undernutrition.

1. Introduction

The current study aims at investigating the consequences of undernutrition in early life on adult height. A large body of evidence has consistently shown associations between tall height and several positive outcomes such as better health, higher cognitive skills, better earning capacity and increased chance of marriage (e.g. Deaton, 2008; Deaton and Arora, 2009). In particular, the pioneering study by Waaler reported strong negative associations between tall height and mortality in Norwegian males and females (Waaler, 1984). More recent studies also reported negative associations between adult height on the one hand and various chronic diseases and causes of death on the other hand (Batty et al., 2009; Silvertoinen et al., 1999). Furthermore, Case and Paxson (2008) also reported strong associations between tall height and higher occupational status and earnings. Case and Paxson suggested that these associations could be explained by higher cognitive ability, in addition to higher self-esteem or social dominance. The findings on socioeconomic status have been confirmed in more recent studies (e.g. Rietveld et al., 2015). Finally, taller individuals are more likely to marry and to have children than others (Fu and Goldman, 1996; Smith and Monden, 2012). These empirical results suggest that adult height plays an important role in many later life outcomes in terms of health and socio-economic status; the investigation of early life determinants of adult height is therefore of great interest to those seeking to emulate these conditions.

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Adult height results from a complex interplay of genetic and environmental factors such as availability of good-quality food, socio-economic conditions and exposure to diseases during early life (e.g. Silvertoinen, 2003; Bozzoli et al., 2009). Roughly 75% (in women) and 90% (in men) of adult height is inherited (Silvertoinen et al., 2003; McEvoy and Visscher, 2009; Yang et al., 2010), which implies that the influence of environmental factors is relatively limited. However, in historical as well as in developing populations, the heritability of height may have been much lower (Alter and Oris, 2008; Wells, 2011). Alter and Oris (2008) showed for instance that in nineteenth-century Belgium the correlation of brothers' heights was much smaller in deprived than in elite families. This may be explained by the fact that poorer people are less able to protect their children from (negative) environmental factors than wealthier parents.

Gestation and infancy, as well as puberty, are crucial periods of time with regard to physical developments including hormonal developments, body composition changes and physical growth (e.g. Silvertoinen, 2003; Siervogel et al., 2003; Kuh and Ben-Shlomo, 2004). Therefore, favorable environmental conditions during these periods of life are especially important to reach genetic height potential.

In particular, appropriate nutrition during early life is essential as growth is partly the result of the balance between energy from nutritional intake and energy needed for body maintenance and other bodily activities (e.g. Rogol et al., 2000). Studies have consistently shown the importance of nutrition at the (very) beginning of life in determining pubertal development and final body stature. For instance, the recent review of Soliman et al. (2014) underlines the importance of nutrition in early life in affecting (the onset and progression of) pubertal development, such as physical growth. Regarding adult height, Martorell (1995, 1999) found for instance that supplementing foods rich in energy, proteins and micronutrients during early childhood reduced the occurrence of "stunting", a term used to describe problematic, long-term reduced height of children in relation to their age. Stunting occurs mostly before the age of two and is often followed by "catch-up growth" (Martorell et al., 1994). Stunting is a direct cause of a short adult height (Dewey and Begum, 2011). Furthermore, the study of Alderman et al. (2006) showed the sizeable impact of pre-school malnutrition on height as a young adult. Also, two Chinese studies observed a remarkable drop in average height for cohorts born between 1956 and 1962 (Zheng-Wang and Cheng-Ye, 2005; Wang et al., 2010). The authors suggested that this was due to the severe famine that China experienced between 1959 and 1961. In contrast with these results, studies among individuals exposed to the famine during the Leningrad siege (1941–1944) showed no significant reduction in body height in exposed individuals during early life compared to non-exposed individuals. Average adult height of exposed females was even taller than that of non-exposed females (Koupil et al., 2007; Shestov et al., 2009).

A healthy diet may be even more important during puberty than in the very beginning of life, since puberty is characterized by increased needs in macro- and micronutrients including protein, calcium, zinc and iron (Klump, 2013; Soliman et al., 2014). To the best of our knowledge, there is limited evidence on the long-term effects of undernutrition during puberty on adult height. Most relevant research investigates the relationship between eating disorders and retarded growth. The findings on adult height are mixed, although the majority of the studies reported reduced adult height after severe eating disorders. For instance, the studies by Modan-Moses et al. (2012a, 2012b) Modan-Moses et al. reported incomplete catch-up growth in adolescent males (2012a) and females (2012b) with anorexia nervosa.

The main aim of our study is therefore to enhance our insight into the consequences of undernutrition during gestation, the first year of life and puberty on adult height. In terms of public health relevance, the study's results further underpin the importance of supporting pregnant women and young parents exposed to undernutrition and of implementing programs preventing restrictive food-intake disorders during puberty. Undernutrition is still a worldwide problem predominantly in developing countries but also to a lesser extent in developed countries for instance in case of diseases such as anorexia nervosa (De Onis and Blossner, 2003; Soliman et al., 2014).

In this study, exposure to undernutrition is determined by experiencing the Dutch famine during World War II. Between November 1944 and May 1945, an estimated 20.000 à 25.000 Dutch citizens died as a result of undernutrition and other harsh conditions (niod.knaw.nl). Although the Allies had begun to liberate several parts of Europe, the majority of the Netherlands was still occupied by the Germans at that time. In September 1944, the Dutch government in exile set up a nation-wide railway strike to weaken the German war machine as much as possible and to stimulate resistance movements in the occupied part of the Netherlands. The German occupiers responded with a complete blockade of all food- and fuel transport to the west of the Netherlands. This resulted in extremely severe survival conditions in the urban areas of the west of the country (Lumey and Van Poppel, 1994, 2013). Average nutritional intakes declined from 1800 kilocalories per day per individual before May 1944 to 500 kilocalories in February 1945, when the famine conditions were at their most severe. Even pregnant and lactating women and infants under age 1 could not be protected at the peak of the famine (Roseboom et al., 2011). In the rest of the country, sufficient amounts of food were available in November 1944–May 45 (Lumey and Van Poppel, 1994). During the Dutch famine, inhabitants of the South of the Netherlands lived under very different circumstances from those of the West and North-East (niod.knaw.nl), because part of the Netherlands to the South of the large rivers (Rhine, Meuse and Waal) had already been liberated in September 1944, but was exposed to ongoing battles and bombing (Barnouw, 1999; De Jong, 1981). Soon after the liberation of the country in May 1945, the average food intake rose to a normal level of 2000 kilocalories per day (Lumey and Van Poppel, 1994).

The Dutch famine of 1944–45 is a very useful source of information on the long-term effects of undernutrition for several reasons. Firstly, the time period of exposure is clear and well-defined (November 1st, 1944–May 15th, 1945) and, secondly, sufficient amounts of food were available in the non-exposed parts of the country during this period, which provides ready control groups (Lumey and Van Poppel, 1994). Thirdly, the relatively short period of the Dutch famine also minimizes the risk of selection of healthier survivors, which otherwise may have masked long-term effects of famine exposure. Finally, many individuals born during the Dutch famine are still alive today, which makes it possible to trace them and to collect information on their current health and height and other individual characteristics.

2. Methods

2.1. Study sample

Our data come from the Longitudinal Aging Study Amsterdam (LASA) (Deeg et al., 2002). The LASA study follows a nationally representative sample of 3107 Dutch individuals aged 55–85 at baseline in 1992–93 (cohort I). The baseline was recruited from three broad, culturally distinct, geographical areas of the Netherlands (West, North-East and South), each area consisting of one large city and several smaller municipalities. At baseline, there was an oversampling of older men such that after five years equal numbers of men and women were expected to be alive in age