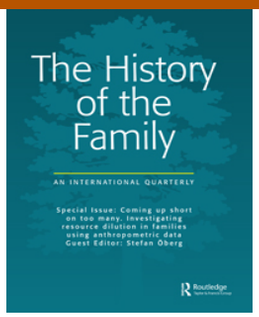

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Temporary and lasting effects of childhood deprivation on male stature. Late adolescent stature and catch-up growth in Woerden (The Netherlands) in the first half of the nineteenth century

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ABSTRACT

This paper compares the statures of men during late adolescence, measured at age 19, with the stature in adulthood, measured at age 25, specially focusing on the influences of household situation and family stress. On average, the men studied became five centimeters taller in the interval, but there was a large individual variation as the shortest men realized the largest 'catch-up' growth. We study how childhood deprivation impacted on growth in adolescence. Childhood deprivation was measured, apart from socioeconomic status and social cultural characteristics of the household, through family size, number of siblings, mortality clustering in the family, and certain characteristics of the mother. In particular, we are interested in the question whether these early-life experiences had a lasting effect, in other words to what extent they were still visible at age 25 and to what extent they influenced the potential for catch-up growth. Our results indicate that the independent influence of family composition was very weak. When comparing temporary and lasting effects on male stature, we see that in general the influences of socioeconomic status and sociocultural factors were, although weaker, still visible at age 25. The results also make clear, that the height at the age of 19 is a better, more sensitive, indicator for the circumstances in which a child grew up. The results of this exercise should be interpreted with caution, as they are based on a small number of cases.

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Stature; catch-up growth; family size; sibship; family crisis; standard of living

1. Introduction

Historical demographers have contributed strongly to the burgeoning study of how early life conditions affect adult health (e.g. Bengtsson & Broström, 2009; Bengtsson & Mineau, 2009; Lumey & van Poppel, 2013; Quaranta, 2013). Thus, the family of origin and its socio-economic conditions during the first years of life have been studied with renewed interest. Most of these studies relate early life conditions to (cause-specific) mortality in later life, but

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frequently body height is also used as an indicator of 'adult health'. This indicator is however not easy to interpret. Body height results from a complex interplay of genetic endowment, conditions *in utero*, availability of food, occurrence or absence of diseases or stress during early life, and workload during adolescence (e.g. Bozzoli, Deaton, & Quintana-Domeque, 2009; Silventoinen, 2003). Moreover, the sources from which heights are culled often suffer from 'selection bias', as they pertain to very specific groups such as professional military, convicts, and students (Bodenhorn, Guinnane, & Mroz, 2013). Finally, and most important for the research we present here, even the best data, the heights of military conscripts, are measured in late adolescence, which was a period in life when young men were still growing (Oppers, 1963, pp. 28–41). This means that it remains unclear whether adverse early life conditions really caused *lasting* effects defined as shorter stature in adulthood.

In this article we make use of a rather unique historical dataset, consisting of a group of men measured at roughly age 19 as well as age 25 in the early and mid-nineteenth century, whom we, moreover, could link to their families of origin. Although the sample is not large, the numbers are by and large sufficient to test hypotheses on the negative effect of childhood deprivation on the height at age 19, and to see to what extent stunted men were able to 'catch up'. Our main question is: do we still find evidence of adverse early life conditions, in particular possible problematic family circumstances, having a lasting effect on the height of adults? If this is the case, the assertion that deprived youths would never achieve their potential heights (e.g. Alter & Oris, 2008, pp. 44–53; Tanner, 1962, p. 149) can be corroborated.

Our research is based on data from Woerden, a small town located in the center of the Netherlands. At this stage, we cannot say whether Woerden stood out with high or low biological standards of living (Tassenaar, 2000a, p. 55), but the latter is more likely. The nearby city of Leiden actually reported the highest proportion of men rejected for military service (because of short stature) in the whole of the Netherlands in the period 1863–1867 (de Meere, 1982, p. 110). In the first half of the nineteenth century, average stature declined in the country, but this was mainly due to deteriorating conditions in cities in the western parts (Tassenaar, 2000, pp. 65–66). In the third section, we will briefly discuss the socio-economic situation of Woerden. Of course, no historical source is without problems of its own. Our research is based upon linkages of conscript records to the records of the civic guards. The matched men were also linked to tax records, and to the civil records and censuses. In the fourth section, we discuss the reliability of our heights measurements. Then, we explain how we have constructed the multivariate models, and in particular our variables of 'childhood deprivation' and family circumstances. In section 5, we describe and analyze the heights of men at the ages of 19 and 25 and we study the 'catch-up' growth. Here we make use of our full datasets but in our final models, discussed in section 6, we compare only those men measured at both 19 and 25. In section 7 of our contribution we pay special attention to the (possible) influences of household crises on the stature of our research population. The last section will present our conclusions. First, however, we will go deeper into the overall causal processes resulting in body heights in late adolescence and adulthood.

2. Factors affecting height in adolescence and adulthood

Adult height is the outcome of various interrelated biological and social processes occurring in early life (defined as the period ranging from conception until late adolescence). To

understand how heights were distributed between individuals and social groups, the following (clusters of) factors need to be taken into account.

Heritability. In developed countries, one can predict, with a fair amount of accuracy, a child's adult height on the basis of the father's and mother's height. The heritability of stature is estimated at about 80%, meaning that 80% of the variation can be explained from parents' height (Silventoinen, 2003; Yang et al., 2010). The remaining variation is attributed to 'environmental' influences, especially the impacts of nutrition and diseases in early life. However, in historical as well as in developing populations, the intergenerational transmitted component of height can be much lower (Wells & Stock, 2011). Alter and Oris (2008) have shown that the correlation of heights between sibling brothers was relatively weak in poor families, implying that poor people were relatively less able to protect their children from shocks.

Epigenetic factors. Individual height is not just the outcome of an inherited (genetic) potential and an adverse or beneficial environment. We should be aware of *epigenetic processes*, or the processes in which environmental factors change the expression of genes, which in turn can be transmitted to future generations. With respect to stature, such processes have been assumed because of the fact that growth potential can be limited *in utero* by the mother during adverse environmental conditions (Cole, 2003; Quaranta, 2013; Schooling et al., 2008). However, in a study on the Dutch famine of 1945 the effects of fetal conditions on adult heights were not found (Silventoinen, 2003, p. 275).

Nutritional status. The proper intake of nutrients (especially proteins) is a crucial determinant of growth (Öberg, 2014, p. 23 ff). In the Netherlands, due to its integrated market economy, local crop failures were not as important as elsewhere. However, a sizeable part of the laboring population already lived at the subsistence level (e.g. Verdoorn, 1981, p. 241 ff; De Meere, 1982), and their food intake deteriorated further in the first half of the nineteenth century due to exports and rising prices of dairy products, the potato crisis of the 1840s, and the effects of the Crimean War on grain imports (Knibbe, 2007). The resulting decline in stature occurred in many industrializing countries at the time (Steckel, 2009, pp. 12–13). Diseases deplete energy from the body and reduce its capacity for the intake of nutrients and thus impair growth. Protracted and repeated diseases, such as diarrhea, can lead to lasting effects on height (Öberg, 2014, p. 28; Öberg, 2015).

Socio-economic position. The socio-economic position of the household during early life affects the growth of children in several ways. Family income is of course directly related to food availability, but social position also affects clothing (fighting a cold also causes a drain on energy), proper care and the effective treatment of diseases (Silventoinen, 2003, p. 265 ff). In the nineteenth century, according to Alter et al. (2004a), differences in height of children from different socio-economic groups were related more to income than to exposure to diseases, as the richer groups were not (yet) able to protect themselves from infectious diseases. The absence of a father or mother created additional problems for poor families. One might expect that children of single mothers, who generally could not apply for municipal poor relief, suffered the most from their 'bad start', but a comparison between legitimate and illegitimate children in the city of Haarlem (1843–1852) did not yield significant differences in height at age 19 (Kok, 1991, p. 88).

Intra-household resource allocation. Household heads constantly have to make decisions on how to spend their incomes. Family size has been shown to be inversely correlated to height of children (Hatton & Martin, 2009; for an overview see also Hatton, 2016). The decision-making depends on whether the head is male or female, and also on the relative

leverage of husband and wife. Often, bargaining power of the mother and/or her educational level translates into better nutrition and medical care for the children (Horrell & Oxley, 2013; Kuh & Wadsworth, 1989; Song, 2008). Cultural preferences, for mostly sons, have been shown to affect differences in height between siblings (Steckel, 2009, pp. 8–9). Also, non-biological children may have been treated differently from own children. A study of the Dutch city of Alkmaar revealed that orphans who were put out with foster parents remained much shorter than orphans who stayed in the orphanage. It is likely that many of those parents tried to make some profit from the compensation money (Van Loo-Mulder, 1984). Even when the parents are devoted to equal treatment of all children, birth order effects can occur. The frequently found negative association between birth order and physical stature might be explained by the fact that first-born children had a period of being an only child and thus had a better environment than later-born children during the growth period (Hermanussen, Hermanussen, & Burmeister, 1988; Wells & Stock, 2011). In some studies, it has been noted that infant and child mortality tends to cluster in specific families, even after controlling for socio-economic status and other factors usually held responsible (Das Gupta, 1990; Edvinsson, Brändström, Rogers, & Broström, 2005; Vandezande, 2012). In this study we assume that children surviving youth in such 'high risk families' were marked by being shorter than children growing up in 'normal' families.

Work. Child labor, especially when it concerns physically demanding work, can be another drain on energy needed for growth. The adverse impact of labor on height was already noted in the mid-nineteenth century, e.g. by the medical doctor Coronel who (in Coronel, 1863) noted a difference in stature of no less than 11.5 centimeters between young factory workers and fishermen's sons (Tassenaar, 2000, p. 313). However, work could also have positive effects, especially when children were fed at work and when their money income strengthened their claim to a larger share of the household food (Meredith & Oxley, 2015, p. 213).

Finally, we need to recognize that the growth of the body in childhood and youth is not an evenly spread process, but instead occurs in distinct spurts. In his thesis, Oppers (1963; also Tanner, 1978) argues that the growth rate of the child decreases initially from birth (in fact from the fourth month *in utero*), but shows afterwards two increases, the 'youth-acceleration' and the 'adolescence-acceleration'. However, the timing of the spurts as well as the number of centimeters grown vary strongly between children. For example, the adolescence-acceleration can vary from 10 to 30 centimeters. The age when this spurt occurs is from 13 to 15.5 years of age, but it can vary from 12 to 17 years. The largest part of the total increase of height is between 0 and 6 years of age. The growth during adolescence is more sensitive to changes in the environment than the growth in the pre-adolescence phase (Oppers, 1963, p. 21). The highest growth rate during adolescence is 10 centimeters per year, which is the same as a child at the age of two has. The difference is that growth velocity during the toddler age group continues longer than during the adolescence-acceleration. We may assume that children in the age groups with the largest growth velocity (0–6 years and the adolescence-acceleration) are also the most vulnerable to external influences. For example, the acceleration between 8 and 10, which is much smaller, is least influenced by external influences like wars.

Children and adolescents can also experience catch-up growth, which can be defined as 'a height velocity above the statistical limits of normality for age and/or maturity during a defined period of time, following a transient period of growth inhibition' (Boersma & Wit, 1997, p. 646). This catch-up growth can undo a lot of the negative effects caused by disease

or food shortage. Many anthropometric studies are based on conscript records of men studied at age 19, when catch-up growth was still possible. Thus the effects of childhood deprivation found in such studies could be, in theory, temporary effects. Based upon military records, Oppers studied in detail the growth between the age of 19 and 25 years. He concluded that during the nineteenth century late catch-up growth was a normal phenomenon. However, the degree of growth after the age of 19 differed strongly. Sometimes it was a few centimeters, sometimes much more. Oppers mentioned percentages of 40 of a cohort who grew more than 6 centimeters after the age of 19, whereas 25% grew even more than 10 centimeters. Overall, during the nineteenth century this catch-up growth diminished (Oppers, 1963, p. 50).

3. The case of Woerden in the first half of the nineteenth century

Although Woerden is a relatively small town, in some respects it might even be considered a small city. It had a central function for the surrounding area, with a market, a hospital, a prison and military barracks. Also, the town was characterized by proto-industrialization in the form of brick and tile works. In the middle of the nineteenth century, the town had a population of around 4000 inhabitants; in 1815 this amount was around 2600. The population growth was not simply the result of a birth surplus, but was partly due to a positive balance of migration; without this strong immigration the population would, at least during the first quarter of that century, have decreased (van der Laarse, 1989, p. 42). This positive net migration was mainly caused by the industry. At the beginning of the 1830s and in the late 1840s, Woerden shows mortality crises with peaks around 1832 and 1848 as a result of intestinal diseases and infectious diseases like malaria, smallpox and cholera asiatica. Woerden was situated in the center of a region that was hit hardest by the cholera epidemics (van der Laarse, 1989, p. 42).

During the first half of the nineteenth century, the population of Woerden can roughly be divided into three socio-economic groups: (a) the brick and tile workers, (b) the farmers and (c) the middle class/elite. The physical structure of the municipality can also be divided into three separate sections: the 'inner city' with its middle class and elite, the agricultural section with its farms, and a third separate section with its brick and tile factories and small houses for the laborers.

The brick and tile works and related industries formed a distinct community at a distance from the 'city' of Woerden; with its own houses, shops, cafes and fairgrounds and even its own dialect (Stadhouders, 2015). Life at the *Pannebakkerijen* (tile works) was not easy; the literature gives the impression that people were living in Dickensian circumstances (Janssen, 1987; van der Laarse, 1989; Stadhouders, 2015). The brick and tile workers were living in small factory houses situated between big ovens and racks from stones and tiles. This led to very bad hygienic conditions, an important cause of all the diseases mentioned earlier. In this industry, the whole family took part in the process of producing bricks or tiles, thus women and child labor was important. The brick and tile industry was a seasonal business. The workers earned their income during the production season that ran from early April to early October – at least if the weather did not make it impossible to work, in which case nothing was earned. During the winter months the workers were without income. They were mostly dependent on aid from the churches or municipal poor relief unless their bosses paid them the so-called 'winter money', a loan with the purpose to bind the workers for the next

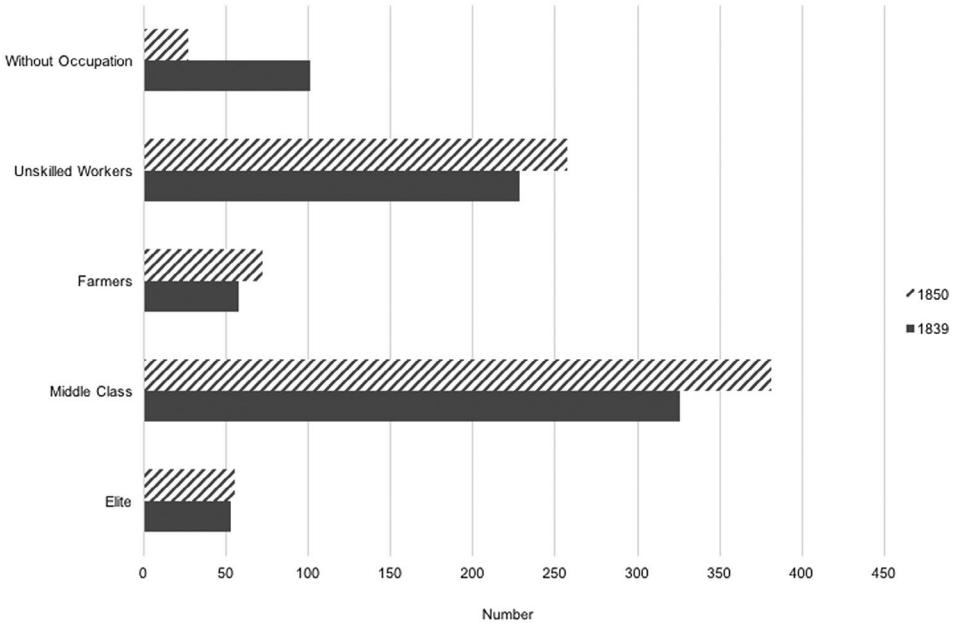

Figure 1. Occupational stratification (HISCLASS) heads of households in Woerden in the years 1839 and 1850 (in absolute numbers).
Source: Census 1839 and population register 1850–1854. Archive Woerden, inv. nr. 911-917.

season to the company. Brick-making was contract work; the workers were hired every year (in July or August) again for the next season by the manufacturers (Stadhouders, 2015, p. 210).

From a demographic point of view, proto-industrialization in Woerden was not associated with an increase in the birth rate, as was assumed for example by the historical demographer Hofstee (1978), but instead led to an increase in the death rate. The mortality crises in Woerden had an ecological background (van der Laarse, 1989, p. 43) and were closely related to increasing population density, especially in the brickwork part of the town.

It is interesting to note that, although the number of laborers increased, we cannot talk of a strong proletarianization. Figure 1 shows that Woerden still had a considerable middle class and small elite. The proletarian part of the population was smaller than in many other Dutch cities. The considerable middle class was partially due to the military barracks and the prison, which attracted all kinds of additional labor. Next to this Woerden had a central function for the surrounding area, and accommodated notaries, medical doctors, civil servants and factory owners. Finally, due to a developing dairy industry, in particular cheese making, the importance of agriculture in the economic structure of Woerden increased during the nineteenth century (Van Drie & Van Es, 1985).

Figure 1 shows that during the period 1839–1850 a few interesting changes in the professional structure of Woerden took place. First, the number of people without a profession decreased, maybe partly a result of better registration, but it might also have been caused by new economic possibilities during that period, for example the growth of the tile and brick factories and the markets. Secondly, we noticed an increase of the middle class, caused by an increase of shopkeepers and especially of craftsmen. However, van der Laarse (1989)

argues that presumably most of these new groups lived in poor circumstances. He suggests that the increase might be attributed to the migration.

4. Sources on male stature

Earlier we mentioned the rather unique dataset used for this study, a dataset which makes it possible to follow life courses of individual recruits and, in several cases, their height at two important moments during their lifespan. This study is primarily based upon registers for the military service and registers for the civic guard. Apart from these registers, secondary information is derived from the civil registers, population registers, censuses and tax registers. Conscription for military service was introduced during the French period; prior to that only a professional army existed in the Netherlands. The idea was that, besides the so-called standing *armée*, the military force would consist of a National Militia. When the number of volunteers was not sufficient, an additional lottery among all available men in a certain birth cohort would take place to complement the necessary military power (Koerhuis & Van Mulken, 1986). Before 1861, the conscription of men took place in their eighteenth year of life, and after 1861 in their nineteenth year (Oppers, 1963, p. 40), which meant that on average men were respectively measured at the age of 18.5 years (most of them were measured during the second half of March) and 19.75 years. After military service, men at the age of 25 could also be recruited for the civic guard. Again, all suitable men were registered and had to undergo a medical examination. These registers, which are only available for towns with a certain minimum number of inhabitants, in combination with the registers of conscription, make it possible to study catch-up growth after age 19. In Woerden both types of military registers are available. Our study is based upon the registration records for the (ordinary) military service during the period 1815–1871 and the registers for the civic guard covering the years 1828–1867.

Who was registered in these sources and could people avoid being measured? We conducted a small exercise with the Woerden birth cohort of 1842, which comprised 79 boys. No fewer than 34 boys died before their nineteenth birthday, and another 10 left town, and were probably measured elsewhere. This leaves us with 35 boys, 32 out of whom were actually registered. We do not believe the three 'missing' boys represent a systematic bias. The same is true for the measuring at age 25. Out of the original 32, 22 were also measured at age 25, whereas six boys had left town before they became 25. What happened to the other four is unknown. The representativeness and the quality of these military registers are discussed in several publications (Drukker, Brinkman, & Van Meerten, 1991; Mandemakers & Van Zanden, 1990, pp. 5–8; Oppers, 1963). According to Brinkman, Drukker, and Stuurop (1989) there was no indication that the higher classes of society were underrepresented in the registers. Reliability of the information is difficult to measure, but as with tax registration, one might assume that for both parties it was important that the registration, especially the height measurement, was done well. After all, the height was an important element in the whole registration as it determined whether one was suitable for military service. Registers show that sometimes when people were only a few centimeters too small they were rejected that year, but were measured again the next year. Interesting in this context is that already in 1863 this source was used for an official report about the influence of child labor on, for example, the height of people (De Vries Robbé, 1872). So we may assume that at the time these military registers were considered a reliable source.

A final remark about the size of our sample. The total sample for this study consists of 2215 recruits; 1211 were measured at the age of (around) 19, 1601 at the age of 25, and for 602 recruits we have the height at both ages; those form the basis of our study. Often recruits came from the same household. To avoid misinterpretation, our analyses control for the 'nested' character of the observations by clustering recruits from the same household. The analyses are based only upon those recruits whose mother could be followed during her reproductive years. At the end, this restriction decreased the number of cases for some analyses to only 178 cases.

5. Indicators of childhood deprivation

As mentioned earlier, our material allows us to test the impact of different aspects of early life conditions on stature at both age 19 and age 25. Next, we will discuss the different characteristics of the background of the recruits, and the way they were operationalized in this study.

5.1. Socio-economic deprivation and socio-cultural factors

Occupations offer important clues to levels of schooling, income, and social status. Thus, we used the father's occupation as noted on the recruit's birth certificate as a prime indicator of early life socio-economic conditions. We have used the well-known HISCLASS classification (van Leeuwen & Maas, 2011) to create broad categories. We adjusted that classification on a few practical points to make it more suitable for the purpose of this study and the local situation. Occupations, as noted in official documents, do not always reveal the level of income of people. There may be a difference between big and small farmers, or between a carpenter with several employees and a carpenter with a small business. As family income is vital to our purpose of finding potential food shortages, we combined occupations with information on income tax. We traced the fathers in the registers of the so-called '*Personele omslag*' (personal tax), which provide information about the occupation and the taxes due. During the observed decades the level of the mandatory tax changed. For this study we divided, per year, the tax amounts into three broad groups in line with the classes in which people were put at the time, for example, the classes 0–2, 3–9 and 10 and higher. Table 1 shows how occupational groups are distributed across taxation levels. Those taxes were recalculated to an average assessment during the youth of the recruits.

Religious affiliation may be another indication of socio-economic differentials. Although the official primacy of the Dutch Reformed Church ended around 1800, when all religions gained equal rights, the Roman Catholic, Jewish and the smaller Protestant minorities might

Table 1. Distribution of occupational group of the father of the recruit by tax group.

Occupation/tax group	No/Low	Middle	High	Total
Unknown	13	2	1	16
Elite	3	12	34	49
Middle class	268	132	64	464
Farmers	98	43	11	152
Unskilled workers	478	2	0	480
Total	860	191	110	1161

Sources: Personele Omslag 1826–1848, Archive Woerden, nr. 784–786.

still have suffered from lingering effects of discrimination. The education of the mother has been found to be an import predictor of a child's health (Steckel, 2009). In the analyses with regard to the influences of socio-cultural factors, we add father's as well as mother's signature on the birth certificate, which we hope will offer some insight regarding the family's openness to information on healthcare practices.

In addition to their family situation, the conscripts themselves may have suffered hardships leading to health problems. Illegitimate children growing up with single mothers experienced poverty, discrimination by poor relief organizations, as well as social stigmatization which may have barred them from specific jobs. Even those who were recognized by their fathers might have suffered lasting consequences, e.g. because they could not inherit fully from their fathers (Kok, 1991). Although adverse health effects (measured through mortality) of illegitimacy seem to have been concentrated in the first year of life (Kok, van Poppel, & Kruse, 1997), we might still see some effects on stature.

Finally, when young children were sent out to perform hard labor, effects on heights were often strong. Brick and tile work was typically work in which the whole family took part, thus including the children. This was necessary in order to bring the household income to a somewhat acceptable level. Next to this, as suggested by Stadhouders (2015), family labor was also enforced by the manufacturers, thereby ensuring sufficient cheap labor for themselves.

5.2. Family-related problems

The family configuration can affect the availability of food to individual children in several ways. Children experiencing the loss of a parent at an early age will be more strongly affected than children who were adolescent and who might not even live at home. Thus, we created a variable indicating whether the mother died within six years after the recruit was born. In several studies on twentieth-century locations, family size has been found to be negatively correlated with height (Öberg, 2014, pp. 110–111), and we can expect this to be the case for the nineteenth century as well. However, the impact of family size may differ by position in the birth order. Children who are born last in a large family may benefit from the income their elder siblings bring in. Infant and child mortality tends to cluster in families. As of yet, we do not know what factors explain this 'death clustering', but possible candidates include genetic factors and 'bad parenting'. We assume that children surviving youth in such 'high risk families' were marked by being shorter than children growing up in 'normal' families. Our definition of high risk families is based upon mortality among children below the age of five within the family (adding child mortality to the procedure described in Edvinsson et al., 2005, pp. 327–328). The age of the mother at the birth of the recruit may be an indication of possible health problems. The literature suggests that children born to either young (in our model before the age of 22) or old mothers (40 and older) may suffer from lasting effects on health (Myrskylä & Fenelon, 2012). Finally, we look at the sex composition of households. In the past, household distribution of resources often favored men at the expense of women (e.g. Klasen, 1998). When boys were privileged in terms of access to food, a relatively large number of girls may have been beneficial for the recruit's growth. Thus, we include the sex composition in the variable percentage of boys in the sibship in the model.

6. Heights at the ages of 19 and 25

In their publication on Eastern Belgium, Alter, Neven, and Oris (2004b, p. 237) suggest a maximum average catch-up growth of three centimeters between age 19 and adulthood. Our findings suggest that we need to allow for a larger catch-up growth. As Table 2 shows, the median height of the recruits at age 19 is 164 centimeters and at age 25 169 centimeters, which means a median catch-up growth of about 5 centimeters. Was the proper food available for soldiers (partly) responsible for this impressive catch-up growth? We checked whether there was a difference in growth between those who were (probably) rejected for military service because they were smaller than the mandatory 156.5 centimeters (Oppers, 1963, p. 44) and those who actually went into service. However, the average catch-up growth of those who were too small for conscription was 12.5 centimeters ($N = 113$) and the average catch-up growth of those who were enlisted was 4.2 centimeters ($N = 489$).

It is more likely that there is a simple relation between the height at age 19 and the level of catch-up growth; the growth after the age of 19 will be higher when the recruit is smaller at that age. For that reason, we use in our multivariate model the height at age 19 as one of the explanatory factors to explain catch-up growth. Figure 2 shows the differences in height between the age of 19 and 25 by birth cohort in the town of Woerden. In general, the figure shows a decrease in height at age 19, while over time the height at age 25 remains stable. These (short-term) trends are again visible in the catch-up growth (Figure 3).

Young adult height is influenced by all kind of social circumstances, as explained earlier. Based upon median heights, Table 2 shows, as an indication, the differences in height between the different socio-economic classes in Woerden. The median heights clearly show the higher catch-up growth within the group of the lower middle class, the less fortunate farmers and the unskilled workers. Obviously, these are also the groups with shorter men at age 19. At age 25 the socio-economic differences in heights had become less pronounced.

This impression is confirmed in a first multivariate regression model of the heights at age 19 and age 25. Table 3 presents a model in which we tried to find out what socio-economic and socio-cultural factors explained height variation at both ages. In

Table 2. Height of recruits at age 19 and 25 and catch-up growth, in Woerden, by socio-economic class of the father (in centimeters).

	Elite	Middle class/ high	Middle class/low	Farmers/ high	Farmers/ low	Unskilled workers	Unknown	Total
	Height at age 19							
Median	168.8	168	164.4	170.1	165	162	164	164.2
Stand. dev.	7.2	7.5	8.6	8.8	9.2	8.3	8.1	8.5
N	40	148	196	38	73	352	364	1211
	Height at age 25							
Median	171	172	168	175	170.6	167.2	169	169
Stand. dev.	6.9	6.3	6.2	8.8	6.2	6.6	7	6.9
N	51	130	181	43	66	388	742	1601
	Catch-up growth							
Median	3.3	3.6	5.2	3.3	5.5	5.1	5	4.8
Stand. dev.	5.6	3.8	5.9	3.3	4.7	5.8	5.2	5.3
N	16	75	101	27	38	175	136	568

Note: The bottom rows give the height of men measured at both 19 and 25, thus presenting actual catch-up growth at the level of individuals. Socio-economic groups are defined by combining occupation and taxation.

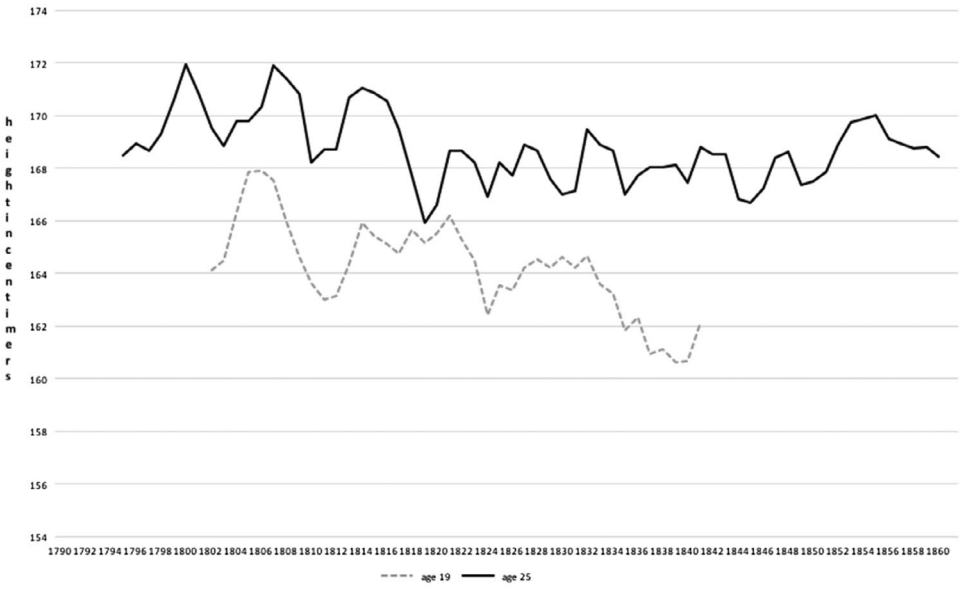

Figure 2. Median height of men (in centimeters) at age 19 and 25, by birth year in Woerden, three years moving average.

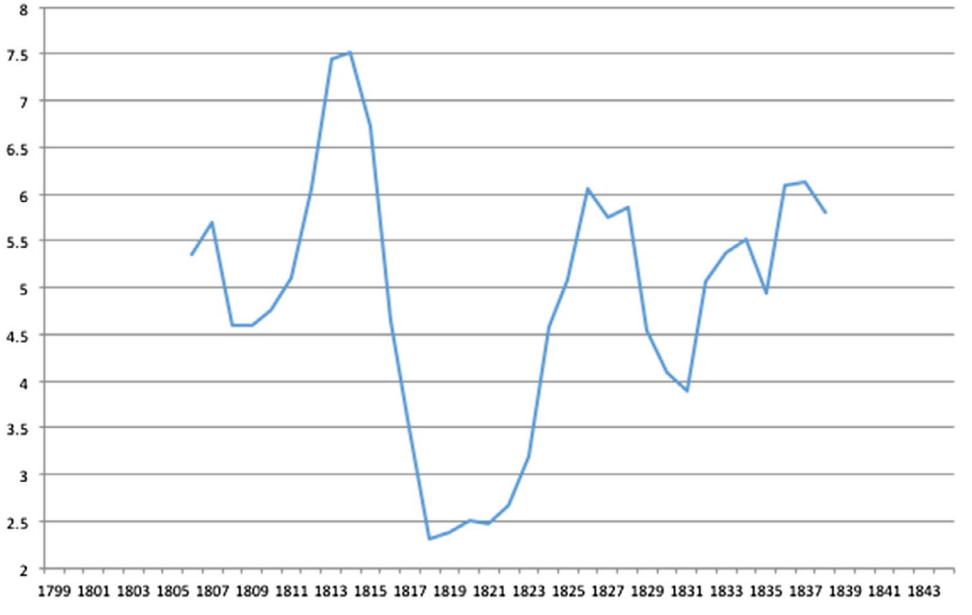

Figure 3. Average catch-up growth (in centimeters) by birth year, in Woerden (three years moving average).

this exercise, we leave out the early life household factors which we can only study in a very limited subset (see next section). We see that boys from well-to-do families had achieved significantly taller stature in adolescence. Boys living in the brick works (who, we assume, had performed child labor) were significantly shorter, as well as illegitimate boys and Jewish boys.

The regression using all our socio-economic and socio-cultural information on men measured at age 25 shows that the coefficients of these variables have become smaller between the two ages, and in some cases (illegitimate boys) that they have become insignificant (Table 4). This suggests that the catch-up growth after age 19 diminished the socio-economic differentials in final adult stature. However, we can only test this assumption on those recruits for whom we actually have two measurements. Moreover, we still need to test the impact of early life household conditions apart from income and religion. Unfortunately, we can only do those analyses on a much smaller sample of men for whom the family situation from birth onward is known.

7. Household crises and their temporary and lasting effects on stature

Owing to the number of cases available for the different analyses, some of the variables used in Tables 3 and 4 had to be skipped, namely being Jewish and being illegitimate. Our socio-economic classification, in which we combined HISCLASS categories with information on wealth culled from the tax registers, shows especially with regard to the recruits measured at the age of 19, a strong impact on height. Sons of fathers in elite and higher middle class occupations and sons of farmers were clearly better fed and had overall more favorable childhood experiences than children from lower middle class parents. In the full models we also include additional socio-cultural information on the military recruit and his family. Heavy labor at a young age – which we assumed was the

Table 3. Ordinary least squares (OLS) linear regression models of stature (in centimeters) at age 19 and 25 on socio-economic and socio-cultural and household variables. Woerden men born respectively in 1790–1849 and 1795–1860.

	Height at age 19	Height at age 25
Birth period		
Birth year	0.11	−0.15***
Birth year^2	−0.00**	0.00**
Socio-economic status		
Lower middle class (ref.)		
Elite	5.24****	1.74
Higher middle class	4.14****	2.80***
Wealthy farmers	6.10***	4.05**
Other farmers	0.52	1.90*
Unskilled workers	−0.87	−0.18
Unknown	0.27	0.63
Socio-cultural factors		
Illegitimate birth (ref. = legitimate)	−3.57*	−1.15
Child labor (ref. = no)	−2.73***	−1.50**
Father illiterate (ref. = literate)	−0.84	−1.03
Father literacy unknown	−1.01	−0.51
Mother illiterate (ref. = literate)	−0.5	0.33
Mother literacy unknown	0.26	0.18
Roman Catholic (Protestant = ref.)	−0.86	0.27
Jewish	−8.33****	−4.32**
Religion unknown	−0.21	1.29*
Model information		
F	8.80	4.51
r^2	0.13	0.07
N observations	1175	1249
N groups	709	914

**** < 0.001; *** < 0.01; **<0.05; * < 0.10.

Table 4. Ordinary least squares (OLS) linear regression models of stature (in centimeters) at age 25 on socio-economic and socio-cultural and household variables. Woerden men born respectively in 1795–1860.

Birth period	
Birth year	−0.15***
Birth year^2	0.00**
Socio-economic status	
Lower middle class (ref.)	
Elite	1.74
Higher middle class	2.80***
Wealthy farmers	4.05**
Other farmers	1.90*
Unskilled workers	−0.18
Unknown	0.63
Socio-cultural factors	
Illegitimate birth (ref. = legitimate)	−1.15
Child labor (ref. = no)	−1.50**
Father illiterate (ref. = literate)	−1.03
Father literacy unknown	−0.51
Mother illiterate (ref. = literate)	0.33
Literacy mother unknown	0.18
Roman Catholic (Protestant = ref.)	0.27
Jewish	−4.32**
Religion unknown	1.29*
Model information	
F	4.51
r^2	0.07
N observations	1249
N groups	914

**** < 0.001 *** < 0.01; ** <0.05* < 0.10

common experience of children growing up in the brick-making quarter – also has the expected negative effect on height.

It is clear that, at least in this limited sample for the town of Woerden, besides the (young) age of the mother at the moment of the birth of the recruit, family composition and family crises did not have any significant effect on stature at age 19. At age 25, we do not see any significant effects at all, apart from mother's age. Our model of catch-up growth shows that it can only be explained by the already achieved height at age 19, which as we know was determined by socio-economic conditions. In the models in Table 5, access to high-quality food seemed to be of prime importance: sons of wealthy farmers had positive coefficients (but statistically significant only for recruits of age 19), even in the case of catch-up growth.

8. Discussion and conclusion

The literature abounds with evidence of how adverse early conditions limited the growth of children and young adolescents. However, such bad periods when not enough energy was available for growth of the body – which could be caused by food shortage but also by illness, stress, or heavy labor – could always be followed by good periods when sufficient nutrition was available and when 'catch-up' growth was possible. For historical populations, following human stature over the life course is rarely, if ever, possible. By using, as well as combining two distinct records for the militia, we were able to model 'lasting effects' of

Table 5. Ordinary least squares (OLS) linear regression models of stature (in centimeters) at age 19 and 25 and catch-up growth on socio-economic, socio-cultural and household variables. Woerden men born in respectively 1790–1849 and 1795–1860.

	Height at age 19		Height at age 25		Catch-up growth	
	Model 1a	Model 2a	Model 1b	Model 2b	Model 1c	Model 2c
	Household factors	*Full model*	*Household factors*	*Full model*	*Household factors*	*Full model*
Birth period						
Birth year	−0.5	−0.7	−0.4	−0.4	−0.03	0.2
Birth year^2	0.004	0.006	0.004	0.004	0.001	−0.001
Stature at age 19	–	–	–	–	−0.4****	−0.4****
Socio-economic status						
Lower middle class (ref.)						
Elite		1.4		2.4		−0.3
Higher middle class		1.3		0.7		−0.1
Wealthy farmers		7.6***		4.0		1.2
Other farmers		3.6		1.8		−1.5
Unskilled workers		−2.2		−1.3		0.2
Unknown		−0.9		1.0		0.5
Socio-cultural factors						
Child labor (ref. = no.)		−2.9**		−1.3		0.8
Father illiterate (ref. = literate)		−1.6		1.0		0.5
Mother illiterate (ref. = literate)		1.5		−0.7		−0.5
Roman Catholic (Protestant = ref.)		−0.5		0.1		1.4
Household factors						
Mother young (ref. = average age)	4.6**	3.9*	2.6	3.7*	1.7	2.3
Mother old	2.5	3.7	1.5	2.0	0.6	0.009
Mother died early (ref. = no.)	−0.6	−1.8	−2.4	−2.3		
High risk	−0.2	0.06	0.2	0.1	−0.4	−0.4
Family size	0.3	0.1	−0.02	−0.09	−0.04	−0.03
Ranking	0.4	0.3	0.3	0.2	0.08	0.09
Perc. boys/girls	0.04	0.03	0.004	−0.002	0.02	0.03
Model information						
F	2.17	3.37	1.27	1.97	14.89	12.91
r^2	0.08	0.2	0.03	0.1	0.5	0.5
N observations	313	313	307	307	178	178
N groups	159	159	188	188	113	113

**** < 0.001; *** < 0.01; **<0.05; * < 0.10.

childhood deprivation on adult height, measured at age 25. Moreover, we were able to catch a glimpse into a part of the ongoing catch-up growth, as it was taking place between age 19 and age 25. On average, men became five centimeters taller after age 19, but this late growth obviously depended strongly on their previous growth. In our regression models, we tried to 'decompose' childhood deprivation into different components: socio-economic conditions of the natal family, illegitimacy, illiteracy, child labor, belonging to a religious minority, having a young mother, loss of the mother, position in the rank order, family size and being born in a family experiencing infant and child mortality clustering. We have created such elaborate models because our main interest was testing hypotheses on the impact of early life (family) conditions on stature.

The best results, in terms of explanatory power, turned out to be the one that included socio-economic status (which we measured through occupation and income), illegitimacy, illiteracy, child labor, and 'Jewishness', which were all associated with shorter stature at age 19. Models in which we tested the impact of household (resource allocation) problems were clearly much weaker, although we had to run the models on a very small sample. We can conclude that income (thus food supply and adequate heating and housing) explains height variation among individuals best, with the most disadvantaged persons being the (unschooled) child workers, and children growing up with a single mother. Jewish boys were smaller during adolescence and did not manage to catch up. Probably, Jews were even less capable than other social groups within Woerden of producing their own food (e.g. through growing vegetables), whereas their ritual prescriptions (Kashrut) tended to make their food expensive (Tassenaar & Karel, 2016).

To a large extent, adolescents were able to overcome a difficult start; the explanatory value of the variables included at age 25 seem to be weaker than at age 19. Finally, the potential for catch-up growth after age 19 (controlling for already achieved stature) appears to be hardly affected by the circumstances in which someone grew up. Thus, our results show that the height at age 19 is a more sensitive indicator than adult stature for the circumstances in which a child grew up. It is clear that the outcomes of this study should be interpreted with some caution. However, interesting patterns and trends can be noted, patterns which call for further research with a larger sample.

Disclosure statement

No potential conflict of interest was reported by the authors.

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