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ORIGINAL ARTICLE

Longitudinal changes in maternal and neonatal anthropometrics: a case study of the Helsinki Birth Cohort, 1934–1944

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Changes in anthropometrics often reflect changes in living conditions, and one's characteristics at birth may be associated with future health. The aim of this study was to investigate the secular trends in maternal and neonatal anthropometrics in the Helsinki Birth Cohort Study. The study participants, thus, comprised all 13,345 live births recorded in Helsinki, Finland, between 1934 and 1944. Adult characteristics of the clinical subsample comprised of 2003 individuals, alive during 2003, were also analyzed. Linear Regression analysis with seasonal terms was applied to see whether clinically and statistically significant trends can be found in maternal age, height and body mass index (BMI) at pregnancy; gestational age, birth weight, ponderal index and sex ratio; and adult height, BMI and fat percentage. Statistically significant trends were found in maternal age and maternal BMI with abrupt changes between 1941 and 1944. Gestational age increased by an average of 0.11% per year ($P < 0.0001$), and the proportion of premature births dropped from 7.9% in 1934 to 4.5% in 1944 ($P < 0.0001$). In the clinical sample, a statistically significant, although small, average annual increase of 0.1% in adult heights was detected ($P = 0.0012$ for men and $P = 0.0035$ for women). In conclusion, although no significant changes were found in either neonatal or adult anthropometrics of babies born in Helsinki between 1934 and 1944, there were abrupt changes in the characteristics of their mothers.

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Key words: longitudinal trends, maternal anthropometrics, maternal obesity, neonatal anthropometrics

Introduction

The evolution of anthropometric measurements has recently received great interest within the scientific community for several reasons. Adult height, for example, often reflects the availability of food and nutrition, as well as better living conditions during childhood and adolescence. Studying the historical records of army and navy recruits have allowed historians to reconstruct past socio-economic conditions.[1–4] On the other hand, there is increasing evidence that life-long health as well as several chronic diseases have their origin during early development, including the prenatal stage.[5] In fact, early life programming may be even more far reaching: Emanuel *et al.*[6] have reported significant positive associations between babies' birth weight and parental birth weight, as well as height and the social class of the babies' grandparents.

Adult heights in Europe have been found to generally increase due to improvement in living conditions, including nutrition as well as hygiene.[7] Komlos and Kuechenhoff[8] reviewed findings of studies of male heights in various European regions during the 18th century. The difference between peaks and troughs ranged from 0.6 to 1.4 cm per decade, with an overall average of 0.9 cm per decade.

Maternal age at birth/when giving birth is another factor of interest, as later motherhood has been found to correlate with increased risk of breast cancer,[9] autism,[10] type I diabetes[11] and dental problems[12] in the offspring. Unlike adult height or birth weight, maternal age at pregnancy is something that can be influenced or controlled to some extent by the individual, and is thus potentially subject to even stronger and more abrupt fluctuations.

Thomas *et al.*[13] concluded that when variations in fitness between individuals mainly result from somatic diseases (e.g. in industrialized countries), or conversely from infectious and parasitic diseases (e.g. in developing countries), selection is expected to favor individuals producing larger children. Birth weight also reflects the conditions during prenatal development and is considered to be a predictor of life-long health.[14–16]

The present study focuses on the data collected on children born in Helsinki, Finland, in the period 1934–1944. This was the time after the Great Depression and included the time of the Second World War. In addition, the three winters during 1939–1942 were unusually severe. All of the above potentially imply rapid and abrupt changes of environment in terms of both physiological and socio-economic conditions. It is, thus,

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of interest to see how the anthropometry of women of child-bearing age and their offspring may have been affected during this period of time and to consider possible environmental reasons for such changes.

Materials and methods

The Helsinki Birth Cohort Study consists of 13,345 people (6975 men and 6370 women) born in Helsinki between the years 1934 and 1944. The cohort has been previously extensively described elsewhere.[17] For this study, we focus on maternal age, height and body mass index (BMI) at the time of child's birth, as well as on the newborn's gestational age and birth weight. For the analysis of the offspring's characteristics, gender and parity, as well as the father's socio-economic status, were taken into account and adjusted for. The ponderal index was calculated as a ratio of the birth weight (in kg) and the cubed birth length (in m).

In 2003, a randomly chosen subset of 2003 surviving members of the cohort still living in Finland were invited for a clinical study in which, among other things, weight, height and body composition were measured. In order to achieve a sample size in excess of 2000 people, 2902 individuals were invited to a clinic and 2003 people visited the clinic. Height was measured with a KaWe stadiometer, and weight was measured using a SECA alpha 770 scale. Body composition was assessed by Bio-impedance using the In Body 3.0 device. The Ethics Committees at the National Public Health Institute in Helsinki and Helsinki and Uusimaa Hospital District approved the study protocol, and written informed consent was obtained from each study participant before any procedures were carried out.

Statistical methods

For each response variable of interest, listed in Tables 1 and 2 along with the sample statistics, the following five models were considered:

(1) Intercept-only model (M0).
(2) Continuous time log–linear trend model (ML). In this model, the date of birth was treated as a continuous variable expressed in years since 1 January 1934. The 15th of September 1936 would thus be coded as 3.73.
(3) Model where the year of birth was treated as a categorical variable (MF) – that is, statistically significant inter-annual variation is posited, but no consistent monotonic trend.
(4) Continuous time seasonality model (MLS), which takes into account smooth intra-annual variation (please see below) while allowing for a log–linear global trend. In this model, too, the date of birth was treated as continuous and expressed as in (2).
(5) Model where both, the year and the month of birth, were treated as categorical variables (MFF).

For all of the above-mentioned cases, the continuous response variables such as BMI, height, birth weight, ponderal index and

Table 1. *Sample statistics of the epidemiological birth cohort and the clinical subsample*

	Birth cohort		Clinical sample	
Variable	Mean	S.D.	Mean	S.D.
Mother's age (years)	28.4	5.4	28.7	5.5
Mother's height (cm)	159.9	5.7	159.5	5.8
Mother's BMI (kg/m^2)	26.2	2.9	26.5	2.9
Gestational age (weeks)				
M	40.0	1.8	39.8	2.0
F	40.0	1.8	40.0	2.1
Birth weight (g)				
M	3492.0	471.3	3475.5	500.7
F	3355.9	448.4	3353.1	465.4
Ponderal index (kg/m^3)				
M	26.7	2.2	26.6	2.2
F	26.9	2.2	26.7	2.2
Sex ratio				
M/F	1.09		0.86	
	n	%	*n*	%
Sex				
M	5634	52	928	46
F	5167	48	1075	54
Parity				
1st	5158	48	953	48
2nd	3109	29	582	29
3rd and later	2534	23	468	23
Father's SES				
Laborer	7305	68	1329	66
Mid lower	2372	22	375	19
Mid upper	1124	10	214	11
Born prematurely (before 37 weeks of gestation)				
M	266	5	55	6
F	233	5	62	6

BMI, body mass index; SES, socio-economic status.

Table 2. *Sample statistics of the clinical subsample*

Variable	*n*	Mean	S.D.
Birth weight (g)			
M	928	3475.53	500.68
F	1075	3353.07	465.38
Adult height (cm)			
M	927	176.82	5.99
F	1074	163.19	5.68
Adult BMI (kg/m^2)			
M	927	27.54	4.22
F	1074	27.71	5.05
Adult fat (%)			
M	886	21.03	8.67
F	1032	25.65	9.63
Sex ratio			
M/F		0.86	

BMI, body mass index.

Table 3. *Model fit and estimated trends for various variables in the cohort and the clinical sample*

Variable	AICw (M0)	AICw (MF)	AICw (ML)	AICw (MLS)	AICw (MFF)	Trend (%)	*P*-value (trend)
Mother's age[a]	0.0000	0.1887	0.0070	0.8044	0.0000	0.51	<0.001
Mother's height[a]	0.2262	0.5563	0.1762	0.0413	0.0000	0.02	0.221
Mother's BMI[a]	0.0000	1.0000	0.0000	0.0000	0.0000	− 0.34	<0.001
Gestational age[a,b]	0.0000	0.0012	0.8744	0.1244	0.0000	0.11	<0.001
M							
F	0.0000	0.0176	0.0205	0.9619	0.0000	0.11	<0.001
Birth weight[a,b,c]							
M	0.2182	0.0126	0.0803	0.6890	0.0000	− 0.06	0.331
F	0.0070	0.0003	0.0027	0.9900	0.0000	− 0.11	0.111
Ponderal index[a,b,c]							
M	0.0976	0.0023	0.0622	0.8379	0.0000	0.00	0.972
F	0.0117	0.1653	0.0043	0.8187	0.0000	− 0.05	0.204
Sex ratio[a,b]							
M/F	0.6431	0.0028	0.2366	0.1175	0.0000	0.61	0.412
Premature birth[a,b]	0.0000	0.7685	0.0600	0.1715	0.0000	− 6.50	<0.001
Clinical							
Adult Height[a,d]							
M	0.0083	0.2139	0.5530	0.2248	0.0000	0.13	0.001
F	0.0037	0.8636	0.0957	0.0370	0.0000	0.10	0.004
Adult BMI[a]							
M	0.4874	0.0030	0.2675	0.2421	0.0000	0.18	0.320
F	0.4839	0.0007	0.3768	0.1386	0.0000	− 0.22	0.231
Adult fat%[a]							
M	0.5880	0.0004	0.2513	0.1603	0.0000	− 0.28	0.639
F	0.3625	0.0009	0.4654	0.1712	0.0000	− 0.89	0.112

AIC, Akaike's information criterion; BMI, body mass index; SES, socio-economic status.
For each response variable, the Akaike's weight (AICw) for each model can be interpreted as the probability that the model is the best of the five. The five models, explained in detail in the Statistical Methods section, are as follows: intercept-only model (M0), categorical birth year model (MF), log–linear time trend model (ML), seasonal time trend model (MLS) and factorial year and month of birth (MFF) model. The trend is reported for the MLS model and should be interpreted in terms of percentage change per year, except for the sex ratio and premature birth, where the trend should be interpreted in terms of percentage change in the odds ratio of being born a boy and being born prematurely, respectively.
[a]Adjusted for husband's/father's SES.
[b]Adjusted for mother's age and parity.
[c]Adjusted for gestational age.
[d]Adjusted for mother's height.

gestational age were logged to improve the model diagnostics (i.e. normality and homoscedasticity of the residuals). This logging of the response variable means that the estimated continuous trends were log–linear rather than linear, although the resulting curvature was very slight. All relevant covariates were adjusted for, as detailed in the footnote to Table 3. For the fat percentage, the logit transformation was used instead. For the sex ratio and the proportion of premature births, a logistic regression was fitted, where the response variable was binary 0/1 for female/male and normal/premature, respectively.

The continuous time seasonality model is a linear regression model with two trigonometric terms:

$$Y = \beta_0 + \beta_1 t + \beta_2 \sin(2\pi t) + \beta_3 \cos(2\pi t) + \varepsilon, \qquad (1)$$

where t is time in years. The inclusion of the sine and cosine terms allows to model a seasonal pattern with exactly one peak and one trough. The model can easily be extended to include further harmonics, and, in fact, treating the month of birth as a categorical variable is equivalent to having six harmonics. However, there was no reason to add further terms in our study.

The models were compared using Akaike weights, which are based on the Akaike's information criterion (AIC), and may be interpreted as probabilities of the model being the best of the set.[18]

When fitting the categorical model MF, a Tukey HSD test for pairwise comparisons was run.

In order to consider possible transgenerational effects, we have also fitted a linear regression model to maternal height and year of birth.

All analyses were implemented in R-software.[19]

Results

The sample statistics for the 5634 men and 5167 women (a total of 10,801) and for the clinical subsample for whom data

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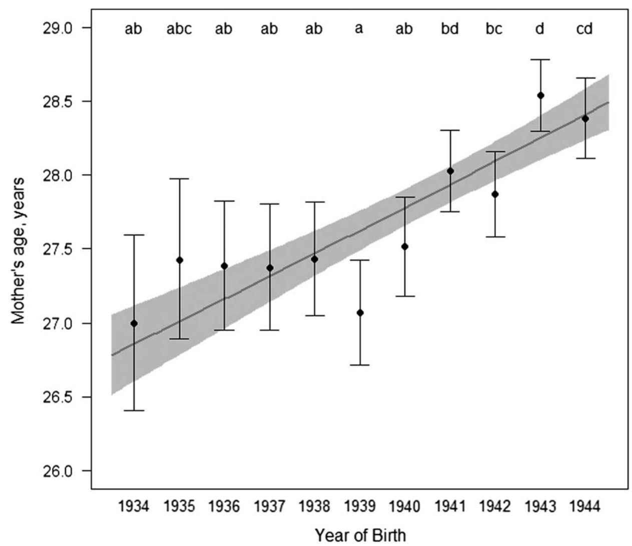

Fig. 1. Estimated annual trend in maternal age at birth, adjusted for the father's socio-economic status. The gray line with the envelope corresponds to the estimated log–linear trend (ML). The year-specific estimates with their respective 95% confidence intervals correspond to the factorial model (MF). The letters above refer to the results of the Tukey HSD test for pairwise comparisons between the years: the years that share a letter do not statistically significantly differ from each other.

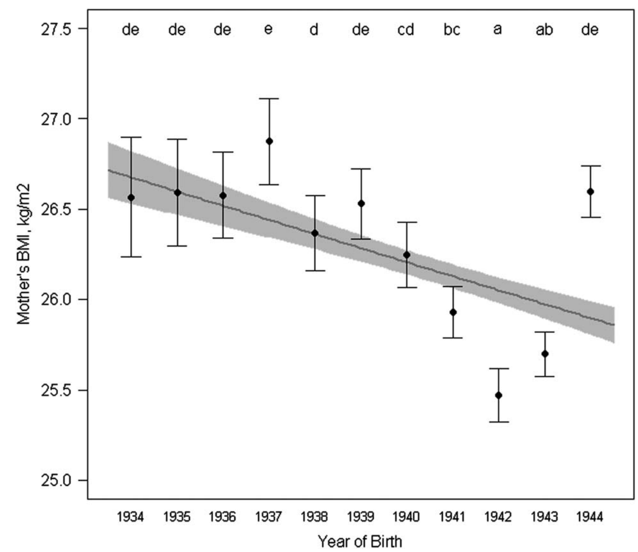

Fig. 2. Estimated annual trend in maternal BMI at birth, adjusted for the father's socio-economic status. The gray line with the envelope corresponds to the estimated log–linear trend (ML). The year-specific estimates with their respective 95% confidence intervals correspond to the factorial model (MF). The letters above refer to the results of the Tukey HSD test for pairwise comparisons between the years: the years that share a letter do not statistically significantly differ from each other.

on all relevant variables were available are shown in Table 1, and the further characteristics for the clinical subsample are shown in Table 2.

Those belonging to the clinical study were on average heavier at birth than the entire epidemiological cohort (3475 *v.* 3403 g for men and 3353 *v.* 3309 g for women); the differences were not statistically significant ($P = 0.590$ and $P = 0.308$, respectively), and thus the results obtained for the clinical study may be considered generalizable over the entire birth cohort.

For maternal age, the best fit was provided by the seasonal model (MLS), and a slight but statistically significant increasing trend of 0.51% (~0.15 years of age) per year ($P < 0.001$) was observed. Maternal height was found to increase by an average 0.02% per year ($P = 0.221$), and BMI was found to decrease by an average 0.34% annually ($P < 0.001$). However, as Table 3 shows, the best model for both maternal height and BMI is not a smooth linear trend (ML), but rather the categorical (MF) model. There was an abrupt statistically significant increase in maternal age between the years 1939 and 1941, and then a further increase between 1942 and 1943, as can be seen in Fig. 1. Figure 2 shows that a similarly abrupt decrease occurred in maternal BMI between the years 1939 and 1941 with consequent return to pre-war levels.

In addition, gestational age was found to increase at a rate of 0.11% annually for both boys and girls ($P < 0.001$). A sinusoidal monthly pattern was found to fit best for girls but not for boys (see Table 3). However, no statistically significant temporal trend or seasonality was found for either birth weight or ponderal index, and no statistically significant trend or seasonality in sex ratio at birth was detected.

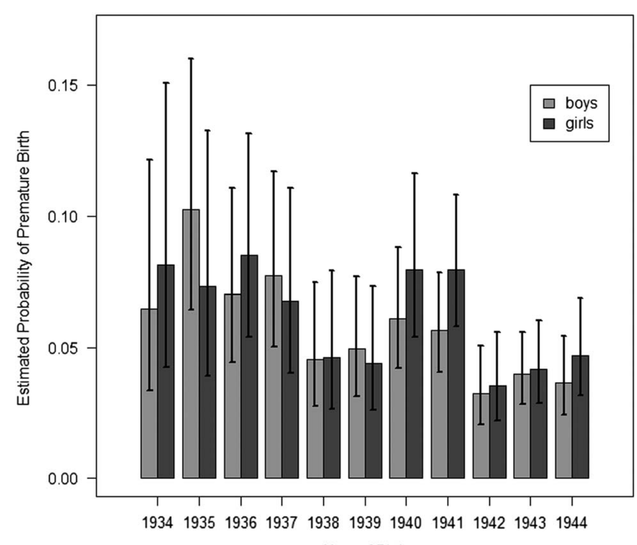

Fig. 3. Estimated mean probability of premature birth (before 37th gestational week) and respective 95% confidence intervals by year of birth for boys and girls. Adjusted by mother's age, father's socio-economic status and parity.

The proportion of children born prematurely – that is, before 37 weeks of gestation – decreased significantly ($P < 0.001$) over the study period from 7.9% in 1934 to 4.5% in 1944 (see Fig. 3). The odds of being born prematurely were found to decrease at an average 6.5% per year.

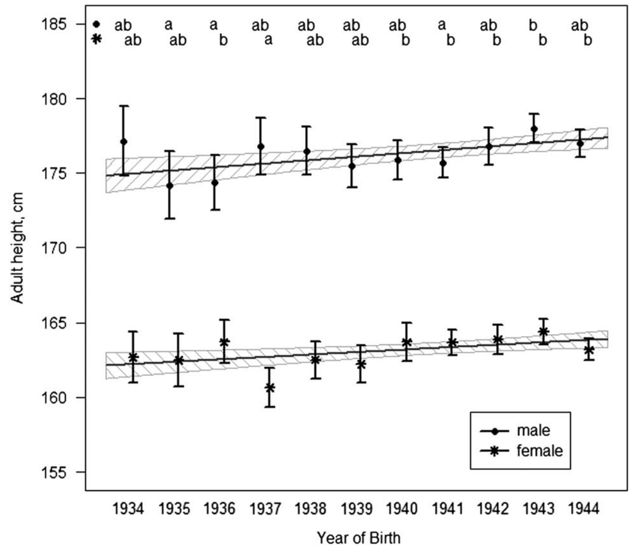

Fig. 4. Trends in adult heights, adjusted for the father's socio-economic status and mother's height. The hatched envelopes correspond to the estimated log–linear trend (ML). The year-specific estimates with their respective 95% confidence intervals correspond to the factorial model (MF). The letters above refer to the results of the Tukey HSD test for pairwise comparisons between the years: the years that share a letter do not statistically significantly differ from each other.

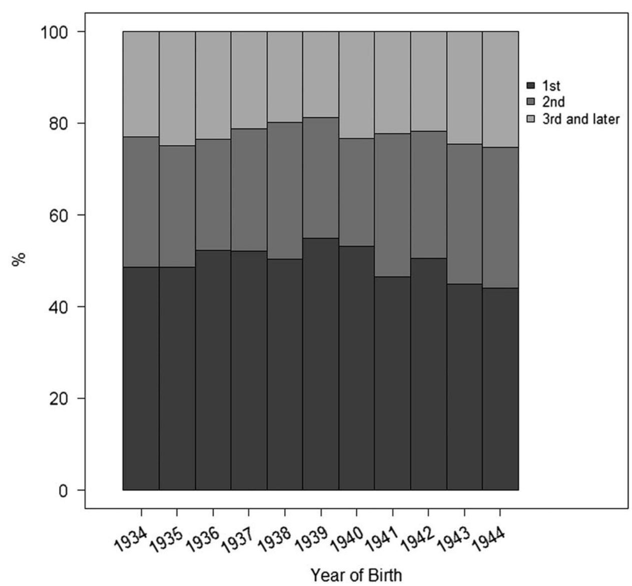

Fig. 5. Parity distribution by the year of birth.

In the clinical sample, a statistically significant, although very small, average annual increase of 0.1% in adult heights was detected ($P = 0.001$ for men and $P = 0.004$ for women, see Fig. 4). No statistically significant trends were found in either adult BMI or fat percentage.

The distribution of parity by year of birth, shown in Fig. 5, remained fairly stable over the study period. Adult height of mothers born between 1895 and 1925 in Fig. 6 shows a clear almost-linear increase of about 12 mm per decade ($P < 0.001$).

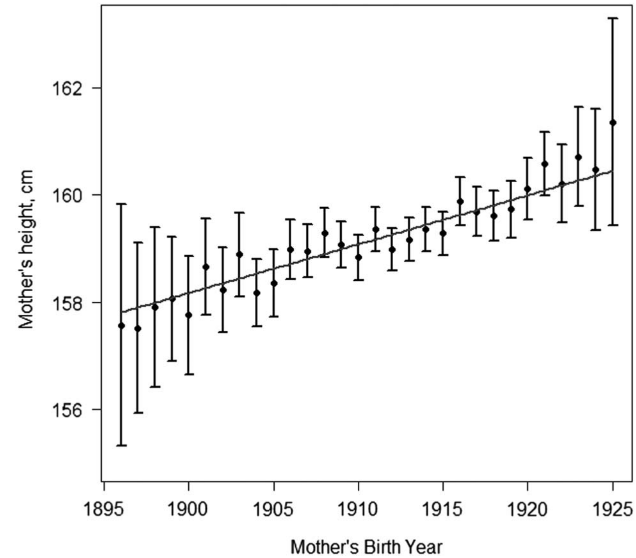

Fig. 6. Mother's average height by her birth year, adjusted for the husband's socio-economic status.

Discussion

Despite the fact that the period 1934–1944 in Finland was a time of upheaval, including the Great Depression, the World War II and three consecutive winters of unusual severity, we have found no major and significant trends in birth weight, adult BMI or adult fat percentage of those born in Helsinki during that period. No statistically significant change was detected in the sex ratio either. Although there is some evidence to support the hypothesis that the sex ratio tends to increase shortly after a war or some other abrupt stress factors, such as an earthquake,[20,21] there are also contrary findings.[22]

Gestational age increased by an average of 0.11% per year for both boys and girls ($P < 0.001$). This would amount to c. 5 days change over the decade. It must be noted, however, that the proportion of babies born before the 37th week of gestation declined almost two-fold between 1934 and 1944. This may be a reflection of the lower probability of their survival. Therefore, the observed increase in the average gestational age does not necessarily reflect an improvement in the overall health of the population. Although among the models of gestational age for girls, the seasonal model appeared to be clearly preferred statistically (AICw = 0.9619), we have no explanation for this finding.

Similarly, the evolution of birth weight is difficult to encapsulate, as considering the average on its own is almost meaningless. For example, modern advances in medicine allow smaller babies to survive, possibly lowering the average. Although adjusting for gestational age helps, we still only have data on the surviving babies, who may be on average more robust. A temporal increase in average birth weight may, thus, equally likely reflect improved prenatal conditions or worsened odds of survival for smaller babies.

The largest and most abrupt changes were observed in maternal age at child birth, which increased from an average of

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27.5 years in 1934 to an average of 28.9 years in 1944. Figure 1 illustrates that it was a stepwise transition around 1941 rather than a smooth transition. At the same time, BMI dipped rapidly to 25.5 kg/m^2 in the years 1941–1943, returning back to pre-war levels of 26.6 kg/m^2 in 1944. The latter is most probably due to harsh winters compounded by the war situation. The reason for the fluctuations in maternal age are, however, less clear. Looking at Fig. 5, which shows change in the distribution of parity in time, one may speculate that, during the 1941–1944, there were slightly fewer first- and second-borns, implying that younger women were more reluctant to start a family during that time. Another possibility is that as younger women tended to have smaller babies, especially the first-borns, their babies may have had lower odds of survival, and were thus not registered in the data set. Many young men were at the front fighting in the war; this probably influenced these findings as well.

Roseboom *et al.*[23] have reported that, although exposure to adverse conditions such as famine does not necessarily affect birth size, it is correlated with worse health outcomes as adults. Therefore, when examining the possible developmental origins of later disease, one should consider a wider range of factors rather than just body size at birth. Moreover, there are suggestions that epigenetic effects may be transgenerational,[24,25] although no consistent statistically significant findings exist thus far. Interestingly, we have found that when the mother's adult height was plotted against her respective birth year, there was a very clear upward trend ($P < 0.001$, see Fig. 6). Unfortunately, however, we lack the data for the full multi-generational analysis in this study.

In conclusion, we have found that, although there were no significant changes in either neonatal or adult anthropometrics of babies born in Helsinki, Finland, between 1934 and 1944, there were abrupt and statistically significant changes in the characteristics of their mothers. As birth size is not necessarily related to later health outcomes, a closer look at other variables such as maternal anthropometrics may provide better insights into possible epigenetic mechanisms, and thus into the health of future populations.

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