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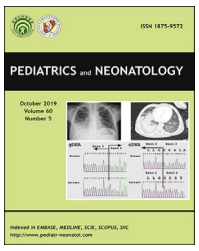

Original Article

Secular trends of birthweight in boys from 1950 to 2010

Jimmy Célind [a,b], Marie Hedlund [b], Maria Bygdell [a], Arvid Sondén [c], Anders Elfvin [d], Jenny M. Kindblom [a,*]

[a] *Centre for Bone and Arthritis Research, Institute of Medicine, Sahlgrenska Academy at University of Gothenburg, Gothenburg, Sweden*
[b] *Pediatrics, The Queen Silvia Children's Hospital, Sahlgrenska University Hospital, Gothenburg, Sweden*
[c] *Bioinformatics Core Facility, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden*
[d] *Department of Pediatrics, Institute of Clinical Sciences, Sahlgrenska Academy, University of Gothenburg, Gothenburg, Sweden*

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Key Words
birthweight;
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Background: Birthweight is an indicator of fetal development and intrauterine conditions and is associated with future health outcomes. Secular birthweight trends prior to the 1970s are mostly unknown. Our aim was to explore secular birthweight trends in Swedish boys from 1950 to 2010.
Methods: We have collected detailed growth data including birthweight from archived School Health Care records for children born in Gothenburg from 1946 and onwards and established a unique population-based cohort, the Body Mass Index Epidemiology Study (BEST). The birthweight cohort spans six decades (1950–2010) and includes 46,548 boys.
Results: The mean birthweight of the complete study cohort was 3580 ± 562 g. Linear regression analysis of the entire period revealed a minimal negative secular trend for birthweight (BETA = −0.4 g/year; $p < 0.01$). However, three distinct trends appeared during subperiods: a decrease 1950–80, an increase 1980–2000 and another decrease 2000–2010.
Conclusion: We demonstrate that birthweight in boys has undergone periodic decreases and subsequent increases, but the overall trend from the 1950s to the present is stable.
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* Corresponding author. Sahlgrenska University Hospital, Vita Straket 11, S-41345, Gothenburg, Sweden. Fax: +46 31 772 96 32.
E-mail address: jenny.kindblom@gu.se (J.M. Kindblom).

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1. Introduction

Birthweight (BW) is a well-recognized indicator of intrauterine conditions and fetal development. A normal BW at term is defined as 2.5—4.5 kg.[1] A variety of factors influence BW, from genetic disposition, gestational age and placenta function, to maternal smoking, maternal weight status, gestational diabetes and gestational weight gain. A BW below (low BW) or above (high BW) normal range has been linked to increased risk of adult morbidity, such as osteoporosis, cardiovascular disease and metabolic syndrome for low BW,[2—5] and metabolic syndrome and cancer for high BW.[3,6] Some risk factors contributing to obesity are present already during fetal life and the effect is probably a combination of genetic and environmental factors.[7]

Knowledge of the secular trends of BW is mainly based on research focused on recent periods when the obesity epidemic or the smoking era, or both, presumably has influenced BW. Two well-powered studies from Denmark and the USA spanning the mid-thirties to the mid-eighties show stable trends for mean BW.[8,9] On the other hand, trends of increasing BW have been reported from the end of the 20th century in Sweden and several other industrialized countries, covering time spans of two-to-four decades.[10—14] The exception is Japan, where a stable negative trend has been shown from 1979 to 2010.[15]

The reported increase during 1980—2000 in mean BW coincides with the obesity epidemic. The trend of increasing BW has therefore been assumed to be associated with the obesity epidemic, both as a consequence of a higher prevalence of obese mothers and as a risk factor of future obesity for the child.[6—8,16,17] The increase in mean BW also coincides with an increased awareness of the negative effects on the fetus from smoking during pregnancy, among them reduced BW.[18] This awareness has led to a more than 80% reduction in smoking among pregnant women in Sweden since the beginning of the eighties.[19]

The Swedish Medical Birth Register (MBR) was initiated in 1973 and includes BW together with other perinatal factors and factors related to mothers and newborns. BW trends in Sweden have been described during the forty years of the MBR, but studies covering the period prior to 1973 are scarce.

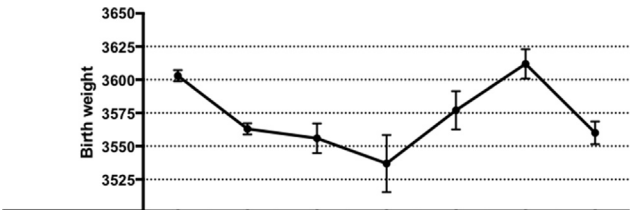
Since BW is associated with a wide range of adult morbidity and health outcome risks, it is important to evaluate secular trends for BW. The BMI Epidemiology Study was initiated with the overall objective to study the association between BMI during development and adult diseases.[20] The aim of the present study was to describe the BW trend for boys born between 1950 and 2010 in the population-based BMI Epidemiology Study (BEST) Gothenburg. Our hypothesis was that certain time periods would present episodic changes in BW, but in the perspective of the 60-year study period, the overall trend for mean BW would be relatively constant. We also hypothesized that developments in neonatal care would result in an increased proportion of light-weight neonates.

2. Patients and methods

2.1. The BMI Epidemiology Study (BEST) and data collection

The data in this study originates from the BMI Epidemiology Study (BEST) Gothenburg, where data from pediatric growth charts from Child Health Care Centres (CHCC), School Health Care (SHC) records, and the Medical Birth Register (MBR) were collected. The CHCC and SHC have monitored overall health (including height and weight) of Swedish children for over a century. The growth charts are stored centrally in the Archives of the City of Gothenburg and the region of Västra Götaland after the children finish school. >98.5% of schoolchildren attend SHC, which makes the study population-based.[21]

In this study of secular BW changes, we included all available boys collected in BEST with a registered BW and a personal identity number (PIN). For reasons related to the overall aim of the BEST Gothenburg Study, data collection initially focused on the forties, fifties and sixties, and thereafter every fifth year. Hence, the main power of the study is concentrated in the earliest decades. The overall aim with the BEST Gothenburg study requires complete growth curves including final height collected from military conscription tests. As Sweden did not have mandatory female military conscription, we were unable to retrieve final height for women, limiting our initial data collection to men only. To increase the statistical power, BWs were grouped into even decades. BWs from 1946—1955 were grouped into the BW cohort of 1950; BWs from 1956—1965 were grouped into BW cohort 1960, etc (Fig. 1). The difference in BW between boys and girls has been reported to be stable at 140 g in a study of all BW reported to the Swedish MBR between 1973—1995.[22] To compare BW trends in the BEST cohort to overall national trends of the MBR, 70 g were added to the aggregated trend line of MBR data of both girls and boys to adjust for the lighter girls in the MBR



Birth cohort	1950	1960	1970	1980	1990	2000	2010
Included birth years	1946-1955	1956-1965	1966-1975	1976-1985	1986-1995	1996-2005	2006-2015
N	17628	16553	2437	681	1635	2683	4931

Figure 1 Cohort description and mean birthweight progression. The neonates included in the study were aggregated in seven birth cohorts distributed in even decades from 1950 to 2010. The number (N) of included individuals in each birth cohort is specified. Mean birthweights (g) with standard error of the mean (SEM) for the seven birth cohorts are presented (n = 46,548).

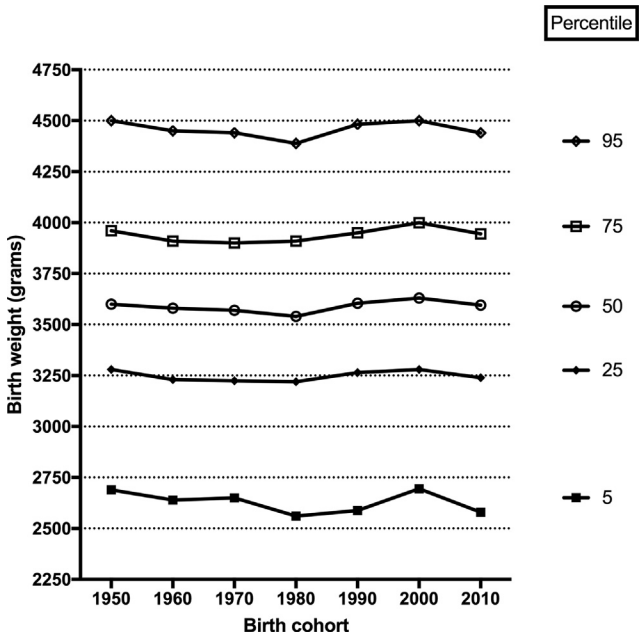


Figure 2 Distribution of birthweights across seven cohorts (n = 46,548). The data are presented as the 95th, 75th, 50th (= median), 25th and 5th percentiles.

data and under the assumption of boys and girls born 1:1 (Fig. 3).

To be able to study secular BW changes with minimal bias from immigration changes in the population, only subjects where Sweden was the country of birth for both parents were included.

The study was approved by the Ethical Review Board in Gothenburg.

2.2. Collection of birthweight

Data of BW for included individuals were collected from the MBR where available (1973–2006) and otherwise from archived pediatric growth charts (birth years 1946–1973). At the time of data collection, birth cohorts after 2006 had not started school and consequently had no SHC records and could not be included in the BEST cohort. Therefore, to describe the secular changes up to the present, BWs from 2011 were collected from birth records at the Sahlgrenska University Hospital, covering the same geographic area as the archived pediatric growth charts. Information regarding country of birth of the parents was not available for individuals born in 2011 and therefore all individuals were included in the study.

2.3. Linkage to the Medical Birth Register and register at statistics Sweden

Information regarding pregnancies, deliveries and newborn babies in Sweden is registered in the Medical Birth Register (MBR), held by the National Board of Health and Welfare since 1973, for surveillance of antenatal, obstetrical and neonatal care, as well as for research.[10] All births in Sweden are recorded in the MBR and the data is of high

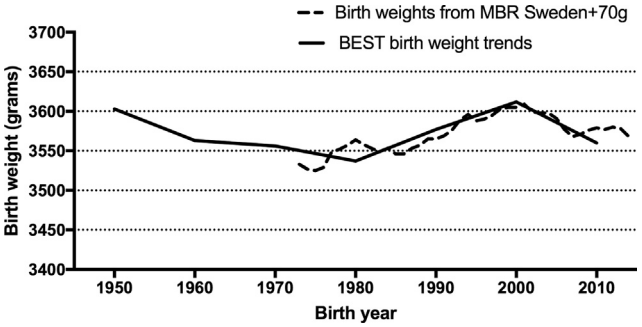


Figure 3 The accordance with the Swedish Medical Birth Register (MBR). The accordance of the mean study birthweight progression of the seven birth cohorts with the national mean birthweights from the MBR. Since birthweights from the MBR are aggregates of both girls and boys, 70 g were added to the MBR data to facilitate comparison. The sex difference in mean birthweights in Sweden is stable at 140 g.[22]

quality.[23,24] Using the PIN, linkage was performed with the MBR. Linkage was also performed with the Longitudinal Integration Database for Health Insurance and Labor Market Studies at Statistics Sweden, for retrieval of information on country of birth of the child and his parents.

2.4. Statistical analysis

For the study period 1946 through 2011, we used BW cohorts of every even decade, which resulted in seven BW cohorts (1950, 1960, 1970 … 2010). Descriptive statistics with mean ± standard error of the mean, and median and percentiles and are presented (Figs. 1 and 2). Linear regression analyses were performed with BW as the dependent variable and birth year as the independent variable. A logistic regression model with BW cohort decades as independent variables was used to test the odds ratio for high, low and very low BW (>4.5, <2.5 and <1.5 kg, respectively).

For the validation of BW data from SHC records, a bivariate correlation was performed between BW data from the SHC records and the MBR. Accuracy between BWs from CHCC or SHC records and BW from the MBR was tested using Student's t-test.

All analyses were performed using SPSS version 24.

3. Results

3.1. Study cohort

In this study, we used BWs of boys born between 1946 and 2011, grouped into birth cohorts of seven even decades from 1950 to 2010 (total n = 46,548). The mean BW (SD) in the complete study cohort was 3580 g ± 562 g. The median was 3600 g, with an interquartile range of 3250–3950 g (Fig. 1). BW demonstrated a normal distribution.

3.2. Secular changes of mean BW during the study period

Mean BW during the study period ranged from 3537 g (birth cohort 1980) to 3612 g (birth cohort 2000) with a range in standard deviation of 553–604 g (Fig. 1). In order to investigate the overall trend during the 60 years covered by the study, a linear regression analysis including BW as a dependent variable and birth year as an independent variable was performed and showed a small negative BW trend (BETA for birth year = −0.4 g/year; $p < 0.005$). Thus, a minimal negative mean BW trend was found in this large cohort spanning 60 years.

3.3. Periodic changes

Despite the overall BW trend with minimal change in BW during the complete study period, three distinct periods of increasing and decreasing BW were identified through visual inspection. We therefore wanted to test whether or not significant short-term changes could be detected. First, for the period 1950–1980, our results revealed a significant decrease in mean BW (BETA for birth year = −2.9 g/year, $p < 0.001$) as tested in a linear regression model including only this period. Secondly, during 1980–2000, our results show an increase in mean BW (BETA for birth year = 3.7 g/year, $p = 0.001$). Thirdly, during the period of 2000–2010, there was a decrease in mean BW (BETA for birth year = −5.2 g/year, $p < 0.001$). Thus, these results demonstrate that short-term changes in BW are present.

3.4. Odds ratio for high, low or very low BW

The numbers of neonates with high, low and very low BW are presented in Table 1. The OR for high (>4.5 kg), low (< 2.5 kg) or very low (<1.5 kg) BW was tested using logistic regression. Birth cohort decade predicted low BW (OR = 1.05 per increment in birth cohort decade, 95% CI 1.02–1.07) and very low BW (OR = 1.38 per increment in birth cohort decade, 95% CI 1.28–1.48), but not high BW (OR = 1.01 per increment in birth cohort decade, 95% CI 0.99–1.03).

Thus, we did not detect a trend of increasing numbers of newborns with a high BW, but birth year predicted increasing OR for low and very low BW.

Table 1 Proportion of newborn with high, low or very low birthweight in the separate birth cohorts.

Birth cohort	High BW %	Low BW %	Very low BW %
1950	4.2	3.0*	0.2*
1960	3.5	3.3*	0.2*
1970	4.0	3.3*	0.1*
1980	2.6	4.6*	0.6*
1990	4.5	4.0*	0.6*
2000	4.9	3.1*	0.4*
2010	4.0	4.2*	1.0*

The risk of being born with a high, low, or very low birthweight related to birth cohort. The number of neonates included in the study with high (>4.5 kg), low (<2.5 kg) or very low (<1.5 kg) birthweight presented as a percentage of the complete birth cohort. The study cohort consists of 7 birth cohorts, $n = 46{,}548$ in total. Trends were tested using logistic regression, significant trends are marked with an * ($p < 0.001$ for both Low BW and Very low BW). Abbreviations: BW = Birthweight.

3.5. Validity of BW from school health records

In subjects with BWs from both sources, school health records and the MBR (n = 820), a bivariate correlation analysis between the two BWs showed good accordance (Pearson's $r = 0.99$). The mean difference between BWs from the two sources was 3.5 g (±87 g; not significant, paired Student's *t*-test) indicating good accuracy between the two sources of data. Furthermore, the BW trends of our cohort are consistent with the MBR national BW trends in boys from 1973 onwards (Fig. 3), indicating that the BEST data prior to the start of MBR is also reliable and representative. The difference in mean BW between boys and girls is stable at 140 g.[22] Public data of mean BW from the MBR is aggregated for both sexes. We therefore used the mean BW of both sexes from the MBR +70 g to compare to our data containing only boys.

3.6. Sensitivity analyses

In sensitivity analyses, exclusion of BWs below 2.5 kg in the linear regression did not alter the overall trend substantially (BETA for birth year = −0.3 g/year, $p < 0.05$). Since the boys born 2011 were recruited from hospital rather than school health records, we also assessed a linear regression analysis excluding boys born in 2011. The linear regression analysis excluding boys born during 2011 did not alter the described overall trend BETA of −0.2 g/year; $p = 0.14$).

4. Discussion

In this study, we evaluated a possible secular BW trend in boys over a 60-year period of time. To our knowledge, this is the first report contrasting recent BW development to the trends of the forties, fifties and sixties. Our results revealed short-term changes, but overall BW development was stable in this large Swedish cohort. Year of birth did not predict high BW but was positively associated with low and very low BW.

Two other studies evaluated possible secular BW trends during half of the 20th century, from the mid-thirties to the mid-eighties, and demonstrated stable BW development in agreement with our findings. Thus, both studies include a long period prior to the obesity epidemic, but end at the rise of it.[8,9] In the present study BW trends remained stable when followed from long before and during the entire obesity epidemic until the present. The sub-trend of rising BW at the end of the 20th century is consistent with the majority of studies reporting increasing BW trends in recent years.[10–14] Our data show good accordance with the Swedish MBR and can therefore be regarded as representative of the Swedish population in general.

Smoking has a well-known impact on BW. A recent study observed a 160 g BW reduction associated with light

smoking during pregnancy and a reduction >200 g with heavy smoking.[18] The observed reduction in BW between 1950 and 1980 (−2.9 g/year) coincides with a dramatic increase in smoking among women. One may speculate that smoking habits among pregnant women contributed to the reduction in BW during this period.

Several studies from different industrialized countries including Sweden have described increases in mean BW during the period following the onset of the obesity epidemic and also a dramatic decline in smoking during pregnancy in the last decades of the 20th century. Some studies also report an increase in the amount of heavy neonates.[10–14] Our data reveal an increase in mean BW from 1980 to 2000 (+3.7 g/year), but no significant increase in the number of heavy babies.

During the final sub-period of the study (2000–2010), mean BW decreased slightly. It is not known what factors contributed to the trend of declining BW, but one possible explanation is an increased rate of induced labor.[25] Zhang et al. found that a dramatic increase of induced labor in the US had negative effects on BWs.[26] Our results reveal that birth year predicts increasing odds for low and very low BW. This is likely a reflection of the remarkable development in neonatal care during the last 30 years, which has resulted in increased survival of neonates with BW below normal.[27]

When BW is regarded in the perspective of the entire post-World War II period, it becomes clear that the reported increase in mean BW from the seventies/eighties to the millennium takes place subsequent to a reduction in mean BW. It is possible that the described increase reflects a normalization following that reduction, or perhaps the passing of a period of fetal growth suppression caused by smoking, and it accentuates the importance of studying trends over long time periods.

The main limitations of our study are that we only have data on boys and that gestational age is not available for the subjects born before the MBR was initiated (i.e birth cohort 1970 and earlier). Gestational age is a major predictor of BW, and an increased frequency of surviving premature babies could influence BW trends negatively. However, our results show that although the frequency of low and very low BW increase over the decades, the premature babies are too few to influence the general trends of BW. Another limitation is that multiple pregnancies were not recorded and since the 2010 cohort babies had not yet started school at data collection, SHC records were not available. Therefore, BWs for these babies had to be collected from hospital records. The prevalence of overweight and obesity in Sweden is still rather low compared to internationally. Thus, a smaller impact from the obesity epidemic could be expected in Sweden. The distribution of participants is uneven in the birth decade cohorts, which could cause bias in the analyses. However, the good concurrence of our data to the trends of the MBR suggest otherwise. Furthermore, the uneven distribution focuses the power of the study to the decades of the study before the Swedish MBR where BW trends are unknown. The strengths of this study include the large population-based cohort, multiple cohorts, and the long time-span covered that elucidates Swedish BW-trends before the MBR and enables identification of sustained trends rather than fluctuations. The present study provides a novel perspective of trends for BW, an important indicator of fetal development, which may also relate to future health outcomes such as cardiovascular disease. It is therefore of clinical importance to follow BW trends.

5. Conclusion

We provide evidence of stable BW trends from 1950 to 2010, a 60-year time span including the years prior to the initiation of the Medical Birth Register. During the long study period, short-term changes were identified, such as the reduced BW in the mid-century that might, at least partly, be explained by increased smoking, and the increased BW at the end of the century possibly influenced by decreased smoking and rising maternal BMI.

Conflicts of interest

None of the authors have any conflicts of interests to declare.

Acknowledgements

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References

1. Niklasson A, Albertsson-Wikland K. Continuous growth reference from 24th week of gestation to 24 months by gender. *BMC Pediatr* 2008;**8**:8.
2. Wang SF, Shu L, Sheng J, Mu M, Wang S, Tao XY, et al. Birth weight and risk of coronary heart disease in adults: a meta-analysis of prospective cohort studies. *J Dev Orig Health Dis* 2014;**5**:408–19.
3. Risnes KR, Vatten LJ, Baker JL, Jameson K, Sovio U, Kajantie E, et al. Birthweight and mortality in adulthood: a systematic review and meta-analysis. *Int J Epidemiol* 2011;**40**:647–61.
4. Antoniades L, MacGregor AJ, Andrew T, Spector TD. Association of birth weight with osteoporosis and osteoarthritis in adult twins. *Rheumatology (Oxford)* 2003;**42**:791–6.
5. Phillips DI. Birth weight and the future development of diabetes. A review of the evidence. *Diabetes Care* 1998;**21**: B150–5.
6. Yu ZB, Han SP, Zhu GZ, Zhu C, Wang XJ, Cao XG, et al. Birth weight and subsequent risk of obesity: a systematic review and meta-analysis. *Obes Rev* 2011;**12**:525–42.
7. Araújo de França GV, Restrepo-Méndez MC, Loret de Mola C, Victora CG. Size at birth and abdominal adiposity in adults: a systematic review and meta-analysis. *Obes Rev* 2014;**15**: 77–91.
8. Johar R, Rayburn W, Weir D, Eggert L. Birth weights in term infants. A 50-year perspective. *J Reprod Med* 1988;**33**:813–6.
9. Rugholm S, Baker JL, Olsen LW, Schack-Nielsen L, Bua J, Sørensen TI. Stability of the association between birth weight and childhood overweight during the development of the obesity epidemic. *Obes Res* 2005;**13**:2187–94.
10. Odlind V, Haglund B, Pakkanen M, Otterblad Olausson P. Deliveries, mothers and newborn infants in Sweden, 1973-2000.

Trends in obstetrics as reported to the Swedish Medical Birth Register. *Acta Obstet Gynecol Scand* 2003;**82**:516—28.
11. Oja H, Koiranen M, Rantakallio P. Fitting mixture models to birth weight data: a case study. *Biometrics* 1991;**47**:883—97.
12. Schack-Nielsen L, Mølgaard C, Sørensen TI, Greisen G, Michaelsen KF. Secular change in size at birth from 1973 to 2003: national data from Denmark. *Obesity (Silver Spring)* 2006;**14**:1257—63.
13. Skjaerven R, Gjessing HK, Bakketeig LS. Birthweight by gestational age in Norway. *Acta Obstet Gynecol Scand* 2000;**79**:440—9.
14. Chike-Obi U, David RJ, Coutinho R, Wu SY. Birth weight has increased over a generation. *Am J Epidemiol* 1996;**144**:563—9.
15. Takemoto Y, Ota E, Yoneoka D, Mori R, Takeda S. Japanese secular trends in birthweight and the prevalence of low birthweight infants during the last three decades: a population-based study. *Sci Rep* 2016;**6**:31396.
16. Ogden CL, Carroll MD, Kit BK, Flegal KM. Prevalence of obesity and trends in body mass index among US children and adolescents, 1999-2010. *JAMA* 2012;**307**:483—90.
17. Adamo KB, Ferraro ZM, Brett KE. Can we modify the intrauterine environment to halt the intergenerational cycle of obesity? *Int J Environ Res Public Health* 2012;**9**:1263—307.
18. Juárez SP, Merlo J. Revisiting the effect of maternal smoking during pregnancy on offspring birthweight: a quasi-experimental sibling analysis in Sweden. *PLoS One* 2013;**8**:e61734.
19. The National Board of Health and Welfare. *Statistikdatabasen. Pregnancies, deliveries and newborn infants*. 2016. Available at http://www.socialstyrelsen.se/statistik/statistikdatabas/graviditeter-forlossningarochnyfodda. Accessed August 18, 2018.
20. Ohlsson C, Bygdell M, Sondén A, Rosengren A, Kindblom JM. Association between excessive BMI increase during puberty and risk of cardiovascular mortality in adult men: a population-based cohort study. *Lancet Diabetes Endocrinol* 2016;**4**:1017—24.
21. Herlitz CW. *The history of school hygiene: an overview primarily of the development in Sweden*. Stockholm: Bergvall. 1961.
22. Rooth G. Increase in birthweight: a unique biological event and an obstetrical problem. *Eur J Obstet Gynecol Reprod Biol* 2003;**106**:86—7.
23. The National Board of Health and Wellfare. *The Swedish medical birth register 1973—2013. Assisted reproduction, treatment 1991-2012*. 2014. Available at http://www.socialstyrelsen.se/publikationer2009/2009-12-11. Accessed August 18, 2018.
24. Cnattingius S, Ericson A, Gunnarskog J, Källén B. A quality study of a medical birth registry. *Scand J Soc Med* 1990;**18**:143—8.
25. Ekéus C, Lindgren H. Induced labor in Sweden, 1999-2012: a population-based cohort study. *Birth* 2016;**43**:125—33.
26. Zhang X, Joseph KS, Kramer MS. Decreased term and postterm birthweight in the United States: impact of labor induction. *Am J Obstet Gynecol* 2010;**203**:124.e1-7.
27. Doyle LW, Roberts G, Anderson PJ, Victorian Infant Collaborative Study Group. Changing long-term outcomes for infants 500-999 g birth weight in Victoria, 1979-2005. *Arch Dis Child Fetal Neonatal Ed* 2011;**96**:F443—7.