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Stumped by the Hump: The Curious Rise and Fall of Norwegian Birthweights, 1991–2007

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Background: There was a distinct rise in mean birthweights in Norway starting in 1991 that plateaued in 1996–2002 and then declined to previous levels. We investigated whether these changes corresponded to trends in neonatal mortality or other birthweight-associated pregnancy outcomes. We also explored known predictors of birthweight and examined whether these could explain the birthweight trends.

Methods: We calculated mean birthweight for all live births in Norway in each year from 1982 to 2016, together with annual neonatal mortality and proportion of infants born preterm, or with low Apgar score. We stratified mean birthweight over time by factors including parity, gestational age, and Scandinavian versus non-Scandinavian origin of mother, to test robustness of the pattern. In addition, we used multivariable linear regression to obtain adjusted estimates for mean birthweight per year.

Results: A 50-g rise and fall of mean birthweights during a 25-year period was not accompanied by corresponding changes in neonatal mortality, preterm births, or Apgar scores. The distinct hump pattern was restricted to term births and was not apparent among infants of mothers born outside Scandinavia. We saw a similar pattern for Sweden but not Finland. Known predictors of birthweight (such as parity, mode of onset of delivery, and marital status) did not explain the hump.

Conclusions: A distinct temporal hump in mean birthweight among Norwegian term births had no obvious explanations. Furthermore, these fluctuations in birthweight were not associated indirectly with adverse outcomes in measures of infant health.

Keywords: Birthweight; Ethnicity; Neonatal mortality; Norway; Preterm

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Birthweight is the most studied birth characteristic, and both high and low birthweights have been linked to adverse short- and long-term outcomes in the child, including infant mortality,[1] cardiometabolic diseases,[2,3] and cancers.[4,5] Known predictors of infant birthweight include maternal body mass index (BMI), gestational weight gain, height, cigarette smoking, blood glucose and insulin levels during pregnancy, ethnicity, and parity.[6–8]

Despite the strong association between birthweight and perinatal outcomes, the shift in birthweight distributions seen with altitude and with maternal characteristics such as ethnicity and parity are not necessarily mirrored by similar shifts in neonatal mortality or other birth outcomes. Previous assumptions regarding birthweight as a causal factor for later disease have been questioned both methodologically[9,10] and by identification of common genetic determinants for both birthweight and later adult chronic diseases.[2,11] Regardless of underlying etiologies, birthweight is an important predictor of later health outcomes, and a better understanding of influencers of birthweight is valuable. Abrupt fluctuations in population birthweight may suggest a role for environmental factors that could be of importance for later health.

Mean birthweight in Norway has been relatively stable over the last 5 decades, with a striking exception: mean birthweights increased by approximately 50 g between 1990 and 2000,[12] remained at this higher level for several years, and then fell back to previous levels in the following 10 years,[13] making a distinctive hump-like pattern (Figure 1).

The objective of the current study was to explore whether the birthweight hump was accompanied by similar trends in adverse perinatal outcomes, and whether the

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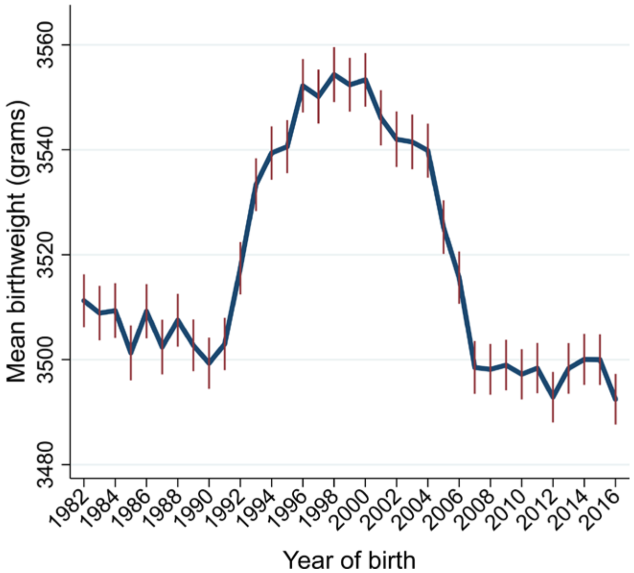

FIGURE 1. Mean birthweight for all live-born children in Norway by year of birth from 1982 to 2016. Vertical lines show the 95% confidence intervals.

birthweight hump itself could be explained by changes in gestational age, maternal parity, ethnic background, or other known predictors.

METHODS

Data Sources

This study included all live births in Norway between 1982 and 2016 registered in the Medical Birth Registry of Norway. We excluded live-born children with implausible or missing registrations, such as missing birthweight or birthweight below 500 g (n = 1,966), and live-born children with either missing gestational length or a gestational length less than 154 days or >315 days (n = 172,711).

We obtained data on Swedish birthweights by year of birth (1982–2016) from the Swedish Medical Birth Registry online database,[14] and Finnish birthweight data (1987–2016) from a Nordic report on perinatal statistics.[15]

Norwegian legislation does not require consent from registered individuals to conduct research using the national health registries. The Regional Committee for Medical and Health Ethics of South/East Norway approved the study (No. 2014/404).

Birthweight and Potential Explanatory Factors for the Changes in Birthweight

Information on birthweight in grams was available in the Norwegian registry. We also obtained information on factors known to predict birthweight, including gestational length (in days) based on the last menstrual period, parity (primipara vs. multipara), onset of labor (spontaneous, medically induced, or by cesarean section), marital status (recorded as either married, cohabiting, nonmarried/single, divorced/separated/widowed, or other/unknown), the presence of a congenital anomaly (yes or no), and maternal country of birth as either Scandinavian (Norway, Sweden, and Denmark) or other (as a proxy for ethnicity). Furthermore, for subanalyses, we obtained information on maternal year of birth, smoking at the end of pregnancy (daily/occasional versus never), diagnosis of preeclampsia, eclampsia or HELLP syndrome (hemolysis, elevated liver enzymes, and low platelet count), diabetes mellitus, and prepregnancy BMI. Information on maternal smoking during pregnancy was available only after 1998, whereas information on maternal prepregnancy height and weight (for calculating BMI) was available only after 2006.

Term birth was defined as delivery after 37–45 completed gestational weeks (gestational days 259–315), and preterm births as delivery before 37 completed weeks (258 days or less).

We defined neonatal mortality as death of a live-born child within the first 28 days, and low Apgar-score as a score less than seven at 5 min. Births in June, July, or August were classified as summer births; September, October, and November as fall births; December, January, and February as winter births; and March, April, and May as spring births.

Information about maternal diabetes mellitus is registered in the birth registry as either type 1, type 2, gestational onset, use of diabetes medication during pregnancy, or diabetes before pregnancy but of unknown type. Screening, diagnosis, and registration of diabetes during pregnancy have changed several times during the study period,[16–18] so we defined maternal diabetes broadly to include any registration of diabetes versus no registration. In addition, we analyzed births by the county the mother was registered as living in at time of delivery (19 counties in Norway).

Statistical Methods

We described the hump by calculating the mean birthweight and 95% confidence intervals (CIs) for all live births in each year. For some subsequent analyses, we grouped year of birth according to the various periods in the hump (Table), namely the years before the rise (1982–1990), the years of rising weights (1991–1995), the zenith (1996–2002), the decline (2003–2006), and the remaining years (2007–2016). We described child and maternal characteristics as well as other birth outcomes for each period (Table). We calculated standard deviation of birthweight and the birthweight corresponding to the 90th, 10th, 5th, and 2nd percentiles for each time period (Table). For subanalyses, we grouped the zenith period into two (zenith I, 1996–1998, and zenith II, 1999–2002). This was done to accommodate the lack of registration of preeclampsia, maternal BMI, and smoking for the earlier part of the study. We described child and maternal characteristics for each period (eTable 1; http://links.lww.com/EDE/B674).

We explored time trends in other outcomes among all births. Annual proportions of neonatal mortality, low Apgar score, and preterm birth were calculated by dividing all

Table. Characteristics of Children Born in Norway From 1982 to 2016.

	Year of Birth					
	1982–1990	**1991–1995**	**1996–2002**	**2003–2006**	**2007–2016**	**Total**
Part of hump	Before	Increase	Zenith	Decrease	After	
Number of live births	486,024	300,287	409,975	230,871	606,480	2,033,637
Missing/implausible birthweight (%)	0.14	0.09	0.14	0.07	0.05	0.10
Missing/implausible gestational age (%)	8.5	9.8	7.4	7.5	8.9	8.5
Study population (n)	444,060	270,506	379,124	213,528	552,094	1,859,312
Preterm births[a] (%)	5.8	6.4	6.7	6.8	6.6	6.4
Term births[b] (n)	418,370	253,093	353,587	198,984	515,801	1,739,835
Mean birthweight (g)	3,567	3,598	3,628	3,608	3,569	3,589
Standard deviation birthweight (g)	500	508	518	508	491	504
90th percentile[c] (g)	4,200	4,250	4,290	4,260	4,200	4,230
5th percentile[c] (g)	2,770	2,790	2,800	2,790	2,780	2,780
2nd percentile[c] (g)	2,550	2,560	2,560	2,570	2,570	2,560
Mean gestational age (d)	283.3	282.9	282.9	282.6	281.9	282.7
Primipara (%)	42.7	41.1	39.8	40.8	42.2	41.5
Mean maternal age (y)	27.6	28.6	29.5	30.2	30.4	29.3
Mothers without known country of birth (%)	15.3	7.9	3.7	1.7	1.4	6.2
Norwegian-born mothers if known country of birth (%)	93.2	90.3	87.2	82.9	75.2	84.7
Congenital anomalies (%)	2.9	3.1	3.2	4.7	3.8	3.4
Neonatal mortality (%)	0.14	0.12	0.09	0.08	0.05	0.10
Apgar-score at 5 min <7 (%)	0.69	0.70	0.81	0.93	1.01	0.84
Summer births (%)[d]	25.2	25.5	25.8	26.3	26.9	26.0
Start of delivery						
Spontaneous start of delivery (%)	82.6	81.6	82.0	79.5	74.5	79.6
Induced start delivery (%)	15.3	14.0	12.6	13.4	18.8	15.4
C-section start delivery (%)	2.2	4.4	5.4	7.1	6.7	5.1
Marital status						
Married (%)	72.6	56.6	50.7	49.4	46.2	55.4
Cohabiting (%)	14.2	34.8	41.2	44.4	47.0	35.9
Unmarried/single (%)	11.7	7.7	5.8	5.0	5.7	7.4
Divorced/widowed (%)	1.28	0.74	0.59	0.50	0.43	0.72
Other/unknown (%)[e]	0.18	0.17	1.73	0.66	0.71	0.71

[a]Born before 37 completed weeks.
[b]Born in gestational weeks 37–45.
[c]Birthweight percentile in term births.
[d]Summer births: births in June, July, or August.
[e]Other or unknown marital status.

observations with each outcome during a given year (nominator) by all births during that year having available information about the outcome (denominator).

Furthermore, we calculated mean birthweight separately for term and preterm births in each year. Because the birthweight hump was apparent only among term births, we conducted subsequent analyses on term births only. Among term births, we estimated mean birthweight each year within the strata of primipara and multipara, seasons of birth, and Scandinavian and non-Scandinavian mothers. We performed subanalyses in the same way, stratifying on boys and girls, diagnosis of diabetes mellitus, the various onset of deliveries, maternal county, and each gestational week.

We used multivariable linear regression to adjust for the change in mean birthweight over time. Adjustment factors included maternal age and maternal age squared (continuous variables); parity (primipara versus multipara); gestational age in days, and gestational age in days squared within term births (as continuous variables); onset of delivery as a categorical variable (spontaneous onset of labor, cesarean section and induction); congenital anomalies (yes vs. no); and marital status as a categorical variable (married, cohabiting, nonmarried/single, divorced/separated/widowed, and other/unknown). We set 1982 as the reference value and used year of birth in one-year intervals from 1983 to 2016 as the main exposure. We restricted this multivariable analysis to term births born to Scandinavian mothers.

Registration of preeclampsia in the Birth Registry was improved substantially in 1999, making adjustment for this variable uncertain before 1999. We therefore performed a subanalysis with linear regression as described above from 1999 to 2016 with an additional adjustment for preeclampsia, which we defined as any diagnosis of preeclampsia, eclampsia or HELLP syndrome (n = 731,219). Information on smoking in pregnancy was collected in the birth registry from 1998, partway through the birthweight hump. We performed a subanalysis with linear regression as described above, including preeclampsia, from 1999 to 2016 with additional adjustment for smoking (n = 631,733), and a separate subanalysis with additional adjustment for maternal BMI, which was available from 2007 (n = 189,992). For all these subanalyses, the year 2007 was set as a reference value, and year of birth in one-year intervals was the main exposure.

To explore possible maternal cohort effects, we performed an additional subanalysis with linear regression as described above for the whole period, adding maternal year of birth in 10-year categories (<1950, 1950–1959, …, 1980–1989, ≥1990) as a covariate (n = 1,410,142), again setting the year 2007 as a reference value. All analyses were performed using Stata (Statacorp, College Station, TX), version 15.0.

RESULTS

Among 1,859,312 live births in Norway between 1982 and 2016, mean birthweight increased by about 50 g from 1991 to 1997, and decreased with a similar magnitude between 2002 and 2007 (Figure 1; Table). There was no evidence of similar patterns for neonatal mortality, preterm delivery, or low Apgar score (Figure 2).

The distinctive pattern of rise and fall in birthweight was present only among term births (Figure 3; Table), among whom birthweights increased and decreased by about 60 g. During the same time period, the standard deviation of birthweights increased by about 20 g as birthweights rose, and then decreased with decreasing birthweight (Table). The pattern of rising and falling birthweights was not present among preterm births. There was a general decline in preterm birthweights during most of the study period, with a hint of an upward trend after 2004 (Figure 3). After stratifying term births by gestational week, the hump pattern remained virtually unchanged for the various weeks, with some slight modifications (eFigure 1; http://links.lww.com/EDE/B674).

Birthweights at the 10th percentile and above generally followed the same hump pattern as mean birthweight. However, at lower percentiles, the hump pattern flattened, and disappeared completely below the fifth percentile (Table).

In line with increased rates of induction for postterm pregnancies, the overall lengths of gestation decreased steadily during the study period (albeit with a slight increase between 1991 and 1994) (Table).

The proportion of deliveries by primipara women first decreased and then increased during the study period (Table). However, this did not explain the birthweight hump, which was present within the strata of both first and later births (Figure 4A). The birthweight hump was also consistent across all seasons (Figure 4B) and in both sexes (eFigure 2; http://links.lww.com/EDE/B674). The birthweight hump persisted after excluding women with a diagnosis of diabetes mellitus (eFigure 3; http://links.lww.com/EDE/B674). The hump persisted in births with spontaneous and medical induction onset of delivery, but is less distinct for births with onset as cesarean section (eFigure 4; http://links.lww.com/EDE/B674). The pattern was similar across all regions (19 counties) in Norway (eFigure 5; http://links.lww.com/EDE/B674).

The birthweight of term infants born in Norway to any Scandinavian mother (those born in Norway, Sweden, or Denmark) showed approximately the same hump (Figure 4C), with an increase in mean birthweight between 1982 and 1997 of

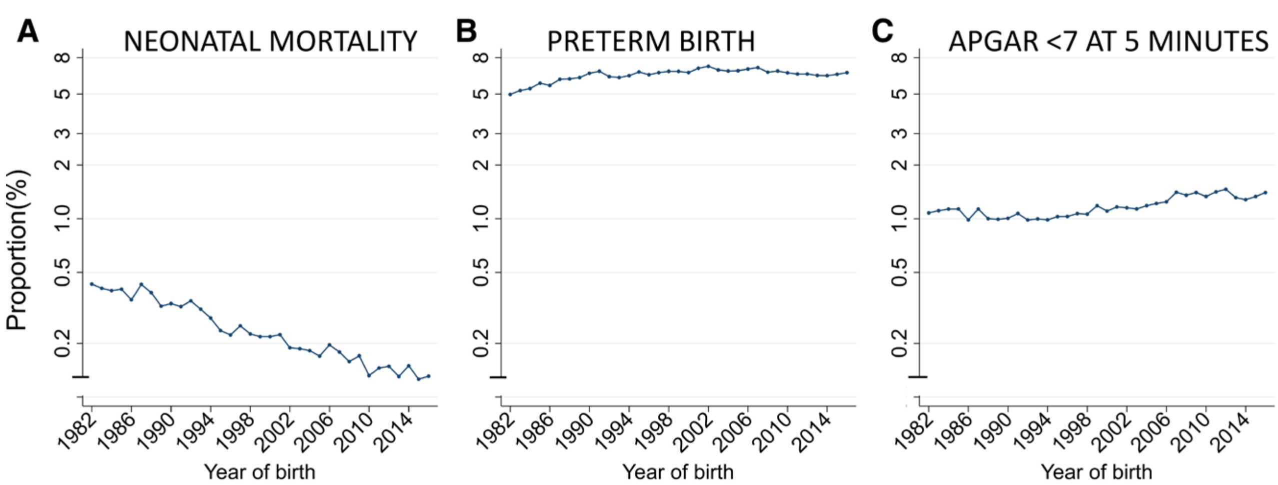

FIGURE 2. Proportion (% of all live-born children) with (A) neonatal mortality, (B) preterm births, and (C) newborns with Apgar score less than seven at five min, in Norway in the years 1982 to 2016. Note the use of log-scale for the y-axes.

about 80 g and a subsequent decrease of about 50 g. The mean birthweight of infants of women born outside of Scandinavia were generally around 100 g lower and increased slightly in the study period (Figure 4C).

Adjusted change in mean birthweight showed similar time trends as the unadjusted, although the posthump level did not fully return to prehump levels (Figure 5). The more limited time frames (eTable 1; http://links.lww.com/EDE/B674) available for data on preeclampsia, maternal smoking, and maternal BMI showed similar birthweight trends as in the main analysis (eFigure 6; http://links.lww.com/EDE/B674). Similarly, adjustment for maternal birth cohort yielded a pattern like that in the main analysis (eFigure 6; http://links.lww.com/EDE/B674). In summary, none of the known predictors examined was able to explain the hump pattern.

We sought to explore the extent of this distinctive birthweight pattern among neighboring countries. Sweden showed a birthweight hump similar to Norway's, while birthweights in Finland followed a quite different pattern (Figure 6).

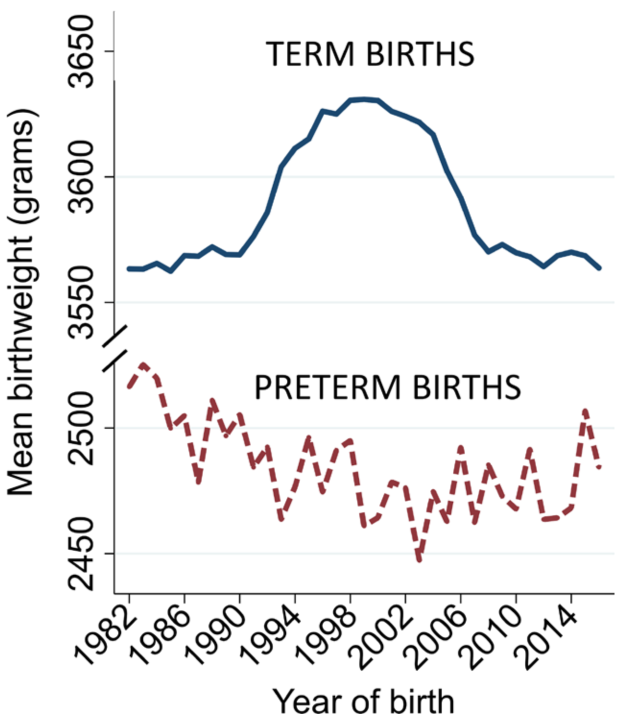

FIGURE 3. Mean birthweight by year of birth in Norway from 1982 to 2016, for preterm births (<37 gestational weeks) and term live-born children by year of birth.

DISCUSSION

Norway experienced a distinct temporal increase in mean birthweight of about 50 g between 1991 and 1995, with a subsequent decrease from 2003 to 2006. This hump in mean birthweight was restricted to term births and was seen only among offspring born to Scandinavian women. The hump could not be explained by trends of maternal parity, infant sex, mode of onset of delivery, county, smoking, or season of birth. Moreover, indicators of perinatal health known to be associated with birthweight (neonatal mortality, 5-min Apgar score less than seven, and preterm delivery) did not show similar or reciprocal patterns. Furthermore, there was no evidence of a maternal cohort effect, although the separation of a possible cohort effect when exploring a period effect is challenging.

In the same period, a similar hump was evident in Sweden, but not in Finland. An increase in mean birthweight during similar time periods was also observed in Canada (1978–1998), the United States (1985–1998), Denmark (1990–1999), and the north of England (1982–2000),

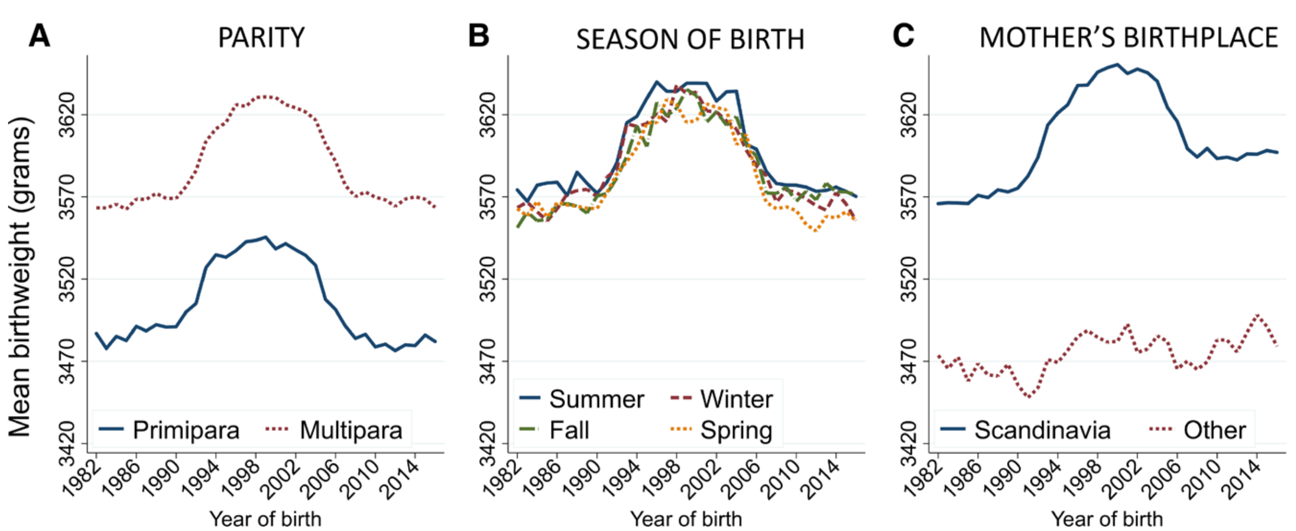

FIGURE 4. Mean birthweight (in grams) in live-born term births by year of birth by following groups. (A), Parity; (B) season of birth (Summer: June, July, August; Winter: December, January, February; Spring: March, April, May; Fall: September, October, November); and (C) mother born in Scandinavia or other country.

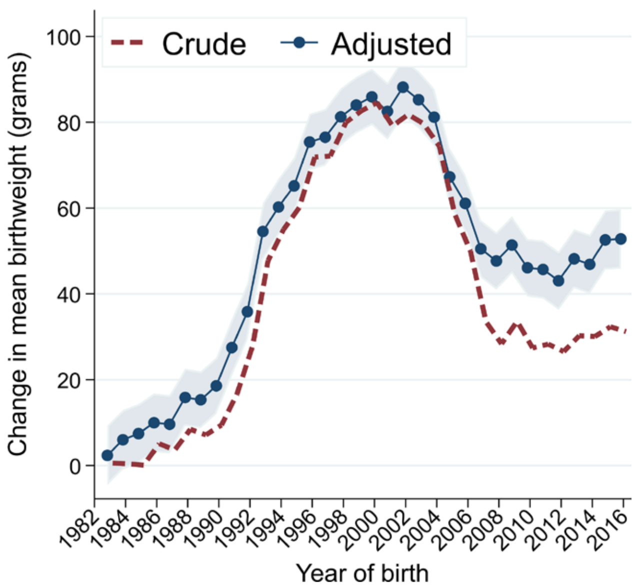

FIGURE 5. Crude and adjusted change in mean birthweight in live-born children born at term to Scandinavian-born mothers by year of birth (1982 as reference). Adjusted estimates obtained by linear regression were adjusted for parity (primipara vs. multipara), maternal age continuous and squared, gestational age continuos and squared, onset of delivery (spontaneous vs. medically induced vs. cesarean section), marital status (married, cohabiting, nonmarried/single, divorced/separated/widowed and other/unknown), and congenital anomalies (no vs. yes). The shaded band shows 95% confidence intervals for adjusted estimates.

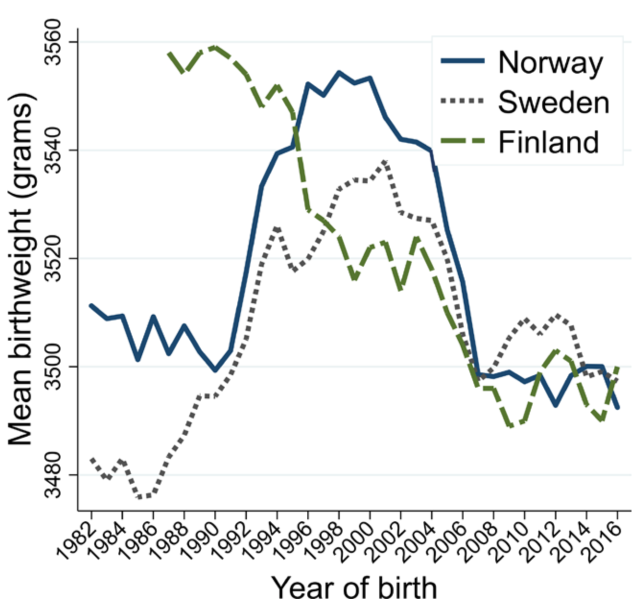

FIGURE 6. Mean birthweight for live-born children in Norway (full line) and Finland (long dashes), all births in Sweden (short dashes), by year of birth. Data from Finland are available from 1987 onward (The Finnish Medical Birth Registry was established in 1987).

with a subsequent decrease in Canada and the United States, leading to a hump-like pattern not dissimilar to the one in Norway.[7,19–25] As in Norway, the increase in birthweight in the United States and Canada was observed mainly for term infants and not for preterm.[19]

Known determinants of birthweight did not explain the Norwegian birthweight hump. Recent increases in birthweight in other countries have been attributed to cessation of smoking, healthier lifestyle habits, and an increase in maternal BMI.[7] These factors did not explain the Norwegian pattern. In fact, the decline in Norwegian birthweights after 2002 paradoxically occurred during a time when maternal smoking levels were steadily decreasing and BMI among fertile women was increasing.[26,27] Furthermore, our subanalyses adjusting for maternal BMI and smoking in the periods for which we had information showed no evidence of their influence on the birthweight trend.

During the study period, induction practices for pregnancies progressing beyond 40 weeks shifted toward more intervention,[28–30] which may explain the decrease in average gestational length. However, adjustment for gestational length in term births in our regression analysis did not explain the observed temporal birthweight changes. Primiparous women have children with lower birthweight as well as an increased risk of many adverse pregnancy outcomes, including preterm birth and neonatal mortality.[31–33] The hump was present in births by both primiparous and multiparous women in our study.

Another predictor of birthweight is ethnicity or country of mother's birth.[8] This was not consistently reported in the earlier years of the study period; mother's country of origin was unrecorded for 15% of births in 1982, and fell to less than 1% in 2016. Among mothers with recorded country of birth, the proportion of deliveries to mothers born in Norway decreased from about 95% in 1982 to 71% in 2016. The temporal change in birthweight was not present when restricting to pregnancies by mothers born outside the Scandinavian countries. Lifestyle and cultural factors may have played a role in the observed birthweight trend, as women of Scandinavian heritage would be expected to be similar in their habits. The fact that Sweden experienced a similar birthweight hump supports this conjecture.

A previous study on the rise and fall of birthweights in a regional cohort in Norway speculated on the possible role of sugar-sweetened carbonated soft drinks as a factor leading to maternal weight gain and higher birthweights followed by decreasing intake and lower birthweights.[34] However, a subsequent study found that increased consumption of soft drinks during pregnancy was associated with lower birthweight, thus not supporting soft drinks as an explanation for the birthweight hump.[35]

A single factor that could shift the birthweight distribution in the pattern observed (or two different factors at work for the increase and decrease) would either have to be very common or have a very strong influence on the birthweight. We explored this idea further with a simple simulation. Assuming a mean birthweight of 3,600 g and a standard deviation of 500 g (close to the situation in this study), a risk factor with a prevalence of 5% would have to decrease birthweight by 1,000 g to lead to an overall population decrease of 50 g. Even with a prevalence of 10%, exposed individuals would have to decrease their birthweight by 500 g. With a more realistic magnitude of effect, such as 100 g, the risk factor would need to have a prevalence of 50% in the population, and an effect of 200 g corresponds to a prevalence of 25%. We were not able to identify any factors that come close to those parameters, with the possible exception of a shift in the proportion of foreign-born mothers. There are apparently important determinants of birthweight that have yet to be identified.

Strengths and Limitations

This study was based on registry data comprising all registered live births in Norway between 1982 and 2016, giving valid estimates of birthweight and other perinatal measures in the complete population of Norway. Some procedures for registration in the birth registry were revised in 1999, but for most measures in this study, the recordings were similar across the study period.

There have been no major changes since the 1970s in the type of scales used to measure birthweights. Standardization procedures for the measurement of birthweight from 1993 are still in use (*personal communication, Nils Magnar Thomassen at the Norwegian Metrology Service, 17.10.19, e-mail*), leaving a measurement error as an unlikely explanation for the observed time trend.

Although we have information on maternal country of birth, we lack specific information on maternal race/ethnicity, a factor known to influence birthweight in the offspring.[19] Second-generation immigrants born in Norway were recorded as having Scandinavian origin, possibly blurring the distinction between Scandinavian and non-Scandinavian origin of mother in later years of the study period. However, given that Norwegian-born mothers contributed 93% of births in 1982–1990, it is unlikely that the distribution would have shifted enough to affect the observed downward change in mean birthweight starting already in 1999.

Furthermore, we did not have access to maternal BMI or smoking habits during pregnancy for the earlier part of the study period or reliable diagnosis of preeclampsia, which limited our ability to adjust for these factors. However, our subanalyses for the years for which we had these data did not indicate that the decreasing smoking trend changed the decreasing segment of the hump. We saw no effect of maternal diabetes on the birthweight hump pattern, although the diagnosis of gestational diabetes mellitus has changed markedly during the study period,[16–18] limiting the interpretation of this adjustment.

CONCLUSIONS

A distinct rise and fall in mean birthweight occurred in Norway from 1992 to 2007. We could not explain this unusual rise and fall of birthweight by known predictors of birthweight. We acknowledge that our explorations to evaluate the effects of changes in birthweight are indirect. Even so, it is clear that the changes in birthweight over a relatively short period had no apparent consequences for either neonatal death or Apgar scores.

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