Journal of Developmental Origins of Health and Disease

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Is increased size at birth associated with longevity on the population level? – A historical and comparative analysis of regions in Sweden

Luciana Quaranta[1], Ankita Sharma[2], Åsa Pontén[3], Karin Källén[4] and Peter M. Nilsson[2]

[1]Centre for Economic Demography and Department of Economic History, Lund University, Lund, Sweden; [2]Department of Clinical Sciences, Lund University, Skåne University Hospital, Malmö, Sweden; [3]Department of Gynecology and Obstetrics, Central Hospital, Halmstad, Sweden and [4]Department of Clinical Sciences, Lund University, Tornblad Institute, Lund, Sweden

Original Article

Cite this article: Quaranta L, Sharma A, Pontén Å, Källén K, and Nilsson PM. (2022) Is increased size at birth associated with longevity on the population level? – A historical and comparative analysis of regions in Sweden. *Journal of Developmental Origins of Health and Disease* **13**: 606–616. doi: 10.1017/S2040174421000684

Received: 29 June 2021
Revised: 31 October 2021
Accepted: 17 November 2021
First published online: 23 December 2021

Keywords:
Birth size; early life programing; epidemiology; longevity; Sweden

Address for correspondence:
Peter M. Nilsson, Department of Clinical Sciences, Lund University, Jan Waldenströms gata 15, floor 5, Skane University Hospital, Malmo S-20502, Sweden.
Email: Peter.Nilsson@med.lu.se

Abstract

Increased population longevity could be influenced by early life factors. Some areas have long-lived populations, also in a historical perspective. We aimed to study these factors in Halland, an area with the highest life expectancy in Sweden. We collected archival data on gestational age and birth characteristics from 995 live singleton full-term births at the Halmstad Hospital, Halland, from the period 1936 to 1938 and compared these to 3364 births from three hospitals in nearby Scania for the period 1935–1945. In addition, data were obtained on maternal and offspring characteristics from the national Swedish Medical Birth Register during 1973–2013. The results show that when controlling for background maternal and offspring characteristics, mean birth weight (BW) and mean birth length were higher in Halland than in Scania, but the proportion of low birth weight (LBW) and small for gestational age (SGA) was lower. However, mean BW for Halland did not differ from the rest of Sweden in recent years 2004–2013. We also conducted a mortality follow-up for children born in Scania, which showed that LBW, being born SGA, or short birth length reduced survival. In conclusion, the high mean life expectancy in Halland compared to the rest of Sweden could have been associated with beneficial early life factors influencing birth size in the past. In more recent decades the mean BW of Halland is not different from the national mean. Thus, longevity could be expected to become more equal to the national mean in the future.

Introduction

Early life programing has been intensively studied for prediction of adult morbidity and mortality, as well as life expectancy in various populations.[1,2] One important measure of this is birth weight (BW) adjusted for gestational age, which reflects fetal growth patterns.[1] BW, as well as birth length, is influenced not only by genetics but also by environmental factors, for example, maternal diet and lifestyle during pregnancy. Some historical examples have been used to link a higher mean BW, as well as adult tallness, with better health conditions and increased longevity on the population level, for example in Åland, a Swedish-speaking archipelago province of western Finland.[3–5]

Halland is a county located in south-west Sweden with 325,000 inhabitants. For more than a century it has been known that this population enjoys the highest mean life expectancy in Sweden. In 2015–2019, period life expectancy was estimated to be 84.95 years in Halland versus 84.24 years as a national mean for women, and 81.87 years versus 80.75 years for men.[6] These values were also higher than the mean life expectancy for the nearby county of Scania (84.34 and 80.82 years for women and men, respectively), which is considered for comparisons. Furthermore, the cardiovascular mortality rate in Halland is significantly lower than the rest of Sweden and cannot be explained only by higher socioeconomic status (SES) as a marker of better material conditions.[7] In 2019, death rates in Halland from diseases of the circulatory system were 201.2 and 284.3 per 100,000 for women and men, respectively, compared to the national averages of 230.1 and 328.1 deaths per 100,000, making Halland the county with the lowest rates for men, and second lowest rates for women after Stockholm.[8] The population in Halland is also amongst the tallest in Sweden. The regions with the highest average height for men and women aged 16+ years in 2018–2019, equal to 172.9 cm, were the West Sweden region, comprising the counties of Halland and Västra Götaland, and the North-Central Sweden region.[9] Average height in the South Sweden region, comprising the counties of Scania and Blekinge, was 172.8 cm, while the national average was 172.5 cm.

Different explanations for the increased mean longevity of the Halland population have been suggested, including access to nutritious food, low infant mortality and traditionally a lower grade of urbanization. The long life expectancy seen in Halland today can be traced back to the early 20th century. The starting point for this development seems to have been a lower infant mortality in Halland compared with Sweden as a nation during the period 1880–1890. The basis for this might have been a greater increase of food production during the whole 19th century as well as other favorable socioeconomic characteristics of Halland compared with the rest of the country, according to Baigi et al.[10] A lower risk of deaths from infectious disease could also have contributed.[11] Such higher levels of nutrition and lower disease burden could have positively influenced size at birth and growth patterns during childhood of Halland's population, leading to (programming of) better health throughout the life course. On the other hand, Scania is a more densely populated region with a dominating urban structure including a larger proportion of working class and factory workers. The closeness to nearby Denmark has also influenced lifestyle habits with, for example, a higher rate of smoking than in other regions.

To summarize, similar to the population of Åland, the Halland population also enjoys the highest mean life expectancy in their respective countries. This could therefore be studied to increase knowledge about the historical contribution of early life determinants of longevity in a life course perspective. A corresponding historical population-based study is the Uppsala Birth Cohort, with obstetrical data from deliveries at Uppsala Academic Hospital in mid-Sweden during 1915–1929, which has reported associations between early life factors and adult disease risk.[12,13] Another historical population is the one in Scania that lived in the city of Landskrona or in the neighboring countryside in southern Sweden, with rich data on early life exposures.[14–16]

The *aim* of this observational study is: (a) to describe the mean BW and mean birth length among children born in Halland in the 1930s, as well as to (b) compare the mean birth measurements for children born in Halland to children born during a similar time period in Scania, and to (c) compare the mean BW in recent decades in Halland to the rest of Sweden, based on national register data. Although we lack follow-up data for children born in Halland, such data is available for children born in Scania during the same period. The final aim of this work is therefore to (d) analyze the associations that exist between size at birth and all-cause mortality at different ages in a historical cohort.

Methods

Data for Halland

Data concerning sex, BW, birth length, gestational age (based on self-reported last menstrual period), the parity and marital status of the mother, and maternal age at delivery, were collected from medical records during delivery at Halland's Central Hospital in Halmstad from the period 1936–1939. These data were manually collected from archival records for 995 births from these years (by Å Pontén). Gestational age was calculated as the number of days between the reported last menstrual period and delivery. Inclusion criteria to define the study sample from the full set of all births, were live births of singletons having gestational age between $37 + 0$ and $42 + 6$ (weeks + day), corresponding to days 259–300, by stated last menstrual period. Individuals with no or improbable stated last menses period were excluded. According to these criteria 42 births were excluded from 1936, 71 from 1937, and 47 from 1938. Data concerning maternal body mass index (BMI) or smoking were not available. This historical birth cohort is referred to as the *Halmstad Birth Study* (HBS) throughout the paper.

Data for Scania

For Scania we used data from the Scanian Economic Demographic Database (SEDD),[14,15] which was constructed using historical parish and civil registers and which contains longitudinal demographic and socioeconomic data for the city of Landskrona and five closely located rural parishes (at a distance 100 km from Halmstad). Individuals can be followed from birth or in-migration until death or out-migration between 1905 and 1968. The SEDD has been linked to the Swedish Death Index (SDI – The Federation of Swedish Genealogical Societies) which includes most deaths in Sweden between 1860 and 2016.[16] The linkage was done using full linkage on date of birth and probabilistic linkage on names. Individuals who out-migrated from SEDD areas can therefore also be followed until their death, if it occurred up to 2016, while those with no observed death date can be assumed to be still alive at the end of such year.

Birth records from the hospitals of Landskrona, Lund, and Helsingborg were digitized for children born between 1935 and 1945, whose mothers resided in SEDD areas at the time of their birth. The data was digitized manually (by research assistants under the guidance of L Quaranta). Out of a total of 4849 children born between 1935 and 1945, in all 4493 were born in the hospitals of Landskrona, Lund, and Helsingborg (4009 of these records were found and digitized), 111 were born in other hospitals or birth institutions, and the remaining 245 were either born at home or their exact place of delivery was unknown. This historical birth cohort is referred to as the *Scanian Birth Study* (SBS).[17] throughout the paper.

The same definition of gestational age and of the criteria for inclusion in HBS were also used for the SBS. Out of the total of 4009 children whose records were digitized, 97 were excluded because they were multiple births, and 536 were excluded because their records stated no or improbable last menses period, or because the gestational age was outside the 259–300 d range. An additional 12 children were excluded because they had missing BW or birth length. The final SBS study sample thus consisted of 3364 children. Of the total sample, 669 individuals died before December 31st, 2016 (i.e., before their 70th birthday).

National register data

The Swedish national Medical Birth Register (MBR) was introduced in 1973, and records information on pregnancies, deliveries, and new-borns on a national basis.[18] Maternal height, weight, and smoking were registered from 1983 onwards. From the MBR we received data on mean BWs from new-borns in Halland and Scania compared to other Swedish counties during the period 1973–2013.

Statistical analyses of birth characteristics

All statistical analyses for HBS and SBS were performed using the statistical program STATA.

We first present descriptive characteristics of the new-born (BW, percentage of low birth weight, percentage small for gestational age, birth length, ponderal index, gestational age, proportion of males) and maternal characteristics (proportion unmarried, proportion primiparous mothers, age at delivery) in both cohorts HBS and SBS. Ponderal index (PI) was calculated as weight (kg)/

length^3 (m), as an indicator of fetal growth status. Low birth weight (LBW) was defined as weight below 2500 g. Infants were defined as small for gestational age (SGA) when weighing less than two standard deviations below the expected BW for gestational age and gender according to the Swedish intrauterine growth curves.[19] The standard deviation was calculated from the distribution, from the pooled HBS and SBS cohorts, of weight deviations from expected weights. For each cohort we present the results separately and for the total combined population, as well as for boys and girls, respectively.

Next, we analyzed factors associated with BW, birth length, and PI using three separate multivariable *linear* regression models. We also analyzed the factors associated with being LBW, or SGA using *logistic* regression analyses. The five models were estimated based on the pooled HBS and SBS datasets to identify differences between the two samples.

Finally, we used data from the MBR (1973–2013). Also in this case infants were defined as SGA, or large for gestational age (LGA), when weighing more than two standard deviations (*z-scores*) below or above, respectively, the expected BW for gestational age and gender according to the Swedish intrauterine growth curve.[19] Multivariable *linear* regression analyses were made to investigate if the mean infant BW *z*-score differed between Halland and the other Swedish counties in recent decades (2004–2013).

Mortality analyses

For SBS and the follow up-data on mortality from SEDD and a Swedish historical death register (SDI), Cox proportional hazard models (Table 5, Models (M) 1–24) were used to measure the influence of BW, birth length and being SGA on the hazard of death. Separate estimations were made for death in ages 0–14, 15–49, and 50–70 years.

BW was first considered as *continuous* (M1, M9, M17). Next, it was considered as *categorical* (M2, M10, M18), based on the mean and standard deviation (>2 SD below the mean; 1 to 2 SD below the mean; 1 SD below the mean to 1 SD above the mean; 1 to 2 SD above the mean, and >2 SD above the mean) rounded to the nearest 100 g, which corresponded to the thresholds <2500 g; 2500–2999 g; 3000–3999 g; 4000–4499 g; and ≥4500 g. BW by gestational age was also taken into account, comparing individuals who were SGA to those that were not (M3, M11, M19). Birth length was also considered first as *continuous* (M4, M12, M20) and next as *categorical* (M5, M13, M21) variable, also in this case based on mean and standard deviation, rounded to 0.5 cm for birth length, which corresponded to <46.5 cm; 46.5–48.9 cm; 49–52.9 cm; 53–54.9 cm; and ≥55 cm. In addition to estimating models to measure the separate effects of BW and birth length on the likelihood of death, we also evaluated their joint association within the same model, first considering both as continuous (M6, M14, and M22), next both as categorical (M7, M15, and M23) and lastly considering weight by gestational age and birth length as categorical (M8, M16, M24).

All models control for gestational age, individual's birth year, sex, first-born status, and father's SES at the time of the individual's birth. Occupational notations in SEDD have been coded into Historical International Standard Classification of Occupations (HISCO).[20] and subsequently classified into the Historical International Social Class Scheme (HISCLASS) categories.[21] Seven occupational classes were created: Higher white-collar workers (HISCLASS 1–2); Lower white-collar workers (HISCLASS 3–5); Medium-skilled workers (HISCLASS 6–7); Lower-skilled workers (HISCLASS 9–10); Unskilled workers (HISCLASS 11–12); Farmers (HISCLASS 8); and Occupation unknown. No evidence of violations to the proportional hazards assumptions was found for the main explanatory variables (BW, birth length and weight by gestational age) in tests based on Schoenfeld residuals.

Results

Birth measurements in the Halmstad Birth Study and the Scanian Birth Study

Characteristics of the HBS and the SBS cohorts are described in Table 1. Mean BW was 3526 g in HBS, which was nearly identical to the mean BW in SBS, 3523 g. Average birth length was higher in HBS (51.5 cm) than in SBS (50.9 cm). Average PI was lower in HSB (25.7 kg/m^3) than in SBS (26.7 kg/m^3), which reflects the fact that children born in Halmstad were longer but weighed nearly the same as those born in Landskrona and surroundings. In fact, relative differences in average birth length between the two areas were wider than relative differences in average BW.

The proportion of LBW infants was lower in HSB (1.1%) than in SBS (1.6%). The proportion SGA was also lower in HSB (1.8%) than in SBS (3.0%). Some additional differences can be observed between the two areas in terms of gestational age and maternal background characteristics.

Table 2 shows the mean BW and standard deviation stratified by gestational week in the HBS and the SBS, respectively. As compared to new-borns in SBS, new-borns in HBS were heavier when born in weeks 38–41, but lighter in weeks 37 and 42. Boys were heavier than girls from gestational week 38 onwards in the HBS, and during all weeks in the SBS.

Results of multivariable linear regression models of predictors of BW, birth length and PI and of logistic regressions of predictors of LBW and SGA in the HBS and SBS are reported in Table 3, which highlight differences in size at birth between the two areas. For BWs, no base level differences in average values were seen between Halmstad (HBS) and Landskrona and surroundings (SBS) in Table 1, but when controlling for maternal and new-born characteristics in Table 3, children are heavier in HBS than in SBS ($p < 0.1$). HSB children were on average longer at birth than SBS children ($p < 0.001$), and also in this case wider differences were seen when controlling for background characteristics. Children in HSB had lower PI than those in SBS, since relative differences in average birth length between the two areas were wider than relative differences in average BW. The results of the two logistic regressions showed that HBS children were at lower risk of being LBW than SBS children ($p < 0.1$) and at lower risk of being SGA ($p < 0.05$).

Swedish national Medical Birth Register data

The two historical cohorts can be compared to modern data from MBR. Mean BW in the historical HSB (3526 g) was very close to the corresponding mean BW in MBR for 1973–2013 (3528 g), but somewhat lower than during the more recent part of the period, 2004–2013 (3546 g). Correspondingly, the mean BW in the historical SBS (3523 g) was lower than mean BW in Scania during 2004–2013 (3535 g), Table 4.

In contemporary analysis based on data from the MBR describing singletons born 2004–2013, the mean BW in Halland (3528 g; *z*-score 0) did not differ from the national mean (*z*-score 0), but some other counties had higher mean BW and *z*-scores. For the most recent period 2004–2013, such difference existed between

https://doi.org/10.1017/S2040174421000684 Published online by Cambridge University Press

Table 1. Population characteristics of 995 new-borns 1936–1938 at the Halmstad Central Hospital (Halland), and 3364 new-borns 1935–1945 at Landskrona, Lund, and Helsingborg Hospitals (Skåne)

	Halmstad						Landskrona and surrounding rural parishes					
	Total population		Boys		Girls		Total population		Boys		Girls	
	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.	mean	s.d.
Newborn characteristics												
Birth weight, grams	3525.7	477.0	3563.6	480.8	3487.8	470.6	3523.0	474.2	3589.7	481.1	3454.7	457.2
Birth length, cm	51.5	2.0	51.8	2.1	51.3	1.9	50.9	2.1	51.2	2.1	50.5	1.9
Ponderal index, kg/m3	25.7	2.4	25.6	2.4	25.7	2.4	26.7	3.0	26.7	3.3	26.7	2.6
Gestational age, days	280.3	10.0	279.8	10.0	280.7	10.0	281.1	8.9	280.8	8.9	281.3	8.9
LBW (<2500 g), %	1.1						1.6					
SGA, %	1.8						3.0					
Male gender, %	50.1						50.6					
Maternal characteristics												
Unmarried, %	8.5		9.2		7.8		10.5		10.3		10.6	
Primiparous mother, %	54.1		53.2		54.9		50.2		51.1		49.3	
Age at delivery, years	29.0	5.9	28.9	5.8	29.0	6.0	28.0	5.7	27.9	5.6	28.1	5.7
Number new-born (n)	995		498		497		3364		1703		1661	

LBW, low birth weight; SGA, small for gestational age, defined as a weight less than two standard deviations below the expected birth weight for gestational age and gender according to the Swedish intrauterine growth curves. Means (SD) and proportions (%).

Table 2. Mean *birth weight* (gram) and standard deviation (SD) by gestational week (w), for HBS and SBS

Gestational week at delivery	Halmstad									Landskrona								
	Total			Boys			Girls			Total			Boys			Girls		
	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n	mean	s.d.	n
w37	3115	430	91	3103	425	48	3128	440	43	3184	428	181	3223	453	94	3143	397	87
w38	3361	433	118	3398	449	70	3308	406	48	3318	438	384	3370	423	210	3254	448	174
w39	3501	451	248	3558	436	118	3450	460	130	3464	431	846	3540	433	415	3391	417	431
w40	3585	428	266	3628	437	132	3542	416	134	3572	455	1014	3636	448	514	3507	452	500
w41	3695	482	171	3746	496	83	3646	465	88	3639	482	639	3713	496	334	3558	454	305
w42	3706	464	101	3790	394	47	3633	510	54	3742	482	300	3855	511	136	3649	437	164

Halland (3546 g, *z*-score 0) and the county of Dalarna (3596 g, *z*-score 0.16) as well as the county of Gävleborg (3578 g, *z*-core 0.16), respectively, the two counties with the highest mean birth-weight at present (Table 4).

The proportion of LBW < 2500 g, SGA and LGA babies was 3.0%, 2.3%, and 3.4% in Halland compared to Dalarna (2.7%, 1.8%, and 4.9%), Gävleborg (2.8%, 2.0%, and 4.8%), and Scania (3.1%, 2.4%, and 3.5%), respectively (Table 4). For data on BW and SGA comparing Halland and the rest of Sweden for the whole period 1973–2013, see Table S1.

Variables explaining prevalence rates in multiple regression analyses (odds ratios, OR) were for *risk of LBW*: maternal age OR 1.01 (95% CI: 1.00–1.02; $p < 0.05$), smoking 1.67 (95% CI: 1.62–1.71; $p < 0.001$), and BMI 0.99 (95% CI: 0.982–0.995; $p < 0.005$); for *risk of SGA*: maternal age 0.97 (0.95–0.98; $p < 0.001$), smoking 1.82 (1.77–1.87; $p < 0.001$), and BMI 0.98 (0.978–0.983; $p < 0.001$), but also birth in Gävleborg county 0.83 (0.76–0.91). Finally, for *risk of LGA* the estimates were for: (more recent) year of birth 0.99 (0.989–0.998; $p < 0.001$), age 1.18 (1.17–1.20), smoking 0.62 (0.59–0.64; $p < 0.001$), BMI 1.11 (1.107–1.111; $p < 0.001$), and birth in Gävleborg county 1.26 (1.18–1.33; $p < 0.001$).

Mortality follow-up in SBS

BW used as a *continuous* variable in the SBS cohort was negatively associated with the hazard of death in ages 0–15, Table 5 (*Model*: M1). When considering BW as a *categorical variable*, (M2) and Fig. 1a, it is seen that such effect is driven by LBW individuals (<2500 g) and for those weighing 2500–2999 g, both of whom are more likely to die at ages 0–14 than individuals with average birthweight. The increased hazard of death of LBW individuals

https://doi.org/10.1017/S2040174421000684 Published online by Cambridge University Press

Table 3. Linear regressions with *birth weight, birth length,* and *ponderal index,* and logistic regressions with *low birth weight* and *small for gestational age* as the dependent variables in the HBS and the SBS

	Birth weight		Birth length		Ponderal index		Low birth weight		Small for gestational age	
Predictor variable	Coeff.	*p*-value	Coeff.	*p*-value	Coeff.	*p*-value	Odds ratio	*p*-value	Odds ratio	*p*-value
Area										
Halmstad	34.629	0.068	1.198	0.000	−1.606	0.000	0.486	0.062	0.492	0.014
Maternal factors										
Unmarried	−77.200	0.001	−0.200	0.045	−0.327	0.027	1.362	0.414	1.911	0.012
Primiparity	−166.540	0.000	−0.388	0.000	−0.663	0.000	1.990	0.018	2.243	0.000
Maternal age	2.929	0.021	0.021	0.000	−0.017	0.038	1.024	0.326	1.014	0.446
Newborn factors										
Male gender	132.899	0.000	0.648	0.000	0.019	0.820	0.575	0.034	0.696	0.057
Gestational age, per day increase	16.395	0.000	0.062	0.000	0.030	0.000	0.913	0.000	1.014	0.164
Birth year, per year increase	3.634	0.140	0.113	0.000	−0.146	0.000	0.969	0.495	0.956	0.176
Constant	−8197.259	0.086	−185.776	0.000	303.18	0.000	9.87E+34	0.363	1.02E+34	0.222
Observations	*4359*		*4359*		*4359*		*4359*		*4359*	

Low birth weight defined as <2500 g. Small for gestational age defined as a weight less than two standard deviations below the expected birth weight for gestational age and gender according to the Swedish intrauterine growth curves.

Table 4. All singletons from the Swedish Medical Birth Register (SMBR) in 2004–2013

	BW	*Z*-score	LBW		SGA		LGA		Total
	Mean	Mean	n	%	n	%	n	%	n
Stockholm	3530.9	0.00	6785	2.9	5213	2.2	7541	3.2	232,592
Uppsala	3570.0	0.12	938	2.8	630	1.9	1541	4.6	33,245
Södermanland	3553.0	0.07	765	3.2	576	2.4	1037	4.3	24,212
Östergötland	3523.3	0.00	1341	3.3	1150	2.8	1270	3.1	40,700
Jönköping	3547.6	0.02	1004	3.0	793	2.4	1155	3.5	32,927
Kronoberg	3529.6	0.05	540	3.1	370	2.1	649	3.8	17,276
Kalmar	3538.3	0.00	626	3.3	435	2.3	658	3.5	18,931
Gotland	3569.0	0.09	143	3.1	81	1.8	190	4.2	4576
Blekinge	3554.3	0.10	410	3.0	248	1.8	580	4.2	13,684
Skåne (Scania)	3535.4	0.01	3846	3.1	2922	2.4	4338	3.5	122,671
Halland	3546.2	0.00	829	3.0	634	2.3	946	3.4	27,717
Västra Götaland	3543.7	0.00	4806	3.0	4019	2.5	5219	3.3	158,828
Värmland	3598.7	0.12	676	3.0	507	2.2	1041	4.6	22,763
Örebro	3552.9	0.04	826	3.1	661	2.5	1040	3.9	26,724
Västmanland	3549.1	0.07	779	3.3	518	2.2	1034	4.4	23,585
Dalarna	3596.0	0.16	629	2.7	417	1.8	1137	4.9	23,232
Gävleborg	3578.0	0.16	660	2.8	455	2.0	1105	4.8	23,253
Västernorrland	3567.8	0.12	653	3.1	411	2.0	902	4.3	20,896
Jämtland	3567.4	0.05	340	3.0	231	2.0	401	3.5	11,331
Västerbotten	3569.1	0.05	615	2.7	450	2.0	818	3.7	22,392
Norrbotten	3579.7	0.08	625	3.0	443	2.1	837	4.0	20,667
Sweden	**3546.0**	**0.00**	**27,836**	**3**	**21,164**	**2.3**	**33,439**	**3.6**	**922,202**

Mean birth weight (grams), mean birth weight *z*-score (0 for national mean), rate of low birth weight (LBW) <2500 g, rate of small for gestational age (SGA), and rate of large for gestational age (LGA), by county for the period 2004–2013.

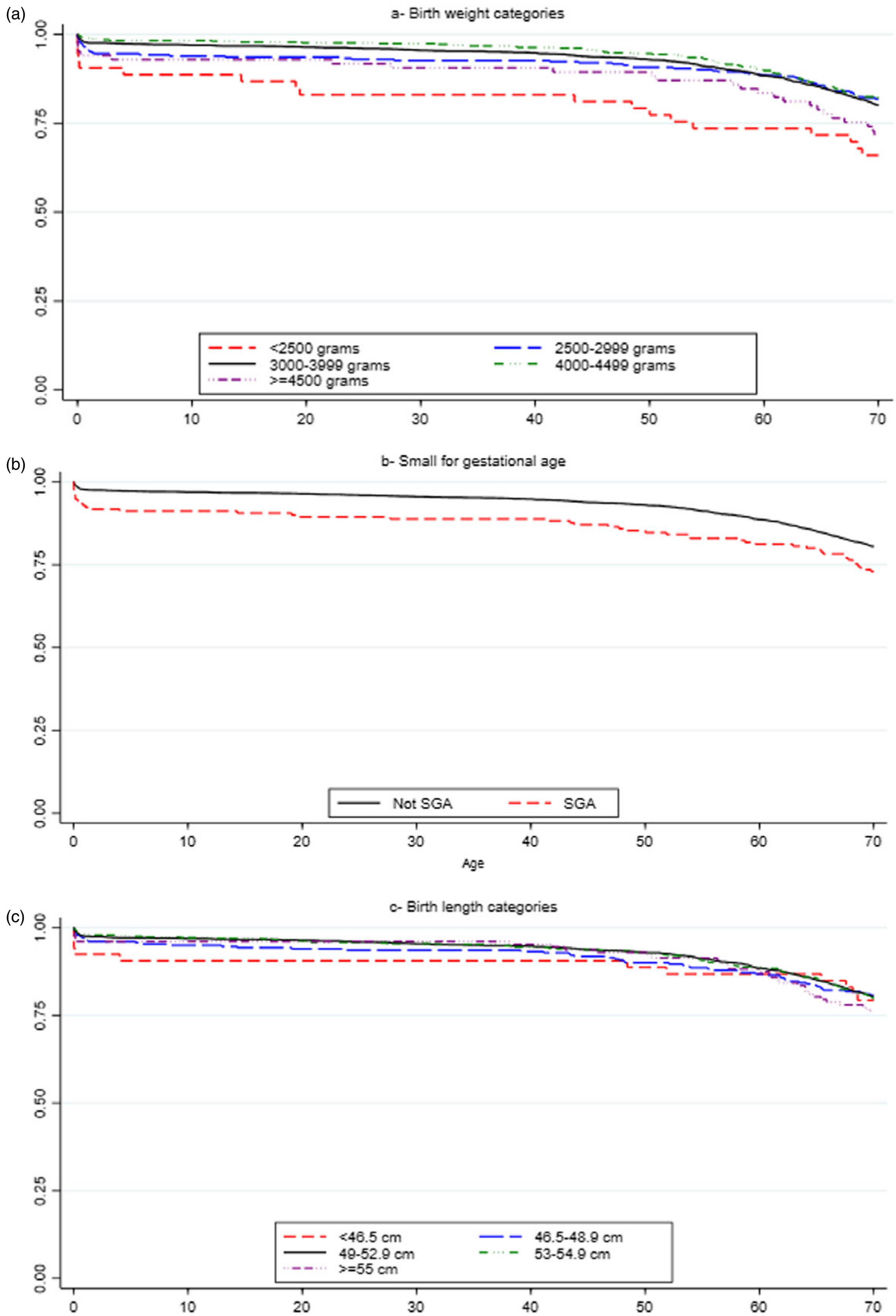

Fig. 1. Survival curves for ages 0–70 years by *birth weight*, *weight for gestational age,* and *birth length* categories, SBS from SEDD.

https://doi.org/10.1017/S2040174421000684 Published online by Cambridge University Press

Table 5. Cox models showing the influence of birth weight and birth length on the likelihood of dying at different ages, SBS

	M1		M2		M3		M4		M5		M6		M7		M8	
Age 0–15	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value
Birth weight, continuous (per gram increase)	0.999	0.000									0.999	0.004				
Birth weight, categorical																
<2500 g			4.855	0.000									4.333	0.007		
2500–2999 g			2.146	0.003									2.126	0.012		
3000–3999 g (ref.)			1.000	(ref.)									1.000	(ref.)		
4000–4499 g			0.588	0.119									0.550	0.094		
≥4500 g			1.803	0.173									1.573	0.356		
Birth weight by gestational age																
Small for gestational age					3.886	0.000									3.053	0.004
Not small for gestational age (ref.)					1.000	(ref.)									1.000	(ref.)
Birth length, continuous (per cm increase)							0.906	0.026			1.026	0.695				
Birth length, categorical																
<46.5 cm									3.708	0.005			1.274	0.694	1.714	0.338
46.5–48.9 cm									1.787	0.038			1.042	0.902	1.380	0.293
49–52.9 cm (ref.)									1.000	(ref.)			1.000	(ref.)	1.000	(ref.)
53–54.9 cm									0.992	0.977			1.170	0.598	1.024	0.933
≥55 cm									1.297	0.580			1.319	0.605	1.351	0.522
Number of individuals: 3364. Number of deaths: 122																
	M9		M10		M11		M12		M13		M14		M15		M16	
Age 15–49	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value
Birth weight, continuous (per gram increase)	1.000	0.121									1.000	0.218				
Birth weight, categorical																
<2500 g			2.784	0.048									3.900	0.028		
2500–2999 g			0.886	0.733									0.826	0.626		
3000–3999 g (ref.)			1.000	(ref.)									1.000	(ref.)		
4000–4499 g			0.703	0.216									0.715	0.265		
≥4500 g			0.697	0.542									0.763	0.672		
Birth weight by gestational age																
Small for gestational age					1.397	0.513									1.383	0.563
Not small for gestational age (ref.)					1.000	(ref.)									1.000	(ref.)
Birth length, continuous (per cm increase)							0.955	0.321			1.006	0.925				

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Table 5. (*Continued*)

Birth length, categorical																
<46.5 cm									0.718	0.743			0.287	0.269	0.596	0.627
46.5–48.9 cm									1.407	0.277			1.275	0.511	1.345	0.364
49–52.9 cm (ref.)									1.000	(ref.)			1.000	(ref.)	1.000	(ref.)
53–54.9 cm									0.958	0.863			1.051	0.851	0.964	0.884
≥55 cm									0.665	0.433			0.794	0.682	0.671	0.442
Number of individuals: 3242. Number of deaths: 125																

	M17		M18		M19		M20		M21		M22		M23		M24	
Age 50–70	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value	HR	*p*.value
Birth weight, continuous (per gram increase)	1.000	0.369									1.000	0.877				
Birth weight, categorical																
<2500 g			1.397	0.386									1.928	0.182		
2500–2999 g			0.755	0.159									0.837	0.414		
3000–3999 g (ref.)			1.000	(ref.)									1.000	(ref.)		
4000–4499 g			0.853	0.280									0.816	0.196		
≥4500 g			1.206	0.485									1.083	0.787		
Birth weight by gestational age																
Small for gestational age					1.339	0.287									1.615	0.118
Not small for gestational age (ref.)					1.000	(ref.)									1.000	(ref.)
Birth length, continuous (per cm increase)							1.031	0.238			1.027	0.434				
Birth length, categorical																
<46.5 cm									0.891				0.625	0.406	0.680	0.432
46.5–48.9 cm									0.811				0.813	0.373	0.752	0.185
49–52.9 cm (ref.)									1.000				1.000	(ref.)	1.000	(ref.)
53–54.9 cm									1.008				1.048	0.745	1.018	0.896
≥55 cm									1.218				1.253	0.378	1.232	0.366
Number of individuals: 3117. Number of deaths: 422																

All models were controlled for gestational age, birth year, gender, first-born, and SES at birth. Percentage of the full sample in each birth weight category: <2500 g: 1.4%; 2500–2999 g: 9.1%; 3000–3999 g: 73.1%; 4000–4499 g: 14.0%; ≥4500 g: 2.4%. Percentage small for gestational age: 2.7%. Percentage in each birth length category: <46.5 cm: 1.5%; 46.5–48.9 cm: 8.2%; 49–52.9 cm: 70.9%; 53–54.9 cm: 15.7%; ≥55 cm: 3.8%. These percentages are based on person years.
HR, hazard ratio.

persists also in the age range 15–49 years (M10), although with a lower magnitude and statistical significance. It should be noted, however, that LBW individuals only constitute 1.4% of the total study SBS sample, so this result should be considered with some caution. No statistically significant effects of birthweight are found on the likelihood of death in ages 50–70 years (M17, M18). Individuals born SGA (Fig. 1b) have increased hazard of death at ages 0–14 (M3). Given that all models controlled for SES at birth, the results are not confounded by the influence of family social background during pregnancy.

Birth length used as a *continuous* variable was also negatively associated with the likelihood of death in age range 0–14 years, Table 5 (M4). When considering birth length as a *categorical* variable, Table 5 (M5) and Fig. 1c, such effects are primarily driven by individuals with birth length <46.5 and 46.5–48.9 cm, both of whom have higher hazards of death at ages 0–14 than individuals born with average birth length. There were no significant effects of birth length on the hazard of death in ages 15–49 and 50–70 years (M12, M13, M20, M21). The models controlled for SES at birth, indicating no confounding.

The effects of BW on the hazard of death in ages 0–14 and ages 15–49 remain consistent when controlling for birth length in the same model (M7, M15). When controlling for birth length, the effect on the hazard of death of being SGA remains consistent in ages 0–14 (M8). When controlling for BW or being SGA, the effects of birth length on the hazard of death are no longer significant (M7, M8).

Discussion

Life expectancy in Sweden is among the highest in the world, and the county of Halland has the longest life expectancy for men and women in Sweden of today.[6] The increased mean longevity pattern in Halland compared to the rest of Sweden is unexplained, but early life programing could play a role according to the Developmental Origins of Health and Disease hypothesis.[22] Cardiovascular diseases constitute the most common cause of death in Sweden since the 1920s and a higher risk of cardiovascular diseases is associated with a lower social economic class. Mortality from cardiovascular disease has been reported to be lower in Halland compared to the rest of Sweden, but this is only partly explained by socioeconomic factors.[7,10,11] This background provides the rational to further study patterns of birth characteristics in Halland compared to a neighboring county (Scania) and the rest of Sweden, both in historical cohorts and based on modern health statistics from national registers.

In this work we compared historical birth characteristics of children born at Halland's Central Hospital in Halmstad during 1936–1939 (HBS) to those of children whose mothers resided in Landskrona and five surrounding rural parishes, who were born in the hospitals of Landskrona, Lund or Helsingborg during the period 1935–1945 (SBS), derived from a larger database, SEDD.[14,15] For SBS we were able to conduct a mortality follow-up to study the influence of birth measurements on all-cause mortality across the life course until 70 years of age.

We observed differences in size at birth between new borns in HBS and SBS, mainly that children in HBS were born larger than children in SBS. Mean BW was 3526 g for HBS, and although there was no difference to average birthweight in SBS (3523 g), after multiple regression analyses with adjustments for birth year, gender, gestational age, and mother's marital status, primiparity and age, a moderately significant higher birthweight was observed for HBS. The proportions of LBW (< 2500 g) and SGA new-born were lower in HBS (1.1% and 1.8%, respectively) than in SBS (1.6% and 3.0%, respectively). Average birth length was higher in HBS (51.5 cm) than in SBS (50.9 cm). Since relative differences in birth length between HBS and SBS were larger than relative differences in BW, PI was lower in HBS (25.7 kg/m^3) than in SBS (26.7 kg/m^3). The differences in LBW, SGA, birth length and PI remained after adjustment for maternal and new-born characteristics in separate multiple regressions analyses, with moderate statistical significance for LBW and high statistical significance for SGA, birth length, and PI.

Comparisons can also be made with other historical cohorts and with modern data. Average birthweight in both HBS and SBS (for full-term births) were somewhat higher than in Åland, Finland, in 1937–1944 (3499 g) and Uppsala, Sweden, in 1915–1929 (3429 g), but in these cohorts also preterm births were included.[12]

Average birth length was also higher in HBS than in Uppsala (50.7 cm). Furthermore, the mean historical BW for new-born in Halland in the late 1930s is close to the mean BW reported from Halland more recently during 1973–2013, and the same is true for new-born in Scania.

When BWs from Åland, described as Finland's healthiest region, were compared with BWs from Helsinki in the 1930s, mean BWs from Åland was shown to be higher.[5] It has been suggested that a high intake of omega-3 fatty acid, from dietary fish consumption, is associated with a longer gestational time period and thereby a somewhat higher BW.[23,24] Since Åland is an archipelago located by the sea, its population can be assumed to have had a high consumption of fish during historical times and even at present, also involving the diet of pregnant women. Therefore an accurate registration of gestational age for comparison between cohorts is of great importance, even if data on dietary intake is lacking. Historically, body height was greater in Sweden than in Finland, but a secular trend has diminished these differences,[25] with implications for adult health.

In several studies, a catch-up growth during childhood was correlated to higher risk for cardiovascular disease and type 2 diabetes, which suggests that it is the SGA new-born that really are at increased risk. However, data on *post-natal* growth patterns was not accessible for comparisons, neither between the historical cohorts (HBS, SBS) nor between the modern county-based (Halland, Scania, etc.) register data and the rest of Sweden.

The Helsinki Birth Cohort Study and the Uppsala Birth Cohort Sweden, have reported a clear association between small birth size and higher incidence and mortality from coronary heart disease as well as higher risk of stroke, hypertension and type 2 diabetes.[12,13,26,27] Unfortunately, we lack corresponding follow-up data from the HBS cohort, although we were able to follow new-born in SBS until age 70 years using data from the SEDD.[14,15,17] and the SDI.[16] We showed that LBW, SGA, and shorter birth length were associated with an increased hazard of death, particularly during childhood and early adolescence before 15 years. The effects of LBW or SGA remained consistent when controlling for birth length in the same model, but when controlling for BW the effect of birth length was no longer statistically significant. Such results were not confounded by SES at birth. These findings indicate that in SBS size at birth affected survival. The larger size at birth of children in Halland, which we found evidence of in the historical cohort (HBS) through greater birth length, lower proportion of SGA, slightly higher BW and slightly lower proportion of LBW, may therefore partly explain longer life expectancy and lower mortality from cardiovascular disease in people from Halland as historical birth

https://doi.org/10.1017/S2040174421000684 Published online by Cambridge University Press

cohort characteristics, even if we cannot test this empirically due to lack of follow up data for HBS.

Three mechanisms correlating small birth size with later cardiovascular disease have been suggested. One hypothesis postulates a vulnerability to poor socioeconomic standard later in life, when born small. Another hypothesis describes a heightened response to mental stress, increased vulnerability to the effects of lack of exercise, and changes in neuroendocrine pathways in smaller new-born. Men with normal birth size seem to be more resilient to suboptimal environmental factors later in life. If, as shown, the BWs and birth lengths in HBS were higher than in Uppsala and Scania, this partly could explain (at least in theory) the lower mortality from cardiovascular disease described in the area, which could account for the higher mean life expectancy seen in a national and historical perspective. However, more recent data from MBR does not provide evidence for a higher BW in the Halland county as a total area (not only based on births at the Halmstad hospital) or Scania compared to the rest of Sweden. This could be due to changing trends in relative BW between counties due to a change of the population composition (i.e., migrants), maternal lifestyle factors or reproductive patterns, or even other unknown factors. In addition, the introduction of preventive maternal health care on a national scale after the Second World War could contribute to more equal patterns of birth characteristics in birth cohorts from that time, and still today, compared to earlier birth cohorts.

Limitations of the study

This observational historical study has some important limitations. Only individuals born at the hospital in Halmstad during 1936–1938 (HBS), and individuals born in the hospitals in Landskrona, Lund and Helsingborg during 1935–1945, whose mothers resided in Landskrona and five surrounding rural parishes (SBS) with a complete medical register data-set, were included. Important data from variables influencing BW and birth length, such as maternal height, maternal BMI, diabetes, preeclampsia, weight gain during pregnancy, and smoking, were lacking. Since gestational age is significantly associated with BW this is an important factor to register when comparing birthweights. In the HBS and SBS, gestational age was calculated based on last menstrual period as recorded by midwifes in the medical records, but this could be inaccurate in some women due to biased reporting or recall bias.

A survival bias might also be present, since only live births were included and adverse conditions during pregnancy is associated with a higher risk of intrauterine fetal deaths. During the 20th century the maternity clinics in Sweden were rapidly growing, with a strong trend towards delivery in hospitals among women.[28] In 1930 the proportion of hospital births in Halland was only 26% but in 1946 a total of 90% of all deliveries were made in one of the three hospitals (Halmstad, Varberg, Falkenberg).[29] The percentage of hospital births among children with mothers residing in Landskrona and the five rural parishes included in SEDD, was high during the study period, and increased from 87% in 1936 to 99% in 1946, with deliveries taking place primarily in the hospital of Landskrona, but also some in Lund and Helsingborg. When births from HBS and SBS took place at hospitals, a selection bias might be present in relation to home deliveries. The Halmstad and Landskrona maternity wards had only 14 and 16 beds, respectively. The mean length of hospital stay for a woman following normal delivery was 10 d, and given the increasing trend of hospital versus home deliveries, delivery wards were described as being highly overcrowded.

In addition to different care received at delivery, smoking patterns are of great importance for pregnancy outcomes and could differ between regions.[30] Finally, conditions during childhood may also have changed and some indications exist of detrimental trends for increasing obesity and insulin resistance in children of Halland today, as followed longitudinally.

Conclusion

The population of Halland has higher life expectancy and lower rates of cardiovascular disease mortality than the rest of Sweden and in this study we considered size at birth as possible determinant of such patterns. In conclusion, we report historical mean BW and birth length in HBS that was higher than in SBS and in other comparative areas, and a lower proportion of LBW and SGA babies in HBS than in SBS. However, there is no indication that the mean BW is higher in Halland today, in fact it is lower than in some other counties in mid-Sweden. This could reflect a more favorable historical situation in the past (birth cohorts) that has now changed for a more equal pattern. We show that the increased longevity of Halland may be a result of more favorable early life conditions in the past, observed here through greater size at birth relative to other historical cohorts, but given that such differences do not exist for more contemporary cohorts, life expectancy in Halland could be expected to gradually become more similar to the rest of Sweden.

Supplementary materials. For supplementary material for this article, please visit https://doi.org/10.1017/S2040174421000684

Acknowledgements. We thank Linda Johnson, MD, PhD, for valuable comments on the manuscript. We are also grateful to Claes Ignell, MD, PhD, for assistance in calculating small for gestational age.

Financial support. This study was supported by the Research Council of Sweden with a grant to PMN. LQ is grateful for research funding from FORTE (2017-00866) and from the Swedish Foundation for the Humanities and Social Sciences (RJ – research program 'Landskrona Population Study'), and for funding received for the digitization of Scanian hospital birth records from the Crafoord Foundation and the Ebbe Kock Foundation.

Conflict of interest. None.

Ethical standards. The Scanian Birth Study (SBS), as part of the Scanian Economic Demographic Database (SEDD), was approved by the Swedish Regional Ethics Committee in Lund (2010/2011, 'Ekonomisk demografi i ett flergenerationsperspektiv'). The Halmstad Birth Study (HBS), with no follow-up, was a historical cohort for which no ethical permission was needed.

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