JP Journal of Biostatistics
Volume 9, Number 2, 2013, Pages 105-118
Published Online: July 2013
Available online at http://pphmj.com/journals/jpb.htm
Published by Pushpa Publishing House, Allahabad, INDIA

FACTORS INFLUENCING BIRTH WEIGHT ON THE ÅLAND ISLANDS (FINLAND)

Johan Fellman[1,2,*] **and Aldur W. Eriksson**[1]

[1]Department of Genetic Epidemiology
Folkhälsan Institute of Genetics
Helsinki, Finland
e-mail: fellman@hanken.fi

[2]Hanken School of Economics
Helsinki, Finland

Abstract

Background. The distribution of birth weights has been extensively investigated. A common result of these studies is that the distributions differ from the Gaussian. A standard attempt has been to split the distribution into two components: a main distribution assumed to be normal and the other a small correction component. Studies have also shown an association between the distribution of birth weights and gestation age.

Methods and results. We consider data from the Åland Islands (Finland) for the period 1885-1998. The birth rate showed significant seasonality, having two peaks, one from March to May and the other from July to September, but only slightly significant seasonality in the birth weights was obtained. We observed significant correlations between birth weight and year of birth, sex of the newborn and type of maternity (single or multiple), condition of the infant (live or

Keywords and phrases: maternal age, sex, type of birth, seasonality, regional variation, temporal trends, regression analysis.

*Corresponding author

Received June 2, 2013

stillborn), maternal age and marital status of the mother. We built a multiple regression model and included time, maternal age, sex of the newborn and type of maternity as influential regressors. We also included regional grouping and found significant regional variations in birth weight. Marital status of the mother and condition of the infant at birth (live or stillborn) had too many missing values for inclusion in the regression model, but the effects of these factors have been analysed separately. The association between birth weight and gestation age was also explored.

Discussion. Comparisons with birth weights presented in data sets from other populations were also performed.

Introduction

Numerous scientists have studied the distribution of birth weights (e.g. [1-10]). The data presented in the literature are usually obtained from such large populations that the studies can be based on annual data or data for very short periods, and consequently, temporal trends were ignored. Scientists often also ignored sex differences in birth weights. In our studies, we have noted that differences between male and female birth weights are large enough that the sex of the infants should be considered. Seasonality in birth rates is commonly accepted (for references, see [11]). However, in the literature disagreement exists about seasonality in birth weights ([12]). Our data enable studies of the effect of such influential factors as year and season (month) of birth, maternal age in years, sex of the newborn, type of birth (single or multiple), marital status of the mother, parity, condition of the child at birth (live or stillborn) and to some extent gestation age.

Materials and Methods

Material. Our birth data are derived from official available birth certificates from the Åland Islands (cf. Figure 1 and [13]) for over one century (1885-1998), and *i.a*. temporal trends can be considered. From 1921 onwards, Åland has been a county of its own and the number of births has been officially registered. Åland was earlier a part of the county of Turku and Pori. For the period 1885-1920, we have estimated the number of births from

[14]. The total number of births on Åland during the period 1885-1998 was estimated to be about 46,940. Our data, consisting of 19,198 births and comprise ca. 41% of all births on Åland for this period.

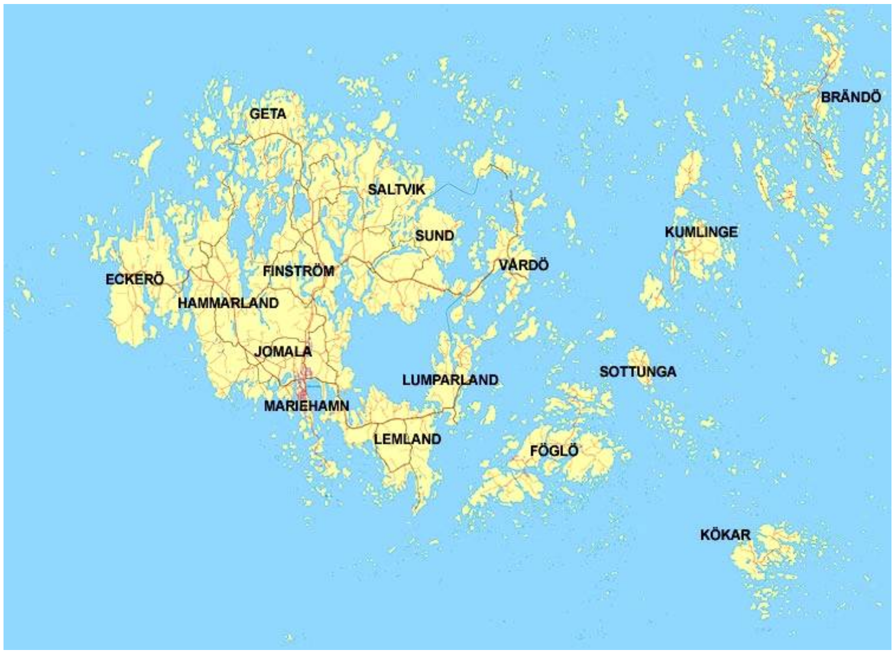

Figure 1. Map of the Åland Islands with the 16 parishes.

On the birth certificates, much information could be registered, but the long period and the large number of midwives working in 16 different parishes resulted in missing values, and the quality of the completed certificates varies. In general, we have ignored the missing values and have not assumed that they correspond to the most common values of the variable (married mothers, single births, etc.). Up to the turn of the 19th century, the Russian pound was commonly used. This pound equals 409.5 grams, and we have transformed all weights registered in pounds to grams. The registered weights were mainly given to an accuracy of 0.5 pound, corresponding to ca. 200 grams. This inaccuracy may influence the exactness of the results obtained before World War I. We estimate that when grams were used the accuracy was within 50 grams.

Methods. In this study, the Åland Islands are subdivided into 13 regions according to the 16 parishes (Figure 1). Temporarily the data set of birth weights in Åland in 1885-1998 is heterogeneously distributed. For the periods 1921-1940, 1981-1990 and 1991-1998, the observations are sparse. Special attention is also paid to the seasonality of birth rates and weights. Our data contain information about presumptive influential factors, and consequently, we can study their effect. The main factors in our study are year of birth, maternal age in years, sex of the newborn and type of birth. These factors are so well-documented that their influence can be simultaneously analysed. Additional factors are the marital status of the mother, parity, condition of the child at birth and gestation age, but these have numerous missing values. The effects of these factors are analysed separately. If all variables had been included in the general regression model, the smallest set of regressor values would define the acceptable number of observations and marked reductions in the number of observations would be noted, reducing the reliability of the results.

Results

Eriksson et al. [11] noted during 1653-1950 a marked temporal decrease in seasonality of births. Especially for the period 1901-1950, the seasonality had almost totally disappeared. The seasonality in the birth rate is statistically significant showing two peaks, one in March to May and another in July to September. We observed significant seasonality at $\chi^2 = 26.9$ with 11 degrees of freedom and $P < 0.01$.

The seasonality of the monthly mean birth weights is presented in Figure 2. Among male infants, maxima were observed in November (3636 grams) and December (3635 grams) and minima in March and June (3563 grams). Among female infants, a maximum was found in March (3505 grams) and a minimum in June (3423 grams). The corresponding ranges in monthly mean birth weights were 72.5 grams for males and 82.3 grams for females. When we applied one-way analysis of variance (ANOVA), we could almost totally ignore the seasonality in birth weight. For all births and for female births, no significant seasonality was detected. However, for males we found a slight significance $\left(F(11, 9779) = 1.87,\ P < 0.05\right)$.

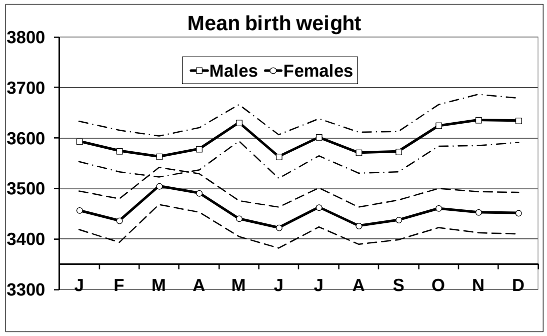

Figure 2. Seasonality in mean birth weights among males and females. The seasonality is slightly significant only for males $\left(F(11, 9779) = 1.87,\ P < 0.05\right)$. The accuracy of the monthly estimates is indicated by 95% confidence bands.

We observed in Table 1 significant correlations between birth weight and year of birth, maternal age in years, sex of the newborn, type of birth, condition of the infant and marital status of the mother, but not between birth weight and month of birth or parity.

Table 1. Correlation matrix for variables. Only statistically significant correlation coefficients are included. If $P < 0.001$, the coefficients are bolded. The correlation coefficients are based on varying numbers of observation pairs. These numbers are therefore also included

	n	**Weight**	**Year of birth**	**Maternal age**	**Sex of infant**	**Type of birth**	**Condition**	**Marital status**
Weight			**–0.107**	**0.138**	**–0.121**	**–0.244**	**–0.213**	**–0.060**
	18 972		18 971	18 639	18 937	18 614	10 352	10482
Year of birth		**–0.107**		**–0.258**		**–0.034**	**0.042**	**–0.104**
	19 197	18971		18 860		18 826	10 506	10679
Maternal age		**0.138**	**–0.258**			**0.046**	**0.034**	**–0.169**
	18 860	18639	18 860			18 492	10 187	10379
Sex of infant		**–0.121**					–0.019	
	19 090	18937					10 477	
Type of birth		**–0.244**	**–0.034**	**0.046**			**0.090**	
	18 827	18614	18 826	18 492			10 225	
Condition		**–0.213**	**0.042**	**0.034**	–0.019	**0.090**		
	10 507	10352	10 506	10 187	10 477	10 225		
Marital status		**–0.060**	**–0.104**	**–0.169**				
	10 680	10482	10 679	10 379				

We performed a stepwise regression procedure with the regressors year of birth, maternal age, sex of the newborn, type of birth and the 16 parishes on Åland grouped into 13 regions. We ignored the variables with a large number of missing values (condition of the infant and marital status of mother). The optimal regression model is based on 18,252 observations. Table 2 presents the model containing statistically significant parameter estimates. Year of birth, maternal age, sex of newborn and type of maternity are included as influential factors. In addition, the regions included show significant deviations in the birth weights. The estimates indicate the average effects of the factors. Birth weight decreases on average by about 1.6 grams per annum and increases by 11.7 grams when maternal age increases by one year. Furthermore, boys are about 140 grams heavier than girls, and singletons are 905 grams heavier than children born in multiple maternities.

Table 2. Significant parameters in the regression model. The total number of observations is 18 252. The estimates are interpreted in more detail in the text

Regressors	β	SE	*t*	*P* <
(Constant)	6200.276	284.824	21.769	0.001
Year of birth	–1.538	0.145	-10.637	0.001
Maternal age	11.731	0.668	17.555	0.001
Sex	–139.965	8.080	-17.323	0.001
Type of birth	–904.834	25.278	-35.795	0.001
Brändö-Kumlinge	155.445	26.257	5.920	0.001
Föglö-Sottunga	137.024	22.422	6.111	0.001
Geta	160.824	19.389	8.295	0.001
Hammarland	195.969	17.816	11.000	0.001
Jomala	76.647	12.747	6.013	0.001
Lemland-Lumparland	126.711	19.318	6.559	0.001
Mariehamn	64.098	11.447	5.600	0.001
Saltvik	77.530	17.347	4.469	0.001

The goodness of fit in the regression model obtained is rather poor ($\bar{R}^2 = 0.111$). Consequently, the residual analysis continued to show strong variations. When normality is tested for the residuals of the regression model, one obtains the Kolmogorov-Smirnov test value $K = 3.840$ with $P < 0.001$. Compared with the corresponding test value for the initial birth weights to be presented by Fellman and Eriksson elsewhere, the discrepancy from the Gaussian is reduced, but the residuals still differ markedly from normal distribution. The slightness in the improvement is obviously a consequence of the inadequate goodness of fit of the regression model.

Figure 3 shows the temporal trends in the birth weight for male and female infants on the Åland Islands in 1885-1998. The figure includes 95% confidence intervals. The birth weights decrease monotonically to a trough in the 1960s, and after which the weights increase. The trend lines in the figure are 3rd degree polynomials.

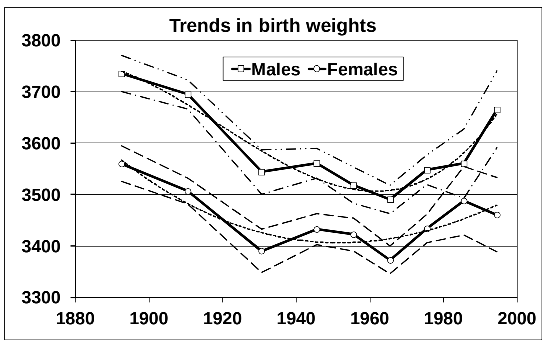

Figure 3. Temporal trends in mean birth weights for males and females on the Åland Islands in 1885-1998. Note the marked troughs in the 1960s. We have included 95% confidence bands, and the trend lines are 3rd degree polynomials.

In Table 3, we present the mean birth weights according to time and region. Both temporal and regional variations occur. The regional and temporal variations are statistically significant; $F(8, 18963) = 38.72$ and $P < 0.001$ for the temporal variations and $F(13, 18958) = 21.80$ and $P < 0.001$ for the regional variations.

Of the subperiods, 1921-1940, 1971-1980 and 1981-1990 show no significant regional differences. The remainder has regional differences that are statistically significant. If one notes that there are relatively few observations in 1921-1940, one can recognize temporally slightly decreasing regional variations. The trough obtained in the 1960s and presented in Figure 3 is also discernible in Table 3. Temporal variations in the birth weights cannot be identified in the parish groups of Finström, Föglö-Sottunga, Kumlinge-Brändö, Kökar, Sund and Vårdö. These parishes, with the exception of Finström, are mainly in the surrounding archipelago. Strong significant temporal variation is observed in the parishes of Eckerö, Hammarland, Jomala, Lemland-Lumparland, Mariehamn and Saltvik. These are mainly located on the Main Island (cf. Figure 1).

Table 3. Mean birth weights grouped according to region and time. The last column presents the tests of the temporal trends for different regions, and the last row the tests of the regional differences for different subperiods. Significant test values are bolded. The tests show both regional and temporal differences

Parish	1885-1900	1901-20	1921-40	1941-50	1951-60	1961-70	1971-80	1981-90	1991-98	Total	F (temp)
Eckerö	3706	3269	3459	3610	3548	3477	3393	3619	3662	3438	**20.7**
Finström	3485	3469	3412	3485	3421	3443	3441	3495	3513	3463	0.9
Föglö-Sottunga	3150	3682	3425	3636	3557	3496	3540	3504	3640	3587	1.5
Geta	3635	3761	3632	3510	3551	3494	3539	3566	3519	3626	**4.3**
Hammarland	3953	3926	3383	3482	3476	3414	3460	3612	. .	3685	**21.4**
Jomala	3662	3645	3446	3469	3426	3421	3522	3561	. .	3539	**12.1**
Kumlinge-Brändö	3732	3722	3471	3572	3577	3677	3574	3546	3549	3646	1.9
Kökar	. .	3475	3523	3729	3677	3477	3423	. .	. .	3510	**2.7**
Lemland-Lumparland	3867	3774	3407	3493	3383	3489	3504	3539	. .	3603	**12.9**
Mariehamn	3760	3674	3422	3441	3444	3411	3504	3501	. .	3476	**15.6**
Saltvik	3430	3850	3471	3544	3412	3389	3509	3491	. .	3544	**16.6**
Sund	3479	3527	3277	3478	3412	3514	3413	3496	. .	3497	0.8
Vårdö	3531	3458	3400	3428	3600	3455	3386	. .	. .	3478	0.5
Other	3210	3218	3380	3412	3925	3150	3223	3222	3625	3385	1.5
Total	3651	3599	3470	3497	3470	3435	3494	3524	3560	3526	**38.7**
F (regional)	**14.0**	**31.6**	**1.9**	**2.5**	**2.5**	**2.3**	0.9	0.3	1.1	**19.0**	

Discussion

General findings. The distribution of birth weight has been studied from different points of view and has been of wide interest among scientists because perinatal and neonatal mortality rates vary in different birth weight groups. A common result of these studies is that the distributions differ from the Gaussian. A standard attempt has been to split the distribution into two components. The main distribution can be assumed to be normal and the other has a small correction component.

Seasonality. Seasonality in birth rates is commonly accepted (for references, see [11]). However, in the literature disagreement exists about seasonality in birth weights. Recently, Chodick et al. [12] analysed the literature concerning the seasonality in birth weight. They discussed both developed and undeveloped countries. They also paid attention to the global pattern. They classified the countries according to latitude. Latitude had an influence, but after grouping according to latitude a marked heterogeneity remained. Of special interest in their study are the results obtained for latitudes over 55°N. The latitude for Åland is between 55° and 60°N. According to [12], winter is the low birth weight period. High birth weight periods could be found during spring, summer or autumn. By contrast, based on our results, males show a maximum mean birth weight in winter (November and December) and a minimum in spring (March) and summer (June). For females, we noted a maximum in spring (March) and a minimum in summer (June). However, seasonality was significant, albeit only slightly, for males alone.

Birth weight and gestation age. Milner and Richards [1] analysed birth weight by gestational age. They considered single babies and the distribution of birth weight was normal at a gestational age above 36 weeks, but was skewed or bimodal in preterm infants. They identified gestation time to be an important factor for the distribution of birth weight. They assumed that the distribution of birth weight can be considered as a mixture of two normal distributions with different means but the same variance. Using this model, they identified that for premature infants the differences between the means are marked, but the difference decreases towards zero with increasing gestation age, reaching zero when the age of 36 weeks is attained. In our data set, registered information concerning gestation age was very sparse, yielding a data set consisting of 547 births of normal gestation age. When we divided the data set according to sex of the infants, the normal distributions could be accepted.

Birth weight and future physical conditions. Erkkola et al. [3] stated that while the neonatal mortality rates are indicators of general obstetric and neonatal care rates in different weight groups, they are also extremely important for obstetricians when the risk of intrauterine environment versus that of pregnancy termination in any particular case is considered. Umbach and Wilcox [6] proposed a technique for measuring certain features of birth weight distributions useful for epidemiologists: the mean and variance of the predominant distribution, the proportion of births in the high and low birth weight residual distributions and the boundary support for these residual distributions. Gage [8] and [9] indicated that birth cohorts are composed of two or more subpopulations heterogeneous with respect to infant mortality. Fellman and Eriksson intend to present elsewhere an association between birth weight and life-span among Finnish triplets.

Effect of environmental factors. Our study has shown that numerous influential factors exist. We have especially identified temporal trends and regional variations and significant effects of maternal age, sex of the infant and type of maternity (single or multiple). Other factors correlated with birth weight are marital status of the mother and condition of the child (live or stillborn). However, these were not represented well enough in our data set for inclusion in the model. In addition, the regression model obtained had a poor goodness of fit.

Conclusions. The distribution of birth weight is influenced by many factors and is a mixture of several distributions, including a main Gaussian one. Consequently, the total distribution cannot be assumed to be Gaussian. Despite this and in agreement with Box [15], our opinion is that the Gaussian distribution is, in general, a useable model. For small data sets, significant discrepancies cannot be found, and for large data sets, although the discrepancies are significant, the pattern of the distribution is close to the normal one. To date, no factor has convincingly been identified as the most influential cause of these discrepancies.

Acknowledgements

This study was in part supported by grants from Finska Läkaresällskapet and the foundations “Magnus Ehrnrooths Stiftelse” and “Liv och Hälsa”.

References

[1] R. D. G. Milner and B. Richards, An analysis of birth weight by gestational age of infants born in England and Wales, 1967 to 1971, Int. J. Obstet. Gynaecol. 81(12) (1974), 956-967.

[2] R. J. David, The quality and completeness of birthweight and gestational age data in computerized birth files, Am. J. Public Health 70(9) (1980), 964-973.

[3] R. Erkkola, P. Kero, A. Seppälä, M. Grönroos and L. Rauramo, Monitoring perinatal mortality by birth weight specific mortality rates, Int. J. Gynaecol. Obstet. 30 (1982), 231-235.

[4] A. J. Wilcox and I. T. Russell, Birthweight and perinatal mortality: I. On the frequency distribution of birthweight, Int. J. Epidemiology 12(3) (1983), 314-318.

[5] P. A. Buescher, K. P. Taylor, M. H. Davis and J. M. Bowling, The quality of the new birth certificate data: a validation study on North Carolina, Am. J. Public Health 83(8) (1993), 1163-1165.

[6] D. M. Umbach and A. J. Wilcox, A technique for measuring epidemiologically useful features of birthweight distributions, Stat. Med. 15 (1996), 1333-1348.

[7] T. Forsén, Early growth and adult disease, Programming of coronary heart disease, Type 2 diabetes and hypertension by fetal and childhood growth, Thesis, University of Helsinki, 2000.

[8] T. B. Gage, Birth-weight-specific infant and neonatal mortality: effects of heterogeneity in the birth cohort, Human Biology 74(2) (2002), 165-184.

[9] T. B. Gage, Update to “Birth-weight-specific infant and neonatal mortality: effects of heterogeneity in the birth cohort,” Reprinted in Human Biology 81(5-6), (2009), 753-772. Human Biology 81(5-6):773-776. Gynaecology of the British Commonwealth 81 (2009), 956-967.

[10] G. M. D. D. Colletto, C. A. M. Segre and S. T. R. C. Rielli, Influence of socioeconomic levels on birthweight of twins and singletons, Twin Research 7(2) (2004), 128-133.

[11] A. W. Eriksson, J. Fellman, L. Jorde and K. Pitkänen, Temporal, seasonal and regional differences in births and deaths in Åland (Finland), Human Biology 80 (2008), 125-140.

[12] G. Chodick, S. Flash, Y. Deoitch and V. Sholev, Seasonality in birth weight: review of global patterns and potential causes, Human Biology 81 (2009), 463-477.

[13] Map of Åland Islands.
http://0.tqn.com/d/goscandinavia/1/0/a/4/-/-/aland-map-large.jpg

[14] A. W. Eriksson, Human twinning in and around the Åland Islands, Commentat. Biol. 64 (1973), 1-159.

[15] G. E. P. Box, Science and statistics, J. Amer. Statist. Assoc. 71 (1976), 573-580.