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BIRTH WEIGHT DISTRIBUTIONS ON THE ÅLAND ISLANDS (FINLAND)

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Abstract

A long series of papers has investigated the distribution of birth weights. A common result is that the distributions differ from the Gaussian. Consequently, an attempt has been made to split the distribution into two components: a predominant Gaussian distribution and an unspecified "residual" distribution. Earlier studies have shown an association between the distribution of birth weights and gestation age. We consider data from the Åland Islands (Finland) for the period 1885-1998. The distribution of birth weight is evaluated and discrepancies from normal distribution are confirmed and discussed. Factors influencing birth weight are identified. The association between birth weight and gestation age is also explored. Comparisons

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with birth weights presented in data sets from other populations are made.

Introduction

Numerous scientists have studied the distribution of birth weights [1-10]. Birth weight data are approximately normally distributed. The data presented in the literature are usually obtained from sufficiently large populations to justify these studies being based on annual data or data over very short periods and ignoring temporal trends. Scientists have also often 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.

Materials and Methods

Material. Our birth data are derived from official available birth certificates from the Åland Islands in Finland for over one century (1885-1998), and i.a. temporal trends can be considered (cf. Figure 1, and [11]). From 1921 onwards, Åland has been a separate county and the number of births has been officially registered. Åland was earlier merged with the county of Turku and Pori. For the period 1885-1920, we have estimated the total number of births from [12]. The number of births on Åland during 1885-1998 was estimated to be about 46 940. Our data consist of 19 198 births, being ca. 41% of all births on Åland for this period. Up to the turn of the century 1800/1900, the Russian pound was commonly used as a measure of weight. 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. Temporal and regional variations in the birth weight data are presented in [13]. In that study, we also considered the association between birth weight and such influential variables as year of birth, region, type of birth (single and multiple), sex of the infant, condition of the infant (live and stillborn), maternal age and marital status of the mother.

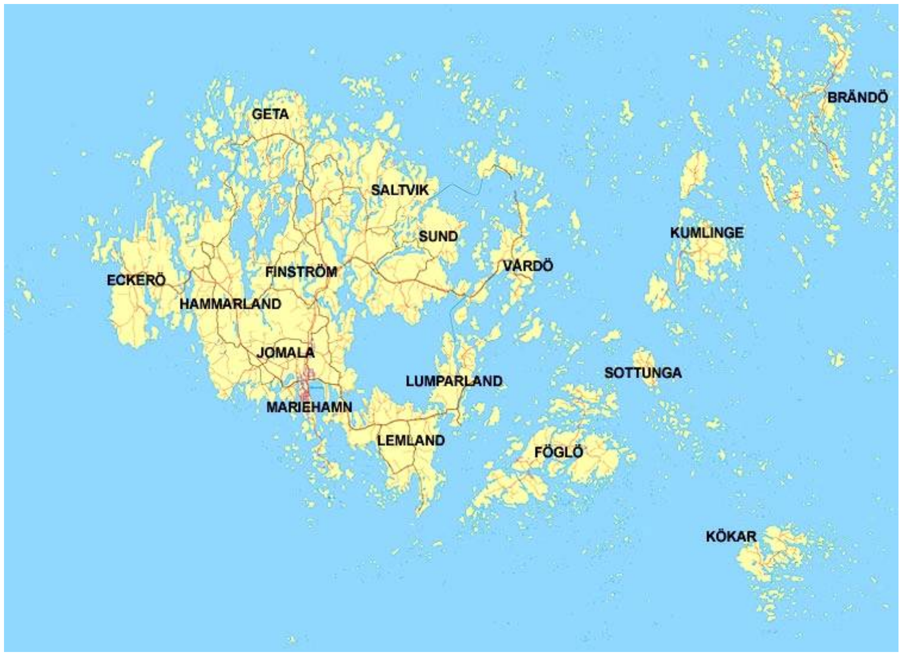

Figure 1. Map of the Åland Islands with the 16 parishes [11].

Methods. Recently, Lindsay and Liu [14] discussed i.a. how to test the normal distribution by QQ (quantile-quantile) plots. In a two-dimensional coordinate system, the quantiles (Q_W) of the observed variable (birth weight in this case) are distributed over the horizontal axis and the quantiles (Q_N) of the normal variable over the vertical axis. If the scatter points (Q_W, Q_N) are linearly distributed, then the observed variable can be assumed to be normal. Lindsay and Liu used the Kolmogorov-Smirnov goodness-of-fit test to evaluate the normality assumption. The test statistic is the greatest absolute vertical distance, $K = \sqrt{n} \sup_x |F_n(x) - F(x)|$, where $F_n(x)$ is the observed distribution function and $F(x)$ the hypothetical normal distribution when the parameters of the normal distribution are estimated from the sample. The critical values for $P = 0.05$, $P = 0.01$ and $P = 0.001$ are $K_{0.05} = 1.358$, $K_{0.01} = 1.628$ and $K_{0.001} = 1.949$, respectively. Lindsay and Liu stressed that for large samples, the normality is rejected, although the QQ plot looks quite normal in the centre.

Results

According to Figure 2, our weight data for male, female and all births are distributed approximately as normal distributions. The QQ plot is rather linear, but discrepancies from linearity are presented at both ends. These discrepancies are statistically significant and indicate that the tails of the birth weight distribution are thicker than the tails of a normal distribution. The central estimates and the test results are given in Table 1. While the discrepancy from the normal distribution is reduced when the data are split into male and female data sets, the discrepancies from the normal distribution are still marked. In general, our findings are in good agreement with earlier results that the distribution of birth weight is mainly normal, but the tails are contaminated with disturbing observations.

Table 1. Central estimates and the Kolmogorov-Smirnov test result for the distributions of male, female and all births. All test results are strongly significant

Data set	n	Mean	SD	K-S test
Males	9 741	3594.2	596.9	5.386
Females	9 196	3454.2	549.6	5.856
All	18 972	3525.5	579.6	7.678

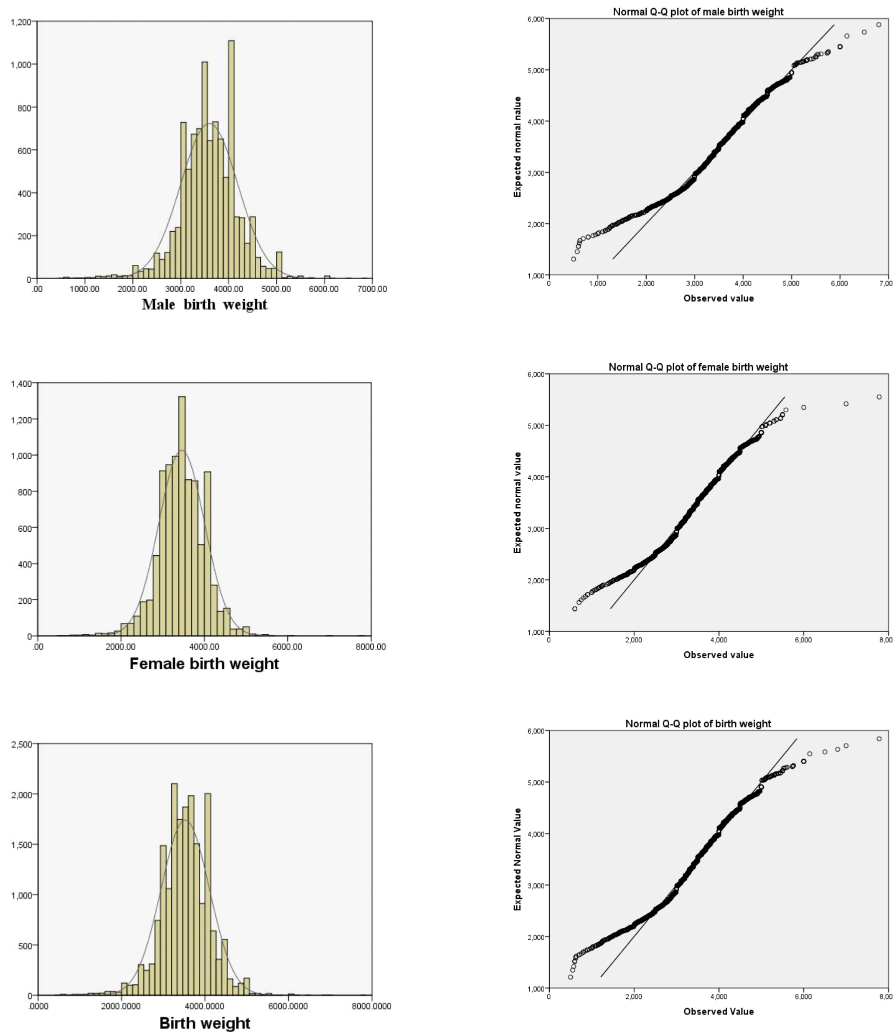

Figure 2. Histogram and QQ plot of the observed birth weights for males $(n = 9741)$, females $(n = 9196)$ and all births $(n = 18\,972)$. Note the discrepancies from normal distribution (from linearity in the QQ plot) in the upper and lower tails, indicating two heavy tails. The Kolmogorov-Smirnov test results are $K = 5.386$ for males, $K = 5.856$ for females and $K = 7.678$ for all births.

In earlier studies, gestation time has been identified as an important factor in birth weight distribution [1]. In our data set, registered, explicit information concerning normal gestation age was very sparse. Our subdata with registered normal age consisted of 547 births. For this subset, we obtained $K = 1.581$ and the test value $P < 0.05$, which is marginally significant. However, when we divided the data set into boys and girls, the K values were reduced and lost significance. For 258 male infants, we obtained $K = 1.339$ and for 289 female infants $K = 1.300$. Consequently, for both males and females with normal gestation ages, the distributions can be accepted as normal.

Fellman and Eriksson [13] performed a stepwise regression procedure with the regressors year of birth, maternal age, sex of newborn, type of birth and the 16 parishes on Åland grouped into 13 regions. 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 birth are included as influential factors. In addition, the regions included show significant deviations.

Table 2. Significant parameters in the regression model obtained by Fellman and Eriksson [13]. The total number of observations is 18 252. The estimates are interpreted in more detail in the text

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

The goodness of fit of the model obtained is rather poor $(\overline{R}^2 = 0.111)$. 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 (see Table 1 and Figure 2), the discrepancy from the Gaussian is reduced, but the residuals still differ markedly from normal distribution (cf. Figure 3). The negligible improvement is obviously a consequence of the inadequate goodness of fit of the regression model.

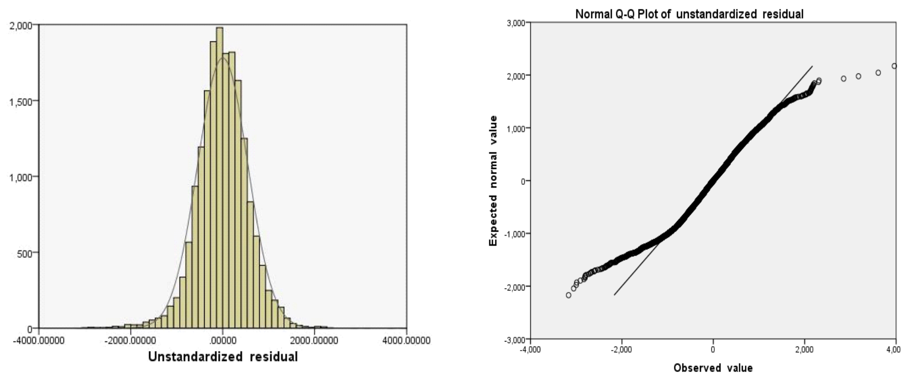

Figure 3. Histogram and QQ plot of the residuals $(n = 18\ 252)$ corresponding to the optimal regression model [13]. Note that the distribution has heavier tails than the corresponding normal distribution. One obtains the Kolmogorov-Smirnov test value $K = 3.840$ with $P < 0.001$. Compared with the corresponding test value for the initial birth weights (see Table 1), the discrepancy from the Gaussian is reduced, but the residuals still differ markedly from normal distribution.

Discussion

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 opinion is that the birth weight distribution is close to the Gaussian, but with some notable discrepancies. A standard attempt has been to split the distribution into two components. The main one can be assumed to be normal and the other one is a small correction component. Wilcox and Russell [4] discussed the frequency distribution of birth weight and identified a predominant Gaussian distribution and a residual distribution, with the complete distribution being characterized by three parameters: the mean and standard deviation of the Gaussian component and the proportions of births in the residual distribution. Buescher et al. [5] studied new birth certificate data and analysed a sample consisting of 395 births in November 1989 in North Carolina. They concluded that many of the new birth certificate items support valid aggregate analyses for maternal and child health research and evaluation. Umbach and Wilcox [6] assumed that the distribution of birth weight is a Gaussian distribution contaminated within the tails by an unspecified "residual" distribution. They 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] examined birth weight-specific infant mortality using a parametric mixture of logistic regressions. His results indicated that birth cohorts are composed of two or more subpopulations that are heterogeneous with respect to infant mortality. Later, Gage [9] published an update of [8]. Besides a general literature review, he presented his recent results. He had especially expanded his analyses to include the full Maximum Likelihood method. He simultaneously fitted the regression and the mixture models. Furthermore, he stressed that for all births weights, the birth weight-specific infant mortality was higher for the main "normal" population than for the "compromised" population. Despite this, due to the different weight distributions, the "compromised" population had a higher overall infant mortality. Coletto et al. [10] analysed the influence of socio-economic levels on birth weight. As an indicator of socio-economic levels, they used three different hospitals. Fellman and Eriksson [13] built multiple regression models for birth weight.

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 noted 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 of 534 births of normal gestation age. When we considered sex differences in birth weights and divided the data set according to sex, 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 considering the risk of intrauterine environment versus that of pregnancy termination. Fellman and Eriksson [15] analysed birth weight among Finnish triplets and found a strong association between it and life-span.

Effect of the accuracy of data sets. David [2] analysed omissions and inaccuracies in computerized birth files compiled by the State of North Carolina for the period 1975-1977. Recorded birth weight showed skewing from the normal distribution. Lindsey and Liu [14] also found an interesting result when they studied height data among 2603 adult females. When the data were registered in centimeters with a one decimal accuracy, the authors obtained no significant deviation from the normal distribution. However, when they rounded the data to integer values, the Kolmogorov-Smirnov test yielded a rejection of normality. Consequently, introduced rounding errors played a role in contaminating the distribution. This finding corresponds well to Edouard and Senthilselvan's [16] interpretation that last digit preference caused observer errors in birth weight registers.

When Lindsey and Liu [14] evaluated assessment tools in their study of models, they had as a starting point Box' [17] statement that all models are wrong, but some are useful. Box stated that since the models are wrong, the scientist cannot obtain a "correct" one by excessive elaboration. Furthermore, he stressed that in nature there are no normal distributions, no straight lines, yet with normal and linear assumptions, known to be false, the scientist can often derive results that match, to a useful approximation, those found in the real world. Lindsey and Liu emphasized that for large data sets, the data may be described well by a model assumed to have a normal distribution without saying that the data are *exactly* normal. This means that normal distribution can often be accepted and used as an approximate model.

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 [17], 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.

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