Twin Research and Human Genetics
Volume 16 ▮ Number 3 ▮ pp. 739–742 ▮ © The Authors 2013 ▮ doi:10.1017/thg.2013.14

Birth Weight Among Single and Multiple Births on the Åland Islands

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Numerous papers have investigated the distribution of birth weight. This interest arises from the association between birth weight and the future health condition of the child. Birth weight distribution commonly differs slightly from the Gaussian distribution. The distribution is typically split into two components: a predominant Gaussian distribution and an unspecified 'residual' distribution. In this study, we consider birth weight data from the Åland Islands (Finland) for the period 1885–1998. We compare birth weight between males and females and among singletons and twins. Our study confirms that, on average, birth weight was highest among singletons, medium among twins, and lowest among triplets. A marked difference in the mean birth weight between singleton males and females was found. For singletons, the distribution of birth weight differed significantly from the normal distribution, but for twins the normal distribution held.

■ **Keywords:** normal distribution, Kolmogorov–Smirnov test, singletons, twins, triplets

In a long series of papers, scientists have studied the distribution of birth weight. The interest in birth weight arises from its central role in the future health condition of a child. Recorded birth weight data showed skewing from the normal distribution. Erkkola et al. (1982) compared perinatal and neonatal mortality rates in different birth weight groups. They stated that while the neonatal mortality rates are indicators of general obstetrical and neonatal care, rates in different weight groups are extremely important for obstetricians. Wilcox and Russell (1983) discussed the frequency distribution of birth weight and identified a predominant Gaussian distribution and a residual distribution, with the complete distribution characterized by three parameters: the mean and standard deviation of the Gaussian component and the proportions of births in the residual distribution. Umbach and Wilcox (1996) 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 for 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.

Yokoyama et al. (2011) recently analyzed size at birth and growth trends among Japanese triplets. They noted that triplets are small at birth and their height deficit relative to the general population in Japan remained between 2% and 5% until 12 years of age.

In our birth weight data set from the Åland Islands (1885–1998), the maternity types, that is, singletons, twins, and triplets, were registered and these data are used here. In fact, in this data set, additional variables were also registered, but their effect is discussed elsewhere (Eriksson & Fellman, 2013). Fellman and Eriksson (2013) compare the birth weight among Finnish triplets with their future survival.

Materials and Methods

Material

Our birth data were collected from official birth certificates from the Åland Islands for more than one century (1885–1998). From 1921 onward, Åland has been a county of its own and the number of births has been officially registered. Earlier, Åland was a part of the county of Turku and Pori. For the period 1885–1920, we estimated the total number of births from Eriksson (1973). The total registered number of births during 1885–1998 was about 46,940. Our birth data

RECEIVED 15 November 2011; ACCEPTED 19 February 2013. First published online 18 March 2013.

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with known maternity type (single, twin, or triplet) consist of 18,821 births and, consequently, our data comprise about 40% of all births on Åland for this period. On the birth certificates, much information could be registered, but the long period and the large number of midwives working in different parishes resulted in missing values, and the quality of the completed certificates varied. For some births (about 200), the weights were missing. During the 19th century, some birth weights were registered in Russian pounds. We have transformed these weights to grams using the conversion of one pound to 409.5 gram. A detailed presentation of the data set is presented in Eriksson and Fellman (2013).

Statistical Methods

Recently, Lindsay and Liu (2009) discussed inter alia how to test the normal distribution by quantile–quantile (QQ) plots. In a two-dimensional coordinate system, the quantiles (Q_W) of the observed variable (birth weight in this study) are distributed over the horizontal axis, and the quantiles (Q_N) of the normal variable, when the parameters of the normal distribution are estimated from the sample, are distributed 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 test the normality assumption. The test statistic is the greatest standardized absolute vertical distance $K = \sqrt{n}\, \underset{x}{sup}\, |F_n(x) - F(x)|$, where $F_n(x)$ is the observed distribution and $F(x)$ is the hypothetical normal distribution whose parameters are estimated from the sample. The critical values for K are $K_{0.05} = 1.358$, $K_{0.01} = 1.628$, and $K_{0.001} = 1.949$ for $p = .05$, .01, and .001, respectively. Lindsay and Liu (2009) stressed that for large samples the normality is rejected, although the QQ plot looks quite linear in the center. This finding is attributed to the Kolmogorov–Smirnov test measuring absolute deviations and therefore being more sensitive to discrepancies in the center than in the tails.

TABLE 1
Overview of the Åland Data Set

Type	Births	Males	Females	Maternities	Sex ratio	Rates
Singletons	18,323	9,385	8,938	18,323	105.0	
Twins	486	254	232	243	109.5	13.09
Triplets	12	7	5	4	140.0	21.54
Total	18,821	9,646	9,175	18,570	105.1	

Note: The rates are the twinning rate per 1,000 maternities and the triplet rate per 100,000 maternities. The Hellin-transformed rate is the squared root of the triplet rate, that is, 14.68 per 1,000.

TABLE 2
Birth Weight Data Grouped According to Sex and Type of Births on Åland, 1885–1998

Type	Mean	Number	*SD*	SE	Min	Max
Male singletons	3,617.8	9,304	572.4	5.93	575	6,800
Female singletons	3,469.9	8,819	533.7	5.68	550	7,781
Male twins	2,663.9	251	657.1	41.48	600	5,000
Female twins	2,705.2	224	600.1	40.10	1,020	4,600
Male triplets	2,214.3	7	679.9	256.98	1,400	3,450
Female triplets	2,340.0	5	451.6	201.96	1,700	2,775

Results

In our Åland series, the births are grouped according to maternity type and presented in Table 1. The data set consisted of 18,570 maternities including 18,323 singleton, 243 twin, and 4 triplet maternities. The twinning rate was 13.09 per 1,000, the triplet rate 21.54 per 100,000, and the Hellin-transformed triplet rate was 14.68 per 1,000.

Comparisons between the mean birth weight of both sexes for singletons, twins, and triplets in the Åland data are presented in Table 2. The ANOVA test yields

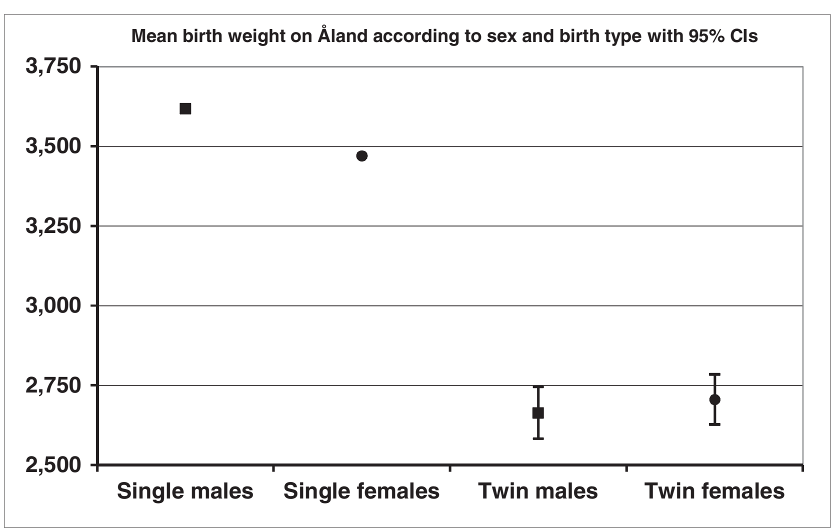

FIGURE 1
Mean birth weight for males and females among singletons and twins. For the twins, 95% confidence intervals are included.

https://doi.org/10.1017/thg.2013.14 Published online by Cambridge University Press

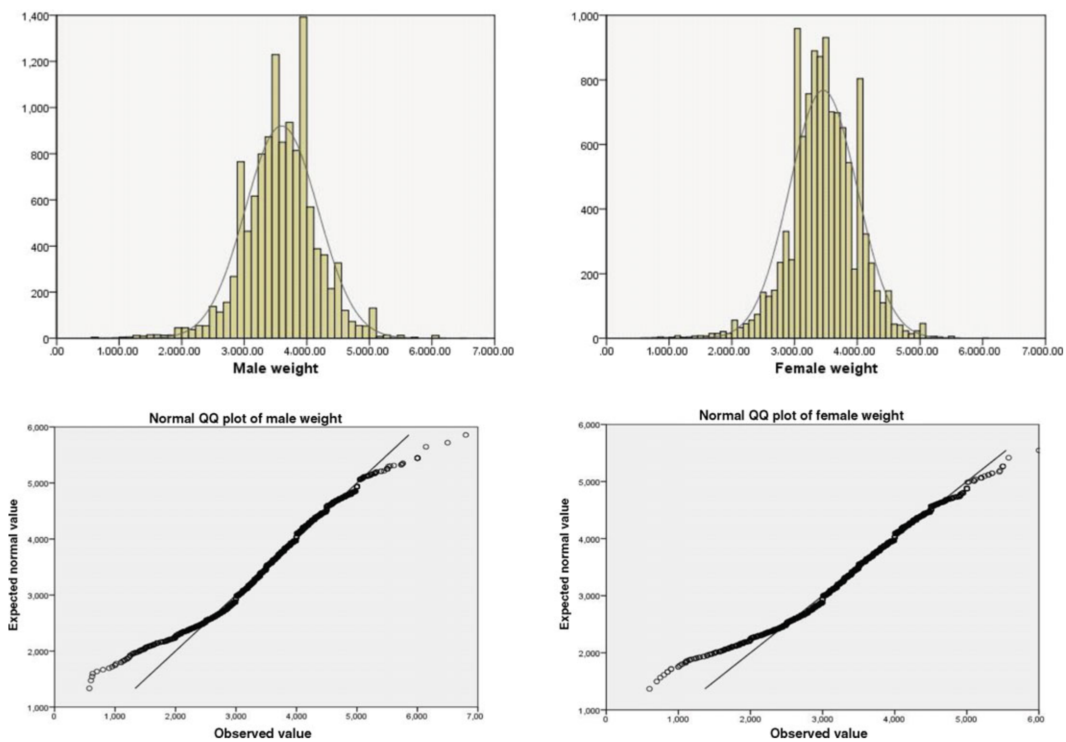

FIGURE 2

(Colour online) Birth weight among male (n = 9,304) and female (n = 8,819) singletons on Åland (1885–1998). The Kolmogorov–Smirnov tests yield significant deviations from the normal distribution ($K = 5.327, p < .001$ for males and $K = 5.435$, $p < .001$ among females). These deviations are apparent in the QQ plots (for details, see text).

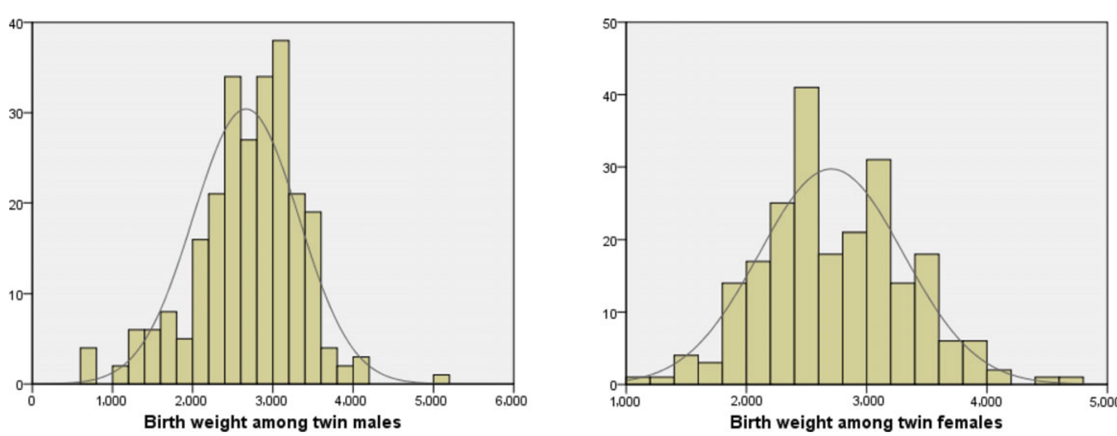

FIGURE 3

(Colour online) Birth weight among male (n = 251) and female (n = 224) twins on Åland (1885–1998). The Kolmogorov–Smirnov tests yield $K = 1.328$, $p > .05$ for males and $K = 1.134$, $p > .05$ for females, and the distributions can be assumed to be normal.

significant differences, $F(5, 18, 604) = 322.7; p < .001$. When we compared the mean birth weight between singleton males and females, we also obtained significant differences, $F(1, 18, 121) = 299.20; p < .001$, but when we compared the mean birth weight between twin males and females no significant differences were found. The mean birth weights for singletons and twins are presented in Figure 1. In the Åland data, there are only four triplet sets. Consequently, we did not apply an ANOVA test for the triplets, nor did we include them in Figure 1.

The distribution of birth weight has been a central topic in all birth weight studies. In the following, we study the distribution for single males and females and for twin males and females in the Åland data. The distributions of the birth weight among male (n = 9,304) and female (n = 8,819) singletons on Åland are presented in Figure 2. The

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Kolmogorov–Smirnov test yields $K = 5.327$, $p < .001$ for males and $K = 5.435$, $p < .001$ for females. Both tests indicate significant deviations from the normal distribution. These deviations can also be identified in the corresponding QQ plots, which are included in Figure 2.

For comparison, in Figure 3 we present the distribution of birth weight among male ($n = 251$) and female ($n = 224$) twins on Åland. The Kolmogorov–Smirnov test yields $K = 1.328$, $p > .05$ for males and $K = 1.134$, $p > .05$ for females, and the distributions can be assumed to be normal.

Discussion

Preliminary studies of the Åland birth data (Eriksson & Fellman, 2013) have indicated that several factors influence the birth weight distribution, but even after the elimination of these factors marked discrepancies remained when the residual distribution was compared with the Gaussian one. Among singletons, the grouping according to sex did not result in normal distributions. For twins, grouping according to sex yielded acceptable normal distributions.

Box (1976) stated that since all models are wrong, the scientist cannot obtain a 'correct' one by excessive elaboration. Furthermore, he stressed that in nature while normal distributions and straight lines do not exist, with normal and linear assumptions known to be false, one can often derive results that provide useful approximations of the real world. Consequently, following Box (1976) and Lindsay and Liu (2009), the distributions of birth weight found in our studies can be considered acceptable approximations of normal distributions.

Acknowledgments

This study was in part supported by grants from the Finnish Society of Sciences and Letters, Finska Läkaresällskapet, and the foundations Magnus Ehrnrooths Stiftelse, Ålands Kulturstiftelse, and Liv och Hälsa.

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