Department
of Health &
Social Care

Sex Ratios at Birth in Great Britain, 2012-16

Technical Appendices

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Contents

Introduction

1. This report provides a supplementary document to the main commentary section of the Sex ratios at birth in Great Britain publication 2012 to 2016. This document provides technical detail on the methodology and statistical tests used in order to assess whether or not there is evidence for sex selective abortions happening at scale within specific communities in Great Britain.

Source data

Ethnicity

2. Analysis on ethnicity is presented for England and Wales only. This is because the birth registration system in Scotland does not collect data on the ethnicity of the child. We therefore exclude Scotland from the sex birth ratio analysis for ethnicity of child.

3. Ethnicity data is presented by nine ethnic groups of the babies born in England and Wales, in line with the ethnic groupings used by the Office for National Statistics.

4. Information on ethnicity of the child is routinely collected from mothers as a part of the birth notification data from the NHS Number for Babies (NN4B) system within England and Wales. The ethnicity information included on the birth notification records are linked to the birth registrations; over 99% of birth registration records are successfully linked to their corresponding birth notification record each year.

Birth Registration Data and Country of Origin Data

5. Analysis is presented by country of origin of the mother for Great Britain.

6. The Office of National Statistics provided data for England and Wales for country of origin of mother and birth order using birth registration data. The registration of births in England and Wales is a service carried out by the Local Registration Service in England and Wales in partnership with the General Register Office.

7. The National Records of Scotland were used as the source data for Scottish births, by country of mother, and birth order.

Birth Order

8. The data on birth order relates to the first, second and third or later born child that a woman has had. There is also a category for where the birth order is unknown.

9. Information on previous children by birth order is only fully available for births from May 2012 in England and Wales and from January 2013 in Scotland. Prior to these time periods, there was no requirement for birth order data to be collected for children born outside of marriage. Therefore, data on birth order was only available for births within marriage. However, due to a policy change, all birth orders of all children born (both inside and outside of marriage) are now recorded. Where birth order data is unavailable, (for example before the policy changes on data collection), these births have been allocated into the unknown category in the tables.

10. Following advice from the Office for National Statistics in their 2016 methodological review, unknown birth order has been included as a separate category within this analysis.

Data Coverage

11. Birth registration data for the most recent 5-year time period (2012-2016) are aggregated for our analysis to ensure sufficiently large sample sizes are used. The sample reflects the most recent five-year time period for which finalised data are available.

12. Even though five years' data have been used in our analysis, the sample sizes for some countries and ethnic groups are still very small. To address this issue, 74 countries with fewer than 100 births in the five-year period have been excluded.

Calculations and Statistical tests

13. The birth ratios were calculated by dividing the number of male births by the number of female births and multiplying this value up by 100 to achieve a ratio of the number of boys born per 100 girls. This calculation was applied to:

- All births in Great Britain
- All births, by country of origin, and birth order, in Great Britain
- All births, by ethnicity of child, and birth order, England and Wales

14. For example, the birth sex ratio for babies born from French mothers over the period 2012-2016 was 104 males to 100 females for first born babies and 108 males to 100 females for the second born babies.

Decision on what to compare birth ratios against: Threshold of 107

15. This analysis uses an upper value for the natural birth ratio of 107. This is based on a review of academic literature[1, 2], advice from academic experts, and an examination of data on birth ratios in more developed countries. The aim of this analysis is to investigate if any birth ratios are statistically significantly higher than 107, i.e. if any group or community has statistically significantly more than 107 boys born for every 100 girls.

16. A lower birth ratio limit was not used, as we are not investigating whether there are many more girls born than boys born in Great Britain than would be expected.

Testing for Birth Ratios that are statistically significant to the threshold

17. Birth ratios are examined for all births and by birth order (so whether a child is first born, second born, third born or more) by the mother's country of origin and by the child's ethnicity.

18. Differences between birth ratios and the 107 threshold do occur, but could be due to chance, rather than a real difference. Statistical significance testing is carried out to

determine whether any differences observed between the birth ratios and the 107 threshold are likely to be "real" or whether they are simply due to chance fluctuations.

19. This publication uses a number of techniques to test whether ratios over 107 are statistically significant. The first stage of the process is to calculate the probability ('p values') that the differences observed could arise by chance as opposed to there being a real difference. We have used the commonly acceptable level of 5% significance level in this analysis, which means that a statistically significant result is found for any p values less than 0.05 (5%) – in other words, such a result would occur rarely by chance alone. However, this methodology presents some difficulties when there are many tests as is discussed below.

The multiple testing problem

20. The 'country of mother's origin' analysis involved testing the significance level for 172 countries and five birth orders, equivalent to 860 statistical tests (although due to missing data 856 tests were done). The 'ethnicity of child' analysis involved testing the significance level for 9 ethnic groups and five birth orders, equivalent to 45 statistical tests.

21. When undertaking so many statistical tests, due to random variation it would be expected that some results appear statistically significant due to chance alone. For example, at the 5% significance level used here, you would expect 1 in 20 results to be significant, even if there were no underlying differences from 107. When applied across the 860 and 45 statistical tests carried out here, there is a high chance of incorrect identification of a significant result (a "false positive"), leading to inferring evidence about sex selective abortions incorrectly.

22. To try and solve this problem, also known as the 'multiple testing problem', a statistical technique called the Benjamini-Hochberg procedure was applied using the p values already calculated as part of our method to assess statistical significance.

Dealing with the multiple testing problem: Benjamini-Hochberg procedure

23. In testing whether a result is statistically significant, it is common practice to determine whether the likelihood of an extreme observation occurring by chance is less than 5%. This is known as the alpha (α) value.

24. As this analysis involves doing multiple tests for the country of origin of the mother and the ethnicity of the child, this leads to a 'multiple testing problem'. This is because the probability of getting at least one significant result purely by chance, increases with the

more tests that are run. The significance level that is set for a single test, α, which measures the probability that a significant result is detected under the assumption that there isn't one, is not a valid way of detecting a significant result, when multiple tests are being run. To assist in the detection of results which are still significant when many tests are run simultaneously, a correction needs to be made to α. Many approaches have been developed, and for this publication, the Benjamini-Hochberg procedure is used in the analyses presented here.

25. The Benjamini-Hochberg procedure (B-H step-up procedure) is a way of setting α where it takes into account the fact that there are multiple tests. The procedure is as follows:

a. Find the significance level (p-value) for each individual test

b. Order the tests in descending order of p-values, and give all of the values a rank, called k, with 1 being applied to the biggest p-value.

c. For a given α find the smallest k such that

$$p_k < \frac{(m-k+1)\alpha}{m}$$

d. Then for all tests which have a rank of i where $i = k, \dots, m$ that they are significant results.

26. A limitation of using this Benjamini-Hochberg procedure is that the groups being tested need to have a large number of births for a relatively small difference in birth rates to be found to lie outside the expected range, and therefore to be identified as being statistically significant. However, the relatively small number of births within many of the groups in this analysis are such that large differences between birth ratios and the expected upper limit of 107 would need to be observed for the ratio to be identified as statistically significant. Therefore, evidence would only be identified through this means if sex selection were taking place on a significant scale.

Sensitivity analysis: Storey Technique

27. Given the limitations of the Benjamini-Hochberg procedure, an alternative statistical analysis was conducted to check the validity of the results. Following a review of the methodology in conjunction with the ONS, a supplementary test, known as the Storey technique was recommended and implemented in the 2016 publication.

28. Storey (2002)[3] and Storey & Tibshirani (2003)[4] suggested an alternative procedure, where the false discovery rate is estimated for a fixed region called the critical region- that is the range of values under which we would reject the hypothesis of there being no countries or groups with a ratio above 107, and so the result would be statistically significant. This area is called the q-value and can be compared for different rejection regions as evidence for what proportion of false discoveries is actually seen across the series of tests.

29. Therefore, the Storey technique is used to estimate how many of the statistical tests performed (856 for ‘country of origin’ and 45 for ‘ethnicity of child’) were ‘true positives’ at the 5% significance level. This differs from the Benjamini-Hochberg procedure which makes adjustments to the critical values for the group of tests being used, in such a way as to control the false discovery rate (that is, to limit the proportion of outcomes where the test says that a result is significant, but no effect is actually present).

Power considerations

30. This information on power calculations has been included for illustration purposes only. Power describes the likelihood of a testing procedure finding a significant result when the underlying sex-ratio is truly in excess of 107.

31. In testing whether a result is statistically significant, it is common practice to construct the test so that the likelihood of getting a value that is significant, when the true sex ratio does not exceed 107, is less than 5%. This figure of 5% is known as the alpha (α) value. It is also called the ‘size’ of the test, or it’s ‘significance level’. The power of the test is the likelihood of achieving a significant result when the true ratio is in excess of 107. In simple circumstances the question is how many births do there need to be to be able to construct a 5 % level significance test that has a specified power, say 80%, against a specific alternative such as the true ratio being 107.5

32. However, the circumstances here are not simple, and we are testing many hypotheses (e.g. one for each country and each birth order) simultaneously. It is not possible to evaluate the power of the Benjamini-Hochberg procedure in a straightforward manner.

33. For illustrative purposes the table below shows how large a particular country’s observed ratio of boys to girls would have to be, before the testing procedure would report a ratio significantly above 107.

34. For example, to identify that one of the ethnic groups with just 100 births is significant, the observed sex ratio for that group would have to be at least 203. Similarly, if one of the countries of mother's origin had 100,000 births it would not be identified as significant unless its observed ratio was 110 or more.

Table 4: Required observed sex ratio for the testing procedure to show a result significant at the 5 % level for the shown number of births.

Number of births	Ratio of Boys to Girls x 100: Single Test	Ethnic Group (45 tests)*	Country of origin (856 tests)**
100	149	203	244
500	124	141	152
1,000	119	130	137
5,000	112	117	119
10,000	111	114	116
50,000	109	110	111
100,000	108	109	110

* The analysis was based on data from 9 ethnic groups, by five lots of parity tests (All, 1st born, 2nd born, 3rd born or more, unknown), total 45 tests.
** The analysis was based on data from 172 country of origin groups, by five lots of parity tests (All, 1st born, 2nd born, 3rd born or more, unknown), total 856 tests. The expected 860 tests were not carried out because it was not possible to calculate a male to female birth ratio for 4 countries in the unknown birth order category (Brunei, Guatemala, Union of Soviet Socialist Republics (NOS), Uruguay), due to there being either zero males or females or zero for both males and females in these countries.

For comparison with the actual data the table below shows how many countries of origin had a number of births in the shown range.

Table 5: Number of Countries of Origin of mother that were in the shown range of birth numbers

Number of births	Number of Countries of origin of mother
0-99	0
100-499	48
500-999	25
1,000-4,999	56
5,000-9,999	12
10,000-49,999	25
50,000-99,999	2
100,000-499,999	3
500,000 or more	1

Previous reports

35. All previous reports (published each year from 2013) looked at male to female birth ratios broken down by the mother's country of origin. Reports from 2014 onwards also looked at the birth sex ratios by the child's ethnicity and birth order of the child, in addition to mother's country of origin.

36. The 2013 to 2014 and 2016 to 2018 reports showed no statistically significant results in any of the groups analysed.

37. In the 2015 publication there was one statistically significant result, for Nepalese-born mothers giving birth to their third or later child.

38. The chances of getting a false positive result (i.e. a positive result that is not real) in at least one of a large number of tests is quite high. The statistical technique used to assess whether a result is statistically significant or not (the Benjamini-Hochberg procedure) reduces the chance of these false positive results happening randomly, however it does not completely eliminate it. To further test this result of Nepalese born mothers, another statistical technique, (a chi square test) was applied which did not find a statistically significant result, implying the initial result using the Benjamini-Hochberg procedure was likely to be a false positive result.

39. Following publication of these results in August 2015, an independent review of the methodology was carried out by The Office for National Statistics (See paragraphs 41 to 42). This review recommended some changes to the existing Benjamini-Hochberg procedure and the inclusion of an additional statistical technique – the Storey technique. Retrospective application of the modified Benjamini-Hochberg procedure and Storey technique on to the birth sex ratio data analysis published in August 2015 did not find any evidence for a statistically significant group.

Users and Uses of Birth Ratio Statistics

40. The sex birth ratio statistics are of interest to the European Council who originally requested their collation. Following the amendment in the Serious Crime Act 2015, Parliament used the statistics within their remit to assess the legality of the Abortion Act and assess the birth sex ratio within the population in Great Britain. Academics and journalists reviewing evidence for sex selective abortions also have an interest in these statistics. Hospital trusts and screening midwives may also have an interest in these statistics when making local decisions for releasing information about the sex of a fetus during routine scans to the public. The United Nations Population Fund review birth ratios at a global level.

Independent Review of Methodology

41. The Office for National Statistics (ONS) quality assured the original methodology for this analysis in 2013. In 2016, following continued interest in these statistics, the decision was made to publish birth sex ratios as Official Statistics. The Department of Health and Social Care asked the Methodology Advisory Service at the ONS to review the methodology and provide assurance that it was a robust approach for reviewing evidence of extreme birth ratios.

42. The recommendations following from the independent methodology review led by the Office of National Statistics in April 2016 have all been incorporated into this analysis from the 2016 publication and are presented below:

A. When implementing the Benjamini-Hochberg procedure, the process should involve calculating the probabilities and then rank all these results is descending order in one operation, rather than doing separate tests by all births and birth order.

B. The Benjamini-Hochberg procedure may be supplemented with an analysis using Storey (2001's) approach to estimate the local positive False Discovery Rate (pFDR).

C. Continue to aggregate 5 years of data in the analysis, to ensure that the sample size is adequate to be able to detect a specified difference.

D. In this analysis, the Department of Health and Social Care uses a birth ratio of 107 males to 100 females. This is based on a review of available literature, advice from academic experts and on examination of data on birth ratios in more developed countries. ONS advised, that on this basis, one-sided tests against a ratio of 107 are appropriate.

E. Previously, the Department of Health and Social Care analysis has reported on male to female birth ratios for two or more children. However, as the birth order data for two or more children is closely related to three or more children, the recommendation is to no-longer report the birth ratios for birth orders for two or more children.

F. There are a large number of births where birth order is unknown. It is possible that any evidence of sex selection could show up in this category. Therefore, given that the birth order is of primary policy interest, the methodology review recommended reporting birth ratios and analyses for the unknown birth order from 2016.

References

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Further Information

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