Department of Health

Birth Ratios in England and Wales

A report on gender ratios at birth in England and Wales

May 2014

Published to gov.uk, in PDF format only.

www.gov.uk/dh

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Introduction

1. In May 2013, the Department of Health published the results of an analysis of male to female birth ratios in the UK. This covered overall birth ratios alongside breakdowns by the mother's country of birth. In that analysis, no group was found to have a ratio that was statistically significantly different from the range that might be expected to occur naturally, leading to the conclusion that analysis of birth ratios did not offer evidence of sex selection occurring in the UK[1].

2. The Department made the commitment to publish further analysis annually, in line with the recommendation of the Council of Europe Parliamentary Assembly that member states should 'collect the ratio at birth, monitor its development and take prompt action to tackle possible imbalances' and 'encourage research on sex ratios at birth among specific communities'[2].

3. The original analysis used the most up to date information that was available at the time, covering births in the five-year period from 2007 to 2011, broken down by the mother's country of birth. Since that analysis was carried out, data has become available for 2012 and so this second report uses data covering the five-year period from 2008 to 2012.

4. In addition to an update of the overall gender ratio analysis carried out in the previous report, two further pieces of analysis have been carried out and are reported here:

    - Birth ratios by birth order, broken down by the mother's country of birth. This is also based on the period 2008 to 2012.

    - Overall birth ratios and birth ratios by birth order, broken down by the child's ethnicity as stated by the mother. This is based on the period 2007 to 2011 – the most recent five-year period for which data are available.

5. The report also contains a discussion of how the results relate to the analysis of household composition data reported by *The Independent* newspaper in January 2014.

[1] Birth Ratios in the UK – A report on gender ratios at birth in the UK (2013)

[2] http://assembly.coe.int/Main.asp?link=/Documents/AdoptedText/ta11/ERES1829.htm

Key Results

- The analyses by country of birth and ethnicity do not offer evidence of sex selection taking place within England and Wales.

- Without exception, the wide variation in birth ratios was within the bounds expected as a result of genetics, socio-economic differences and random variation. In both the analysis by country of birth and the analysis by ethnicity, no group was associated with a boy to girl birth ratio higher than the expected upper limit of 107. That was the case for both the overall birth ratio and by birth order.

- However, it should be noted that the numbers of births within many groups in the analysis are such that large differences in birth ratios would need to be observed for the ratio to be identified as higher than the expected upper limit. That is, evidence would only be identified through this means if sex selection is taking place on a significant scale. It is therefore important to remain receptive to reports of such practice.

Method

6. As with the results reported in May 2013, this analysis has been quality assured by the Methodology Advisory Service at the Office for National Statistics.

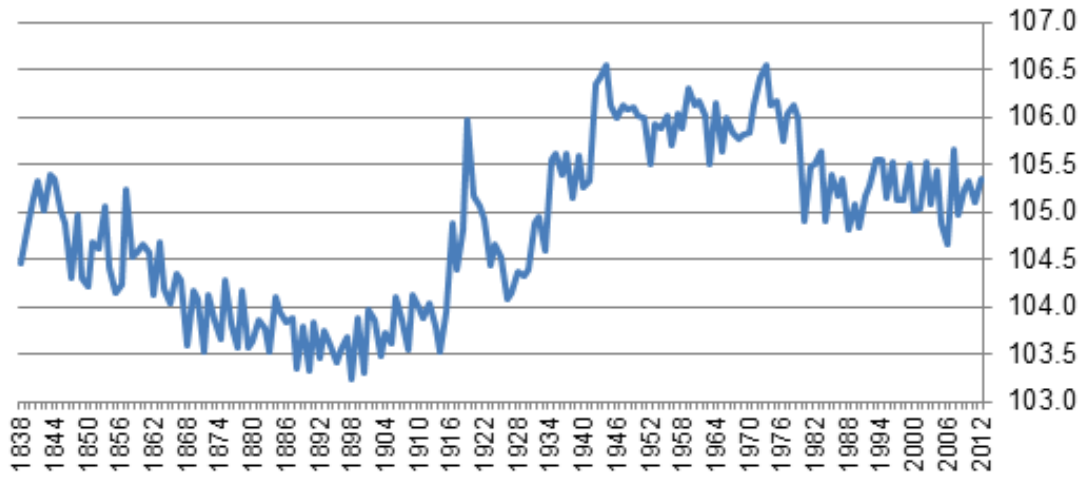
7. The gender ratio at birth is the subject of numerous academic articles, with general consensus that a birth ratio of around 105 male births for every 100 female births is normal[3]. There is evidence that a number of factors can influence the sex of a child, including paternal and maternal age, coital rates and the number and sex of previous children[4]. Even within large populations, observed birth ratios vary considerably over time. For example, Figure 1 below shows that the birth ratio in England and Wales has varied considerably, ranging from 106.5 in 1944 and 1973 to 103.2 in 1898. The previous analysis examined whether any ratios were statistically significantly higher than 108. This analysis uses 107 instead. Using 107 means it is more likely that a result will be found to be statistically significant. This change has been made in the light of a further

[3] Eberstadt, N. (2011) The Global War Against Baby Girls. The New Atlantis.

[4] Jacbosen, R. et al (1999). Natural variation in the human sex ratio. Human Reproduction vol.14 no.12.

review of the available literature[5,6], advice from academic experts and an examination of data on birth ratios in more developed countries. Data from the UN database[7] show that birth ratios in the 34 OECD countries in the period 2005-10 ranged from 104 in Chile to 107 in Ireland and the Republic of Korea (Figure 2).

Figure 1: Live male births per 100 live female births, England and Wales, 1838-2012

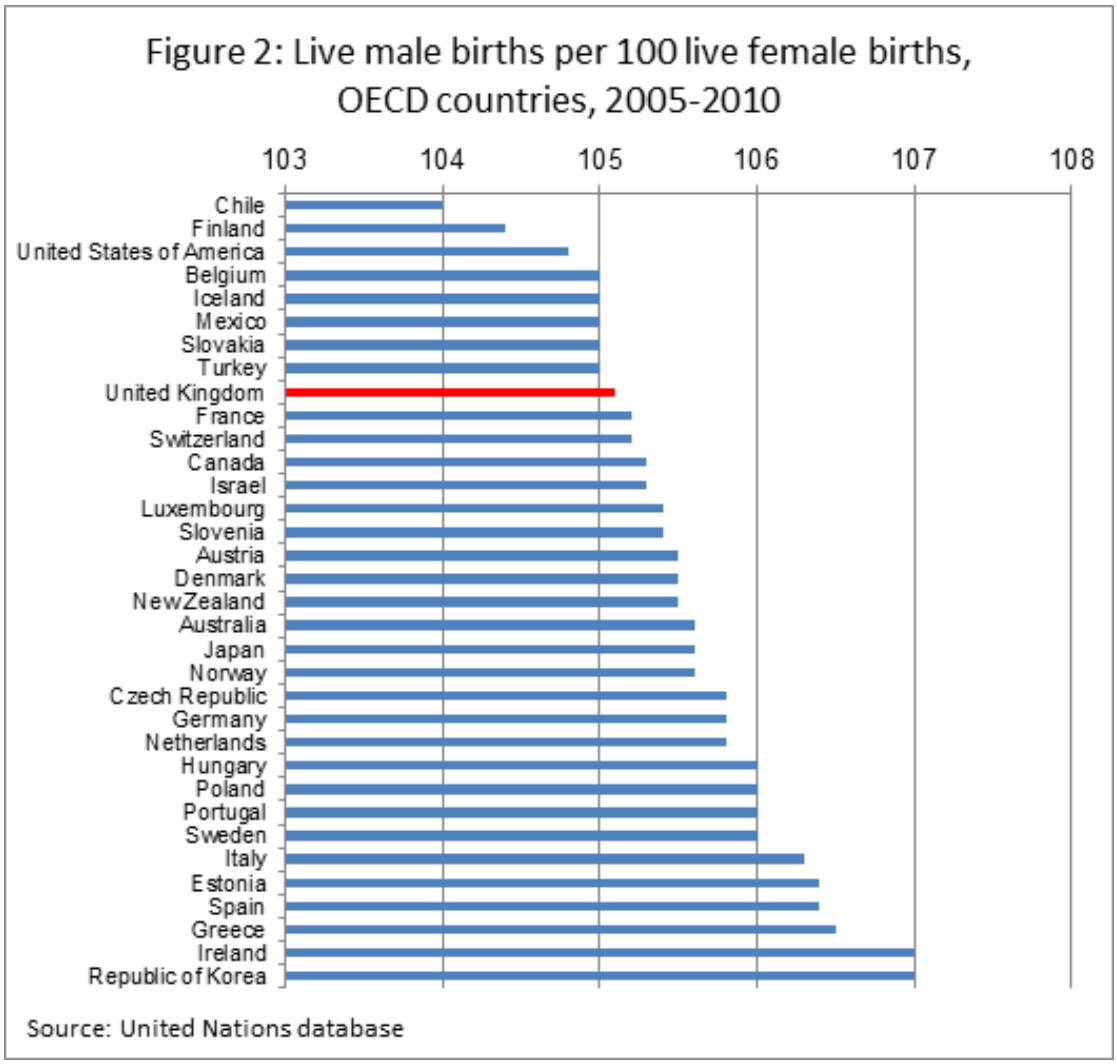


Source: Office for National Statistics

[5] Hesketh, T. and Xing, Z W. (2006) Abnormal sex ratios in human populations: Causes and consequences. Proceedings of the National Academy of Sciences

[6] Chahnazarian, A. (1988). "Determinants of the sex ratio at birth: Review of recent literature." Biodemography and Social Biology 35(3-4): 214-235

[7] See http://esa.un.org/unpd/wpp/Excel-Data/fertility.htm.



8. When the previous analysis is rerun based on 107, no ratios are found to be statistically significantly above this level.

9. In this latest analysis, birth ratios are examined (i) for all mothers, (ii) by the mother's country of birth and (iii) by the child's ethnicity. In each case, the analysis looks at (a) overall birth ratios and (b) births ratios by birth order (that is, for firstborn children, second born children, etc.)

10. For many countries of birth and for some ethnic groups, the number of births occurring each year is too small to draw meaningful conclusions and/or to have a reasonable chance of spotting anomalies in the male to female birth ratios. We therefore aggregate data across a number of years to ensure we have reasonably large sample sizes. By including data from earlier years, however, the analysis is less likely to reflect current circumstances. To strike a balance between these two competing demands, this analysis covers the most recent five-year period for which data are available. Calculations suggest that moving from five to six years would add little to the power of these tests (see Appendix B). The

information by country of birth is derived from birth registrations, for which the latest five-year period runs from 2008 to 2012. The information by ethnicity is derived from birth notifications[8], for which the latest five-year period runs from 2007 to 2011.

11. Even though five years' data have been used, the numbers for some countries and ethnic groups are still very small. We excluded those countries with fewer than 100 births in the period and merged some ethnic categories. This gives us datasets comprising over 3.5 million live births and figures for 171 countries and 13 ethnic groups. The majority of births were to mothers born in England and Wales (74%) and were of children in the 'White British' ethnic group (64%).

12. Information on parents' country of birth is routinely collected from parents/guardians when births are registered. Although both mothers' and fathers' country of birth are recorded, we report results for mothers only, as information for fathers is not recorded for births outside of marriage and registered only by the mother. We believe there to be no substantial quality issues affecting the data on mothers' country of birth, and any unidentified issues are likely to impact equally on male and female births.

13. Information on the child's ethnicity is routinely collected from mothers as a part of the birth notification data from the NHS Number for Babies (NN4B) system. The Office for National Statistics carried out an assessment of the quality of these ethnicity data for 2005 to 2008. The data at that time were assessed as being of sufficient quality at national level, but not consistently robust sub-nationally. The proportion of 'not stated's were higher than country of birth, although that is not expected to affect male and female births differently. The ethnic categories used are groupings of the NHS categories collected at birth notification and are broadly in line with the GSS harmonised standard on ethnic group.

14. The information on previous children used for the analysis by birth order was only available for births within marriage. There is no evidence that natural sex ratios are affected by marital status.

15. In testing whether a result is statistically significant, it is common practice to determine whether the likelihood of an extreme observation occurring by

[8] The Office for National Statistics (ONS) routinely produces statistics on births and infant deaths in England and Wales using information collected when the birth or death is registered. But some important information – including on ethnicity - is not collected at birth registration. This information is however available to the NHS. ONS has been provided with access to full year's information since 2006 and is derived from the birth notification record (known as the NN4B linked dataset). Over 99% of birth registration records are successfully linked to their corresponding birth notification record each year. These figures will not, therefore, match figures based solely on birth registrations.

chance is less than 5% (that is, the odds are less than 1 in 20). However, as there are nearly 171 countries and 13 ethnic groups being tested in this analysis, we would expect a birth ratio with that level of deviance to occur for several countries and some ethnic groups through random variation (around 8 to 9 countries). We could then be in the position of mistakenly stating that some groups have birth ratios which are so low/high that they are unlikely to happen naturally. To deal with this problem, known as the 'multiple testing' problem, we used a technique called the Benjamini–Hochberg procedure (as for the May 2013 analysis). Details of the procedure are given in Appendix A.

16. It should be noted that a consequence and a limitation of using the techniques for multiple testing are that the groups being analysed will generally need to be large (that is, have a high number of births) for relatively small differences in birth rates to be found to lie outside the expected range. Many of the groups in this analysis are small and so would require large differences in birth rates to be identified as different from the expected range.

Results

Births in England and Wales

17. In the period 2008 to 2012 there were 3.6 million births registered in England and Wales and a ratio of boys to girls of 105.2. This is not statistically significantly higher than the expected upper limit of 107.

18. The ratio did not vary significantly by birth order (see Table 1 below). The ratio among the 780 thousand second born children was 105.4 and among the 490 thousand children born third or more in line was 105.0. Again, these are within the expected range of 104 to 107 and not statistically significantly higher than 107.

Table 1: Birth ratios by birth order, England and Wales, 2008-2012

Birth order	Number of births	Birth ratio
All births	3,588,909	105.2
First born	876,889	105.2
Second born	774,175	105.4
Third born or more	488,942	105.0

Births by mother's country of birth

19. An analysis was conducted of birth ratios by the mother's country of birth, both for the overall ratio and by birth order. As stated above, tests were carried out to examine whether any ratios were statistically significantly higher than 107. In doing so, account was taken of the issue of multiple testing. Table 2 shows the births ratios for the countries analysed.

20. In the case of the overall birth ratio and birth ratios by birth order, no ratio was found to be significantly higher than 107.

Births by ethnicity

21. An analysis was also conducted of birth ratios by the child's ethnicity, again both for the overall birth ratio and by birth order. Table 3 reports the results.

22. As before, in the case of both the overall birth ratio and birth ratios by birth order, no ratio was found to be significantly higher than 107.

Discussion on relationship with the analysis by The Independent

23. In January 2014[9], *The Independent* published an article summarising its analysis of household data from the 2011 Census in England and Wales. The analysis focussed on households where the mother was born in one of a handful of particular countries and where the oldest usually-resident dependent child was female. The analysis looked at the gender mix of the younger dependent children living in the household. Figures for the number of boys per 100 girls that were significantly higher than the England and Wales average were presented as evidence that sex selection had taken place within some of those households.

24. There are a number of factors other than sex selection that may affect the gender mix of dependent children within households, such as differences in:

    - Mortality rates between boys and girls (both before and after migration)
    - The extent to which parents are accompanied by their male and female offspring when emigrating

[9] See http://www.independent.co.uk/news/science/the-lost-girls-thousands-of-missing-girls-revealed-by-analysis-of-uks-2011-census-results-9059905.html

- The proportion of boys and girls staying on in education after the age of 16
- The proportion of boys and girls leaving the household to live elsewhere in England and Wales or overseas (for example, because of marriage or living with family)

25. These and other factors could account for the observed household gender mix. It cannot therefore be concluded from the results that sex selection has taken place and, more specifically, that it has taken place within the UK.

26. The results presented in this report are therefore not at odds with the household data. Births data have considerably greater utility in assessing whether or not sex selection is taking place in England and Wales, as they are not affected by a wide range of events that occur after birth.

Summary

1. Analyses by country of birth and ethnicity do not offer evidence of sex selection taking place within England and Wales.

2. Without exception, the wide variation in birth ratios was within the bounds expected as a result of genetics, socio-economic differences and random variation. In both the analysis by country of birth and the analysis by ethnicity, no group was associated with a boy to girl birth ratio higher than the expected range of 107. That was the case for both the overall birth ratio and by birth order.

3. It should be noted that the numbers of births within many groups in the analysis are such that large differences in birth ratios would need to be observed for the ratio to be identified as higher than the expected upper limit. That is, evidence would only be identified through this means if sex selection is taking place on a significant scale.

4. DH will repeat this analysis on an annual basis following publication of birth data by ONS and in the light of any other analyses that are conducted.

Table 2: Birth ratios (number of boys per 100 girls) by mothers' country of birth, births registered in England and Wales, 2008-2012

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Total for all countries	105.2	105.2	105.4	105.0	105.0
Afghanistan	104.7	99.9	107.0	106.9	107.0
Africa (NOS)	105.0	117.1	102.4	111.6	107.1
Albania	110.9	103.5	115.9	136.8	120.9
Algeria	105.3	108.8	99.6	107.0	103.2
Angola	102.1	108.2	104.6	91.2	96.2
Argentina	116.0	125.0	96.4	133.9	106.3
Armenia	92.0	84.0	78.9	181.8	102.0
Asia (except Middle East) (NOS)	101.4	102.4	86.2	128.3	103.6
Australia	107.0	107.9	107.1	117.0	109.7
Austria	100.8	116.9	89.3	92.2	90.4
Azerbaijan	104.9	114.1	110.9	81.5	101.2
Bahrain	105.3	118.1	101.8	90.0	97.7
Bangladesh	102.9	103.8	99.6	104.2	102.4
Barbados	91.7	56.6	134.4	104.5	122.2
Belarus	110.0	105.7	120.4	113.8	118.9
Belgium	104.2	91.8	112.8	104.4	108.8
Benin	137.5	222.2	157.1	140.0	147.1
Bermuda	115.2	92.3	131.6	285.7	173.1
Bolivia	103.5	87.1	121.0	126.5	122.9
Bosnia and Herzegovina	97.4	101.2	91.3	125.6	99.4
Botswana	113.7	98.1	102.1	150.0	116.4

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Brazil	109.2	108.1	107.9	104.3	107.1
Brunei	101.6	84.2	106.1	83.3	96.5
Bulgaria	106.9	109.4	102.6	122.9	105.3
Burma	126.7	116.0	150.0	110.2	133.6
Burundi	95.7	115.4	117.6	82.4	97.2
Cambodia	102.7	96.8	100.0	84.6	94.9
Cameroon	102.3	92.9	88.5	105.2	96.1
Canada	103.3	103.0	100.9	109.3	103.2
Canary Islands	131.3	178.6	84.6	120.0	94.4
Cape Verde	111.5	266.7	125.0	166.7	147.1
Chile	101.4	105.7	88.5	153.8	103.5
China	108.0	106.3	106.6	112.1	107.9
Colombia	107.4	115.5	96.6	117.3	101.6
Congo	102.1	102.7	115.2	101.0	105.5
Congo (Democratic Republic)	104.4	106.9	97.7	102.8	101.2
Croatia	113.9	110.7	128.9	116.2	125.4
Cuba	130.6	123.1	113.3	140.0	120.0
Cyprus	108.8	100.3	117.3	113.3	115.8
Czech Republic	106.5	106.0	103.0	98.9	101.6
Denmark	110.3	113.3	112.7	111.8	112.4
Djibouti	90.7	131.3	72.7	69.0	70.6
Dominica	131.7	182.4	136.4	85.7	108.0
Dominican Republic	100.0	160.0	84.0	114.3	94.9
East Timor	89.0	70.6	105.3	78.9	92.1

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Ecuador	104.4	107.8	100.7	99.0	100.0
Egypt	105.9	103.5	108.7	105.6	107.3
El Salvador	84.2	71.4	70.0	12.5	53.6
England	105.3	105.0	105.6	105.3	105.5
Eritrea	99.7	108.3	108.1	98.1	102.6
Estonia	108.0	111.7	110.6	108.8	110.1
Ethiopia	104.6	105.9	102.5	107.8	104.9
Fiji	101.8	100.7	104.3	103.2	103.8
Finland	106.8	111.7	104.9	79.5	98.2
France	104.5	105.0	102.2	105.2	103.2
Georgia	103.3	102.1	129.1	108.0	122.5
Germany	104.6	102.6	109.1	100.1	106.0
Ghana	101.1	100.6	102.3	97.1	99.8
Gibraltar	102.8	101.1	100.0	90.2	96.2
Greece	109.8	110.2	115.3	106.9	113.5
Grenada	97.7	117.4	52.0	89.5	68.2
Guadeloupe	119.1	150.0	69.2	183.3	105.3
Guernsey	111.6	125.0	108.6	56.8	88.4
Guinea	109.6	120.6	119.2	104.5	111.2
Guinea-Bissau	83.8	96.8	77.1	77.3	77.2
Guyana	106.5	102.9	122.2	94.0	107.1
Hong Kong (special admin. region of China)	100.4	100.6	101.1	102.8	101.6
Hungary	105.0	104.0	106.3	107.3	106.5
Iceland	109.8	105.9	100.0	88.9	94.9

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
India	106.5	104.5	107.2	112.1	108.3
Indonesia	103.9	106.9	110.2	96.7	105.8
Iran	104.6	101.7	108.5	104.3	107.5
Iraq	105.7	108.2	103.8	104.0	103.9
Ireland	105.3	105.4	103.5	107.9	105.2
Isle of Man	97.9	83.0	119.5	75.7	105.3
Israel	110.5	100.6	114.5	112.8	113.5
Italy	105.8	105.6	107.8	110.2	108.4
Ivory Coast	112.3	136.3	121.6	94.9	107.1
Jamaica	102.0	100.6	100.2	105.6	102.8
Japan	106.1	109.5	104.4	102.8	104.1
Jersey	126.9	118.1	153.6	78.0	125.5
Jordan	98.8	92.4	102.1	104.9	103.5
Kazakhstan	102.0	101.5	103.4	133.3	109.7
Kenya	105.1	105.9	105.3	96.4	102.3
Korea (South)	113.8	123.7	99.2	115.5	102.9
Kosova	117.5	109.3	125.3	122.6	123.9
Kuwait	105.4	117.0	114.9	93.1	102.5
Kyrgyzstan	125.0	116.7	135.5	200.0	150.0
Latvia	105.3	103.5	98.3	101.5	99.1
Lebanon	103.4	90.7	106.1	119.2	112.7
Liberia	124.6	173.9	104.7	111.5	108.4
Libya	104.0	100.3	113.2	101.9	106.5
Lithuania	106.5	103.0	107.1	121.6	110.1

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Macedonia	106.1	119.8	109.6	92.6	105.8
Madagascar	98.3	110.0	85.0	85.7	85.3
Malawi	104.9	83.2	119.0	122.4	120.7
Malaysia	105.7	102.3	107.2	108.6	107.6
Malta	94.8	95.0	93.1	94.8	93.7
Mauritius	108.5	100.0	113.6	113.6	113.6
Mexico	110.3	121.5	95.1	143.2	104.4
Moldova	127.1	112.8	119.8	176.2	128.8
Mongolia	116.2	132.1	111.5	124.1	115.6
Montserrat	114.2	137.5	95.2	109.7	103.8
Morocco	104.3	110.6	102.1	101.9	102.0
Mozambique	99.4	85.1	94.2	111.9	101.2
Namibia	102.2	83.3	101.8	100.0	101.3
Nepal	108.5	107.5	104.3	146.5	111.0
Netherlands	96.1	105.3	98.4	98.1	98.3
New Zealand	107.7	109.8	109.3	103.6	107.8
Nigeria	102.0	101.7	99.7	103.1	101.2
Northern Ireland	104.7	104.5	106.6	102.6	105.2
Norway	106.5	107.7	115.6	98.5	110.2
Oman	142.2	143.3	213.3	120.0	151.1
Pakistan	102.9	105.3	102.7	101.6	102.1
Palestine	120.3	107.7	111.4	128.1	122.2
Papua New Guinea	115.8	88.5	119.0	136.4	125.0
Peru	114.0	118.3	108.3	93.3	104.2

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Philippines	111.7	115.5	108.6	113.2	110.1
Poland	105.2	106.0	104.6	100.5	103.8
Portugal	103.1	100.1	114.1	106.4	111.3
Qatar	102.5	138.9	83.8	91.4	87.5
Romania	104.9	106.7	100.0	95.2	98.4
Russia	106.1	111.8	98.5	114.3	102.3
Rwanda	117.4	123.6	129.2	122.9	125.9
Sao Tome and Principe	112.0	106.7	139.1	147.6	143.2
Saudi Arabia	107.9	109.5	107.3	107.2	107.2
Scotland	105.8	107.5	105.4	106.5	105.7
Senegal	110.4	100.0	126.5	91.5	107.4
Serbia	115.0	122.4	111.1	71.7	97.0
Seychelles	112.1	97.8	128.1	145.5	132.6
Sierra Leone	100.6	104.2	95.0	105.9	100.2
Singapore	107.6	98.5	133.6	93.9	121.0
Slovakia	107.9	106.2	113.3	108.4	111.6
Slovenia	95.5	61.5	105.0	50.0	84.4
Somalia	102.4	104.5	102.6	102.5	102.6
South Africa	105.4	102.0	103.8	115.3	106.7
Spain	107.4	106.5	103.0	102.1	102.7
Sri Lanka	101.2	99.0	101.2	104.1	102.2
St Helena and Dependencies	121.3	100.0	107.1	112.5	109.1
St Lucia	105.8	85.5	91.3	177.3	119.1
St Vincent	106.0	88.1	70.3	126.7	86.5

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Sudan [2]	108.2	110.9	111.4	101.1	105.4
Swaziland	146.5	133.3	105.9	166.7	126.9
Sweden	108.1	109.9	107.2	105.1	106.6
Switzerland	109.3	111.7	114.1	95.9	105.4
Syria	114.1	105.5	117.3	123.5	120.1
Taiwan (Province of China)	97.1	98.2	91.2	112.0	95.0
Tanzania	105.4	114.1	101.2	103.9	102.4
Thailand	108.0	105.2	111.0	109.3	110.5
The Bahamas	139.1	82.8	188.9	300.0	213.0
The Gambia	100.6	111.4	84.2	106.4	94.6
Togo	102.0	112.0	90.3	93.2	92.0
Trinidad and Tobago	103.6	110.9	100.9	114.3	105.3
Tunisia	112.0	113.6	98.0	105.2	100.6
Turkey	107.2	107.6	111.8	104.4	108.8
Turkmenistan	116.4	185.2	58.3	114.3	71.0
Uganda	97.4	105.0	97.3	86.2	92.1
Ukraine	104.4	100.9	104.8	99.2	103.6
Union of Soviet Socialist States	140.6	162.1	100.0	166.7	112.9
United Arab Emirates	102.5	98.0	101.4	102.0	101.6
United States	105.7	104.3	107.9	106.8	107.5
Uruguay	113.2	95.7	115.8	150.0	125.9
Uzbekistan	113.4	106.2	122.9	86.8	111.6
Venezuela	101.8	92.2	106.9	110.3	107.6
Vietnam	108.4	110.8	111.3	109.1	110.6

Country of birth	All live births	First born children	Second born children	Third born or more	Second born or more
Wales	105.5	106.8	106.3	104.3	105.6
Yemen	109.4	101.9	108.0	114.8	112.5
Yugoslavia	132.1	175.0	142.9	128.6	135.7
Zambia	109.5	108.9	110.9	106.7	109.2
Zimbabwe	100.9	101.5	101.3	103.0	102.0
Not Stated	98.1	220.0	22.2	60.0	42.1

Note: The information on previous children used for the analysis by birth order was only available for births within marriage.

Table 3: Birth ratios and test results by child's ethnicity, births notifications in England and Wales, 2007-2011

Ethnicity	All live births	First born children	Second born children	Third born or more	Second born or more
	Ratio	Ratio	Ratio	Ratio	Ratio
Total	105.3	105.3	105.4	104.8	105.2
White British	105.4	105.1	105.6	105.3	105.5
Other White	105.9	106.3	106.1	104.7	105.7
Mixed	105.5	106.0	107.7	103.3	106.2
Black Carribean	103.2	101.4	104.8	103.1	104.0
Black African	102.5	104.2	102.6	101.0	101.7
Other Black	102.8	108.5	100.7	102.5	101.7
Indian	104.7	103.3	104.6	110.6	106.3
Pakistani	104.4	106.3	102.6	104.4	103.6
Bangladeshi	102.9	103.7	103.3	101.6	102.3
Chinese	107.8	106.0	104.5	118.8	107.9
Other Asian	105.1	102.7	104.6	106.9	105.5
Other ethnic group	106.5	105.6	107.3	109.8	108.4
Not stated	105.7	106.3	106.4	103.1	105.1

Appendix A

The multiple testing problem and the Benjamini–Hochberg procedure

The 'multiple testing problem' arises because the significance level for a single test, *α*, (which measures the probability that we detect a difference under the assumption that there isn't one) is not maintained if we do lots of tests. The chances of getting a significant result in at least one of a large number of tests is actually quite high. In order to detect results which are still unusual when we are doing lots of tests, we need to make a correction to *α*. Many approaches have been developed and one of them, the Benjamini-Hochberg procedure, is used in the analyses presented here.

The *Benjamini–Hochberg procedure* (BH step-up procedure) controls the false discovery rate (at level *α*). This means that the proportion of tests in the set which *falsely* find a significant effect is no more than *α*. The B-H procedure works as follows:

1. Find the significance level (p-value) for each individual test.
2. Rank the tests in descending order of p-values, and call the rank of a test in the ordered list *k*.
3. For a given overall *α*, find the smallest *k* such that $p_k < \frac{(m-k+1)\alpha}{m}$
4. Then say that for all tests $i = k,\ldots,m$ that there is a significant effect.

Appendix B

Power calculations

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% (that is, the odds are less than 1 in 20). This is known as the alpha (α) value.

However, as there are nearly 171 countries and 13 ethnic groups being tested in this analysis, we would expect a birth ratio with that level of deviance to occur for several countries and some ethnic groups through random variation (around 8 to 9 countries). We could then be in the position of mistakenly stating that some groups have birth ratios which are so low/high that they are unlikely to happen naturally. To deal with this problem, known as the 'multiple testing' problem, we used a technique called the Benjamini–Hochberg procedure (see Appendix A).

A consequence and a limitation of using this technique for multiple testing is that the groups being analysed will generally need to be large (that is, have a high number of births) for relatively small differences in birth rates to be found to lie outside the expected range. Many of the groups in this analysis are small and so would require large differences in birth rates to be identified as different from the expected range.

Calculations were conducted to determine the birth ratio that would need to be observed for a particular country of birth or ethnic group in order to have a good chance (i.e. 80%) of correctly concluding that the true value lies above the expected upper limit of 107 boys for every 100 girls. The required ratio depends on the number of births registered for that country or ethnic group. The fewer the number of births, the greater the observed ratio needs to be to ensure this chance is maintained. The levels of power and significance were set to 80% and 5% respectively and the calculation carried out for a one-tailed test, i.e. results greater than 107:100.

Use of the Benjamini-Hochberg (B-H) procedure cannot easily be factored into a power calculation. A minimum level of power was deduced by using the critical value of (i/N) * α that is associated with the 171st country and 13th ethnic group, rather than the α that is used when calculating the effect size for a single hypothesis test. In the case of the 171st country, i=1, N=171 and α=0.05, giving a critical value of 0.000292. In the case of the 13th country, i=1, N=13 and α=0.05, giving a critical value of 0.00384.

The required effect size for groups of varying size is shown in the table below. For example, an ethnic group with 10,000 registered births would need a birth ratio of 114 or more; and a country associated with 10,000 registered births would need a birth ratio of 116 or more.

	Ratio of Boys: 100 girls		
Sample size:	**Single test**	**13th ethnic group**	**171st country**
500	133	146	157
1000	125	133	140
5000	114	118	120
10000	112	114	116
50000	109	110	111
100000	108	109	109