Sex ratio in relation to fathers' occupations

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Abstract

***Objective*—To investigate whether the sex ratio of children varies between fathers of different occupations.**

***Methods*—The sex ratio (the ratio of the number of boys to the number of girls at birth) was calculated in relation to paternal occupation in the cohort of all 253 433 live births in Cumbria, north west England, from 1950–89. Exact binomial confidence intervals were used to estimate whether the sex ratio in each occupational category was significantly different from that for the rest of the cohort.**

***Results*—There were fewer occupational categories with significantly different sex ratios at the 5% level than expected by chance alone, assuming the same binomial distribution of sexes at birth within each paternal occupation.**

***Conclusions*—Significant variation of the sex ratio with fathers' occupations was not found. There is some evidence that the sex ratio shows less variance than expected under a binomial model which assumes independence of the sex of each child; a possible explanation of this may be parental preference for limiting family size after children of both sexes have been born or some other factor which results in children within a family being more likely to be of both sexes rather than the same sex.**

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There has been speculation that the sex ratio (the ratio of the number of male births to the number of female births) varies with fathers' occupations, possibly due to the effect of occupational exposures.[1–9] This has been explored in the cohort of all live births in Cumbria, north west England, between 1950 and 1989.

Methods

A database was constructed comprising birth registration data of all 263 949 live births to mothers domiciled in Cumbria between 1 January 1950 and 30 September 1989.[10] The fathers' occupations, as recorded on the birth registration, were coded.[11] The 10 516 live births for which the father was not recorded on the birth registration, or for which his occupation was not noted or could not be coded, were excluded from the study. The sex ratio was calculated for children fathered by men in various occupational categories. 95% Confidence intervals (95% CIs) on the sex ratio were calculated with the exact binomial method as implemented by the statistical software package Stata.[12] The numbers of male and female births to fathers in each occupational category were compared with those for the rest of the cohort with the χ^2 test, yielding significance levels which should be valid except for categories with small numbers of births. Where the trend of sex ratio with time was of interest, this was estimated with logistic regression.[12] These statistical tests are based on the assumption that the sex of each birth is independent.

The results were compared with those of McDowall,[1] who calculated the sex ratio in relation to paternal occupational category in a study of over 190 000 births comprising a random 10% sample of births from 1980–2 in England and Wales and drew attention to various occupational categories which produced children of a low sex ratio not only in his study but also in an unpublished study of all 601 526 births in England and Wales in 1978. As he used an earlier classification system[13] to code occupations, we determined which occupational code of the more recent system[11] corresponded most closely to the older occupational categories before calculating the sex ratios for them.

Meta-analyses of the results presented by McDowall for 1978 and 1980–2 and those of the current study were carried out, having first checked that there was no significant difference between the overall sex ratios in the three periods. As the periods studied by McDowall overlapped with the current study, the small numbers of overlapping children were estimated and appropriate adjustment was made.

Results

The 253 433 children in the study group had a sex ratio of 1.056 (95% CI 1.048 to 1.064) and their fathers fell into 367 unique occupational categories. Without making any allowance for multiple testing, the sex ratio was significantly different ($P<0.05$ with the χ^2 test) from that for the rest of the cohort in 14 (4%) of these occupational categories (table 1). However, for three of these categories, officers in foreign armed forces, domestic housekeepers, and road sweepers, the 95% confidence interval derived with exact binomial methods overlapped the 95% CI of the sex ratio for the entire cohort, implying that the borderline significance ($P=0.041$, 0.050, and 0.042 respectively) obtained from the χ^2 test was probably not valid for these small samples (13, 7, and 35 children respectively). These three categories should therefore not be regarded as being significantly different from the rest of the

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Table 1 Live births in Cumbria, 1950-89: paternal occupations for which the sex ratio was significantly different from that for the rest of the cohort on the basis of a χ^2 test

Occupational code and category[11]	*Births (n)*	*Sex ratio (95% CI - exact binomial)*	*P value from χ^2 test*
151 Officers in foreign and commonwealth armed forces	13	0.300 (0.053 to 1.165)	0.041†
211 Mechanical engineers	1504	1.225 (1.105 to 1.358)	0.004
300 Laboratory technicians	973	1.237 (1.088 to 1.407)	0.014
512 Grinding machine setters and setter-operators	57	2.167 (1.210 to 4.020)	0.010
532 Plumbers, heating and ventilating engineers and related trades	3696	0.973 (0.912 to 1.039)	0.013
581 Butchers, meat cutters	1375	1.193 (1.071 to 1.329)	0.024
670 Domestic housekeepers and related occupations	7	0.167 (0.004 to 1.370)	0.050†
733 Scrap dealers, scrap metal merchants	474	1.268 (1.054 to 1.527)	0.047
851 Assemblers and line workers (vehicles and other metal goods)	168	1.471 (1.070 to 2.032)	0.034
873 Bus and coach drivers	1669	0.941 (0.853 to 1.037)	0.018
899 Other plant and machine operatives not elsewhere classified	2005	0.965 (0.884 to 1.053)	0.039
902 All other occupations in farming and related*	389	1.329 (1.083 to 1.635)	0.024
957 Road sweepers	35	2.182 (1.028 to 4.935)	0.042†
958 Cleaners, domestic workers	298	0.828 (0.654 to 1.047)	0.036

*Excluding farm workers and agricultural machinery drivers and operatives.
†Not significantly different from the rest of the cohort on the basis of exact binominal CI.

cohort, leaving the sex ratio significantly different in 11 occupational categories.

Table 2 shows that McDowall[1] noted four groups of paternal occupational categories: warehousemen, textile workers, United Kingdom armed forces, and food and drink workers other than bakers and butchers, for which the sex ratio of the offspring was non-significantly lower than that for the rest of the cohort not only in his study of 1980–2, but also in the study of births in 1978. In the present study, the sex ratio for warehousemen was non-significantly higher than that for the rest of the cohort, and the sex ratio for the other three groups was non-significantly lower. For these four groups the results of the present study were combined with those from both the 1980–2 study and the 1978 study but in the combined sample none of these occupational groups had children with a significantly lower sex ratio (table 2).

McDowall[1] highlighted as deserving further study four other groups: road transport drivers, welders, railway workers, and medical radiographers, which had children with a sex ratio lower than the national sex ratio in his 1980–2 study, although in only one group, children of railway workers, was this significant (P<0.01). In the present study, the sex ratio for children of road transport drivers was non-significantly lower than that for the rest of the cohort, whereas that for the other three groups was non-significantly higher. As before, for these four groups the results of the present study were combined with those from the 1980–2 study (the raw data from the 1978 study not being available for these groups); again none of the occupational groups in the combined sample had children with a significantly lower sex ratio (table 2).

It has been suggested that butchers fathered more girls than expected in the period from the 1950s to the middle of the 1970s, when oestrogenic hormones were used as growth promoters in cattle, but more boys in the following period when androgens were used instead.[6] This hypothesis was not supported by the present study: the sex ratio of children born to butchers during the periods 1950–70 and 1980–9 was 1.169 (95% CI 1.017 to 1.345) and 1.398 (95% CI 1.103 to 1.777) respectively, showing no significant difference

Table 2 Selected paternal occupations and groups of paternal occupations highlighted by McDowall[1] as having a low sex ratio

Occupational codes †	*Group of occupational categories*	*Births (n)*	*Sex ratio (95% CI - exact binomial)*	*P value from χ^2 test*
Current study (sex ratio of entire cohort, 1.056 (95% CI 1.048 to 1.064):				
441	Storekeepers and warehousemen	3137	1.079 (1.005 to 1.158)	0.546 NS
550-553,559,811-814	Textile workers	2618	1.022 (0.945 to 1.104)	0.395 NS
600,601	Officers, UK armed forces	4743	1.052 (0.994 to 1.115)	0.905 NS
582,809	Food and drink workers (other than bakers and butchers)‡	1231	1.018 (0.909 to 1.140)	0.520 NS
872,873,874	Road transport drivers	14353	1.034 (1.000 to 1.068)	0.186 NS
537	Welders	2834	1.058 (0.982 to 1.140)	0.957 NS
881-884	Railway workers	3375	1.082 (1.011 to 1.158)	0.476 NS
342	Medical radiographers	85	1.073 (0.685 to 1.684)	0.941 NS
McDowall's 1980-2 study (sex ratio of entire cohort, 1.052 (95% CI 1.043 to 1.062):				
333	Storekeepers, warehousemen	3017	0.999 (0.930 to 1.074)	0.155 NS
176-183,199,289,339	Textile workers	1941	1.030 (0.942 to 1.127)	0.644 NS
135	Officers, UK armed forces	3663	0.998 (0.935 to 1.066)	0.109 NS
187,202	Food and drink workers (other than bakers and butchers)	1034	0.947 (0.837 to 1.072)	0.091 NS
325-327	Road transport drivers	8381	1.024 (0.981 to 1.069)	0.204 NS
265	Welders	2048	0.984 (0.902 to 1.075)	0.131 NS
319-322	Railway workers	479	0.842 (0.700 to 1.012)	0.015*
45	Medical radiographers	31	0.842 (0.376 to 1.775)	0.496 NS
Meta-analysis of current study, McDowall's 1980-2 study, and 1978 study:				
	Storekeepers and warehousemen	6125	1.038 (0.987 to 1.092)	0.547 NS
	Textile workers	4537	1.025 (0.967 to 1.087)	0.348 NS
	Officers, UK armed forces	8391	1.029 (0.985 to 1.074)	0.258 NS
	Food and drink workers (other than bakers and butchers)‡	2254	0.984 (0.905 to 1.070)	0.101 NS
Meta-analysis of current study and McDowall's 1980-2 study:				
	Road transport drivers	22665	1.030 (1.004 to 1.058)	0.076 NS
	Welders	4862	1.026 (0.969 to 1.086)	0.337 NS
	Railway workers	3849	1.048 (0.984 to 1.117)	0.862 NS
	Medical radiographers	115	1.018 (0.694 to 1.493)	0.849 NS

*P<0.05.
†1990 Standard occupational classification[11] used for current study; 1980 classification of occupations[13] used for McDowall's study.
‡Current study includes tobacco and process operatives not elsewhere classified.

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(P=0.19). This was confirmed by logistic regression analysis of the sex ratio of children of butchers in relation to year of birth for the entire period 1950–89, which showed no significant trend, the odds ratio for change with year being 1.003 (95% CI 0.993 to 1.012), P=0.59, indicating that the ratio of the probability of having a boy to that of having a girl is, on average, 1.003 times that of the preceding year. However, as the 95% CI included 1.0, the observed numbers of boys and girls were consistent with a lack of any underlying trend in this ratio.

A complete list of sex ratios for the cohort, by the occupational category of the father, including those groups not presented in the tables, is available from us on request.

Discussion

As the sex ratio among the 10 516 live births excluded from the analysis because of lack of information on the fathers' occupations was 1.049 (95% CI 1.009 to 1.090), not significantly different from that for the rest of the study cohort, it is unlikely that their exclusion has biased the results. Some misclassification will have occurred, as the occupation of the father, as recorded on the child's birth certificate, may not have been his occupation before the child's conception. Misclassification may also occur as a result of inaccuracies in the reporting of paternal occupation on the birth certificate, especially as a proportion of births are registered by someone other than the father.[14] Also, the coding system used to classify occupations is based on the activity carried out by the worker rather than the industry in which he is employed,[11] and in some cases the industry rather than the activity would be expected to be associated with exposures. Within a particular occupation or industry, there is likely to have been a wide range of exposures, which will have changed over the period considered.[15]

The study showed that children born to fathers in 11 occupational categories out of 367 (3%) had children with a sex ratio significantly different from that for the rest of the cohort at the 5% significance level (table 1). This is less than the 18 categories which would be expected to seem to be significant at this level by chance alone under the null hypothesis, assuming the same binomial distribution of sexes in all occupation categories. Two occupational categories were significant at the 1% level, again fewer than the three to four expected and no result was more extreme than this. Hence there was little evidence for effects of occupational exposures on the sex ratio. However, the study covered a 40 year period during which the exposures and lifestyles associated with specific occupations may have changed.

In his study of the 10% sample of children born in 1980–2, McDowall[1] found that children born to fathers in 10 out of 350 occupational categories (2.9%) had a sex ratio which was significantly different from the national sex ratio at the 5% level, whereas 17 to 18 occupational categories would be expected to have a significantly different sex ratio at this level by chance alone.

Only one occupational category, butchers and meat cutters, had children with a sex ratio significantly different from the rest of the cohort in both studies: 1.210, (95% CI 1.079 to 1.357) in McDowall's study and 1.193, (95% CI 1.071 to 1.329) in the present study. Again, this is consistent with what would be expected by chance: out of 10 occupational categories, the number expected to seem to be significant at the 5% level by chance is 0.5 and, with exact binomial methods, this corresponds to a 40% chance that at least one category will seem to be significant in both studies by chance alone under the null hypothesis. There was no evidence to support the suggestion that the sex ratio of the children of butchers was associated with the different growth hormones used in cattle in different periods.[6]

Both studies found fewer significant categories than would be expected by chance alone. Assuming the underlying distribution to be binomial, the probability of observing 11 or fewer significant occupational categories out of 367 at the 5% level, as in the present study, is 0.043 and the probability of observing 10 or fewer out of 350, as in McDowall's study, is 0.035. Overall these results support the hypothesis that the distribution of the sexes has less variance than the binomial.[16] This phenomenon has been found not only in a subset of 16 039 children from the Cumbrian cohort among whom families of two live born children were significantly more likely to have one boy and one girl than expected under the binomial distribution,[15] but also in a cohort of 160 317 children[17 18] who were more likely to be in completed families if the last two children were of opposite sexes. Taken together, these studies imply that the assumption of independence implicit in a binomial model of the distribution of the sexes is not valid—that is, siblings are more likely to be of different sexes rather than the same sex. As a result of this, reported significance levels are likely to be an underestimate.

McDowall[1] highlighted 26 fathers' occupations from a 1978 study of all births in England and Wales in 1978 and 17 fathers' occupations from a similar study of births in 1931, which seem to be those for which children have unusually high or low sex ratios although none are in fact significantly different from the sex ratio for the rest of the cohort. None of these occupations is represented among the occupational categories in table 1 that were found in the present study to produce children with a significantly higher or lower sex ratio.

Studies combining occupational categories with similar exposures may be more likely to show consistent changes in the sex ratio.[8 9] None of the groups with a lowered sex ratio to which McDowall drew attention had a significantly lowered sex ratio either in our study or in a meta-analysis combining the two studies (table 2). However, we noted in an earlier similar meta-analysis[9] that children of professional drivers had a significantly lower sex ratio, that study used a wider classification of drivers than

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the current study, including not only road transport drivers but also drivers of agricultural and constructional machines, ambulance men, roundsmen, and driving instructors, which shows the importance of including all groups with similar exposures.

Several studies reporting altered sex ratios are of selected small groups rather than complete population cohorts or unbiased samples from such cohorts.[2 3 5 7] Many of these groups could not be considered in the present study. Unusually low sex ratios have been reported in the 157 children of 87 anaesthetists in Sheffield, United Kingdom[5] (0.764 (95% CI 0.549 to 1.060)) and in the 130 children of 58 abalone divers in Australia[3] (0.529 (95% CI 0.361 to 0.769)). There were insufficient numbers in the present study for valid comparisons: fathers of only six children (five of whom were boys) were recorded as anaesthetists and fathers of only 25 children (14 of whom were boys) were recorded as divers. An unusually low sex ratio (0.616 (95% CI 0.429 to 0.878)) was found in 139 children of carbon setters in Washington, United States,[7] but neither this term nor its homologues, anode setter and carbon changer, appeared as occupations of Cumbrian fathers; these terms refer to occupations of aluminium workers and the word aluminium did not appear either. In a study of 222 children of 111 fathers, Snyder found an unusually low sex ratio (0.593 (95% CI 0.379 to 0.916)) in 94 children whose fathers flew fighter planes before they were conceived, but a high sex ratio (1.560 (95% CI 1.080 to 2.273)) among the rest 128 children whose fathers flew other types of planes or did not fly in the immediate preconception period.[4] It was not possible to compare with these results as we had no information on the types of planes flown by those fathers whose occupation was pilot. There were similar difficulties in estimating the sex ratios for these groups from McDowall's study.[1 13]

James[19] has speculated that welders might be more likely to produce an excess of girls due to exposure to heat, which may result in poor sperm quality and low testosterone concentrations. Bernstein[2] has claimed that men in "masculine" occupations are more likely to father boys, although these masculine occupations were not clearly specified and little supporting numerical evidence was presented. The current study does not support either of these theories.

If the distribution of the sexes at birth shows less variance than the binomial, then reports of altered sex ratios are more significant than indicated by statistical tests such as χ^2 or logistic regression. However, there is the possibility that, in some previous studies, occupational groups may have been identified for analysis because of their altered sex ratios, thus invalidating statistical tests of their significance. The publications of altered sex ratios may be biased in that studies reporting significant associations may be more likely to be published.[20] Further, some of these studies were under ascertained.[3 5] In small groups which contain several children from the same family, the sex ratio may be more likely to show extreme values due to correlations between the sex of successive children in a family.[16] Alternatively, the sex ratio may be influenced by unknown factors, the effects of which average out in large studies carried out over wide geographical regions or long periods, but which may cause notable deviations in small samples localised in space and time. Exploration of such factors would ideally require not only prospective measurements of exposures suspected of being influential, but also a modelling of factors which might affect the distribution of sexes within families: not only family limitation but also possible correlations between the sexes of successive children.[17]

Conclusion

The present study of Cumbrian births from 1950–89, combined with a reconsideration of McDowall's study of 1980–2 births throughout England and Wales, shows that the actual incidence of significantly altered sex ratios among children whose fathers work in specific occupations is no more than would be expected by chance assuming a binomial distribution, and may actually be less. There is certainly no evidence for variation of the sex ratio with occupational category, except when those categories sharing the same exposures are combined. Ideally, investigations should be based on occupational exposures measured prospectively, in known periods including that of spermatogenesis,[15] and analysis should allow for factors influencing the distribution of sexes within families and the possibility of consequent departures from the binomial distribution.

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