

RESEARCH REPORT

Secular trends in sex ratios at birth in North America and Europe over the second half of the 20th century

V Grech, P Vassallo-Agius, C Savona-Ventura

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See end of article for authors' affiliations

Correspondence to:
Dr V Grech, Paediatric Department, St Luke's Hospital, Guardamangia, Malta;
victor.e.grech@govt.mt

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Context: A previous study showed that significantly more boys were born in southern latitudes in Europe than in northern latitudes and the converse pattern was observed in North America.

Objective: This study analyses secular trends in gender ratios for live births over the second half of the 20th century.

Design, setting, participants: Analysis was carried out from a World Health Organisation dataset comprising live births over the above period. This included 127 034 732 North American and 157 947 117 European live births.

Main outcome measures: Analysis of trends in gender ratios for countries in both continents.

Results: The findings show a highly significant overall decline in male births in both Europe and North America ($p < 0.0001$), particularly in Mexico ($p < 0.0001$). Interestingly, in Europe, male births declined in North European countries (latitude $> 40^\circ$, $p < 0.0001$) while rising in Mediterranean countries (latitude $\approx 35\text{--}40^\circ$, $p < 0.0001$). These trends produced an overall European male live birth deficit 238 693 and a North American deficit of 954 714 (total male live birth deficit 1 193 407).

Conclusions: No reasonable explanation/s for the observed trends have been identified and the causes for these trends may well be multifactorial.

Sex in reptiles and fish is determined after conception, during embryogenesis, according to ambient environmental temperature.¹ In contrast, in mammals and birds, sex is determined at conception. In mammals, male births invariably occur slightly in excess.² The male to female ratio of live births is generally expressed as the ratio of male live births divided by total live births (M/F), and the human M/F is expected to be 0.515, with approximately 3% more males born than females.³ The reason for this discrepancy is uncertain as testicles produce equal numbers of X-bearing and Y-bearing spermatozoa.⁴

Several theories have been put forward to explain why this ratio should not be 0.5, with equal number of male and female births. These theories include the timing of conception within the ovulatory cycle,³ endocrine effects,⁵ and immunological effects.⁶

We have shown that M/F varies in geographical space, exhibiting a latitude gradient,⁷ and that this gradient is different in Europe and North America, with more males born towards the south of Europe, compared with the North American continent where more males are born towards the north of the continent.⁸

Other studies have also shown that M/F may vary with time. Several authors have shown that M/F has declined over the second half of the 20th century in various industrialised countries. These include Denmark,⁹ the United Kingdom,¹⁰ the Netherlands,¹¹ Germany,¹² Canada,¹³ the United States of America,¹⁴ and Finland.¹⁵ In contrast, M/F has been noted to have risen in Ireland over the same period.¹⁶ A non-significant rise in M/F has also been noted in Australia¹⁷ and Japan.¹⁸

James has proposed that M/F fluctuates over a 30 year cycle.¹⁹ In this study, we identify secular trends in M/F in different countries and continents from a World Health Organisation dataset for the second half of the 20th century. We also analysed these trends by geographical latitude in Europe and briefly review the relevant literature regarding this topic.

METHODS

Data sources

Annual male and female live births were obtained directly from WHO. Data were available for 1950–97 for the North American continent (Canada, USA, and Mexico), and for European countries for the period 1950–99, with the following exceptions:

Data were not available for Mexico for the period 1950–8 and for 1996–7. Data were not available for the years 1998–9 for the following countries: France and Spain. Data were not available for 1999 for the following countries: the Netherlands, Poland, United Kingdom, Germany, Norway, and Greece. Data for Romania were not available for the period 1950–54. Stillbirths are not included in this study and neither were data from small countries.

Statistics

The quadratic equations of Fleiss were used for exact calculation of 95% confidence limits for ratios.²⁰ Linear regression was used for the calculation of association of annual M/F with time. Graphs are drawn as five year moving averages. A p value ≤ 0.05 was taken to represent a statistically significant result.

RESULTS

There has been a significant decline in M/F ratios during the second part of the 20th century in both the European and North American continents (fig 1). Live birth data and regression calculations for countries studied are shown in table 1.

Europe

This continent included a study (live birth) population of 157 947 117. A statistically significant decrease in M/F was noted in Greece, Hungary, Poland, and Sweden. A decline in M/F, albeit not statistically significant, was found in Austria, Belgium, Bulgaria, Norway, Portugal, Romania, and Switzerland. In contrast, M/F rose significantly in France and Italy. M/F rose and then fell in Spain, with an overall significant rise.

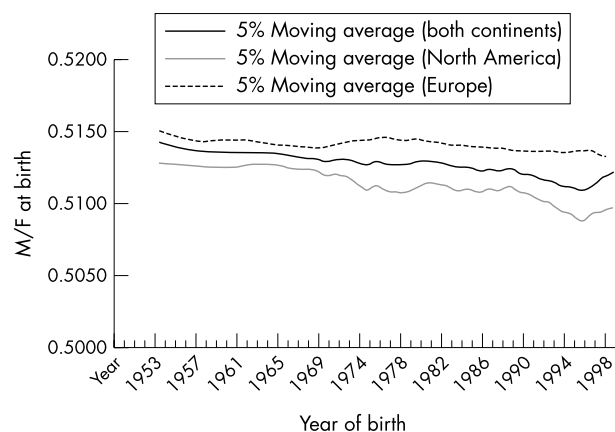


Figure 1 M/F ratios for Europe (combined), North America (combined), and both continents combined.

Summation of live births for Mediterranean countries that span latitude $\approx 35\text{--}40^\circ$ (Bulgaria, Greece, Italy, Portugal, and Spain) showed a significant rise in M/F. Live births for the remaining European countries above latitude 40° (Austria, Belgium, Denmark, Finland, France, Germany, Hungary, Ireland, the Netherlands, Norway, Poland, Romania, Sweden, Switzerland, and the United Kingdom) showed a significant fall in M/F (fig 2).

Assuming an expected M/F of 0.515, these trends produced a male birth deficit of 12 744 in the Mediterranean region, 212 780 in central Europe and 13 169 in the Nordic countries; a total male birth deficit of births 238 693.

North America

This continent included a study (live birth) population of 127 034 732. The combined North American continent data (Mexico, USA, and Canada) showed a significant decline in M/F (fig 1). M/F declined significantly in the USA and Mexico (fig 3).

Once again, assuming an expected M/F of 0.515, these trends produced a male birth deficit of 21 993 in Canada,

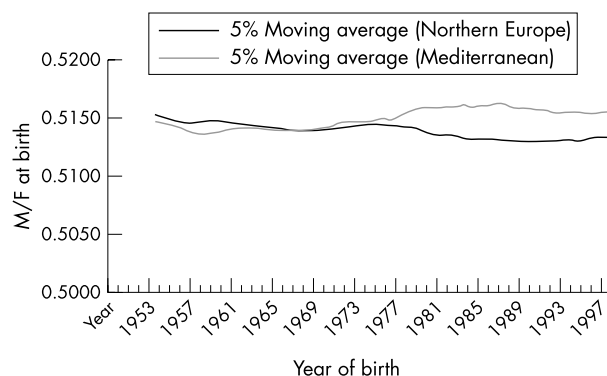


Figure 2 Summation of M/F ratios for Mediterranean and northern European countries.

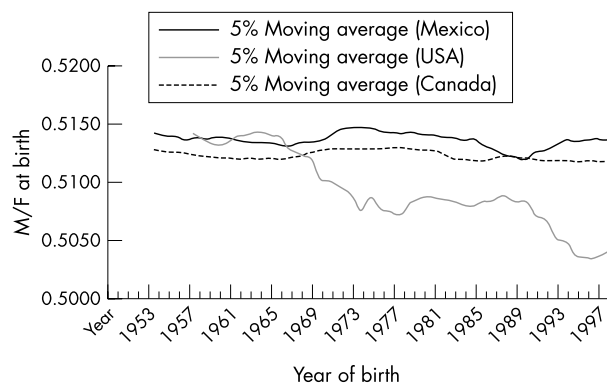


Figure 3 M/F ratios for Canada, the United States of America, and Mexico.

410 932 in the United States, and 521 789 in Mexico; a total male birth deficit of 954 714.

The combined live male birth deficit for the two continents was 1 193 407.

Table 1 Male, female, total births and linear regression of sex ratio with time for countries included in this study

Country	Male live births	Female live births	Total live births	r	p	M/F	95% CI
Denmark*	1680922	1588490	3269412	-0.29	0.49	0.5141	0.5136 to 0.5147
Finland*	1741682	1652473	3394155	-0.10	0.50	0.5131	0.5126 to 0.5137
Germany*	25678261	24239453	49917714	-0.75	<0.0001	0.5144	0.5143 to 0.5146
Ireland*	1498481	1416062	2914543	0.45	0.002	0.5141	0.5136 to 0.5147
Netherlands*	5160590	4899973	10060563	-0.60	<0.0001	0.5130	0.5126 to 0.5133
UK*	20441737	19330020	39771757	-0.61	<0.0001	0.5140	0.5138 to 0.5141
Austria	2600186	2466512	5066698	-0.13	0.38	0.5132	0.5128 to 0.5136
Belgium	3138073	2965932	6104005	-0.17	0.26	0.5141	0.5137 to 0.5145
Bulgaria	3176760	3000118	6176878	-0.22	0.13	0.5143	0.5139 to 0.5147
France	19579581	18634567	38214148	0.52	<0.0001	0.5124	0.5122 to 0.5125
Greece	3395944	3168572	6564516	-0.43	0.002	0.5173	0.5169 to 0.5177
Hungary	3815036	3587994	7403030	-0.65	<0.0001	0.5153	0.5150 to 0.5157
Italy	18671513	17652250	36323763	0.73	<0.0001	0.5140	0.5139 to 0.5142
Norway	1444600	1363935	2808535	-0.15	0.31	0.5144	0.5138 to 0.5149
Poland	15295234	14359427	29654661	0.80	<0.0001	0.5158	0.5156 to 0.5160
Portugal	4283717	4015694	8299411	-0.03	0.81	0.5161	0.5158 to 0.5165
Romania	8082232	7649545	15731777	-0.27	0.07	0.5138	0.5135 to 0.5140
Spain	13600342	12805240	26405582	0.69	<0.0001	0.5151	0.5149 to 0.5152
Sweden	2607559	2459796	5067355	-0.51	<0.0001	0.5146	0.5141 to 0.5150
Switzerland	2103563	1995775	4099338	-0.07	0.65	0.5131	0.5127 to 0.5136
Mediterranean (35-40°)	43128276	40641874	83770150	0.66	<0.0001	0.5147	0.5148 to 0.5149
Northern Europe (>40°)	114818841	108564205	223383046	-0.84	<0.0001	0.5139	0.5140 to 0.5141
All Europe	157947117	149206079	307153196	-0.68	<0.0001	0.5142	0.5142 to 0.5143
Canada (>50°)*	8012882	7588817	15601699	0.26	0.79	0.5136	0.5133 to 0.5138
USA (30-50°)*	76827922	73150435	149978357	-0.73	<0.0001	0.5123	0.5122 to 0.5123
Mexico (<30°)	42193928	40749212	82943140	-0.76	<0.0001	0.5087	0.5086 to 0.5088
North America	127034732	121488464	248523196	-0.73	<0.0001	0.5112	0.5111 to 0.5112

*Previously reported.

DISCUSSION

In utero, the male fetus is more prone to morbidity and mortality from external influences than the female fetus. Moreover, the male fetus is at greater risk of all obstetric complications than the female fetus and readers are referred to the review by Kraemer.²¹ Despite these adverse factors, males are invariably born in excess of females,² implying an even higher conception rate of males over females than evinced by the sex ratio at birth.

In the first half of the 20th century, antenatal care improved dramatically in industrialised countries, which led to a fall in stillbirths, most of which would have otherwise been male. This therefore led to an increase in the M/F ratio.^{9, 22}

M/F then declined in several countries in the second half of the 20th century, and one study has proposed that M/F could be used as a sentinel health indicator.²³ This is supported by data from Italy that showed that in metropolitan areas, M/F declined in comparison with the rest of the country where M/F increased.²⁴

However, there are several arguments against this hypothesis. Firstly, in Finland¹⁵ and in Malta,⁷ the decline in M/F predated the countries' industrialisation or the widespread use of pesticides. Secondly, it has been noted that in the United States, M/F was overall higher in the black population than in the white population,¹⁴ and that M/F rose and then fell in the white population (1964–1988), while rising throughout the study period in the non-white population.²⁵ The overall decline is accounted for by the fact that over 80% of the USA population falls in the "white" category. Thirdly, Ireland has reported a rise in M/F despite increasing industrialisation,¹⁶ and in this study, M/F was also seen to rise in France, Italy, and Spain. These findings do not support the sentinel health indicator hypothesis.

Our earlier study provoked several useful comments.⁸ Jacobs commented that the differences that we showed were very small,²⁶ which is perfectly true. However, this small difference has resulted in an overall deficit of 1 193 407 male births in the European and North American continents for this same study period.⁸ Voracek and Fisher commented that as the onset of the study period in the 1950s is slightly different for Europe and North America, the peak in male live births after the second world war may have skewed our results. However, after the war, the ratio rapidly declined to the baseline and is therefore unlikely to have affected our overall results.^{11, 12} They also pointed out that that the area of the North American continent is 4.8 times the 24 European countries in our study. However, the data on which the paper is based show that the number of actual births is quite similar (North America 127 034 732, Europe 157 947 117, ratio 0.80). They also reanalysed the dataset and showed a curvilinear relation of latitude and sex ratio that is consistent with an effect related to photoperiod. However, the secular trends cannot be explained, to our mind, by such an effect.²⁷ Shields *et al* showed a significant relation between cytomegalovirus seropositivity in cord blood and female sex, but again, we cannot see how CMV infection may possibly be implicated in these secular trends.²⁸

James also reiterated the influence of maternal oestrogen levels on birth weight and the likelihood of dizygotic twins.²⁹ While an interesting hypothesis, we cannot see how this factor alone could explain the widely varying secular trends in different countries over the same timespans.

An earlier study had noted declining trends in several countries in various continents, but a latitude effect had not been perceived.³⁰ This same study also showed no overall change in M/F over 1926–1990, whereas our study only looked at the second half of 20th century. It may be that Parazzini *et al*'s early part of the dataset trends nullified the trends in the second half of 20th century.³¹

External factors that influence M/F have also been described. Germany, for example, experienced two M/F peaks

that were related to the two world wars,¹² and these peaks were also supported by data from the Netherlands.³²

James has proposed that M/F fluctuates over a 30 cycle, and that this is attributable to a homeostatic mechanism that correlates sex at birth negatively with the adult sex ratio at the time of conception.³³ The current decline in M/F would therefore be a negative feedback response to the increase in M/F in the first half of the 20th century. This hypothesis is partly supported by data from the USA that demonstrated a degree of cyclicity over a 55 year period.³⁰ More interestingly, this same study showed a strong degree of correlation between parental age and birth weight. However, the overall decline in M/F in our 50 year study seems constant in both Europe and North America (fig 1) with no evidence of a 30 year cycle.

Diverging cultural attitudes may also potentially influence M/F. For example, Latino and Eastern cultures prefer male over female offspring.^{34, 35} In such cultures, families would be more likely to settle for a single son, than for a single daughter, and on first having a daughter, may therefore opt to have additional children in order to have a son. Male offspring bias may also be evinced by female infanticide and/or sex selective abortion. However, it is unlikely that such factors could have played an important part in determining the observed M/F ratios in the developed countries considered in this study.^{36, 37} Moreover, any such skew would have mitigated against our finding of an overall male deficit.

Several other hypothesis have been put forward to explain different trends in M/F ratios, with various factors assumed to influence the female genital tract environment in ways to favour the Y-bearing spermatozoa.²⁵ For example, it has been claimed that caloric availability per capita correlates positively with M/F.³⁷

In an earlier study we showed a latitude gradient for both Europe and the North American continent.⁸ Our current European results are interesting in that they show a rising M/F ratio in Mediterranean countries and a falling M/F ratio in more northern European countries (fig 2). Since the early 1980s, in Mediterranean countries, M/F ratio seems to have stabilised at just over the expected value of 0.515, while in more northern countries, M/F ratio seems to have stabilised at 0.513. Should these secular trends increase in magnitude, with an increasing male deficit, this will naturally have social, occupational, epidemiological, and community health related effects. The results of this study yield highly significant p values because of the large numbers of births involved despite the comparatively small shifts in secular trends. The p values are usually used to enable inferences to be drawn about populations from samples. In this context, the p value is only useful as an indicator that shows how likely it is that these results should occur by chance alone, assuming that the dataset is correct. One final point that must be borne in mind is that the differences that we demonstrated are very small, and could theoretically have been produced by even very small differential reporting in male and female births, although such errors are unlikely to produce the observed, rather smooth secular trends.

In conclusion, while we have expanded our findings on the sex ratio at birth by studying secular trends, we still cannot put forward any reasonable explanation for the observed trends, which may well be attributable to several factors and not just one.

Authors' affiliations

V Grech, Paediatric Department, St Luke's Hospital, Malta
 P Vassallo-Agius, Medical School, University of Malta
 C Savona-Ventura, Department of Obstetrics and Gynaecology, St Luke's Hospital, Malta

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APHORISM OF THE MONTH

Starting a rumour, following Christopher Columbus, and spending other people's money

Readers will recall that Columbus was adept at following his strategy for exploration by spending other people's money.¹ Bridging the gap between starting a rumour and mobilising resources for change is at the heart of public health—how often have you heard somebody say that they can't do anything to improve health without knowing where the money is coming from first, yet public health is essentially about shaping and influencing the actions of others and other sectors. An effective public health practitioner should be adept at spending other people's money, but for this to happen on any meaningful scale it is essential for other players involved to feel a sense of ownership.² I have long contended that in health and health care we need not Directors of Finance, but Directors of Resources. The mindset that starts with financial resources in health finishes up with doctors, nurses, bricks and mortar, and bits of kit. In reality, the resources for health run much wider, including many human and environmental resources that lie outside the bailiwick of something called health.

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