

Declining sex ratios in Canada

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Abstract

Objective: To examine the trends in the proportion of annual live births that were male in Canada and to compare the trends with those in the United States.

Design: Analysis of census data.

Setting: Canada as a whole and 4 main regions (West, Ontario, Quebec and Atlantic).

Subjects: All live births from 1930 to 1990.

Outcome measures: Sex ratio (expressed as the proportion of total live births that were male [male proportion]) overall and by region.

Results: The male proportion in Canada decreased significantly after 1970 ($p < 0.001$); this represented a cumulative loss of 2.2 male births per 1000 live births from 1970 to 1990. Although a decrease was observed in all four regions studied, only that in the Atlantic region was significant ($p < 0.001$), representing a cumulative loss of 5.6 male births per 1000 live births from 1970 to 1990. A significant decrease in the male proportion was also observed in the United States from 1970 to 1990 ($p < 0.001$), although to a lesser degree than that observed in Canada, and represented a cumulative loss of 1.0 male births per 1000 live births.

Conclusions: The decreased sex ratio in Canada adds to the growing debate over changes in biological markers and their potential causes. In addition, the study illustrates the potential use of the sex ratio as a widely available, unambiguous measure of the reproductive health of large populations.

Résumé

Objectif : Examiner les tendances de la proportion des naissances annuelles vivantes de sexe masculin au Canada et les comparer à celles des États-Unis.

Conception : Analyse des données du recensement.

Contexte : Canada au complet et les quatre grandes régions (Ouest, Ontario, Québec et Atlantique).

Sujets : Toutes les naissances vivantes de 1930 à 1990.

Mesures des résultats : Ratio entre les sexes (exprimé en proportion du total des naissances vivantes de sexe masculin [proportion masculine]) dans l'ensemble et par région.

Résultats : La proportion masculine au Canada a diminué considérablement après 1970 ($p < 0,001$), ce qui a représenté une perte cumulative de 2,2 naissances de sexe masculin par 1000 naissances vivantes entre 1970 et 1990. Même si l'on a observé une diminution dans les quatre régions à l'étude, elle a été significative dans la région de l'Atlantique seulement ($p < 0,001$), où elle a représenté une perte cumulative de 5,6 naissances de sexe masculin par 1000 naissances vivantes de 1970 à 1990. On a observé aussi une baisse significative de la proportion des naissances de sexe masculin aux États-Unis entre 1970 et 1990 ($p < 0,001$), même si elle a été moindre que celle qui a été observée au Canada. Cette baisse a représenté une perte cumulative de 1,0 naissance de sexe masculin par 1000 naissances vivantes.

Conclusions : La baisse du ratio entre les sexes au Canada ajoute des données au débat qui prend de l'ampleur sur l'évolution des marqueurs biologiques et sur leurs causes possibles. L'étude illustre en outre l'utilisation possible du ratio entre les sexes comme mesure facilement disponible et sans ambiguïté de la santé génésique de populations importantes.



Evidence

Études

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The sex ratio, usually reported to be about 105 liveborn males per 100 liveborn females,¹ can vary within and between populations and change over time. For example, the sex ratio in some Latin American countries decreased from 1967 to 1986,² whereas in Japan and Italy it increased during the periods 1900 to 1978³ and 1930 to 1990⁴ respectively.

Reasons for such changes are difficult to identify, but numerous demographic and environmental factors have been shown to be associated with variations in sex ratios within and between populations.

Race appears to be a factor. Sex ratios are reported to be lower in black populations than in white populations^{5,6} and relatively higher in Asian populations.^{7,8}

Parental age has also been shown to affect the sex ratio. James and Rostron⁹ reported that as paternal age increased, the sex ratio decreased. Although the association with maternal age in their study was inconclusive, Ulizzi and Zonta⁴ found that as maternal age increased, the sex ratio also increased.

Animal studies have suggested that decreased maternal condition or adverse environmental conditions during pregnancy are associated with a decreased sex ratio.^{10,11} In studies of human populations, a decreased rate of stillbirths was associated with an increased sex ratio,^{3,4} which perhaps reflected the effect of improved perinatal care.

Exposure to environmental toxins has been shown to alter the sex ratio of live births in both human populations and animal models.^{7,12-20} This may reflect differential toxicity, which occurs when the reproductive system is exposed to agents that stimulate ovulation.²¹⁻²⁶ It has been postulated that the mechanism of action of some toxins may be similar to hormonally induced ovulation, which causes an excess of female births,^{7,21,27} and that the toxins may alter female gonadotropin levels at the time of conception.⁷

Several other factors have been reported to affect sex ratios, including seasons, wars, birth order, certain diseases and various social factors.^{7,28-34}

Trends in the sex ratio of live births in Canada have not been previously investigated. We undertook this study to examine the ratio from 1930 to 1990 in Canada overall and in 4 main regions within Canada.

Methods

The "livebirth sex ratio" is the standard term used to report the ratio of male:female live births and is either the number of liveborn males per 100 liveborn females or the proportion of liveborn males of all live births. The former statistic is a true sex ratio, whereas the latter (which is the statistic reported in this study) is more properly referred to as the "male proportion." For example, a sex ratio of 105 equates to a male proportion of 51.2%.

We obtained from Statistics Canada the annual number of live births by sex and province for the period 1930 through 1990.³⁵ From this information we calculated the annual male proportion by dividing the number of liveborn males by the total number of live births for each study year. These proportions were calculated for Canada as a whole and for 4 main regions within Canada: the West (British Columbia, Alberta, Saskatchewan and Manitoba); Ontario; Quebec; and the Atlantic region (New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland). These regions represented approximately 29%, 25%, 37% and 9% of the Canadian population respectively (based on the 1990 population of 27.3 million).

We analysed the data semiparametrically using a generalized additive model³⁶ to fit a smooth, nonlinear trend to the male proportion from 1930 to 1990. The resultant plot (Fig. 1) motivated us to explore the data from 1970 to 1990 for a decreasing trend. We examined the data using the Durbin-Watson test for serial correlation,³⁷ but since none was indicated we used ordinary logistic regression to fit and test trends. Estimated 20-year trends and 95% confidence intervals (CIs) were derived from the fitted values and their asymptotic multivariate normal distributions.

For confirmatory purposes, we examined livebirth data from the United States for the period 1970-90³⁸ using the methods we applied to the Canadian data. We calculated the male proportion in the United States overall and in 9 major regions: New England, Middle Atlantic, South Atlantic, East North Central, East South Central, West North Central, West South Central, Mountain and Pacific.

Results

Examination of the smoothed trend in the male proportion from 1930 to 1990 (Fig. 1) revealed a declining trend from about 1970 onward, which followed a period

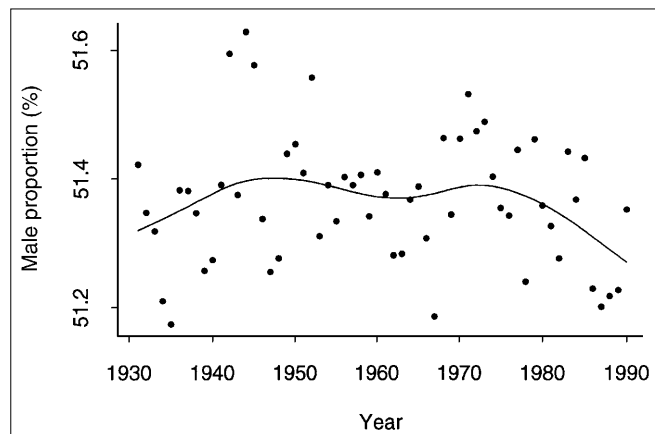


Fig. 1: Smoothed curve of deviations in the sex ratio (male proportion) in Canada from 1930 to 1990. Male proportion = proportion of live births that were male.

of 30 years during which the male proportion had been relatively stable.

The number of live births in Canada from 1970 through 1990 was 6 996 348, with 333 159 per year on average.³⁵ The male proportion decreased significantly in Canada overall during this period ($p < 0.001$), for a cumulative loss of 2.2 male births per 1000 live births (Fig. 2). The male proportion also decreased in each of the 4 regions (Fig. 3); however, the change reached statistical significance only in the Atlantic region ($p < 0.01$), representing a cumulative loss of 5.6 male births per 1000 live births (Table 1). Tests of homogeneity indicated that the trends differed significantly between the regions ($p = 0.045$).

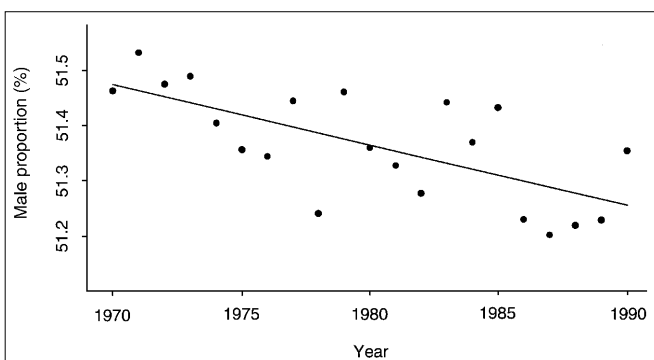


Fig. 2: Estimated trend in the male proportion in Canada from 1970 to 1990.

The US data also revealed a significant decline in the male proportion from 1970 to 1990 in the country overall ($p < 0.001$); the change represented a cumulative loss of 1.0 male births per 1000 live births (Fig. 4). In 4 of the 9 regions (East North Central, West North Central, South Atlantic and Pacific) the decrease was significant ($p < 0.05$), and in 3 (New England, West South Central and Mountain) it was not significant. In 2 (Middle Atlantic and East South Central) there was an increase in the male proportion, but it was not significant.

Discussion

The livebirth sex ratio decreased significantly in the Canadian population from 1970 through 1990. When evaluated by region, the decrease suggested a west-east gradient. The sex ratio also decreased significantly in the United States, although to a lesser degree.

Although census data have limitations, this type of information is readily accessible for investigating population parameters such as sex ratios. However, the inherent risk of systematic reporting bias should be considered when interpreting results derived from census data.

The decrease in the sex ratio represented a cumulative loss of 8639 liveborn males in Canada (95% CI 4433 to 12 850) and 37 840 in the United States (95% CI 25 950 to 49 730). A large population would be required to observe

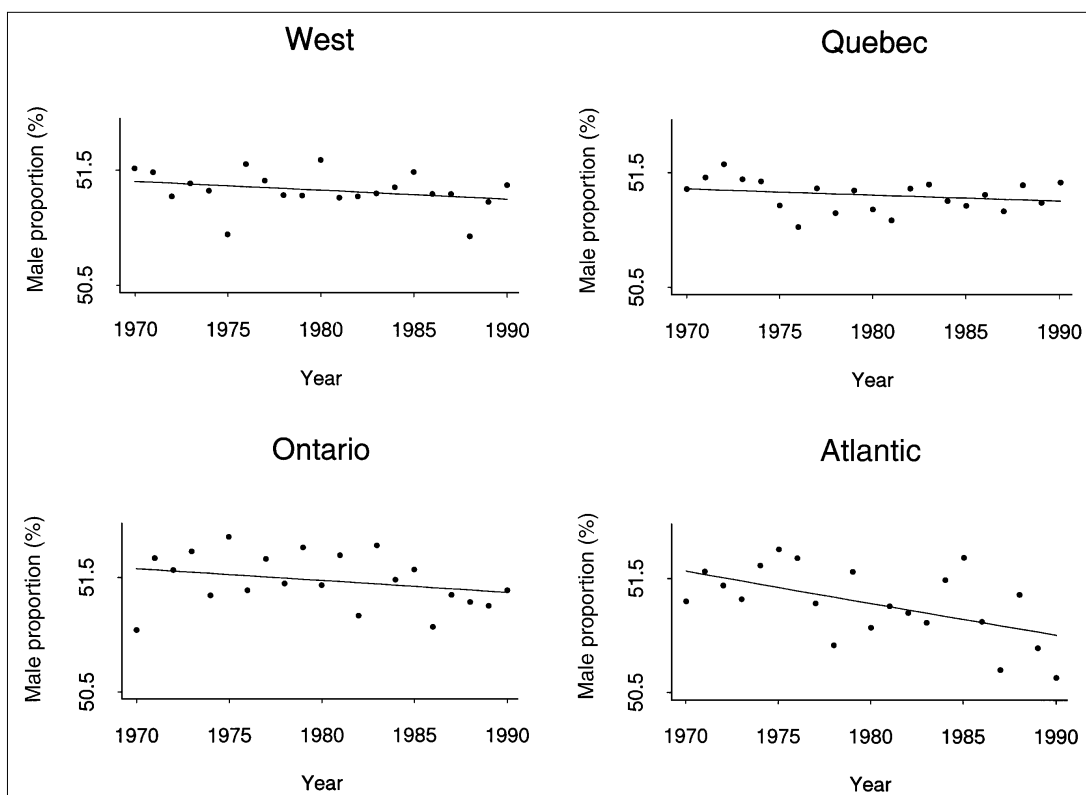


Fig. 3: Estimated trend in the male proportion in Canada from 1970 to 1990 by region.

this magnitude of change, and a power analysis indicated that a population with approximately 4.7 million live births over a similar period would be required to measure this reduction with an α value of 0.05 and a β value of 0.90.

Drugs used for ovulation induction have been associated with decreased sex ratios.^{21,27} Thus, advances in the treatment of infertility, or increased access to such treatment, during the study period may have affected the sex ratio.

Demographic changes in the Canadian population did not provide an obvious explanation for the declining trend. The proportion of Asian immigrants to Canada increased from 4% in 1970³⁹ to 53% in 1991.⁴⁰ However, this change did not agree with the literature reports of higher sex ratios in Asian populations.^{7,8} Second, the mean maternal age in Canada increased from 26.1 years in 1970 to 28.1 years in 1990,³⁵ which does not agree with Ulizzi and Zonta's finding of an association between maternal age and sex ratio.⁴ Finally, the average size of a Canadian family decreased from 3.7 people in 1970 to 3.1 people in 1990.⁴¹ However, previous studies have shown that newborns of women of low parity are more often male than female.^{4,42}

Of interest is the decreased sex ratio observed in the United States and reports of decreasing ratios in several Latin American countries over a similar period.² These

observations raise the possibility of the effects of broader environmental factors. Many animal and human studies have indicated an association between environmental toxins and altered sex ratios.^{11-20,43-45} Other biological markers such as semen quality have also shown changes over time.⁴⁶⁻⁵¹ For example, Auger and associates⁵⁰ demonstrated a decrease in concentration, motility and percentage of morphologically normal sperm in fertile men over the past 20 years and speculated that these changes may reflect the effect of environmental toxins.

It is possible that certain biological markers such as sex ratio and semen quality are being altered by as yet unidentified factors that may include environmental toxins. The decrease in the sex ratio observed in our study, subtle as it was, portends a greater biological significance as a highly sensitive and unambiguous measure of the reproductive health of large populations.

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Table 1: Logistic regression analysis of the year-to-year change in the sex ratio (male proportion*) from 1970 to 1990 by region of Canada and the estimated 20-year cumulative change in the male proportion per 1000 live births

Region	Slope	p value	Cumulative change in male proportion per 1000 live births (and 95% CI†)
West	-0.00028	0.20	-1.4 (-3.7 to 0.9)
Ontario	-0.00020	0.31	-1.0 (-2.9 to 0.9)
Quebec	-0.00041	0.09	-2.0 (-5.4 to 1.3)
Atlantic	-0.00112	< 0.01	-5.6 (-9.4 to -1.8)
Canada	-0.00044	< 0.001	-2.2 (-3.3 to -1.1)

*Proportion of live births that were male.
†CI = confidence interval.

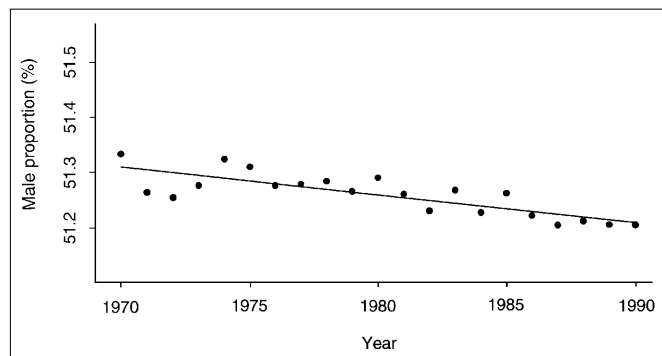


Fig. 4: Estimated trend in the male proportion in the United States from 1970 to 1990.



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