Early Human Development 91 (2015) 801–806

Contents lists available at ScienceDirect

Early Human Development

journal homepage: www.elsevier.com/locate/earlhumdev

Best practice guidelines

Temporal and regional trends in the secondary sex ratio: The Nordic experience

Johan Fellman

Hanken School of Economics, Helsinki, Finland

ARTICLE INFO

Keywords:
Crude birth rate
Stillbirth rate
Total fertility rate
Denmark
Finland
Iceland
Norway
Sweden

ABSTRACT

The sex ratio (SR) at birth, also known as the secondary sex ratio, is defined as the number of males per 100 females and approximates 106. According to the literature, the SR shows notable heterogeneity and attempts have been made to identify factors influencing it, but comparisons demand large data sets. Attempts to identify associations between SRs and stillbirth rates (SBRs) have yielded inconsistent results. A common pattern observed in different countries is that during the first half of the twentieth century, the SR showed increasing trends, but during the second half, the trend decreased. Secular increases are thought to be caused by improved socio-economic conditions. The recent downward trends have been attributed to new reproductive hazards. Similar findings have been made in the Nordic countries. Factors affecting the SR within families remain poorly understood. Although these factors have an effect on family data, they have not been identified in large

Contents

1. Introduction

The sex ratio (SR) at birth shows marked regional and temporal variations. In a long series of papers, attempts have been made to identify factors influencing the SR, but statistical analyses have shown that comparisons demand large data sets.

Attempts to identify reliable associations between SRs and stillbirth rates (SBRs) have yielded inconsistent results. Hawley [1] stated that where prenatal losses are low, as in the developed countries with a high standard of living, the SRs at birth are usually around 105 to 106. On the other hand, in developing countires, where the frequencies of prenatal losses are relatively high, SRs at birth are around 102. Visaria [2] could not find any correlation between late foetal death ratios and the SRs of live births. He stressed that available data on late foetal mortality lend at best only weak support to these findings and concluded that racial differences seem to exist in the SR. SBRs are usually higher among males than females, and hence, the SR among stillborn infants is markedly higher than normal values, but the excess of males has decreased during the last decades. Hence, the SR among live-born infants is slightly lower than among all births, but this difference is now minute. Furthermore, the SR among multiple maternities is lower than among singletons. The SR in multiple births is also known to be low. The reason is unclear, but several hypotheses have been presented, including theories involving maternal gonadotrophin level at the time of conception or the higher prenatal mortality of twin males [3,4]. Visaria [2] noted that the observed SRs are strongly influenced by random errors and pointed

E-mail address: fellman@hanken.fi.

http://dx.doi.org/10.1016/j.earlhumdev.2015.10.005
0378-3782/

out that confidence intervals (CIs) are crucial when differences in SRs are interpreted. Fellman and Eriksson [5] presented Visaria's and their own CIs with respect to the sample size *N* given on a logarithmic scale. They noted that for small data sets, the CIs are broad, and consequently, it is difficult to identify statistically significant differences. In addition, they observed that for small values of *N*, there is a notable upward shift in Visaria's CIs. With increasing *N*, this shift vanishes.

2. Methods and materials

2.1. Maximum likelihood estimation [5]

If the theoretical proportion of males is p_0, then the observed relative frequency of males p is a maximum likelihood (ML) estimator of p_0 being unbiased, consistent, efficient, and asymptotically normal with $E(p) = p_0$ and $\mathrm{Var}(p) = \frac{p_0(1-p_0)}{N}$. According to the ML theory, $\mathrm{SR} = \frac{p}{1-p}$ is an ML estimator of the transformed parameter $\mathrm{SR}_0 = \frac{p_0}{1-p_0}$, but SR is not unbiased. Consider the difference $\mathrm{SR}-\mathrm{SR}_0 = \frac{p}{1-p} - \frac{p_0}{1-p_0} = \frac{p-p_0}{(1-p)(1-p_0)}$.

Hence, $E(\mathrm{SR}) = \mathrm{SR}_0 + E(\frac{p-p_0}{(1-p)(1-p_0)}) \neq \mathrm{SR}_0$. When $N \to \infty$, then $p \to p_0$ and $\mathrm{SR} - \mathrm{SR}_0 \to 0$ and the estimate *SR* is consistent, biased, but asymptotically unbiased, and normally distributed.

2.2. Materials

Several studies have shown marked temporal variations in recent time series. A review of studies of temporal variations in the SR is given by Fellman and Eriksson [5]. In the 1870s, Berg published SR data for live births in the counties of Sweden in for 1749–1869 (Table 1) [6]. He presented (in Swedish) a study with a detailed analysis of the SR in Sweden. Berg considered not only the SR among births but also in the population. He considered all births, live births, stillbirths, and regional differences among the births. Hofsten and Lundström [7] presented (in Table 6.1) the crude birth rates (CBRs) for the counties in Sweden for the decades between 1751 and 1970. In our study, the variable CBR is defined as the mean value of the decennial CBR data given by them for the period 1751–1870. Furthermore, Hofsten and Lundström have also presented the total fertility rates (TFRs) per 1000 women for all decades starting from around 1860 to 1970 (in Tables 6.2–6.16). The variable TFR used in our study is their data for 1860. In Table 1, Fellman and Eriksson [8] included the regional data for SR, CBR, and TFR and the number of live births (n) associated with the SRs. Table 1 in this study is an excerpt of their Table 1.

Table 1
Geographical coordinates, the number of live births associated with the SR, the secondary sex ratio (SR), the crude birth rate (CBR), and the total fertility rate (TFR) for the counties of Sweden. The residences are given in Fig. 3. This table is an excerpt of Table 1 of Fellman and Eriksson [8].

Code[a]	Period[b]	Lat.	Long.	n[c]	SR	CBR[d]	TFR[e]
A	1749–1869	59.32	18.07	336854	103.4	34.5	3583
B	1749–1869	59.32	18.07	324901	104.6	31.4	4070
C	1749–1869	59.90	17.80	246343	104.2	30.7	4011
D	1749–1869	58.76	17.01	319940	104.6	31.0	4448
E	1749–1869	58.42	15.64	581692	104.5	32.4	4494
F	1749–1869	57.78	14.18	424184	104.9	31.6	4771
G	1749–1869	56.86	14.82	356405	104.7	34.2	4942
H	1749–1869	56.80	16.00	516021	105.8	33.7	4776
I	1749–1869	57.63	18.30	119541	105.3	28.2	3612
K	1749–1869	56.16	15.58	283511	103.7	35.6	4738
L	1749–1869	56.02	14.13	455200	104.8	32.8	4613
M	1749–1869	55.61	13.06	637249	104.6	34.9	4629
N	1749–1869	56.67	12.86	271859	104.5	32.0	4646
O	1749–1869	58.35	11.93	482251	103.9	34.8	4226
P	1749–1869	58.37	12.32	597113	104.8	32.5	4574
R	1749–1869	58.71	13.82	522657	104.8	33.5	5004
S	1749–1869	59.38	13.50	552016	105.1	33.0	4825
T	1749–1869	59.27	15.22	367499	104.5	32.3	5067
U	1749–1869	59.67	16.55	272943	104.3	31.4	4277
W	1749–1869	60.61	15.64	395484	104.7	30.5	4681
X	1810–1869	60.68	17.16	188398	104.8	29.0	4085
Y	1810–1869	62.63	17.94	175813	105.1	32.6	4880
Z	1810–1869	63.18	14.65	77473	106.4	27.3	4539
AC	1749–1869	63.83	20.27	169733	104.4	37.6	5366
BD	1749–1869	65.59	22.17	153877	105.1	37.6	5509
Total	1749–1869	59.18	15.87	8828958	104.66		

[a] The codes are explained in Fig. 3.
[b] For Stockholm city and the county of Gotland, data are known for the whole period, but the rest of the counties have missing data for the period 1774–1794.
[c] The number of live births for the defined period. The twinning rate for the period 1751–1860, but for some decades and some counties, data are missing.
[d] CBR is the mean value of the decennial CBR data given by Hofsten and Lundström [7].
[e] TFR for 1860 given by Hofsten and Lundström [7].

2.3. Temporal variations in the SR

Fellman and Eriksson [9] compared the temporal trends in the SR in the Nordic countries and among all births (SR) and live births ($\mathrm{SR_L}$) for Sweden (1751–2005). The study of the Swedish data is based on a combination of old data published by Berg [6] and Sundbärg [10] and new data published by Statistics Sweden and "Socialstyrelsen." The SBRs have a very slight influence on the $\mathrm{SR_L}$. However, as noted above, some effects can be identified if long data series are analysed. During the period 1751–1960, the $\mathrm{SR_L}$ and the SR for all births in Sweden had unexplainable fluctuations, but they showed increasing tendencies. After 1960, both decreased. Fellman and Eriksson [8] obtained for $\mathrm{SR_L}$ a time series for the period 1751–2007, and for SR for the periods 1751–1800 and 1861–2004. In Sweden, the more marked increasing trend in the SR for live births than for all births is obviously a result of the decreasing trend in the SBR.

Fellman and Eriksson [9] compared $\mathrm{SR_L}$ data for Finland and Norway. Live births in Finland for the period 1751–2007 are given in the Statistical Yearbook of Finland (2008). Increasing trends are observed for Finland for 1751–1950 and for Norway for 1801–1950. Their findings for Finland and Norway are in good agreement with the results for Sweden. Good agreement was also found between the Danish and Icelandic series (*Icelandic Historical Statistics.* Reykjavík, 1997, 957 pp). In Finland and Denmark, the increasing trends are more pronounced than in Sweden and Norway. For Iceland, the trend is most marked. The applied regression models up to 1950 indicate statistically increasing trends in all countries. After the maxima the series decreased. Fig. 1, is a reprint of Figure 1 [9].

Fellman and Eriksson [9] also presented the SBR for Sweden, Finland, Norway, Denmark, and Iceland, and the temporal trends in all countries are very similar (Fig. 2). They attempted to identify associations between the SRs and the SBRs, but the associations may have been disturbed by the fact that both may be influenced by external, time-dependent, and still unknown factors. Fellman and Eriksson [9] tried to eliminate the effect of the unknown factors by studying partial correlation coefficients between SR and SBR when time is kept fixed. Following Kendall and Stuart [11], they used the formula $r_{\mathrm{SR,SBR.t}} = \frac{r_{\mathrm{SR,SBR}} - r_{\mathrm{SR,t}} r_{\mathrm{SBR.t}}}{\sqrt{(1-r^2_{\mathrm{SR,t}})(1-r^2_{\mathrm{SBR,t}})}}$ for the partial correlation between SR and SBR when time (t) is kept fixed. The approximate standard error is $SE(r_{\mathrm{SR,SBR.t}}) = \frac{1-\rho^2_{\mathrm{SR,SBR.t}}}{\sqrt{n}}$. According to the theory, the proposed influence of SBR on SR should produce negative correlation coefficients, but this is not generally obtained. Consequently, universally consistent associations between SR and SBR were not found, and the negative results of Visaria [2] were confirmed.

2.4. Regional variations

Fellman and Eriksson [8] checked the regional heterogeneity in the SR for live births. This was performed with χ^2 tests so that the number