

The effects of artificial gender imbalance

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Therese Hesketh & Jiang Min Min

One of the problems of sexual reproduction, especially in predominantly monogamous species that pair 'for life', is to ensure a balance between the birth rate of males and females. In humans, this balance has been remarkably even, but the past few decades have seen a substantial shift towards men, notably in some Asian countries. The reason, however, is not biological; there has simply been a cultural preference for sons in the affected societies, which together with recent availability of prenatal sex-selection technologies has led to widespread female feticide. The result has been a huge excess of males in several countries. Whilst it is not yet fully clear how a surplus of millions of men will affect these societies—perhaps even leading to civil unrest—some countries have already taken steps to alleviate the problem by addressing the underlying cultural factors. However, the problem is about to come to a crisis point, as a large surplus of men reach reproductive age. It will take many decades to reach a balanced representation of both sexes again.

The sex ratio at birth (SRB) is defined as the number of boys born to every 100 girls. It is remarkably consistent in human populations, with around 103–107 male babies for every 100 female ones. John Graunt first documented this slight excess of male births in 1710 for the population of London, and many studies have since confirmed his finding [1]. Higher mortality from disease, compounded by the male tendency towards risky behaviours and violence, means that the initial surplus of boys decreases to roughly equal number of males and females during the all-important reproductive years in most populations.

Researchers have studied a large number of demographic and environmental factors that could affect the SRB, including

family size, parental age and occupation, birth order, race, coital rate, hormonal treatments, environmental toxins, several diseases and, perhaps most intriguingly, war [2–4]. It is well documented that wars are associated with a small increase in the sex ratio. This phenomenon occurs both during the war and for a short period afterwards. The best examples of this were reported for the First and Second World Wars in both the USA and Europe, and for the Korean and Vietnam Wars in the USA [5,6]. However, these findings were not reproduced in the more recent Balkan Wars and the Iran–Iraq war [7]. There have been several biological explanations for these increases. It has been proposed, for example, that the stress of war adversely affects the viability of XY-bearing sperm. Alternatively, a higher frequency of intercourse after prolonged separation during times of war is thought to lead to conception earlier in the menstrual cycle, which has been shown to result in more males [4,8]. There have been evolutionary explanations, such as the loss of large numbers of men in war leading to an adaptive correction of the sex ratio [4,9]. Nonetheless, the real causes of the altered SRB during war remain elusive: all of the discussed biological and social factors have been shown to cause only marginal deviations from the normal sex ratio.

Whilst war has only slightly shifted SRB towards more male babies and only for a limited time period, cultural factors, namely a strong preference for sons, has been causing large distortions of gender balance during the past decades. Son preference is most prevalent in a band of countries from East Asia through to South Asia and the Middle East to North Africa [9]. For centuries, sons have been

regarded as more valuable, because males can earn higher wages especially in agrarian economies, they generally continue the family line, are recipients of inheritance and are responsible for their parents in illness and old age. By contrast, daughters often become members of the husband's family after marriage, no longer having responsibility for their biological parents [10]. There are also location-specific reasons for son preference: in India, the expense of the dowry, and in South Korea and China, deep-rooted Confucian values and patriarchal family systems [11].

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Until recently, son preference was manifest post-natally through female infanticide, abandonment of newborn girls, poorer nutrition and neglect of health care, all causing higher female mortality [12]. Studies have shown that unequal access to health care is the most important factor in differential gender mortality [13,14],



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Fig 1 | Sex ratio at birth for China's provinces in 2005.

especially in countries where health care costs are borne by the family [15]. As early as 1990, the Indian economist Amaryta Sen estimated that differential female mortality had resulted in around 100 million missing females across the developing world with the overwhelming majority of these in China, India, Pakistan and Bangladesh [16].

To make matters worse, during the 1980s, diagnostic ultrasound technology became available in many Asian countries, and the opportunity to use the new technology for prenatal sex selection was soon exploited. Indeed, the highest SRBs are seen in countries with a combination of son preference, easy access to sex-selection technologies and abortion, and a small family culture. The latter is important because where larger families are the norm, couples will continue to have children until they have a boy. If the couple plan, or are legally restricted, as in China, to only one or two children, they will use sex selection to ensure the birth of a son [17]. This combination has resulted in serious and unprecedented sex ratio imbalances that are now affecting the reproductive age groups in several countries, most notably China, South Korea and parts of India.

South Korea was the first country to report a very high SRB, because the widespread uptake of sex-selection technology preceded other Asian countries. The sex ratios started

to rise in the mid-1980s in cities; ultrasound was already widely available even in rural areas by 1990 [17]. By 1992, the SRB was reported to be as high as 125 in some cities.

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China soon followed. Here, the situation was further complicated by the one-child policy introduced in 1979. This has undoubtedly contributed to the steady increase in the reported SRB from 106 in 1979 to 111 in 1990, 117 in 2001, 121 in 2005 and as high as 130 in some rural counties [18]. The latest figures for 2010 report an SRB of 118 [19] (National Bureau of Statistics of China 2011), the first drop in three decades, suggesting an incipient downturn. However, the number of excess males in the reproductive age group will continue to increase for at least another two decades. Because of China's huge population, these ratios translate into massive numbers: in 2005, an estimated 1.1 million excess males were born across the country and the number of males under the age of 20 might exceed females by around 30 million [18].

These overall figures conceal wide variations across the country (Fig 1): the SRB is higher than 130 in a strip of heavily populated provinces from Henan in the north to Hainan in the south, but close to normal in the large sparsely populated provinces of Xinjiang, Inner Mongolia and Tibet. Some are sceptical about these high SRB figures or have suggested that, under the constraints of the one-child policy, parents might fail to register a newborn girl, so that they might go on to have a boy [20]. However, recent evidence shows that such under-registration explains only a small proportion of missing females and that sex-selective abortion undoubtedly accounts for the overwhelming majority [18].

There are marked regional differences in SRB in India. Because incomplete birth registrations make the SRB difficult to calculate accurately, the closely related ratio of boys to girls under the age of six is used, showing distinct regional differences across the country with much higher levels in the north and west. According to the most recent census in 2010, the SRB for the whole country was 109, a marginal increase on the previous census in 2001, which showed an SRB of 108. These national figures, however, hide wide differences from a low SRB of 98 in the state of Kerala to 119 in Haryana State. The highest SRBs at district level for the whole of India are in two districts of Haryana state, where the SRBs are both 129 [21]. The Indian figures contrast with the Chinese in two ways: nowhere in China is the sex ratio low, and in India the sex ratio is higher in rural than urban areas, whereas the reverse is true for China [22].

A consistent pattern in all three countries is a clear trend across birth order, that is first, second and subsequent children, and the sex of the preceding child. This is driven by the persistence of the 'at least one boy' imperative in these cultures. Where high fertility is the norm, couples will continue to reproduce until they have a boy. Where couples aim to restrict their family size, they might be content if the first child is a girl, but will often use sex selection to ensure a boy in the second pregnancy. This was shown in a large Indian study: the SRB was 132 for second births with a preceding girl, and 139 for third births with two previous girls. By contrast, the sex ratios were normal when the first born was a boy [23].

The sex ratio by birth order is particularly interesting in China (Table 1) because of the differences in implementing the one-child policy between urban and rural areas. In urban China, only one child is allowed, so some urban Chinese make the choice to select the sex of their first pregnancy. In most rural areas, two children are allowed, so if the first is a girl, couples are increasingly likely to select the sex of the second pregnancy. In some provinces, the rural population are allowed a second child only after the birth of a girl. This variant of the one-child policy seems to lead to the highest sex ratios in second births. The SRB across the country for first births is 108, for second 143, and for rare third births 157. In some provinces, the sex ratio for second births rises to 190, and for third to more than 200 [18].

South Koreans are inclined to use sex selection, even in their first pregnancy, as there is a traditional preference for the first-born to be a son. This tendency towards sex selection rises for third and fourth births as parents try to ensure they produce a son. In the peak years of the early 1990s, when the overall SRB was 114, the sex ratio for fourth births was 229 [17].

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Since prenatal sex determination only became accessible during the mid-1980s, and even later still in rural areas, the large cohorts of surplus young men have only now started to reach reproductive age. The consequences of this male surplus in the all-important reproductive age group are therefore still speculative and the existing literature about the consequences of distorted sex ratios is predominantly theoretical with few hypothesis-testing investigations [24,25]. In addition, most research focuses on countries in which sex ratios differ only marginally from biological norms [26]; few researchers have systematically examined the massive sex ratio distortion in China and India. However, it is clear that large parts of China and India will have a 15–20% excess of young men during the next 20 years. These men will be unable to get married, in societies in which marriage is regarded as virtually universal, and where social status depends, in large part,

Table 1 | Sex ratio at birth for China's provinces in 2005.

	Total	First order	Second order	Third order
Total	120	108	143	157
Urban	115	110	138	146
Rural	123	107	146	157

Adapted from Zhu *et al* 2009 [18].

on being married and having children. An additional problem is the fact that most of these men will come from the lowest echelons of society: a shortage of women in the marriage market enables women to 'marry-up', inevitably leaving the least desirable men with no marriage prospects [27]. As a result, most of these unmarriageable men are poor, uneducated peasants.

One hypothesis assumes that not being able to meet the traditional expectations of marriage and childbearing will cause low self-esteem and increased susceptibility to psychological difficulties, including suicidal tendencies [28]. A recent study using in-depth interviews with older unmarried men in Guizhou province, in south west China, found that most of these men have low self-esteem, with many describing themselves as depressed, unhappy and hopeless [29].

The combination of psychological vulnerability and sexual frustration might lead to aggression and violence. There is empirical support for this prediction: gender is a well-established individual-level correlate of crime, especially violent crime [30,31]. A consistent finding across cultures is that most crime is perpetrated by young, single males, of low socioeconomic status [32]. A particularly intriguing study carried out in India in the early 1980s showed that the sex ratio at the state level correlated strongly with homicide rates, and the relationship persisted after controlling for confounders such as urbanization and poverty [33]. The authors had expected to find that the high sex ratio would lead to increased violence against women, but their conclusion was that high sex ratios are a cause of violence of all types in society.

However, no other study has found similar results. The study mentioned above from rural Guizhou, for example, could find no evidence that unmarried men were especially prone to violence and aggression. Rather, the men were characterized

as shy and withdrawn, rather than aggressive [29]. In addition, reports of crime and disorder are not higher in areas with a known excess of young, single men. This might be because there is not yet a large enough crucial mass of unmarriageable men to have an impact, or assumptions about male aggression do not apply in this context.

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In China and parts of India, the sheer numbers of single men have raised other concerns. Because these men might lack a stake in the existing social order, it is feared that they will bind together in an outcast culture, turning to antisocial behaviour and organized crime [34], thereby threatening societal stability and security [35]. Some theorize that it could lead to intergroup conflict and civil war could erupt [32]; other authors go further, predicting that such men will be attracted to military-type organizations, potentially triggering large-scale domestic and international conflicts [36]. However, there is no evidence yet to support these scenarios. Crime rates are relatively low in India and China compared with other countries [37]. Such outcomes are probably multifactorial in their causes, and therefore the role of sex imbalance is difficult to determine.

An excess of men, however, should be beneficial for women, especially in those Asian societies in which women have traditionally low social status. In fact, much of the literature on sex ratios has focused on women's status and role in society, and on mating strategies; but again the literature has come from scenarios in which the sex ratio is only marginally distorted [38,39]. It is intuitive to see that

women are a valuable commodity when sex ratios are high [40,41]. Because women generally prefer long-term monogamous relationships [42], it is predicted that monogamy will be more prevalent in high sex ratio societies, with less premarital and extramarital sex [43], lower divorce rates [38,24] and less illegitimacy [31]. In India and China, tradition militates against some of these eventualities; for example, divorce and illegitimacy are rare in both countries, owing to the traditional values of these societies. But other effects can be explored. If women are more highly valued, it is predicted that they will have higher self-esteem, resulting in lower rates of depression and suicide [24]. In China, where suicide rates in rural women have been among the highest in the world [28], women now show improved self-esteem and self-efficacy: 47% of university graduates are female and women account for 48% of the labour force [19].

However, this increase in the value of women could also have paradoxically adverse effects on women, especially in rural societies. Benefits might accrue to men, such as fathers, husbands, traffickers and pimps, who control many female lives [35]. Increases in prostitution, kidnapping and trafficking of women in China have already been attributed to high sex ratios [44]. Hudson and Den Boer [36] cite the increase in kidnapping and trafficking of women, which has been reported from many parts of Asia, and the recent large increases in dowry prices in parts of India.

Despite the negative and potentially damaging culturally driven use of prenatal sex selection, there might be some positive aspects of easy access to this technology. First, access to prenatal sex determination probably increases the proportion of wanted births, leading to less discrimination

against girls and lower postnatal female mortality. India, South Korea and China have all reported reductions in differential mortality [45]. Second, it has been argued that an imbalance in the sex ratio could be a means to reduce population growth [46]. Third, the improved status of women should result in reduced son preference with fewer sex-selective abortions and an ultimate rebalancing of the sex ratio [4].



Other consequences of an excess of men have been described, but the evidence for causation is limited. Much has been made of the impact on the sex industry. It is assumed that the sexual needs of large numbers of single men will lead to an expansion of the sex industry, including the more unacceptable practices of coercion and trafficking. During the past 20 years the sex industry has in fact expanded in both India and China [47,48], but the role that the high sex ratio has played is impossible to isolate. The marked rise in the number of sex workers in China, albeit from a low baseline, has been attributed more to

a relaxation in sexual attitudes, increased inequality, and much greater mobility in the country, than an increase in the sex ratio. For example, the sex ratio is close to normal in border areas of Yunnan Province, where there is known to be the highest number of sex workers [49].

Similarly, it is impossible to say whether gender imbalance is a contributory factor to the reported, largely anecdotal, increases in trafficking for the sex industry and for marriage. Most unmarried men in China and India are in the poorest echelons of society, and thus unable to buy a bride. In addition, trafficking is probably far more common in parts of Eastern Europe and Africa where the sex ratio is normal [50]. Several commentators have suggested that an excess of men might encourage an increase in homosexual behaviour [17]. This is clearly highly contentious, and begs questions about the aetiology of sexual orientation. However, if this leads to increased tolerance towards homosexuality in societies where homophobia is still highly prevalent, it is perhaps a positive consequence of the high sex ratio.

There is clear concern at the governmental level about high sex ratios in the affected countries. In 2004, clearly risible with hindsight, China set a target to lower the SRB to normal levels by 2010 [51]. The Chinese government expressed concerns recently about the potential consequences of excess men for societal stability and security [52]. In the short term, little can be done to address the problem. There have been some extreme suggestions, for example recruiting men into the armed forces and posting them to remote areas [35], but such suggestions are clearly not feasible or realistic.

However, much can be done to reduce sex selection, which would have clear benefits for the next generation. There are two obvious policy approaches: to outlaw sex

selection, and to address the underlying problem of son preference. In China and India, laws forbidding infanticide and sex selection exist. It is therefore perplexing that sex-selective abortion is carried out, often quite openly, by medical personnel in clinics and hospitals that are often state-run and not in back-street establishments [20]. Enforcement of the law should therefore be straightforward—as the lessons from South Korea demonstrate. In the late 1980s, alarming rises in the SRB, because of easy access to sex-selective abortion, caused the government to act decisively. Eight physicians in Seoul, who had performed sex determination, had their licenses suspended in 1991 leading to a fall in the SRB from 117 to 113 in the following year. Following this success, laws forbidding sex selection were enforced across the country. This was combined with a widespread and influential public awareness campaign, warning of the dangers of distorted sex ratios, focusing especially on the shortage of brides. The results led to a gradual decline in the SRB from 116 in 1998 to 110 in 2009 [11].

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The lessons are clear. The fact that in China and India sex-selective abortion is still carried out with impunity—by licensed medical personnel and not even in back-street establishments—makes the failure of the government to enforce the law all the more obvious. One of the problems is that although sex-selective abortion is illegal, abortion itself is readily available, especially in China, and it is often difficult to prove that an abortion has been carried out to select the sex of the child, as opposed to family planning reasons.

To successfully address the underlying issue of son preference is, of course, hugely challenging, and requires a multi-faceted approach. Evidence from areas outside Asia strongly supports the idea that a higher status for women leads to less traditional gender attitudes and lower levels of son preference [52]. Laws in China and India have made important moves towards

gender equality in terms of social and economic rights. These measures, together with socio-economic improvements and modernization, have improved the status of women and are gradually influencing traditional gender attitudes [44].

The recognition that intense intervention would be necessary to change centuries-long traditions in China led to the Care for Girls campaign, instigated by the Chinese Population and Family Planning Commission in 2003. It is a comprehensive programme of measures, initially conducted in 24 counties in 24 provinces, which aims to improve perceptions of the value of girls and emphasizes the problems that young men face in finding brides. In addition, there has been provision of a pension for parents of daughters in rural areas. The results have been encouraging: in 2007, a survey showed that the campaign had improved women's own perceived status, and that stated son preference had declined. In one of the participating counties in Shanxi Province, the SRB dropped from 135 in 2003 to 118 in 2006 [53].

Surveys of sex preference are encouraging. In 2001, a Chinese national survey found that 37% of the female respondents—predominantly younger, urban women—claimed to have no gender preference for their offspring, 45% said the ideal family consisted of one boy and one girl, and the number expressing a preference for a girl was almost equal to those who wanted a boy [54]. A study conducted ten years later in three Chinese provinces showed that around two-thirds of adults of reproductive age classify themselves as gender indifferent; of the remainder, 20% said they would prefer to have a girl, with just 12% admitting to wanting a boy [52].

Other policy measures that can influence social attitudes include equal social and economic rights for males and females—for example, in relation to rights of inheritance—and free basic health care to remove the financial burden of seeking health care for daughters. Neither of these has yet been implemented. However, another suggestion that special benefits be given to families with no sons to ensure protection in old age has been introduced in some Chinese provinces.

Despite the grim outlook for the generation of males entering their reproductive years over the next two decades, the future is less bleak. The global SRB has probably

already peaked. In South Korea, the sex ratio has already declined markedly and China and India are both reporting incipient declines: in China the SRB for 2010 was reported as 118 down from the peak of 121 in 2005, and, importantly, 14 provinces with high sex ratios are beginning to show a downward trend [19]. India is now reported to have an SRB of around 109, down from a peak of around 111 in 2005 [21]. Whilst the combination of these incipient declines in SRB, and the changing attitudes towards the imperative to have sons, are encouraging, they will not start to filter through to the reproductive age group for another two decades. In China and India the highest sex ratio cohorts have yet to reach reproductive age, so the situation will get worse before it gets better. Normal sex ratios will not be seen for several decades.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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Therese Hesketh is at the University College London Institute of Global Health, London, UK. E-mail: t.hesketh@ucl.ac.uk
Jiang Min Min is at the Department of Public Policy and Law, Zhejiang Normal University, Jinhua, PR China.

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