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Distortions of sex ratios at birth in the United States; evidence for prenatal gender selection†

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Objective The normal male to female livebirth sex ratio ranges from 1.03 to 1.07. Higher ratios in China, India and Korea reflect prenatal sex selection. We reviewed sex ratios for US births to investigate potential prenatal sex selection.

Methods We reviewed all US livebirths from 1975 to 2002 using National Center for Health Statistics birth certificates in 4-year intervals. We compared the sex ratios of Blacks, Chinese, Filipinos, Asian Indians and Koreans relative to Whites. We also compared the sex ratios by birth order for first, second and third and more births (third+) from 1991 to 2002.

Results The male to female sex ratio from 1975 to 2002 was 1.053 for Whites, 1.030 ($p < 0.01$) for Blacks, 1.074 ($p < 0.01$) for Chinese and 1.073 ($p < 0.01$) for Filipinos. From 1991 to 2002, the sex ratio increased from 1.071 to 1.086 for Chinese, 1.060 to 1.074 for Filipinos, 1.043 to 1.087 for Asian Indians and 1.069 to 1.088 for Koreans. The highest sex ratios were seen for third+ births to Asian Indians (1.126), Chinese (1.111) and Koreans (1.109).

Conclusion The male to female livebirth sex ratio in the United States exceeded expected biological variation for third+ births to Chinese, Asian Indians and Koreans strongly suggesting prenatal sex selection.

KEY WORDS: male sex selection; prenatal diagnosis; ultrasound

INTRODUCTION

Male sex selection at birth has been well-documented in China, India, Korea and some other countries (Hesketh and Xing, 2006). The cultural basis for this in China and Korea is rooted in the tenets of Confucianism, which mandate a strict patrilineal inheritance (Chung and Das Gupta, 2007; Das Gupta, 2009) Sons were also traditionally responsible for the care of elders in the family and daughters were effectively lost to their parents after they married. This social structure made producing and raising male children the most important role for women in the family. The explanation for India may be more complex but probably also reflects similar patrilineal values (Das Gupta, 1987) Although these cultural preferences for male children existed for centuries, it was not until the 1980s that the technology for prenatal sex selection, i.e. second trimester ultrasound to determine fetal sex and thereby provide the choice for the termination of a female fetus, was widely available.

Although contemporary laws in these countries have made discrimination against women illegal, there is still evidence for continuing prenatal sex selection in areas of China and India (Park and Cho, 1995; George, 2006; Zhu *et al*., 2009). A distortion in the sex ratio for a country or a population has many social and ethical implications. The potential consequences of a surplus of males include fewer women to marry, long-term economic stresses associated with declining population numbers, more mental health problems, increased mobility and violence in young men devoid of family responsibilities and a growing sex industry with coercion and trafficking of women.(Hesketh *et al*., 2005; Hesketh and Xing, 2006)

The sex ratio is defined as the ratio of male births to female births. The sex ratio at birth ranges from 1.03 to 1.07 in most western industrialized countries with a median of 1.059 (Parazzini *et al*., 1998; United Nations, Department of Economic and Social Affairs, 2008). Sex ratios generally decline with increasing parity and increasing age (Mathews and Hamilton, 2005). A reversal of this normal trend in the sex ratio with increasing parity might be indicative of prenatal sex selection because it may be motivated by parents wishing to be assured that there is a male heir.

Mathews and Hamilton(2005) analyzed trends in the sex ratios for US births from 1910 to 2002. They noted

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a high sex ratio for births to Chinese mothers (1.074) and Filipino mothers (1.072) but did not separately analyze other Asian minorities where gender selection is common or consider patterns associated with birth order in these populations. We reanalyzed the sex ratios in US births from 1975 to 2002 for various populations and sex ratios by birth order to determine if there were patterns consistent with prenatal sex selection.

METHODS

Various definitions of the sex ratio at birth are available (male to female, males per 100 females, males per 1000 females and female to male). We defined the sex ratio as the number of male births divided by the number of female births (Davis *et al*., 1998).

Using data from the US National Center for Health Statistics (NCHS) from 1975 to 2002, we recorded the birth sex ratios by maternal race and nationality and birth order and grouped them into 4-year intervals (Centers for Disease Control and Prevention, National Center for Health Statistics, 1975–1990; Centers for Disease Control and Prevention, National Center for Health Statistics, 1990–2006). We included singleton and multiple births and also tracked maternal place of birth. Maternal race and nationality was based on birth certificate data and may include individuals of mixed race. Through 2002, NCHS classified mothers by a discrete race and/or nationality category, i.e. there was no overlap in the groups reported. For example, 'White' excludes all Asian and Pacific Islanders. Some race/nationality classifications changed during the study, so certain categories were only available for limited time periods. We confined our analysis to those Asian populations residing in the United States with the highest numbers of births. We assumed that the reporting of gender at birth was equally accurate for all populations and all time intervals included in this study.

Ratios for Black, Chinese, Filipino, Asian Indian and Korean were compared to those reported for White births. We also determined sex ratios by birth order for first, second and third or more children (third+), the mother's place of birth (i.e. in the 50 United States and the District of Columbia, or elsewhere) and singleton and multiple births from 1991 to 2002 by race and nationality. The quadrennial data for 1975–2002 allowed the analysis of race/nationality for many groups, but 1991–2002 was the only time period where data for parity was available for these specific Asian and Pacific Island populations in the United States.

Because the data is an entire population, statistical sampling errors are not present and the results can be interpreted directly. However, we also used the statistical test of proportions suggested by Mathews and Hamilton (2005) where the data is considered to be one possible set of outcomes that could have arisen in similar circumstances. This provided a measure of the strength of the observed patterns given the size of the populations. For the large number of comparisons involving differences in the sex ratio for populations relative to White, we used a two-tailed test with $p < 0.01$ considered significant. For the more limited analyses that evaluated whether there was an excess of males with higher parity, we compared the ratios using a one-tailed test with $p < 0.05$ considered significant.

This data is publicly available, de-identified data so our institutional human subject review board approval was not required.

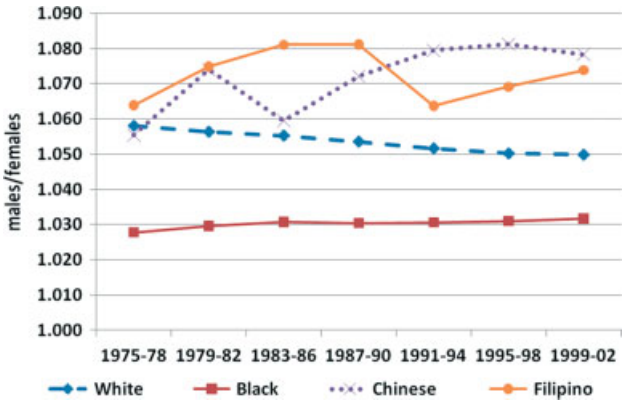

Figure 1—Male to female sex ratios at birth in the United States in 4-year intervals from 1975 to 2002 by selected races

RESULTS

The male/female sex ratio for all 105 939 732 US births from 1975 to 2002 was 1.050. The ratio declined from 1.053 in 1975–1978 to 1.048 in 1995–1998 before returning to 1.053 in 1999–2002. For White births, the ratio declined from 1.058 in 1975–1978 to 1.050 in 1999–2002 (Figure 1). At the same time, the ratio for Black births increased from 1.028 in 1975–1978 to 1.032 in 1999–2002 and this was significantly different from White births for all quadrennials (Table 1). The highest ratios were seen in several Asian-American populations. Ratios exceeded 1.08 for Filipinos from 1983 to 1990 and Chinese from 1995 to 1998. Chinese had significantly higher sex ratios when compared to White births for quadrennial intervals from 1991 to 2002 but there was no significant difference for 1975–1990. Filipino populations also showed significantly elevated ratios for the time periods of 1983–1990 and 1995–2002 (Table 1).

From 1991 to 2002, NCHS provided additional nationality sub-categories allowing the analyses to include Asian Indians and Koreans (Figure 2). Throughout this time period, both Asian Indian and Korean births showed higher sex ratios relative to Whites, but these differences only reached statistical significance for the 1991–1994 quadrennial (Table 1).

For 1991–2002, information was also available for sex ratios by birth order. Figure 3 compares the sex ratio in first versus second and subsequent births. For both White and Black populations, there was a statistically significant decrease in sex ratio for second

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Table 1—Sex ratios at birth in 4-year groups by maternal race/ethnicity in the United States from 1975 to 2002

Year	White		Black		Chinese		Filipino		Indian Asian		Korean	
	Total	Ratio m/f	Total	Ratio m/f	Total	Ratio m/f	Total	Ratio m/f	Total	Ratio m/f	Total	Ratio m/f
1975–1978	10 491 596	1.058	2 121 821	1.028*	39 605	1.055	50 572	1.064				
1979–1982	11 557 875	1.056	2 347 909	1.030*	52 138	1.074	61 792	1.075				
1983–1986	11 789 564	1.055	2 408 164	1.031*	66 704	1.060	81 512	1.081*				
1987–1990	12 521 278	1.054	2 671 001	1.030*	85 916	1.072	98 603	1.081*				
1991–1994	12 713 788	1.052	2 651 501	1.031*	99 667	1.080*	115 324	1.064	32 673	1.069*	24 329	1.093*
1995–1998	12 383 309	1.050	2 407 735	1.031*	112 372	1.081*	124 328	1.069*	65 097	1.072	33 269	1.080
1999–2002	12 678 892	1.050	2 428 415	1.032*	128 198	1.078*	128 268	1.074*	102 328	1.066	40 132	1.071
Total	84 136 302	1.053	17 036 546	1.030*	584 600	1.074*	660 399	1.073*	200 098	1.068*	97 730	1.080*

Racial/ethnic data was not available for Indian Asians and Koreans from 1975 to 1990.
m/f, male/female.
*$p < 0.01$, for two-tailed test.

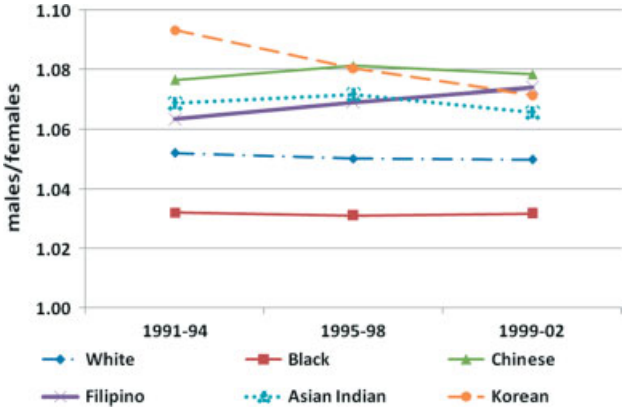

Figure 2—Male to female sex ratios at birth in the United States in 4-year intervals from 1991 to 2002 by maternal race with a focus on mothers of Asian or Pacific Island origin

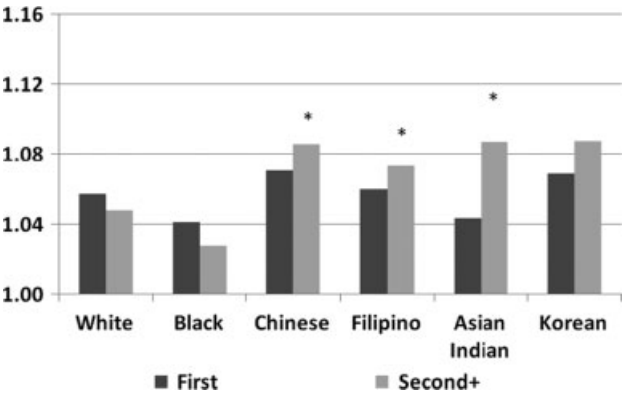

Figure 3—Male to female sex ratio by birth order (first and second+) in the United States by maternal race with a focus on mothers of Asian or Pacific Island origin from 1991 to 2002. *Significantly different when compared to White

and subsequent births, relative to that seen for first births. In contrast to this decrease, the male/female sex ratio for second and subsequent births increased relative to first births for Chinese, Filipino, Asian Indian and Korean populations. For Asian Indians, the sex ratio in second and more births was 1.087 ($p < 0.01$) and for Chinese was 1.086 ($p < 0.05$) and for Filipino, it was 1.073 ($p < 0.05$) (Table 2).

Figure 4 shows a further division of the sex ratios by birth order comparing first, second and third or higher livebirths. The highest ratios were seen for third+ births to Asian Indians (1.147), Chinese (1.101) and Koreans (1.140) for 1991–1994. These data show considerable differences between race/nationality in the sex ratios for first, second and third+ births. For Asian Indians, the very high rate for third+ births declined in each successive quadrennial although the ratio for first pregnancies increased. For Koreans, there also appeared to be a trend toward more normal sex ratios over time (Table 2).

The mother's place of birth from 1991 to 2002 was in the 50 states or the District of Columbia for 82.1% of Whites, 89.7% of Blacks, 9.6% of Chinese, 17.9% of Filipinos, 5.2% of Asian Indians and 5.3%

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Table 2—Male to female (m/f) ratio at birth of first births, second, third + (i.e. third or more) and all births subsequent to first births (i.e. second +) in the United States by selected races from 1991 to 2002

Year	Total	Ratio m/f	Total	Ratio m/f	Total	Ratio m/f	total	ratio m/f
White	*First*		*Second*		*Third+*		*All subsequent to First*	
1991–1994	4 093 864	1.059	3 716 627	1.052	4 486 387	1.046	8 203 014	1.049
1995–1998	4 130 400	1.056	3 679 125	1.051	4 471 840	1.044	8 150 965	1.047
1999–2002	4 186 856	1.056	3 779 526	1.051	4 657 455	1.043	8 436 981	1.046
1991–2002	12 411 120	1.057	11 175 278	1.051	13 615 682	1.044	24 790 960	1.047
Black								
1991–1994	693 374	1.043	622 637	1.030	1 063 065	1.026	1 685 702	1.028
1995–1998	728 003	1.042	616 486	1.031	1 039 877	1.023	1 656 363	1.026
1999–2002	719 449	1.038	624 424	1.036	1 073 512	1.025	1 697 936	1.029
1991–2002	2 140 826	1.041	1 863 547	1.032	3 176 454	1.025	5 040 001	1.028
Chinese								
1991–1994	34 346	1.082	28 761	1.055	20 305	1.101	49 066	1.074
1995–1998	44 585	1.069	39 510	1.084	27 542	1.103*	67 052	1.092*
1999–2002	51 873	1.065	44 401	1.086	31 659	1.089	76 060	1.087*
1991–2002	130 804	1.071	112 672	1.077	79 506	1.097	192 178	1.086*
Filipino								
1991–1994	59 126	1.060	48 733	1.062	54 557	1.069	103 290	1.066
1995–1998	47 219	1.054	38 239	1.089*	38 295	1.068	76 534	1.079
1999–2002	47 027	1.066	40 063	1.084	40 744	1.072	80 807	1.078
1991–2002	153 372	1.060	127 035	1.077*	133 596	1.070	260 631	1.073*
Asian Indian								
1991–1994	13 297	1.026	10 752	1.063	8 370	1.147*	19 122	1.099*
1995–1998	26 170	1.024	21 609	1.086*	16 970	1.128*	38 579	1.105*
1999–2002	44 186	1.060	33 354	1.059	24 472	1.089*	57 826	1.071
1991–2002	83 653	1.043	65 715	1.068*	49 812	1.112*	115 527	1.087*
Korean								
1991–1994	9 516	1.085	8 686	1.071	5 942	1.140	14 628	1.098
1995–1998	12 630	1.045	11 579	1.095*	8 822	1.119*	20 401	1.105*
1999–2002	16 096	1.077	13 412	1.077	10 484	1.052	23 896	1.066
1991–2002	38 242	1.069	33 677	1.082	25 248	1.095	58 925	1.088

We compared the first to each of the other groups.
* $p \leq 0.05$ for one-tailed test.

of Koreans. The percentages of all livebirths that were twins or higher order multiples from 1991 to 2002 were 2.8% for Whites, 3.1% for Blacks, 2.2% for Chinese, 1.9% for Filipinos, 2.6% for Asian Indians and 1.8% for Koreans. In all the above categories, the male to female sex ratio was lower for multiples than singletons, specifically Whites 1.013 to 1.052, Blacks 0.990 to 1.032, Chinese 1.077 to 1.080, Filipinos 1.022 to 1.070, Asian Indians 0.994 to 1.071 and Koreans 1.038 to 1.082 for multiples and singletons, respectively. Although there were differences in sex ratios for multiples, the inclusion of multiple births was insufficient to explain the overall distortions in sex ratios for the total population.

DISCUSSION

In the absence of extrinsic factors, the sex ratio at birth is widely considered to be consistent across human populations with values of 1.03 to 1.07 (Coale, 1991). In China, India, Korea and some other countries rates in excess of 1.08 have been found and these have been interpreted as having arisen through prenatal gender selection (Park and Cho, 1995; George, 2006; Hesketh and Xing, 2006; Sahni *et al*., 2008; Zhu *et al*., 2009). Our analyses show that there are also significant differences in the male to female sex ratio at birth for different populations in the United States. For some populations, notably, Chinese, Filipino, Asian Indian and Korean, the ratios did at times exceed that historically encountered as a consequence of normal variation. However, these ratios were lower than some of the values reported for the same populations in their native countries.

Differences in the sex ratios may be attributable to maternal age, parity, prenatal healthcare, stress and other environmental factors as well as prenatal sex selection (Davis *et al*., 1998). It is well established that fetal loss rates are higher when the fetal gender is male (Catalano *et al*., 2009) and it is reasonable to think that a broad spectrum of additional environmental challenges or sub-optimal healthcare will potentially have a greater toll on male fetuses. Our data for White and Black births indicate that such factors do not have an acute

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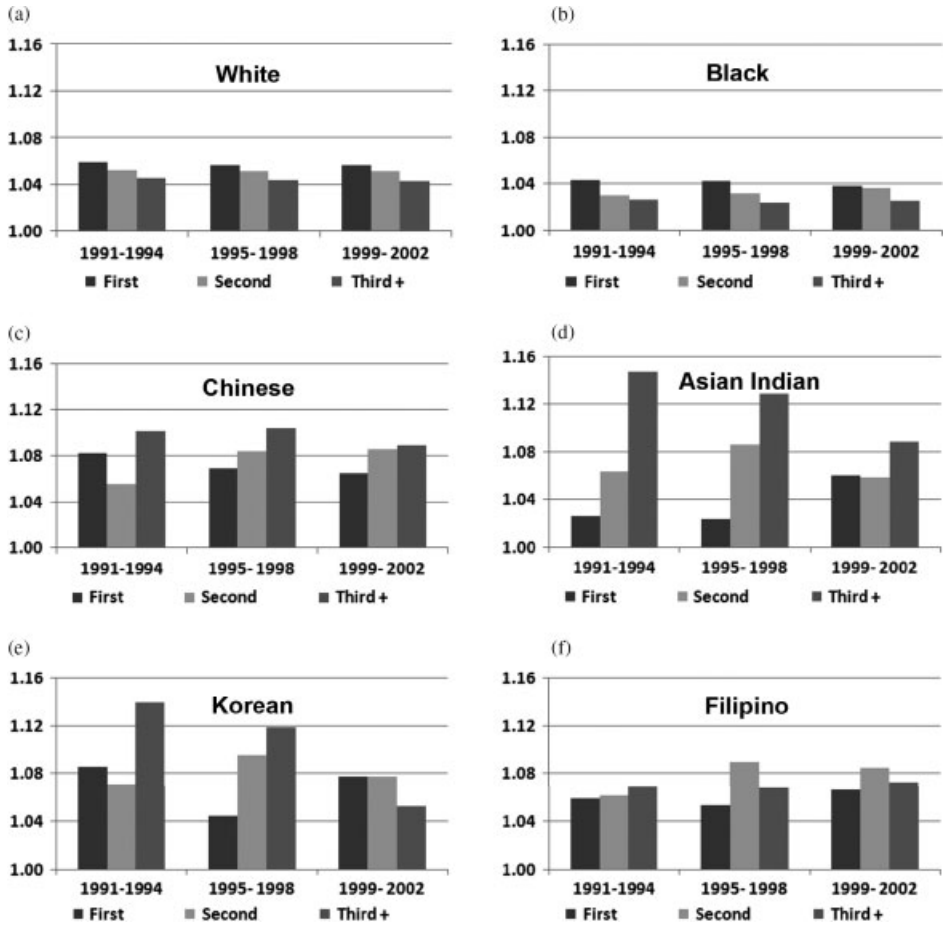

Figure 4—Sex ratios for first, second and third or more births for six races. Data for each quadrennial, 1991–1994, 1995–1998 and 1999–2002 is shown separately

impact on sex ratios; the observed rates show consistency over time with only very minor changes in the ratios over from 1975 to 2002. However, maternal demographics, environmental factors and healthcare could still account, at least in part, for observed race and nationality differences. Therefore, even though we observed statistically significant elevations in overall sex ratios for Chinese Filipino, Asian Indian and Koreans, the component attributable to prenatal sex selection cannot be easily established from these data.

Analyzing the data from the perspective of differences in the sex ratio across birth order for each race/nationality has the advantage of substantially controlling for the confounding environmental and healthcare differences. For each population group, the sex ratios for first, second and third+ births should be comparable with a slightly lower ratio for higher order births reflecting advancing maternal age (Mathews and Hamilton, 2005). Consistent with this, we did indeed see the expected slight decline in sex ratios with increasing parity for White and Black women (Figure 4). For Chinese, Filipino, Asian Indian and Korean populations, we observed the opposite, i.e. increases in sex ratios with higher parity with some of the ratios substantially higher than that expected for normal biological variation. Limited data from the U.S. year 2000 census provides independent evidence for an excess of males in second and third births to Chinese, Korean and Asian Indian parents (Almond and Edlund, 2008). This same trend of increased sex ratio with higher parity has also been reported in China, India and Korea and it is consistent with prenatal sex selection (Park and Cho, 1995; George, 2006; Zhu *et al*., 2009)

The data shown in Figure 4 indicate that the greatest departure from the normal sex ratio occurred in the 1991–1994 quadrennial for third+ pregnancies. In the two subsequent quadrennials, there were lower sex ratios for the Chinese, Korean and Asian Indian populations. Possible explanations for the peak in the early 1990s include greater demand for sex selection at the time when the ultrasound technology was first being introduced in the 1980s, differences in education and acceptance or rejection of gender selection by different immigrant populations, assimilation and changes in laws in Korea, China, India and elsewhere that have reduced discrimination and increased societal opportunities for women(Park and Cho, 1995; Hesketh *et al*., 2005; Lai-wan *et al*., 2006; Zhu *et al*., 2009). Our data on the maternal birthplace documents that over 90% of the Chinese, Asian Indian and Korean mothers and 82% of Filipino mothers were born outside of the 50 United States and District of Columbia. Those women

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who came to the United States more recently were less likely to have had acculturation. Declining use of gender selection has been reported for native Koreans (Chung and Das Gupta, 2007). More data are needed to evaluate these temporal trends.

Limitations of our analyses include inaccurate or incomplete reporting, inability to separately take into consideration mixed parentage and the limited numbers of births in some subgroups. Although sex selection has not been identified as an issue in Whites, we assumed that if there were any gender selection in the control White population it was minimal or was minimal or neutral, in its effect on sex ratios. In evaluating sex ratio differences with increasing parity, it should be recognized that birth certificates do not provide data for the sex of previous children and slightly more than one half of first births are male. Therefore, many parents may not consider intervention in a subsequent pregnancy because their goal of having a male has already been met. There is also presumably a countering component of preferential selection for females to be considered; either because of X-linked genetic conditions, for family balancing, or other personal preferences.

It is not possible from our analyses to reliably estimate the overall deficit in the number of female infants for each year. However, from Figure 1, it would appear that at least for Chinese and Filipino, the ratios are very similar to White for the earliest (1975–1978) quadrennial when any gender selection would have been minimal. Applying the White sex ratio, to all Asian or Pacific Islanders, we can very crudely estimate that that there were approximately 20 000 (1.25%) missing females in this subset of US births from 1983 to 2002 or an average of 1000 per year. This 20-year interval was chosen as ultrasound identification of fetal sex became generally available in the early 1980s. The American College of Obstetrics and Gynecology (ACOG) opposes prenatal gender selection when it is motivated by, and reinforces, the devaluation of women (Committee on Ethics, 2007). However, ACOG acknowledges that 'it will sometimes be impossible for health care professionals to avoid unwitting participation'. George (2006) notes that it is not appropriate for dominant communities in Western societies to accept sex selection for Asian minorities and that the problem requires global responsibility. Indeed, the long-term consequences of sex ratio distortions (Hesketh *et al.*, 2005; Hesketh and Xing, 2006) will not necessarily be confined to the societies where gender selection is currently the most common.

CONCLUSION

We report evidence which strongly suggests that male sex selection occurs in some populations of Asian and Pacific Island origin/culture who deliver in the United States. Although the magnitude of prenatal sex selection in the United States is not on the scale of that seen in China and other Asian countries where it results in major sex ratio imbalances, the practice does raise serious ethical issues in the United States. Future monitoring of sex ratios will be especially important because inexpensive and non-invasive prenatal sex identification tests in the first trimester are becoming increasingly available (Benn and Chapman, 2010).

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