MILITARY MEDICINE, 174, 5:523, 2009

Sex Ratio Shift in Offspring of Male Fixed-Wing Naval Aviation Officers

*LCDR Rebecca Baczuk, MC USN; LCDR Anthony Biascan, MC USN;
LT Erik Grossgold, MC USN; LT Ari Isaacson, MC USN; LT Joel Spencer, MC USN;
LT Eric Wisotzky, MC USN*

ABSTRACT The concept that aviators father more daughters than sons is a persistent rumor within aviation circles. This study was designed to determine the sex ratio among offspring of male fixed-wing naval aviation officers and to look for associations between sex ratio, flight hours, and mission. Through an online questionnaire, we asked for gender and date of birth of the child, monthly flying hours during the 4 months before conception, and the type of aircraft flown. Analysis revealed that the sex ratio of offspring from all participants in our study was not statistically significantly different from the general population. However, a significant sex ratio shift favoring daughters existed as the officer flew more hours during the 11th month before birth. As the implications of this are unknown, officers should be counseled that their chance of having a son or daughter is no different than the general population.

INTRODUCTION

There is a persistent rumor within aviation circles that aviators father more daughters than sons. This is neither new nor domestic; it was researched in the U.S. decades ago and has been studied in Europe as well. As a result of personal observations within our respective squadrons, and after considering the existing literature, we engaged in a study to determine the sex ratio among the offspring of male naval aviation officers and to look for associations between sex ratio, flight hours, and mission. For the purpose of this study, the term “naval aviation officers” includes both navy pilots and naval flight officers (NFOs).

In 1961, a study to determine if a relationship between military aviators and their proclivity to father more daughters than sons was undertaken in the United States by fighter pilot Richard Snyder.[1] Snyder began researching the issue after observing that within his squadron, 27 female compared to two male offspring had been born to pilots, and that he, himself had fathered two daughters. After discontinuing flying, Snyder and his wife gave birth to three sons. Snyder gathered data from 236 pilots from all types of aircraft and found an overall male-to-female sex ratio of 113:109 (222 total offspring, 50.9% male), which was consistent with the general population. However, of the 94 offspring conceived by fighter pilots, the sex ratio was 35:59 (36.0% male). He concluded that there was a statistically significant shift in the sex ratio of offspring of aviators who flew fighter aircraft compared with that of offspring conceived by all pilots.

In 1976, the Director of the German Air Force Institute of Aviation Medicine ordered the Aviation Psychology Branch to determine the sex ratio of offspring of pilots in the German Air Force, Navy, and Army, and to then compare these results with the general population in an effort to investigate the effect of occupational stress on human performance and physiology.[2] This study was initiated to refute an “old rumor” that pilots of high-performance military aircraft were “girl-fathers” who would otherwise be entitled to “compensation for damages incurred in cases where their procreative capacity had been detrimentally affected by activities in the line of duty.” The authors defined high flying stress as having less than 1,000 total flying hours, because during that period the pilot is still training, inexperienced, and subject to frequent academic tests. Alternatively, those with greater than 1,000 hours were defined as being under less stress: for them, flying was more routine. With these definitions in hand, they subsequently found “no immediate and direct relationship” between the degree of flying stress and the sex ratio of offspring and concluded that they had “reduced to absurdity” the notion that flying high-performance military aircraft had any effect on fertility. This study contrasts from ours in many ways, most notably in that participation was mandatory; that total flight hours up to the birth of the child, rather than number of flight hours per month before conception, were analyzed; that “flying stress” high and low categories were defined and used to explain results which could arguably be reversed (i.e., the more senior one gets in the aviation pipeline, the higher the stress); and that the motivation for the study was to absolve the German government.

In 1987 another U.S. study emerged. Little, et al. looked at the possible G-force effects on the fertility of U.S. Air Force Officers and U.S. astronauts.[3] The reproductive data for pilots, nonpilots, and astronauts were assimilated with respect to G-force exposure. High G-force was defined as −2 to +6 Gs (tactical pilots and astronauts), and low G-force between −0.5 to +2 Gs (nonpilots and nontactical pilots). Of the 166 offspring born to those who were exposed to high

---

Clinical Investigation Department, Naval Medical Center San Diego, 34800 Bob Wilson Drive, San Diego, CA 92134-1005.

This manuscript was received for review in March 2008. The revised manuscript was accepted for publication in December 2008.

G-forces, 40% were male, compared to the 582 offspring born to those exposed to low G-forces, where 50.71% were male. This difference was tested with χ^2 and found to be statistically significant ($p < 0.0001$). The authors concluded that high G exposure may affect reproduction.

A case report was presented in 1996 by Jequier of an Australian fighter pilot who complained of infertility, which was confirmed to be the result of severe oligozoospermia with low numbers of motile sperm on semen analysis.[4] After 2 months of limiting his sorties to high-altitude navigation exercises without high G maneuvers, a repeat sample revealed normal semen and his wife soon became pregnant.

In 1999, Norwegian researchers conducted a study to compare the sex ratio of offspring of military and commercial pilots in Norway to that of the general population between 1970 and 1993.[5] During that period, a total of 1,180,374 infants were born within the general population, 869 to commercial pilots, and 65 to military pilots. Of those born to military pilots, the male proportion was 36.9% compared to 51.4% in the general population and 52.6% for commercial pilots. This study concluded that, although there was no difference between the sex ratio of offspring born to commercial pilots compared to the general population, the relative risk for Norwegian military pilots of having a male offspring compared to the general population was significantly reduced at 72% (CI, 0.57–0.92); i.e., the probability of a Norwegian military pilot having a son was reduced by almost 30% when compared to the general population.

SPERMATOGENESIS

Spermatogenesis consists of three phases that take place in the seminiferous epithelium of the testicle: proliferative, meiotic, and spermiogenic.[6] In the first phase, spermatogonia undergo mitosis, or duplication, to produce diploid spermatocytes. In the second phase, the diploid spermatocytes undergo meiosis, or reduction division, to produce four haploid spermatids. During meiosis, chromatids cross over and exchange base pairs, providing a mechanism for genetic variability and repair of damage in the DNA helix. The mitotic and meiotic phases together are referred to as spermatocytogenesis. Finally, in the spermiogenic phase, metamorphic changes take place, as the spermatids undergo nuclear condensation, form the acrosomal cap, and develop flagella to become spermatozoa.[6]

The total time from spermatogonia to a mature, motile sperm is about 3 months. Spermatogenesis itself takes 64 days; however, spermatozoa are immotile and lack the ability to fertilize. Subsequent maturation occurs in transit through the ductus epididymis, and takes about 2 weeks. The mature sperm are then stored in the distal portion of the ductus epididymis before ejaculation. Sperm can live for several weeks within the ductus epididymis, but can survive only a few days in the female reproductive tract. Males undergo spermatogenesis continually, as there are normally over 100 million spermatozoa in each milliliter of semen. Spermatogenesis is regulated by hormones, such as testosterone, follicle stimulating hormone (FSH), luteinizing hormone (LH), estradiol, and dihydrotestosterone (DHT).[6,7]

METHODS AND MATERIALS

Our study method was similar to that of the aforementioned study by Snyder; however, instead of collecting data on index cards, we used an online questionnaire on a Website, which was set up for us by Naval Hospital Camp Pendleton (NHCP). The survey was performed under the guidance of NHCP and Naval Medical Center San Diego (NMCSD) in Southern California. After receiving Investigational Review Board (IRB) and command approval, emails were sent to inform various commands within Naval Air Forces of the protocol and of the Website. Both emphasized that participation was entirely voluntary, and no identifying information would be asked of the participants. Male naval aviation officers of fixed-wing aircraft were invited to fill out the online questionnaire, which asked for the gender and date of birth (DOB) of the child, flying hours per month during the 9th, 10th, 11th, and 12th months before the birth of the child, and the type of aircraft flown. The officers were asked to choose from the following ranges of flying hours per month: 1–10, 10–25, 25–50, 50–75, 75–100, and 100+. For purposes of simplicity, no distinction was made between naval pilots and NFOs, nor did we invite rotary-wing aviation officers to participate. The Website remained online for 6 months.

Data from 567 individuals were downloaded into an Excel spreadsheet. NMCSD provided a statistician to assist us with our statistical analysis. Twenty-six entries had no or incomplete data for flying hours per month, and therefore could only be used to calculate overall and aircraft-specific sex ratios. Three entries were incomplete because of DOB omission and would not be useful if not for the fact that this parameter (DOB) was ultimately not analyzed in our results. Two entries had to be thrown out entirely: one participant failed to list the gender of his child and one participant's response was excluded because she did not contribute the sex-determining chromosome to her offspring.

The data were then separated by the type of aircraft flown by each participant during the 4 months before conception. A few participants were flying multiple aircraft during this period, to include fixed and rotary-wing aircraft, and were given their own category accordingly (e.g., "H-3 + C-12"). When possible, aircraft were then grouped according to mission and tactics to enable us to determine the offspring sex ratio and note any shift within these mission-specific groups (e.g., F-18, F-14, and A-6 aircraft were grouped together as "fighter/attack aircraft"), as in Table I. Aircraft groups could then be combined into "supergroups" to analyze mission and sex ratio on a broader scale (e.g., all carrier-based aircraft), illustrated in Tables II and III.

Turning our attention to flight hours, the data were then entered into the data analysis and statistical software (STATA) for logistic regression analysis. To format the data for STATA, each response for hours flown was coded as the

TABLE I. Number of Children and Male Ratio by Aircraft Flown

Aircraft Group	Aircraft Flown by Participants	Offspring	Male:Female Sex Ratio
None	None, were not flying	31	0.581
E-2	E-2	126	0.437
E2 + Trainers	E2 + T34	1	0
C-2	C2	14	0.714
C-2+ Trainers	C2 + T44	1	0
E-2 + C-2	E-2 and C-2	2	0.5
Fighter/Attack	F18, F14, F4, A6, A4, Super Etendard Modernise (SEM)	147	0.51
Fighter Trainers	T38, T6, T45, T2, T1, TA4J	33	0.515
Fighters + Trainers	Fighters + Fighter Trainers	1	1
Other Fighters	F15, F16, F5	2	0.5
NFO trainer	T39 + T34, T2, or E2	10	0.516
T34	T34	31	0.548
EA6B	EA6B	55	0.527
S3	S3	15	0.5333
Carrier-Based Aircraft (CBA) Combo	F18 + E2, EA6B + F18	5	0.2
C130	C130	12	0.583
P3	P3	20	0.55
P3 + T34	P3 + T34	2	0.5
Commercial Transport	B727, C9, DC9, C40, CRJ200, C12	30	0.3333
Misc/TPS	“Miscellaneous” or “Test Pilot School”	4	1
Helos	CH46, H60, SH60, H3	10	0.4
Helos + Trainer	Helos + T34	3	0.667
H3 + C12	H3 + C12	5	0.6
E3	E3	1	1
Total		560	0.499

TABLE II. Offspring Number and Male Portion by Aircraft Flown, Larger Groups and Supergroups

Group	Aircraft Flown by Participants	Number	Male:Female
None	None, were not flying	31	0.581
E-2	E-2	126	0.437
Fighter/Attack	F18, F14, F4, A6, A4, Super Etendard Modernise (SEM)	147	0.51
Fighter Trainers	T38, T6, T45, T2, T1, TA4J	33	0.515
NFO Trainer	T39 + T34, T2, or E2	10	0.516
T34	T34	31	0.548
EA6B	EA6B	55	0.527
S3	S3	15	0.5333
C130	C130	12	0.583
P3	P3	20	0.55
Commercial Transport	B727, C9, DC9, C40, CRJ200, C12	30	0.3333
Total		560	0.499
Supergroups:			
All CBA	E2, Fighters, EA6B, S3, CBA Combo	348	0.483
All Cargo, Transport	C130, P3, Commercial Transport	62	0.453
All CBA + All Cargo, Transport	All CBA + All Cargo, Transport	410	0.479

TABLE III. Male Fraction of Offspring of Larger Aircraft Groups and Probability using the Binomial Test

Group	M:F Sex Ratio	*p*-value
CBA	0.483	0.284
Cargo + Transport	0.453	0.375
CBA + Cargo + Transport	0.479	0.182
E-2	0.437	0.091
EA6B	0.527	0.893

$p < 0.05$ is significant, all values obtained using binomial test.

lower end of the time range; e.g., all responses of having flown 25–50 hours in a month were recorded in the computer model as “25 hours,” 10–25 hours recorded as “10 hours,” etc. Within the supergroups, the number of flight hours flown per month during the 9th, 10th, 11th, and 12th months before the birth of the child was analyzed to determine if any statistically significant difference in sex ratio existed.

For comparison, the sex ratio of the general population was gathered from the U.S. Census Bureau, which reports gender in 5-year increments. The ratio over the past 25 years was analyzed; an average of 51.2% males were born during that time with very little variation.[8] This value was also compared to the CDC's statistics, which reports the sex ratio of the United States as being 1,048:1,000 (1,048 males:1,000 females), or [0.512] in 2002, the most recent year for which data were available.[9] The CDC report also states that for the 63 consecutive years in the study, the U.S. male-to-female sex ratio at birth has hovered between [0.511] and [0.515]. The U.S. general population sex ratio average of 0.512 was used as the control against which all offspring sex ratios were compared to determine the presence or absence of a sex ratio shift.

RESULTS

The complete list of aircraft groups, offspring, and percent male is shown in Table I. Table II shows the subsequent reduction when only those aircraft groups large enough to analyze were listed. Of note, although only fixed wing aviation officers were invited to participate, some flew both fixed and rotary wing aircraft before conception, and therefore a few rotary wing entries are listed for completeness. The overall ratio of male:female offspring from all participants in our study was 0.499. When translated to a sex ratio as used by the CDC, the result is 998 males per 1,000 females, or 1 male for every 1.002 females. This was not statistically significantly different from the general population (0.512).

Because of the inherent error in analyzing small numbers, further analysis with respect to hours flown focused primarily on the three larger categories, or supergroups (Table III). Just as for the overall group, there was no significant sex ratio difference found for any of the three supergroups when compared to the general population. Although several of the values for percent male appear impressively different from the national average of 51.2% male, none of the groups reach significance via the binomial test (Table III). Only the E-2 group approaches significance ($p = 0.091$), although it is not reached.

Logistic regression revealed a trend that held for the entire group as well as for each of the supergroups; the more hours flown during the 11th month predelivery (6–10 weeks preconception), the more likely an officer was to father a female child. Table IV presents the odds ratio of having a male child within the CBA/cargo/transport supergroup on the basis of hours flown in the 9th, 10th, 11th, and 12th months before birth. An odds ratio of <1.00 states that the odds of having a male is less than 50:50 with increasing flight hours during that month, and an associated p-value of <0.05 would imply that this smaller odds ratio is statistically significant (less than 5% risk of having occurred by chance). The odds ratio of having a male was less than that of the general population (OR = 1.048 in 2002)[16] in all cases; however, the only time in which statistical significance was reached was during the 11th month before birth. Next, by calculating the means and standard deviations for the values of hours flown during the 11th month separated by offspring gender, we found the average number of flight hours leading to either a male or female child to be 16.2 and 24.1, respectively. Finally, an even more pronounced shift in sex ratio favoring females was noted for carrier-based aircraft (CBA) officers who flew greater than 50 hours during the 11th month before the birth of their offspring (Figs. 1 and 2). This is not the case for officers who flew transport or cargo aircraft.

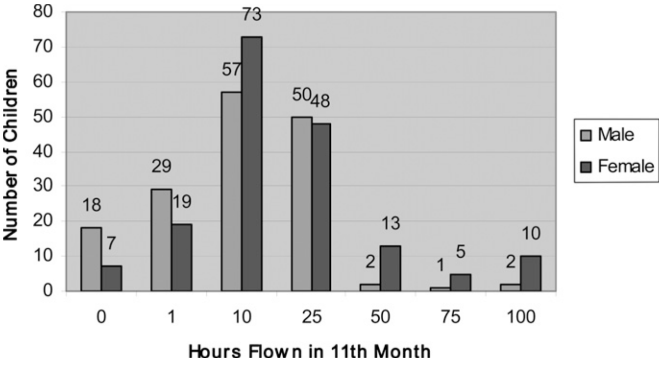

FIGURE 1. Number of children born to aviators of carrier-based aircraft by hours flown in 11th month before birth (groups expanded).

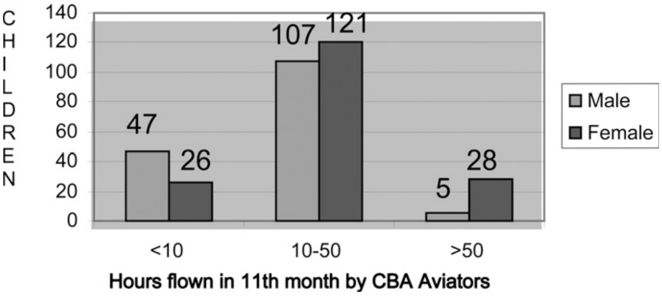

FIGURE 2. Number of children born to aviators of carrier-based aircraft by hours flown in 11th month before birth (groups collapsed).

TABLE IV. Odds Ratio of Having a Male Offspring in Supergroup CBA + Cargo + Transport with Increasing Flight Hours During Selected Months Before Delivery Using Logistic Regression

Months Before Birth	Odds Ratio of Having a Male	Standard Error	p-value
9th month	0.996	0.011	0.699
10th month	1.021	0.015	0.174
11th month	0.953	0.017	0.007
12th month	1.017	0.014	0.212

$p < 0.05$ is significant.

DISCUSSION

There are a few aspects of our study that should be addressed. First, the utilization of a voluntary Website was an area of concern in that data might have a selection bias toward fathers of primarily female offspring. However, that the overall sex ratio of offspring from all participants in our study, aircraft groups, and aircraft supergroups was not statistically significantly different from the general population makes this selection bias less likely. Second, the anonymous Website assumes the participants correctly entered their flight hours from their log books; the complete accuracy of this data entered by the participants could not be ascertained. Third, grouping monthly flight hours into ranges of hours instead of entering exact hours flown ultimately limited our statistical analysis. The intention was to maximize participation by making the Website as simple as possible to complete, although we then became restricted to analyzing our flight hour data in broad groupings rather than as individual values. Finally, we assumed all children were full-term for ease of analysis. This may not have been true in all cases and thus may have offset the "hours flown per month" data.

The statistically significant difference in odds ratio during the 11th month demonstrates that, for all groups between 1.5 and 2.5 months before conception, the greater number of hours an officer flew, the greater the odds that he would father a female child (Table IV). Interestingly, Snyder's study also shows an increased percentage of female offspring when flight duties were performed during the 11th month compared to other months, with those percentages in the 9th through 12th months of 57%, 56%, 60%, and 58%, respectively.[1] The fact that the sex ratio in the 11th month is significantly different from the general population suggests an etiology in spermatogenesis. This seems plausible, in that actively dividing cells may be more susceptible to variance under the physiologic stress of flying. Perhaps this environment provides a mechanism that favors X chromosome selection during spermatogenesis. That the 9th and 10th months are not significantly different makes it less likely that the mature sperm already stored in the epididymis are affected and thus offers further evidence toward this X chromosome selection hypothesis. A small number of studies conducted worldwide have attempted to explain observed sex ratio shifts within certain occupations. Gravity,[1] radiation,[10] stress,[2] hormone levels,[11] toxins,[12] sexual intercourse frequency,[13] order of offspring,[14] drinking water,[15] paternal age,[14] and tobacco use[16] have all been implicated.

Since our naval aviation officers are generally in excellent health and are closely monitored for changes in health status, factors such as dietary deficiencies, infection, and toxins (to include medication use) are unlikely causes. Elevated testicular temperature, stress, gravity, and radiation are more likely possibilities. Aviation officers in tactical aircraft must wear tight gear which could restrict testicular venous flow, elevating temperature. It is widely accepted that elevated scrotal temperatures lead to infertility. However, if temperature were a cause of sex ratio shifts, then it would follow that equatorial countries would have a sex ratio which would differ from those at higher or lower latitudes, and this is not supported by statistics. According to the latest CDC's National Vital Statistics Reports, "…the sex ratio [expressed as the number of male births divided by the number of female births × 1,000] at birth for most countries is between 1,050 [0.512] and 1,060 [0.515]…." In the same report, the Russian Federation, with latitudes above 45°N, had a sex ratio in 2001 of 1,063 [0.515], although equatorial Columbia had a sex ratio in 2000 of 1,058 [0.514].[9]

Goerres and Gerbert investigated the possible effects of flying stress on the sex ratio of jet pilots in the German Armed Forces.[2] Although they concluded that no "immediate and direct relationship" existed between the degree of flying stress and the sex ratio, they did note a shift from "boy-fathers" to "girl-fathers" after the 1,000th flight hour. They were not able to offer an explanation for this, leaving us to speculate: if it was not flying stress related to hours flown, perhaps it is flying stress related to more advanced tactical flying or repetitive high G exposure. Snyder[1] asserted "it would seem reasonable to consider the possibility that continual high G and high-stress type of flight may trigger (or impede) some chemo-physiological reaction particularly effecting the Y-bearing gametes in man." That officers of carrier-based aircraft, as opposed to those of transport and commercial aircraft, have an even greater sex ratio shift favoring female offspring with increasing flight hours during the 11th month, argues in favor of Snyder's assertion (Figs. 1 and 2). These officers are routinely exposed to acceleration and deceleration G-force exposure with each catapult launch and arresting gear recovery. Simply put, the more flight hours aboard an aircraft carrier, the more consistent high G exposure. Irgens[5] agreed with Snyder's[1] observation. Little[3] thought the difference in sex ratio was the result of high G exposure and concentrated on "metabolic effects on neuro- and haemo-chemistries." He postulated that metabolic energy demands increase considerably with high gravitational stress, which might affect the Y gamete more than the X because of the smaller size of the Y chromosome. In actuality, the Y chromosome is not that small: it has only 2.9% less chromosome mass than the X chromosome. The effect of gravity on spermatogenesis requires further investigation.

Another possible etiology is that naval aviation officers may be exposed to low levels of radiation while flying, which might cause temporary reproductive dysfunction. That the E-2 officers, whose platform carries a high-powered surveillance radar (APS-145), have the lowest male:female sex ratio of the larger groups supports radiation as a possible etiology. However, it should again be noted that this difference was not statistically significant. To further investigate this notion, pilots of C-2 aircraft could be compared to the E-2 population. The C-2 has the same airframe as the E-2, but does not contain the same radiation-emitting equipment. Unfortunately, in our survey, the C-2 population was too small to study.

There are several factors external to flight hours that could act as confounders for this study. Specifically, fatigue, operational tempo, marital and personal stress, and other social factors could all play a role in the sex ratio shift and should be considered. However, an argument could be made that a relationship exists between these external factors and hours.

That is, as flight hours increase, these other factors may indeed become more significant.

CONCLUSION

We feel we were successful in our goal of investigating the sex ratio of male naval aviation officer offspring and of determining whether associations exist among sex ratio, flying hours, and aircraft type. Although the ratio of male offspring from all participants in our study, aircraft groups, and aircraft supergroups was not statistically significantly different from the general population, this study provides statistical support that there is a sex ratio shift among offspring of male aviation officers when they fly more hours during the 11th month before birth. Furthermore, for officers who fly carrier-based aircraft, that shift is even more dramatic as they approach and exceed 50 hours per month. Although this was not hypothesized specifically, we believe it to be significant and certainly worth reporting. The explanation for these findings remains unknown; however, several hypotheses currently exist, and further research is warranted. When counseling an aviation officer and his spouse, however, it is important to emphasize that on the individual level, the likelihood of having a male or female child is ultimately the same as the general population.

ACKNOWLEDGMENTS

We thank all aviators who participated in the study, the information/technology team at NH Camp Pendleton, Dr. Robert Riffenburg, NMCSD, for providing statistical analysis, LT Sean Merritt, COMACCLOGWING, for his assistance in stratifying into mission/type the unexpected enormous number of different type aircraft we had to sort through, and Ms. Waine MacAllister at NMCSD for her help with the submission and editing process.

REFERENCES

1. Snyder RG: The sex ratio of offspring of pilots of high performance military aircraft, Human Biology, 1961; volume 33, number 1, pp 1–10.
2. Goerres HP, Gerbert K: Sex ratio of offspring of pilots: a contribution to stress research. Aviat Space Environ Med 1976; 47: 889–92.
3. Little B, et al: Pilot and astronaut offspring: possible g-force effects on human sex ratio. Aviat Space Environ Med 1987; 58: 707–709.
4. Jequier A: High-performance aircraft: a possible cause of male infertility. Br J Urol 1996; 77: 920–922.
5. Irgens A, Irgens L: Male proportion in offspring of military air pilots in Norway. Norsk Epidemiol 1999; 9(1): 47–9.
6. Wein AJ, Kavoussi LR, Novick AC, Partin AW, Peters CA: Campbell-Walsh Urology, Ed 9, pp 592–595, Chapter 18. New York, Saunders, Elsevier, 2007.
7. Ross MH, et al: Histology: A Text and Atlas, pp 641–647. Baltimore, MD, Williams & Wilkins, 1995.
8. Mathews TJ, Hamilton BE: Trend analysis of the sex ratio at birth in the United States. CDC Natl Vital Stat Rep, volume 53, number 20, pp 1–5, June 14, 2005.
9. U.S. Census Bureau Estimates of the Population by Sex and Five-Year Age Groups for the U.S. April 2000 to July 2005. Available at http://www.census.gov/popest/national/asrh/NC-EST2005/NC-EST2005-01.xls; accessed August 19, 2006.
10. Irgens A, et al: Male proportion in offspring of parents exposed to strong static and extremely low-frequency electromagnetic fields in Norway. Am J Int Med 1997; 32: 557–61.
11. James WH: The hypothesized hormone control of mammalian sex ratio at birth: a second update. J Theor Biol 1992; 155: 121–8.
12. Washam C: PCBs legacy: fewer boys. Environ Health Perspect 2003; 111(3): A480.
13. James William H. Coital Rates and Sex Ratios in the South Pacific. *Soc Biol*, 1994. Fall-Winter; 41(3-4) 278–9.
14. Jacobsen R, et al: Natural variation in the human sex ratio. Hum Reprod 1999; 14(12): 3120–5.
15. Yang CY, et al: Chlorination of drinking water and sex ratio at birth in Taiwan. J Toxicol Environ Health 2000; 60(7): 471–6.
16. Adid MM, Khan UA: Offspring sex ratio in smokers. J Pak Med Assoc 2004; 54(8): 442–3.