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Live birth sex ratios and father's geographic origins in Jerusalem, 1964–1976

J Groeger^a, M Opler^{b,c}, K Kleinhaus^b, MC Perrin^b, R Calderon-Margalit^d, O Manor^d, O Paltiel^d, D Conley, S Harlap^b, and D Malaspina^{b,§}

^aCollege of Medicine, SUNY Downstate, Brooklyn, NY, 11203, USA

^bDepartment of Psychiatry, New York University School of Medicine, 1 Park Avenue, Floor 8, New York, NY, 10016, USA

^cProphase, 3 Park Avenue, New York, NY, 10016, USA

^dBraun School of Public Health, Hebrew University-Hadassah School of Public Health, 91120 Jerusalem, Israel

^dDepartment of Sociology, Princeton University, Princeton NJ 08544

Abstract

Objective—To examine whether ancestry influenced sex ratios of offspring in a birth cohort before parental antenatal sex selection influenced offspring sex.

Methods—We measured the sex ratio as the percent of males according to countries of birth of paternal and maternal grandfathers in 91,459 live births from 1964 to 1976 in the Jerusalem Perinatal Study. Confidence limits (CI) were computed based on an expected sex ratio of 1.05, which is 51.4% male.

Results—Of all live births recorded, 51.4% were male. Relative to Jewish ancestry (51.4% males), significantly more males (1,761) were born to Muslim ancestry (54.5, 95% CI=52.1–56.8, $p=.01$). Among the former, sex ratios were not significantly associated with paternal or maternal age, education, or offspring's birth order. Consistent with a preference for male offspring, the sex ratio decreased despite increasing numbers of births over the 13-year period. Sex ratios were not affected by maternal or paternal origins in North Africa or Europe. However, the offspring whose paternal grandfathers were born in Western Asia included fewer males than expected (50.7, 50.1–51.3, $p=.02$), whether the father was born abroad (50.7) or in Israel (50.8). This was observed for descendants of paternal grandfathers born in Lebanon (47.6), Turkey (49.9), Yemen & Aden (50.2), Iraq (50.5), Afghanistan (50.5), Syria (50.6), and Cyprus (50.7); but not for those from

[§]Corresponding Author: Dolores Malaspina, MD, MS, MSPH, Department of Psychiatry, New York University School of Medicine, 1 Park Avenue, 8th Floor, Rm 222, New York, New York 10016, Telephone: (718) 877-5708, dolores.malaspina@nyumc.org.

The authors declare no conflicts of interest.

Authors' Contributions

JG analyzed the data and drafted the manuscript. OP, OM, DM and SH collaborated in collecting and interpreting the data and DC participated in the writing of the paper. DM and SH obtained the funding; and, with OM, provided administrative oversight. SH conceived and designed the study. All authors provided critical review of the manuscript and approval of the final version for publication.

India (51.5) or Iran (51.9). The West Asian group showed the strongest decline in sex ratios with increasing paternal family size.

Conclusions—A decreased sex ratio associated with ancestry in Western Asia is consistent with reduced ability to bear sons by a subset of Jewish men in the Jerusalem cohort. Lower sex ratios may be due to pregnancy stress, which may be higher in this subgroup. Alternatively, a degrading Y chromosome haplogroup or other genetic or epigenetic differences on male germ lines could affect birth ratios, such as differential exposure to an environmental agent, dietary differences, or stress. Differential stopping behaviors that favor additional pregnancies following the birth of a daughter might exacerbate these lower sex ratios.

Keywords

Sex ratio; ancestry; birth cohort

Introduction

Sex ratios are influenced by parental selection and societal gender norms as well as environmental exposures. At birth, the sex ratio (proportion of males) is slightly over 51%; historically, it has been subject to a number of perturbations, most of which have been too slight to be of any importance to public health (James, 1987). These include a decreasing proportion of males with increasing paternal age (Jacobsen *et al.*, 1999b; James and Rostron, 1985) and differences between ethnic groups, countries, and races (Davis *et al.*, 2007; Grech *et al.*, 2003b; Parazzini *et al.*, 1998). In many settings, lower sex ratios are observed in sub-Saharan Africans and their descendents while higher ratios are observed in Eastern Asians, with a few exceptions (Garenne, 2008; James, 1984; James 1985; Marcus *et al.*, 1998; Ruder, 1985). In the United States and South Africa, such differences were attributed to the race of the father rather than that of the mother (Khoury *et al.*, 1984; Ruder, 1986).

Other factors found to be relevant to variation in human sex ratios include androgenic hormones and gonadotrophin levels in parents (James, 2004), geographic latitude (Figa-Talamanca *et al.*, 2003; Grech *et al.*, 2002; Voracek and Fisher, 2002), temperature at conception (Lerchl, 1999; McLachlan and Storey, 2003), season of birth (Cagnacci *et al.*, 2003; Garry *et al.*, 2002; Grech *et al.*, 2003a; Lerchl, 1998; Melnikov and Grech, 2003; Nonaka *et al.*, 1998), height and weight of mother (Cagnacci *et al.*, 2005; Kanazawa, 2005), weight gain by mother (Villamor *et al.*, 2008), and maternal diet immediately prior to conception, or soon after (Andersson and Bergstrom, 1998; Mathews *et al.*, 2008; Williams and Gloster, 1992). In the last 2 to 3 decades of the 20th century, falling sex ratios were noted in a number of countries (Dickinson and Parker, 1996; Marcus *et al.*, 1998; Ohmi *et al.*, 1999; Orvos *et al.*, 2001; Parazzini *et al.*, 1998). Disturbed sex ratios were observed in offspring of parents exposed to toxic environments (Garry *et al.*, 2002; James, 1997b, d, e; Williams *et al.*, 1992) and distressed environments such as during the Iran-Iraq war (Ansari-Lari and Saadat, 2002). Sex ratios are also proposed as a sentinel indicator of industrial pollution (Davis *et al.*, 1998; James, 1997a, c; Williams *et al.*, 1995a; Williams *et al.*, 1995b).

A theoretical and practical question (reviewed by James, 2000; James, 2011) is whether the probability of a male or female birth can vary within sibships (Poisson variation), between couples (Lexis variation), or as a consequence of the sex(es) of a previous birth(s) (Markov variation). Detection of any of these is made difficult by the “stopping rule” whereby some couples are less likely to continue reproducing if their families include a desired mix of sexes among the offspring, such as at least one of each sex, or a certain number of the preferred sex, such as two males that comprise “an heir and a spare” (Jacobsen *et al.*, 1999a). Where there is a preference for a specific family structure, the stopping rule may obscure other influences on a population’s sex ratio. Diamond-Smith and Bishai (2014) provide evidence for “self-corrective” forces in response to socially driven changes in sex-ratios that favor male children. However, selective abortion has led to profoundly altered sex ratios in countries such as China and India (George, 2006; Zhu *et al.*, 2009). With this, it is no longer realistic to study live births in these populations to understand other determinants of sex ratios.

In societies with a strong preference for males, Lexis variation would lead to progressively larger sibships where there is a lack of male births. Evidence for or against this is sparse (James, 2000) and difficult to interpret, given that it is often based simplistically on births to mothers, rather than those to fathers. While conception of a male requires a Y-chromosome, and maintenance of the pregnancy requires that the female’s physiology senses and responds to the pregnancy appropriately, the couple’s or a mother’s decision to continue reproducing may depend on numerous and competing social factors. For example, parents may gain status and self-esteem by giving birth to males (Hank, 2007) and those who do not give birth to sons may be more at risk for divorce (Morgan *et al.*, 1988).

A previous study in the Jerusalem Perinatal Cohort demonstrated an association between sex of offspring and the incidence of prostate cancer in fathers, with lack of male offspring predicting a higher probability of prostate cancer some 30–40 years later (Harlap *et al.*, 2007c). This association was strongest in the Jewish men whose origins were in Western Asia (Harlap *et al.*, 2007a).

The current study asked the broader question of whether live birth sex ratios from 1964 through 1976 for the offspring of Jewish men born in Jerusalem varied based on the geographical ancestry of the fathers.

Methods

The Jerusalem Perinatal Study is a research database. During 1964–76, all 92,408 births to residents of Western (Israeli) Jerusalem were surveyed. Demographic information on the parents and both grandfathers were abstracted from the birth certificate and were supplemented with data from medical records, interviews, and surveillance of pediatric inpatients. The methods and characteristics of the population have been previously described (Davies *et al.*, 1969; Harlap *et al.*, 2007b; Harlap *et al.*, 1977). Live births were reported regardless of gestational age; fetal deaths were included from 28 weeks gestation or 1000 gm. All births took place in hospitals or en route.

Data abstracted from the birth certificate included the newborn's and mother's identity numbers, sex, the parents' years of birth, immigration, marriage and education, each parent's country of birth, and each grandfather's country of birth. No information was available on grandmothers. The data on countries of origin were processed and stored via a coding system in use in the mid-1950s that reflected the political boundaries of existing countries at the time, rather than ethnic divisions.

In 2000–2005, the identities of offspring and mothers were verified by comparing their identification numbers and demographic information with data in Israel's national Population Registry. More than 98% of live-born offspring were verified along with 99% of their mothers. The rare ones that were not verified were mainly offspring of foreign subjects or offspring assumed to have been adopted. The fathers' identity numbers, which were not recorded in the Jerusalem cohort, were obtained from the Population Registry via offspring identity numbers for 94%. For subjects with verified identities, family sets were constructed based on either the mother or the father. These represented only those offspring born in 1964 to 1976 and not any offspring of these parents born earlier or later, so they do not represent completed families. This study was approved by Institutional Review Boards in Jerusalem and New York and exempted from the requirement for informed consent.

Data were analyzed using software from SAS[®] version 9.1. In sets of categorical variables, the distributions of birth order and maternal and paternal characteristics were assessed using Chi². Unless otherwise stated, we assessed individual sex ratios using tests of proportions; tests were calculated based on an expected proportion of 0.5141, with a 2-tailed p, using the exact method. No adjustments were made for multiple observations.

Results

There were 92,408 offspring in the Jerusalem Perinatal Study. After excluding 34 with unknown sex, there were 51.4% males among 91,467 live births, versus 53.3% among the 907 late fetal deaths, which did not reach statistical significance. Among the live births, there were no significant differences in sex ratios between singletons (51.4), twins (51.3, N=2,143) or higher orders of multiple births (50.00, N=68). Table 1 shows sex ratios according to the father's denomination. Compared with Jews, offspring of Muslims were significantly more likely to be male, while those with fathers of unknown denomination were more likely to be female. The remaining analyses were restricted to the offspring of Jewish fathers.

Table 2 shows sex ratios related to Jewish parents' ages and education levels, birth order, and the numbers of offspring born from 1964 to 1976. Whereas younger, more educated fathers tended to sire more males, the mothers' characteristics were less clearly related to sex ratios, and none of the aforementioned demographic characteristics or birth order showed statistically significant relationships to sex ratios.

In contrast, there were strong variations according to family size; the sex ratios were significantly increased in sets with only one birth, and they decreased progressively with increasing numbers of births observed. This trend was somewhat stronger for fathers than

for mothers. Because the cohort was a “snapshot” of births occurring from 1964 to 1976 and not completed families, we considered whether the sets with small numbers of offspring might be biased by male “last births” in families who had offspring before 1964. This possibility is suggested by data comparing sex ratios for the 1st, 2nd, 3rd, and 4th or later births from the cohort years of 1964 to 1976 ($n=54,643$), which were 52.1, 51.3, 51.2, and 50.4 ($p=.096$) to birth sex ratios from before 1964 ($N=33,169$), which showed significant decreases in sex ratios for later births; 52.8, 52.5, 51.2, 51.0 ($p=.05$).

Table 3 shows sex ratios in offspring related to the paternal grandfathers’ places of birth, broadly grouped. Men with ancestries in Western Asia sired significantly fewer boys, whether they or their fathers were born in Western Asia. A lower sex ratio was observed in the 18,513 progeny of immigrant fathers born in Western Asia (50.7, 50.0–51.4) and in the 9,093 progeny of native Israeli men whose fathers were Western Asian immigrants (50.8, 49.7–51.8). Comparing all 51,501 offspring of any immigrant men, the West Asian group showed a sex ratio that was more than 1% lower than that of men of other origins ($p=.024$). Similarly, among the 36,977 offspring of native-born Israelis, the sex ratio was almost 1% lower in those with ancestries in Western Asia than in those with other ancestries.

Between mothers of different origins, differences in the sex ratios of their offspring were not marked. Offspring of West Asian women seemed to show a somewhat reduced sex ratio overall (Table 3). Table 4 separates the consequences of combinations of paternal and maternal grandfathers from Western Asia, versus all others. It shows that while the lower sex ratio in progeny of Western Asian men was seen most obviously in those married to women from other origins, it is also present among those with wives from the same origin.

Table 5 shows another post hoc analysis in which the sex ratios are related to the individual countries of birth of the paternal grandfather. We arbitrarily limited the analysis to countries for which there were at least 100 births. In the West Asian group, 7 of the 9 origins were associated with lower sex ratios, the only exceptions being Iran and India. Regarding countries in other areas, sex ratios were somewhat higher than expected for offspring of men with ancestries in the Balkan countries and in the western areas of North Africa; however, none of the individual countries showed a statistically significant difference from the expected value of 51.4, except for Iraq.

Table 6 explores how the fathers’ family size related to the ethnic differences in sex ratios. Within each of the four ethnic groups there were relatively more males born to fathers who sired only one or two children during the observed 13-year period, and relatively fewer males in the offspring of fathers siring large numbers of offspring. These are consistent with a desire for male offspring. While the West Asian group showed significantly lower sex ratios even for those with only one or two children, a strong contribution to their lower overall sex ratio derived from the very low ratio in sets with four or more offspring. Table 6 shows that the West Asian group was not the only contributor to the declining sex ratios with increasing family size. The average values for the combined other groups also tended to decrease: For families of 1, 2, 3, and 4+ offspring, respectively, the sex ratios were 52.8, 51.9, 51.0, and 51.3, based respectively on 11,081, 16,765, 13,056, and 17,056 births ($p=.024$).

Discussion

This study demonstrated an unusually low sex ratio in offspring of fathers whose ancestries are in Western Asia and come from families with fewer male births than expected. This tendency, which is unlikely to be due to chance, was seen in offspring of both immigrants and Israeli-born men and held true for 7 of the 9 countries that comprised the West Asian group. The decreased sex ratio was significant even for the first birth and was most obvious in the offspring of fathers who sired larger numbers of progeny during the 13 years of our observations. Although the countries of origin for the West Asian group were Muslim countries, the sex ratio for the small number of Muslims was significantly higher than the Jewish subgroups, suggesting something specific to the Jewish families with those origins.

The study also shows strong evidence suggesting Lexis variation, in that the proportion of males progressively decreased with increasing numbers of offspring born during the 13 years of observation. This bias towards having sons is associated with fertility “stopping behavior” that curtails reproduction after a male birth, but favors pregnancies following a female birth. This trend was seen more clearly in the two groups of men with origins in Islamic countries, i.e. the West Asian and the North Africans. These observations are consistent with fathers possessing a stronger preference for males, being less likely to limit reproduction after a pre-planned number of births, and choosing to continue to bear offspring until a desired mix of sexes is achieved. An interaction of biologically driven sex ratio reductions from genetic or environmental etiologies, combined with the behavior to continue reproducing in order to have sons, could underlie their significantly reduced sex ratios.

Cultural transmission of expectations, norms, and values that influenced stopping behaviors among men with this ancestry might also have produced more stress or conflict within the family in Israel. The well-established literature demonstrating that maternal stress during pregnancy is associated with female-skewed sex ratios, cited above, may be relevant. Marital conflict prospectively predicts an excess birth of female offspring (Hamoudi and Nobles 2014). If grandparents from Western Asia create an environmental climate for their own children, it may, in turn, lead to stress or conflict within the parental household. In this way, the grandparental effects need not be mediated only through the chromosomal or trans-generational epigenetic effects, but rather be through a cultural legacy. If such a legacy involved gender roles and expectations, it would not be surprising that it worked through the paternal line, though ultimately it might act indirectly on the pregnancies through maternal stress. The current results suggest that the effects of stress favor females through the differential loss of male fetuses, and show a particularly low sex ratio among offspring of unknown ancestry, presumed to have unmarried and more stressed mothers.

One possible explanation for biologically lower sex ratios could be differential exposures to environmental influences that affect live birth ratios through epigenetic effects on the male germ line. Most Jews from Western Asia, especially those from Iraq, immigrated to Israel between 1950 and 1952 as refugees. They were housed in transit camps (ma'aborot), first in tents, and later in tin shelters. Immigrants experienced crowding, inadequate sanitation (Immigration and Absorption of Immigrants, 1961) and exposure to DDT (Massad, 1996;

Ministry of Health, 1951), a known environmental toxin. DDT may act as a carcinogen (Eskenazi *et al.*, 2009), and has, in high levels, been linked to low semen volume and impaired sperm motion (Eskenazi *et al.*, 2009). Further, paternal exposure has been linked to birth defects (Salazar-Garcia *et al.*, 2004). However, exposure to DDT also occurred outside of the camps and was extremely high (Westin, 1993). Israel used DDT in national anti-malarial campaigns from 1949 to 1957, with sprayings varied according to the prevalence of vectors and periods of transmission (Grushka, 1959). Although we speculate that West Asian immigrants might have experienced a greater exposure to DDT or some other toxic agent compared with the established Israeli population or subsequent immigrant groups, we know of no specific evidence to support this.

Evolutionary biologists have pondered whether stress and differences in diet might explain changes in sex ratio. Trivers and Willard (1973) first proposed the theory that if even small gains in maternal fitness disproportionately improve reproductive success of sons, then healthier women should sire more male children (Trivers and Willard, 1973). At the country level, it has been found that a higher level of caloric intake or an increase in caloric intake is correlated with more male births (Williams and Gloster, 1992). Even in a well-nourished population, higher energy intake, higher macro and micro nutrient consumption, as well as greater consumption of cereal were all found to be associated with male offspring, and it has been suggested that differences in sex ratio over time may be explained at least in part by changes in diet rather than changes in chemical exposures (Mathews *et al.*, 2008). Short height and obesity in mothers, the former being a marker of chronic energy deficiency, have been found to be associated with decreased sex ratio, though they are also associated with low socioeconomic status and social stress (Andersson and Bergstrom, 1998). Experiments in mice suggest that maternal diets high in saturated fat and low in carbohydrates favor male offspring while diets with energy predominantly supplied through carbohydrates favor female offspring (Rosenfeld and Roberts, 2004). Polyunsaturated fatty acids have also been shown to affect male and female fertility; however how they influence the sex ratio of offspring is less clear (Fountain *et al.*, 2008; Green *et al.*, 2008; Wathes *et al.*, 2007). Though it is difficult to discern how diet may have affected sex ratio in this cohort, researchers in Israel have reported ethnic differences in nutrient intake even after controlling for the effects of social class and education (Kaufmann *et al.*, 1982). Among females from Asia, mean cholesterol consumption was lowest and mean intake of carbohydrates and starch was highest compared to females from North America and Europe, consistent with animal studies that suggest such diets may result in decreased sex ratios among offspring. Although not all studies have found links between maternal nutrition and sex ratio (Stein *et al.*, 2004), diet may contribute to the decreased sex ratio seen among West Asians in our cohort.

In addition to diet, stress resulting from both natural and human-made disasters has been found to cause an excess of female births (Kemkes, 2006; Ansari-Lari and Saadat, 2002). Bruckner *et al.* (2010) reported a decline nationally in the proportion of male births in the US following the September 11th attacks, even though the attacks were localized to the greater New York metropolitan area (Bruckner *et al.*, 2010). The authors hypothesize that the widespread stress experienced by pregnant women resulted in an excess of male fetal deaths and therefore an increase in female births. Relative to our study, whether West Asians experienced increased stress compared to other Jewish ethnic groups is hard to say;

regardless, human-made and natural disasters often result in changes in diet and/or environmental exposures, making the exact cause of any change in sex ratio difficult to pinpoint. A significantly lower secondary sex ratio was found among offspring born to African American women diagnosed with anxiety disorders compared to African American women diagnosed either with other psychiatric disorders or no psychiatric disorder. This association was not found among other ethnic groups (Subbaraman *et al.*, 2010). Bruckner *et al.* (2015) found that male offspring from cohorts with lower sex ratios had less infant mortality themselves, and raised 4% more offspring to reproductive age, consistent with some portion of sex ratios reflecting culling of less fit males through spontaneous abortions.

Interpretation of the trends in sex ratio in relation to family size of the grandfathers born in Israel or Europe is complicated by the knowledge that, with increasing family size, these two groups are progressively selected for ultra-orthodox denominational observance. Such subjects follow a different lifestyle, including dietary practices and ritual monthly sexual separation that may influence sex ratios in older women with shorter menstrual cycles, consistent with some evidence that the ultra-orthodox experience higher sex ratios (Harlap, 1979). Other evidence that orthodoxy influences sex ratios in Israel is shown by secondary sex ratios during 1980 to 1995 of 52.1 in religious kibbutzim versus only 51.6 in other nonreligious (secular) kibbutzim (Riis 1999).

An excess risk of early breast cancer in Israel is also associated with ancestry from Iraq, Iran, and Afghanistan (Weiss-Salz *et al.* 2007). This risk could also entail transmitted genetic or epigenetic factors, or could be a consequence of environmental exposures and/or lifestyle factors. A degrading Y-chromosome haplogroup is another possibility for the sex ratio finding. Haplogroups are related to both male infertility and prostate cancer (Jobling and Tyler-Smith, 2003; McElreavey and Quintana-Murci, 2003). A previous study in this cohort found an elevated risk of prostate cancer among men lacking male offspring and that this risk increased with increasing family size (Harlap *et al.*, 2007c). The strongest association occurred among men of West Asian ancestry (Harlap *et al.*, 2007a). Although Jewish immigrants from diverse populations (with the exception of those in Ethiopia and India) are most closely related to each other and to non-Jewish Middle Eastern populations that share a common origin in the Levant (Atzmon *et al.*, 2010; Behar *et al.*, 2010; Hammer *et al.*, 2000; Kopelman *et al.*, 2009; Nebel *et al.*, 2001; Nebel *et al.*, 2000), Jewish populations do vary genetically by ethnicity (Atzmon *et al.*, 2010). A degrading haplogroup among Jews of West Asian ancestry may explain both their elevated risk of prostate cancer and their tendency to father fewer male children.

This study does have several limitations. First, 34 births of unknown sex and 907 late fetal deaths were excluded from the 92,408 total births of the cohort. While fetal deaths are more likely to be male (McMillen, 1979), the percentages of births of unknown sex and of stillbirths are so small that possible bias resulting from their exclusion would be minimal. An advantage of this study lies in its population-based cohort approach and the denominational conservatism of the population such that non-paternity within wedlock and out-of-wedlock births are less frequent than in other samples. Another benefit is that there was little opportunity for errors, given the straightforward nature of the data collected. Finally, because Israel's cash payment to all mothers was contingent on delivery in hospital

(or en route), births outside of hospital were extremely rare; such that any such births would have been too few to have biased our findings.

The immigrants from Iraq to Jerusalem include a large proportion of Kurdish Jews (Goldschmidt and Cohen, 1964) from the mountainous regions of northern Iraq and Iran and eastern Turkey. Despite their historical separation and different languages, analysis of Y chromosome variation shows that Kurdish Jews and other Iraqi Jews are very closely related to each other and to other North African Jews, and have largely preserved the original Y-chromosome pools (Nebel *et al.*, 2001). However, there are some genetic differences between Kurdish and non-Kurdish Iraqi Jews (Goldschmidt and Cohen, 1964; Nebel *et al.*, 2001) and it is a limitation that we cannot quantify the proportion of Kurdish Jews among the Iraqi Jews in this study. A final idiosyncrasy in our data is that the snapshot includes only 13 years, so it is not an analyses of “completed” families. None of these disadvantages invalidate these observations.

In summary, this study demonstrated significantly lower sex ratios for Jewish men having West Asian ancestry, even for the 1st and 2nd birth, which is consistent with an environmental or heritable factor that presented a disadvantage for male birth. Although the predominant religion in these countries of origin is Muslim, the small subset of Muslims in the cohort did not show a reduced sex ratio. Additionally, further lowering of the sex ratio was shown with increasing numbers of offspring, consistent with the lack of “stopping behavior” that typically follows male births in cultures with a preference for sons. Such stopping behaviors appear to have more broadly influenced all groups, with declining sex ratios shown with larger numbers of offspring for all subgroups. Our findings raise the possibility that a subset of Jewish men in the Jerusalem cohort were unable to sire sons or had a reduced probability of doing so, but give no evidence of potential causes. An important strength of the study is that it examined sex ratios before it became routinely possible to detect fetal sex in early pregnancy for selective abortions.

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Table 1
Number of live births (N), sex ratio (% male) and 95% confidence interval (CI), by religion of father.

Religion	Jewish	Muslim	Christian	Druze	Unknown	Total
N	88,478	1,744	200	7	1,038	91,467
% male	51.41	54.47	47.50	57.14	47.98	51.43
95% CI	51.08–51.74	52.10–56.83	40.41–54.66	18.41–76.15	44.90–51.07	51.10–51.75
p	-	.0105	.2686	.7615	.0269	-

Table 2

Number of Jewish live births (N), sex ratio (% male) and 95% confidence interval (CI), by selected demographic variables.

Characteristic	N	% Male	95% CI	p (from Chi ²)
Total Offspring	88,478	51.41		
Father's age (years)				
<25	11,818	51.68	50.77 52.58	
25-34	50,439	51.33	50.89 51.77	.187
35-44	22,007	51.76	51.09 52.42	
45+	3,895	49.70	48.12 51.29	
Unknown	319	52.35	46.71 57.94	
Mother's age (years)				
<25	29,903	51.08	50.51 51.65	
25-34	46,462	51.70	51.24 52.15	.060
35+	12,017	51.24	50.34 52.13	
Unknown	96	40.63	30.71 51.13	
Father's education (years)				
13+	27,684	51.97	51.37 52.56	
9-12	30,931	51.21	50.65 51.77	.155
0-8	24,236	51.04	50.41 51.67	
Unknown	5,627	51.43	50.12 52.74	
Mother's education (years)				
13+	23,333	51.55	50.90 52.19	
9-12	30,270	51.46	50.89 52.02	.927
0-8	29,372	51.26	50.69 51.83	
Unknown	5,503	51.44	50.11 52.77	
Offspring's birth order				
1	25,940	51.43	50.82 52.04	
2-4	45,344	51.22	50.87 51.80	.115
5+	17,050	51.84	51.09 52.59	
Unknown	144	59.72	51.23 67.80	
Number of births observed per father				

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Characteristic	N	% Male	95% CI	p (from Chi ²)
1	14,902	52.59	51.78 53.39	
2	23,932	51.76	51.12 52.39	.001
3	20,221	51.02	50.32 51.71	
4+	25,752	50.69	50.07 51.30	
Unknown	3,671	51.68	50.04 53.30	
Number of births observed per mother				
1	16,468	52.38	51.61 53.15	
2	24,363	51.71	51.08 52.34	.004
3	20,352	51.20	50.51 51.89	
4+	26,629	50.67	49.95 51.15	
Unknown	666	53.00	49.13 56.85	

Table 3

Number of live births (N), sex ratio (% male) and 95% confidence interval (CI), by geographic origin of paternal and maternal grandfathers.

Predictor	N	% Male	95% CI*	p (exact)
Total births (including unknown)	88,478	51.41		
Paternal grandfather's place of birth				
Israel	12,782	51.87	51.00 52.74	.309
Other Western Asia	27,606	50.73	50.14 51.32	.024
North Africa	18,925	51.65	50.93 52.36	.516
Europe, etc	28,905	51.70	51.13 52.28	.318
Maternal grandfather's place of birth				
Israel	12,057	51.66	50.77 52.56	.578
Other Western Asia	26,458	51.03	50.42 51.64	.218
North Africa	20,204	51.35	50.65 52.04	.856
Europe, etc	29,598	51.72	51.15 52.29	.292

Table 4

Number of live births (N), sex ratio (% male) and 95% confidence interval (CI) for combinations of paternal and maternal grandfathers' places of birth.

Maternal grandfather's place of birth	Paternal grandfather's place of birth			p (Chi ²)
	Western Asia	Others	Total	
Western Asia				
N	19,700	6,758	26,458	
% male	50.94	51.30	51.03	
95% CI	50.24–51.64	50.10–52.50	50.43–51.64	
p	.186	.859	.2184	.612
Others				
N	7,906	54,114	62,020	
% male	50.22	51.78	51.58	
95% CI	49.11–51.32	51.35–52.20	51.18–51.97	
p	.034	.089	.406	.010
Total				
N	27,606	60,872	88,478	
% male	50.73	51.72	51.41	
95% CI	50.14–51.32	51.33–52.12	-	
p	.024	.122	-	.006
p (Chi ²)	.281	.470	.138	

Table 5

Number of live births, sex ratio (% male) and 95% confidence interval (CI), by geographic origin of offspring's paternal grandfather.

Paternal grandfather's country of birth	Live births	% male	95% CI	p (exact)
Israel	12,964	51.80	50.94–52.67	.368
Western Asia				
Turkey	2,690	49.85	47.94–51.76	.106
Syria	1,509	50.56	48.01–53.12	.511
Lebanon	143	47.55	39.15–56.06	.356
Cyprus	140	50.71	42.14–59.26	.869
Iraq	12,141	50.47	49.58–51.37	.039
Iran	6,074	51.93	50.66–53.19	.431
Afghanistan	392	50.51	45.45–55.57	.722
Yemen & Aden	2,770	50.22	48.34–52.10	.209
India (includes Pakistan & Ceylon)	559	51.52	47.29–55.74	.958
North Africa				
Morocco	14,463	51.17	50.35–51.99	.567
Algeria	798	56.02	46.66–66.60	.292
Tunisia	1,267	53.35	50.56–56.13	.166
Libya	242	52.89	46.39–59.32	.645
Egypt	811	54.25	50.75–57.72	.105
Europe				
USSR	4,954	50.50	49.10–51.91	.202
Poland	8,362	51.55	50.48–52.63	.791
Romania	3,263	52.68	50.95–54.41	.146
Yugoslavia	555	53.33	49.08–57.55	.365
Bulgaria	376	53.46	48.27–58.59	.427
Greece	227	56.39	49.67–62.94	.134
Germany	2,277	52.79	50.71–54.86	.188
Austria	650	50.77	46.85–54.68	.744
Switzerland & Lichtenstein	130	47.69	38.86–56.63	.396
Czechoslovakia	1,323	51.55	48.82–54.27	.919
Hungary	2,488	51.17	49.18–53.15	.807
United Kingdom	481	55.30	50.73–59.80	.088
Benelux countries	344	53.20	47.77–58.57	.507
France	271	53.87	47.74–59.92	.417
Spain, Gibraltar, Andorra	293	53.58	47.69–59.40	.456
Italy	126	44.44	45.60–53.56	.118
Other				
USA	1,295	51.58	48.82–54.34	.901
Argentina	240	51.25	44.74–57.73	.960
South Africa	108	56.48	46.60–66.00	.292

Table 6

Number of live births (N), sex ratio (% male) and 95% confidence interval (CI), according to number of births observed per father.

Birthplace of paternal grandfather	Number of births per father				Total	p (Chi ²)
	1	2	3	4+		
Israel						
N	1,783	3,328	2,869	4,439	12,419	
% male	51.93	52.76	50.58	51.63	51.74	.391
95% CI	49.59–54.28	51.05–54.47	48.73–52.42	50.15–53.11	50.85–52.62	
p (exact)	.657	.118	.371	.766	.468	
Western Asia						
N	3,821	7,167	7,165	8,696	26,849	
% male	51.92	51.50	51.08	49.44	50.78	.018
95% CI	50.33–53.52	50.34–52.66	49.92–52.25	48.38–50.49	50.18–51.38	
p (exact)	.525	.879	.578	<.001	.039	
North Africa						
N	2,723	4,698	4,446	6,538	18,405	
% male	53.84	52.06	51.24	51.13	51.80	.094
95% CI	51.94–55.72	50.62–53.50	49.76–52.72	49.91–52.35	51.07–52.52	
p (exact)	.011	.369	.818	.653	.295	
Europe etc						
N	6,530	8,664	5,703	6,011	26,908	
% male	52.68	51.36	51.03	51.32	51.60	.242
95% CI	51.46–53.90	50.30–52.42	49.72–52.33	50.05–52.59	51.10–52.20	
p (exact)	.040	.929	.562	.892	.529	
Total						
N	14,902	23,932	20,221	25,752	84,807	
% male	52.59	51.76	51.02	50.69	51.40	.001
95% CI	51.78–53.39	51.12–52.39	50.32–51.71	50.07–51.30	51.07–51.74	
p (exact)	.004	.280	.262	.020	.966	