Secondary sex ratio in Greece: evidence of an influence by father’s occupational exposure

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BACKGROUND: Several medical, occupational and environmental paternal exposures have been suggested to be associated with low offspring sex ratios. The purpose of this study was to analyse trends and variations in the secondary sex ratio in Greece during the last 50 years and among different occupational groups of male employees of a shipyard. METHODS: Data were retrieved from National Statistics Agency databases through the period 1955–2005, and linear regression was administered to examine the evolution of the sex ratio of newborns. In addition, 587 male shipyard employees with 1012 children were included in the study. Binary logistic regression analysis was conducted to study the influence of father’s job title on offspring sex ratio. RESULTS: Total births in Greece declined by ~30% between the mid 1950s and 1980, while little change in sex ratio occurred. In contrast, while between 1980 and 2000, the birth rate continued to decline at the same rate (by ~30%), there appeared to be a trend toward a decrease in sex ratio. The groups of sandblasters/painters and of ship carpenters showed a significantly lower proportion of boys among newborn children. CONCLUSIONS: Data from men working in a Greek shipyard suggest that the trend toward a decrease in secondary sex ratio observed in this country may be accounted for by a decrease in male births associated with specific workplace exposures of the father.

Keywords: sex ratio; chemical exposure; sandblasters; painters; carpenters

Introduction

The secondary sex ratio (defined as the proportion of male births) differs remarkably from the theoretically expected equality of 1:1. The fact that more boys are born than girls (104–107 boys for every 100 girls) has been known since 1662. The sex ratio of 1.06:1 has been declining in the last four–five decades in a number of industrialized countries (Davis et al., 1998; Parazzini et al., 1998; Grech et al., 2003).

Many adverse paternal medical, occupational and environmental exposures are known or strongly suspected to be associated with endocrine modifications and significantly low subsequent offspring sex ratios (James, 2006). Working from the assumption that high levels of circulating gonadotropins and/or low testosterone/gonadotropin ratios in men imply a higher probability of conceiving girls, chemical exposure has been investigated as a possible cause of the changes in the sex ratio. Moreover, secondary sex ratio has been regarded as a marker of paternal endocrine disruption.

Petrochemicals, polychlorinated biphenyls, dioxin and dioxin-like compounds, boron, aromatic hydrocarbons, pesticides and other chemicals have been investigated with controversial results. Additionally, specific occupational groups have been linked to a reduced sex ratio, including radiologists, divers, drivers, workers at gasoline filling stations, metal workers and others (James, 2006). Whether this decline is due to an effect of environmental or occupational exposure remains a matter of debate (Dickinson and Parker, 1997; Schnorr et al., 2001; Figa-Talamanca et al., 2003).

The purpose of this study was twofold. Firstly, to investigate whether there is a trend in secondary sex ratio in Greece during the last the last fifty years. Secondly, to analyze the variation of secondary sex ratio among different occupational groups of male employees of a ship construction and repairing company. We specifically sought to identify occupations associated with a significantly decreased proportion of male births.

Materials and Methods

Data concerning the evolution of the sex ratio of newborns at a national level were retrieved from Greek National Statistics Agency (ESYE) databases through the period 1955–2005.

We examined the sex ratio of children born to shipyard industry workers. All current employees (n = 1309) of a shipyard were initially considered. Company workers consisted of persons with various job titles, including metal workers (30.3%), white collars (20.6%), welders (8.3%), electricians (6.4%), tugboat personnel (5.3%), sandblasters/painters (5.0%), carpenters (3.1%), trainees (3.4%), cranes and forklift operators (3.2%) and others. In order to identify persons who have children, the union employees archive was retrieved. This
archive is a continuously updated database through both the human resources department and employees themselves. The registry is considered to have a good reliability since its compilation provides parents of newborns with benefits such as gifts at holidays, scholars and invitations. Information about the sex and birth date of each child is carefully recorded at the registry. In addition, ship carpenters working in ship repairing zone in Perama, Attica were interviewed in December 2005 and January 2006. All male employees with at least one child were initially included in the database. Excluded subjects were 3.8 percent of the total number of participants. Fathers were excluded if unemployed for at least one year at the time of the birth or in case of missing data. Finally, a total of 587 shipyard employees with 1012 children were included in the study. Live births were the measured end point and the proportion of males was assessed. Information on job title and detailed employment history were retrieved from the workers’ employment records.

**Statistical analysis**

Time trends for the sex ratio of newborns at the national level were examined through the period 1955–2005 by multivariate linear regression after controlling for residence (urban, semi-urban, rural).

To study the influence of the father’s job title on offspring sex ratio, binary logistic regression analysis was conducted using the gender of the newborns as the dependent variable. Occupational group, rank of birth and fathers’ age were included in the model as predictors (independent variables). Odds ratios (ORs) were calculated for each occupational group versus all other employees, after adjustment for the rank of birth and the father’s age at birth time. Occupational groups were categorized into seven main categories: white collars (i.e. accountants, clerks, naval architects and telephone operators), metal workers (plotters, fitters, pipe fitters and propeller fitters), ship carpenters, welders, sandblasters/painters, electricians and other blue collars. The group ‘other blue collars’ included employees with various duties such as mechanics, practical engineers, drivers, fire watchmen, plumbers, inspectors, tugboat personnel, building workers, security personnel and others.

**Results**

Birth rate has been declining in Greece over the last 50 years. Live births per 1000 inhabitants fell from 19.7 in 1956 to 14.5 in 1981, with a further fall to 9.7 in 2005. A sharp decrease by almost 50 000 (30%) live births was observed between 1981 and 1989. Since 1990, the rate of live births has stabilized to ~105 000 annually, whereas a slight increase was evident in the last five years. Regarding the evolution of the secondary sex ratio of newborns in Greece, it seems that between the mid 1950s and 1980, little change in sex ratio occurred, while between 1980 and 2000, there appeared to be a trend toward a decrease in sex ratio. Between 1956–1985 (male proportion 0.5172) and 1986–2005 (male proportion 0.5158), the difference in secondary sex ratio reached a statistically significant level ($P = 0.013$).

Figure 1 shows the ratios of male:female newborns in Greece over the last 25 years and in different groups of male shipyard employees. Overall, the male:female ratio was 1.016:1 (male proportion 0.504), a lower value compared with the respective ratio in the general Greek population (0.516). Male offspring was substantially less than females in three occupational groups, namely sandblasters/painters ($n = 45$), carpenters ($n = 62$) and sheet metal workers ($n = 54$). The sex ratios (male proportions) in these groups were 0.61:1 (0.380), 0.70:1 (0.413) and 0.84:1 (0.457), respectively. The observed secondary sex ratio was higher than expected in welders and white collars (0.581 and 0.565, respectively).

In logistic regression, after adjustment for birth rank and father’s age at birth time, sandblasters/painters (OR 0.55; 95% CI 0.34–0.88) and ship carpenters (OR 0.68; 95% CI 0.46–0.99) showed a statistically significant lower proportion of boys among newborn children compared with the rest of employees. Moreover, both welders and white collars showed an increased proportion of boys, albeit not statistically significant.

**Discussion**

In Greece, total births declined by ~30% between the mid 1950s and 1980, while little change in sex ratio (male:female ratio at birth) occurred. In contrast, while between 1980 and 2000 the birth rate continued to decline at the same rate (by ~30%), there appeared to be a trend toward a decrease in sex ratio. It should be noted, however, that a slight increase at birth rate has been observed the last five years. The sharp decrease occurring between 1981 and 1989 was due to several demographic and socioeconomic factors, including aging and urbanization. Thereafter, this phenomenon stopped mainly due to immigrants entering the country since 1990. Our findings are in keeping with other studies suggesting a secular trend in male:female ratio at birth in several countries. The postwar secular decline of the male:female ratio at birth should not be regarded as an isolated phenomenon and parallels the decline of perinatal morbidity and mortality, congenital anomalies and various constitutional diseases. This parallel decrease suggests a possible common etiology and may be ascribed to a reduction of conceptopathology, as a correlate to increasing socioeconomic development (Jongbloet *et al.*, 2001).
Several chemical and environmental factors (i.e. dioxins, nematocides and cocktails of unidentified agricultural chemicals) have been linked to change in sex ratio at birth (James, 2006). It should be noted, however, that the role of environmental factors in the change of male:female ratio among newborn infants remains controversial for the general population. Some studies have focused on specific occupational groups considered as having a prolonged exposure to factors suspected to be associated with endocrine modifications and significantly low subsequent offspring sex ratios. Such reports have suggested an association between occupation or occupational exposures and sex ratio at birth (Mocarelli et al., 2000; Ryan et al., 2002).

Hereo we have examined the sex ratios at birth among seven occupational groups in a Greek shipyard. Our study included only male employees inasmuch as the majority of women in the shipyard are men. Moreover, parental exposure to chemicals is considered to affect sex ratio at birth differently in men than in women. Other studies published in the field focused on male workers for the same reason. Our results provide evidence that the proportion of newborn males decreased significantly in the offspring of ship carpenters and sandblasters/painters. Both occupational groups were referred for the first time.

Ship carpenters fabricate, assemble, install or repair wooden furnishings in ships or boats. During their work they are exposed to hazardous substances including glues, adhesives, solvents, pesticides and insulation material. The main duties of sandblasters/painters in shipyard industry include various types of painting, the removal of old finishes and sandblasting. They remove grease, dirt, paint and rust from surfaces in preparation for paint application, with the use of abrasives, solvents and various antifoaming agents. It is posited that both groups have been exposed to hazardous chemicals that are known or suspected to influence sex ratios. These chemicals include solvents (glycol ethers and other degreasers), pesticides (organochloride, herbicides and other biocides), polychlorinated biphenyls and dioxin-like products in wood preservatives and polyaromatic hydrocarbons (Gijsbers et al., 2004; Links et al., 2006). Studies have clearly shown that these substances may exert significant estrogenic or antiandrogenic activities (Cheek et al., 1999; Figa-Talamanca et al., 2003).

We did not find any significant variations of sex ratios in other occupational groups such as metal workers or welders (exposure to metal fumes), which have been previously suggested as possibly exposed to factors influencing the endocrine functions (Figa-Talamanca and Petrelli, 2000). In contrast, welders showed a trend for increased probability for male newborns, albeit not statistically significant.

The raw assessment of exposure to suspected chemicals is a potential limitation of our study. Another limitation is the lack of information on other factors known or suspected to be associated with the secondary sex ratio. These variables include mother characteristics (age, health status and possible exposures) as well as time-to-pregnancy (TTP). It is worth noting that TTP did not show any significant association with secondary sex in a recent study (Joffe et al., 2007).

Our current findings support the hypothesis of an altered sex ratio due to chemical exposure in specific occupational groups. Although small in the people involved, this preliminary study in a shipyard warrants examination of exposure to chemicals or other hazards that may be associated with the work being performed by the carpenters and sandblasters/painters who showed evidence of producing fewer sons. Further studies on the possible association of occupational activities with the secondary sex ratio are needed to clarify the potential effects of occupational factors on the decline of secondary sex ratio observed in several countries.

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References

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