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Demographic parameters and sex ratio

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RESUMO

No presente trabalho são apresentados os resultados derivados da análise da razão secundária dos sexos de 502469 nascimentos ocorridos na Catalunha entre 1975 e 1979. Os resultados foram obtidos através de regressão Linear Múltipla, utilizando o método «Stepwise», confrontando as variáveis que podem afectar a razão dos sexos no Homem (i. e., idades dos pais e ordem de nascimentos), com a variável dependente p, a probalibilidade de um nascimento masculino. Os resultados mostraram que apenas uma destas variáveis, a idade da mãe, explica uma pequena percentagem da variância de p (1,64%), enquanto as outras duas têm um efeito praticamente insignificante.

Para além das diferenças na razão dos sexos entre populações, tem sido encontrada uma grande divergência na fracção da variação explicada pelos parâmetros demográficos. Assim, é pouco provável que exista uma base genética que possa explicar a incidência diferencial daquelas variáveis na razão dos sexos.

Palavras-chave: Idade dos pais; Idade da mãe; Ordem de nascimentos; Razão dos sexos; Regressão múltipla.

ABSTRACT

In this paper we present the results derived from the analysis of the secondary sex ratio of 502469 births occurred in Catalonia between 1975 and 1979. This was done by means of a stepwise linear regression, which confronted the variables supposed to affect the sex ratio in man (i.e., parental ages and birth order) with a dependent variable p, the probability of a male birth. The results showed us that only one of these variables, the age of the mother, could account for a slight percentage of the variation of p (1.64%), while the other two had an almost negligible effect.

Besides the differences on sex ratio among populations, a great divergence has been found in the fraction of the variation explained by demographic parameters. Therefore, we wonder if there could be a genetic basis that could explain the differential incidence of these variables on sex ratio.

Key-words: Sex ratio; Age of father; Age of mother; Birth order; Stepwise regression.

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INTRODUCTION

Sex ratio at birth, or secondary sex ratio, is a parameter that has long interested scientists since Darwin proposed that there should exist a selective mechanism that could explain and control its observed differences among populations. The analysis of the secondary sex ratio may be performed at distinct levels, from immunology to demography. The studies at population levels have focused mainly on the analysis of the demographic variables that may have an influence on sex ratio; that is, they have tried to explain the observed differences in space and time by means of the reproductive patterns of the diverse populations.

Since the first works of Novitski (NOVITSKI and SANDLER 1956; NOVTSKI and KIMBALL, 1958), the studies centred basically on three factors: age of the mother, age of the father and parity or birth order. According to these authors, the first parameter would not show any relationship with sex ratio, while a negative correlation with the other two variables would be evident. TEITELBAUM et al. (1971) critisized these works because the high correlation among the three variables had been ignored, and proposed that, in fact, the most influential factor was parity. Working with different data and statistical methods, ERICKSON (1976) confirmed this result in its basic lines; nevertheless, he pointed out that parity could only account for less than 10% of the total variation of sex ratio.

IMAIZUMI and MURATA (1979), however, came to different conclusions when analyzing japanese births: althought the effect of parity was still evident, maternal age showed a slightly positive correlation with sex ratio, and the effect of paternal age on it appeared to be negligible. RUDER (1985), in a recent study, besides proposing new statistical methods, concludes that both parity and paternal age (or biological factors associated with them) play a significant role in the determination of secondary sex ratio.

Efforts have been made to find out a ~~biolo~~gical basis for these observed associations at the population level (DEWEY *et al.*, 1965; JACKSON *et al.*, 1969), although until now results are far from satisfactory. Thus the interest of delimiting the demographic parameters persists. It is at this point that the present work stands, being a complement of a previous study (SALA and BERTRANPETIT, 1985). In both of them we have worked with p, the probability of a male birth (p = male births / total births), instead of with the sex ratio itself. In this former analysis we came to the following conclusions:

— The decrease of p with the increase of material age was significant.

— We did not find any significant association between p and paternal age. However, we were able to detect a general pattern of a decrease of p when the age of the father increased.

— Regardless of the fact that it is considered the principal factor affecting sex ratio in man, parity did not seem to have any influence at all, showing, on the contrary, a series of unexplained oscilations that did not follow any general pattern.

The present work improves on his previous analysis by confronting the already mentioned parameters with p, by means of a multiple linear regression.

MATERIALS AND METHODS

Data used for this study were recorded on tapes, which contained all the information related to the 502469 births occurred in Catalonia between 1975 and 1979. This information was gathered by the Instituto Nacional de Estadística, and made available to us through the conselleria de Sanitat de la Generalitat de Catalunya. Of the 502469 births, 259594 correspond to male births and 242875 to female births, the global sex ratio thus being 0.5166. For each birth, 32 variables are described. We only use, in this work, parental ages, birth order and sex. The others had already shown not to have any influence on p (SALA and BERTRANPETIT, 1985).

Statistical analyses of data were carried out at the Centre d' Informática of the University of Barcelona, with an IBM 3083 computer.

A multiple regression was used in order to examine the possible association between the above-cited parameters and p simultaneously. First of all the three factors were divided into classes; the number of classes per factor was as follows:

parameter	classes
maternal age	(<20, 20 —, 25 —, 30, 30 —, 35 —, 40+)
paternal age	(<20, 20 —, 25 —, 30, 30 —, 35 —, 40 —, 45+)
parity	(1, 2, 3, 4, 5, 6, 7, 8, 9+)

Next, we built a series of cells, each of them being an unique combination of the three parameters confronted with p. The number of cells thus obtained was 378. The information contained in each of them was: number of male births, number of female births, total births and sex ratio. Cells containing any zero value were excluded from the analysis; thus, the total number of non-empty cells was 296.

The independent variables of the regression were parental ages and parity, p being the dependent one. The parameters of the equation were estimated by the least-squares method, using a weighting factor, which was taken as the inverse of the variance of $\hat{p}$:

$wf = N_c / p_c q_c$ Where $Nc =$ total births of cell c.
$p_c = p$ of cell c
$q_c = 1 - p_c$

The use of such a factor usually generates a high number of cases, which is, of course, unreal; therefore, a correction was made so that the final number of cases was the number of non-empty cells (296).

The regression was carried out using a program of the the SPSSX statistical package. This program performs a stepwise regression, which consists of the construction of an equation with the least possible number of terms. The independent variables enter one at a time, and only if they reach certain statistical criteria. The order of inclusion depends on the respective contribution of each variable to the explained variance of the dependent variable. That is, at each step the analysis includes in the equation the variable that accounts for the greatest percentage of the variance of p which is not explained by the variables already entered in the equation.

RESULTS

The 296 non-empty cells contained a total of 493277 births (254834 males and 238443 females; $p=0.5166$). The order of inclusion of the variables into the equation was maternal age, parity and paternal age. Table 1 shows the values of the multiple correlation coefficient (R), R^2 and the change of R^2, which represents the contribution added to the explained variance of p by each variable that is included in the equation.

The first variable (maternal age) acounts for 1.5% of the variation of sex ratio; a very low percentage if we think that it is the most important factor in the regression. By adding parity, this percentage increases only by 0.05%, the contribution of paternal age being almost negligible (0.007%). When the three variables are taken into account, only 1.64% of the variation of p can be explained.

Although the regression is significant for the first variable ($F=4.379$ for 1 and 294 degrees of freedom; significance$=0.030$), when the three parameters are considered altogether regression becomes clearly non-significant ($F=1.652$ for 3 and 292 degrees of freedom; significance$=0.1837$).

Table 2 presents the parameters of the regression equation for all the possible models. It can be clearly seen that all regression coefficients are very low, which means that p would hardly change if any of the independent variables were modified. In the present case, R and R^2 measure the correlation between each variable, or group of variables, and p when controlling for the others. It must be noted that, although they are of very little importance in the regression as a whole, parity and paternal age have relatively high correlation coefficients with p, mainly due to their high relationship with maternal age, the most influential variable.

Partial correlations (Table 3) show that the age of the mother is really the only factor that has some interest in the regression, and that the other parameters, when controlling for the former, have an almost irrevelant correlation with p.

As R^2 reached such a low value, even when considering all three factors together, we searched for some kind of non-linear relationship that could explain a higher percentage of the variation of sex ratio. For this purpose we used some functions of p, such $p=\mathrm{Ln}(p)$, $p=e^p$ and $p=p^2$, and applied the

TABLE 1. *Order of inclusion of the variables in the regression equation*

variable	R	standard error	R^2	R^2 change	Analysis of variance F	d. f.	signif.
maternal age	—0.12595	0.01186	0.01586	0.01586	4.739	1,294	0.0303
parity	—0.12788	0.01190	0.01635	0.00049	2.435	2,293	0.0893
paternal age	—012813	0.01245	0.01642	0.00007	1.625	3,292	0.1837

TABLE 2. *Correlation coefficients and parameters of the regression equation for all possible models*

Model	R	R^2	b_1 ($\times 10^{-4}$)	b_2 ($\times 10^{-4}$)	b_3 ($\times 10^{-4}$)
MA	—0.1259	0.01586	—13.3		
BO	—0.0502	0.00252		—4.889	
PA	—0.0965	0.00932			—9.638
MA, BO	—0.1279	0.01635	—14.86	2.569	
MA, PA	—0.1260	0.01587	—13.06		—3.478
BO, PA	—0.0966	0.00932		0.398	—9.862
MA, BO, PA	—0.1281	0.01642	—13.99	2.814	—1.275

MA = maternal age; BO = birth order; PA = paternal age.

TABLE 3. *Partial correlations of the variable(s) V_1 with p, when controlling for the variable(s) V_2*

V_1	V_2	partial correlation
MA	BO	—0.1177
MA	PA	—0.0813
MA	PA, BO	—0.1259
BO	MA	0.0222
BO	PA	—0.0034
BO	MA, PA	—0.0502
PA	MA	—0.0023
PA	BO	—0.0825
PA	MA, BO	—0.0965

same regression program. However, the results did not differ from the previous ones; as a matter of fact, the logarithmic model could only account for less than 2% of the variation, maternal age and also being the most important parameter.

DISCUSSION AN CONCLUSION

The linear regression used to show the relationship between sex ratio and the variables parity and parental ages in the births occurred in Catalonia between 1975 and 1979, led us to conclude that these parameters can only account for a very low percentage of the variance of the former (1.64%). This figure, however, seems to be rather close to the values obtained by ERICKSON in his study of 1.5 milion white American births (1976), in which R^2 was only about 8%. Likewise, the analysis of 1 milion Scottish births (ROSTRON and JAMES, 1977) reported that the variation of sex ratio was so small that it was difficult to detect any significant association. It is remarkable that, working with such high numbers of births, the explained variation is so different among the distinct studies. This fact may suggest that the possible influence of the demographic variables on p should not be considered uniform among the different populations, as long as the observed divergences cannot be atributed to sample oscillations.

In the present case, results seem to point to maternal age as the main source of variation of p. However, and contrary to what was expected (and observed by other authors), parity and paternal age contributions are very low.

Because of hypothetical biological reasons, maternal age was one of the first factors to be considered when trying to explain the variation of secondary sex ratio. It seemed logical to think that changes in woman's physiology as age increased could have some kind of influence on sex ratio. However, the first statistical analysis clearly showed that the factors to take into account were paternal age and birth order (NOVITSKI and SANDLER, 1956; NOVITSKI and KIMBALL, 1958). The variation due to maternal age could be explained, according to the first studies, by its high correlation with them.

It is also known, since the works of RENKONEN and SEPPALA (1962) on Rh blood group system, that there exist immunological mechanisms which are able to induce maternal sensitization after pregnancy, modifying thus the probability of new male (or female) conceptions. DEWEY *et al.* (1965) and JACKSON *et al* (1969) postulated the existence of a similar maternal immune reponse due to Xg^a blood group. Recently, it has been proposed that the male antigen (H-Y) may induce maternal sensitization against male conceptions, although this theory does not seem to have enough experimental support (HOPPÉ and KOO, 1984). In front of these facts, and as suggested by ERICKSON (1976), it could be plausible that a maternal immune response against male antigens could provoke a decrease of p with the increase of parity.

An explanation of the effect of paternal age was also sought in the cytological field (NOVITSKI and SANDLER, 1956): the relative frequency of sperm bearing X and Y chromosomes increased with the age of the father. However, this interpretation, that has not been experimentally refuted, does not seem very probable nowadays.

As parity and paternal age are tightly correlated, their respective effects on sex ratio may accumulate, so they appear as the main sources of its variation in most of the analysis.

Our figures differ, globally, from this scheme in the sense that birth order is not the most important variable. However, it is necessary to put into question whether results from different studies do really describe diverse situations. It is difficult, from a biological point of view, to cast such diverse conclusions of the mentioned works with a unique reality. Given the high correlation among the three variables, slight random variations may cause changes in the inclusion of variables into the regression equation. But it is difficult to interpret the differences in the fraction of explained variation.

As a consequence, time-space variations of secondary sex ratio cannot be explained by these demographic variables. Another question is whether the intensity of their impact among different populations could have a geographic and, possibly, genetic variation. Therefore, we propose the possible existence of a genetic regulation of the intensity with which some concrete parameters may influence human sex ratio.

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