The Inbreeding Load in Brazilian Whites and Negroes as Estimated with Sib and Cousin Controls

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INTRODUCTION

Data from two different surveys of rural and urban populations of the southern region of the Brazilian state of Minas Gerais led to the working hypothesis that whites and nonwhites (mulattoes and Negroes) living in that area had inbreeding loads of different magnitudes [1, 2]. Freire-Maia and Azevedo [3], on the basis of a new analytical approach, concluded that this difference should better be ascribed to a bias by socioeconomic concomitant variables (environmental disturbances) rather than to a biological phenomenon (genetic load).

This paper presents in detail the data with sib and cousin controls obtained in the same region and already mentioned in [3, 4]. For an analysis of the larger reliability of sib controls as compared with controls obtained at random in the population, see [5].

MATERIALS AND METHODS

Consanguineous couples whose names and addresses were obtained from the records of our previous fieldwork were contacted again, and a new form was filled out to include the events that had occurred after the first visit. When possible, names and addresses of two sibs of the spouses were obtained. These individuals were visited later and compose the control sample. When at least one sib was not living in the same town, cousins and/or close neighbors were chosen to replace him. The neighbors were chosen on the basis of two criteria: high residential propinquity and ethnic group. The cousin and sib controls had ages which were the closest possible to those of the corresponding consanguineous parties. All the fieldwork was done by J. B. C. A. For other details on methods of data collection and analysis, see [2, 6].

THE DATA

Our data are subdivided into two main categories: "total" (i.e., including neighbors) and "with sib and cousin controls" (i.e., excluding neighbors). The frequency

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of sibs and neighbors in the control fraction is roughly 44% for each, the remainder being composed of cousins, mainly first cousins.

Tables 1 and 2 present some parameters for the two categories. While some differences (mean number of pregnancies per couple, mean marriage age of wives, and mean age of husbands at the year of the survey among whites; mean age of wives at the year of the survey among nonwhites; and mean cohabitation time among

TABLE 1

DATA ON TOTAL CONTROL AND CONSANGUINEOUS SUBSAMPLES (CONTROL INCLUDES NEIGHBORS, COUSINS, AND SIBS OF CONSANGUINEOUS PARTIES)

Comparison	Control	Consanguineous	t
Number of sibships:			
Whites	100	50	.....
Nonwhites	70	35	.....
Mean number of pregnancies per couple:			
Whites	7.56±0.40	9.06±0.63	2.01*
Nonwhites	6.56±0.43	7.89±0.80	1.47
Mean number of births per couple:			
Whites	6.79±0.36	7.32±0.50	0.86
Nonwhites	6.03±0.39	6.80±0.68	0.98
Mean number of live births per couple:			
Whites	6.64±0.37	6.84±0.50	0.32
Nonwhites	5.74±0.38	6.26±0.62	0.71
Mean marriage age of husbands:			
Whites	25.84±0.67	24.88±0.63	1.05
Nonwhites	25.13±0.76	24.00±0.96	0.93
Mean marriage age of wives:			
Whites	19.98±0.40	18.72±0.46	2.07*
Nonwhites	19.71±0.56	19.38±0.61	0.39
Mean age of husbands at the year of the survey:			
Whites	48.27±1.44	52.93±1.80	2.03*
Nonwhites	43.59±1.80	47.28±2.61	1.16
Mean age of wives at the year of the survey:			
Whites	43.88±1.28	47.85±1.86	1.76
Nonwhites	40.69±1.85	47.15±2.46	2.10*
Mean cohabitation time:			
Whites	22.30±1.21	28.20±1.75	2.77**
Nonwhites	18.47±1.59	24.65±2.28	2.22*

* Signficant at .05 level.
** Significant at .01 level.

both ethnic groups) are significant in the total (table 1), no significant difference has been verified with regard to the category including only sibs and cousins (table 2). It is to be noted, however, that the comparisons in table 2 have only about half the precision of those of table 1.

Schooling rates have also been analyzed. While whites consistently show better schooling, no significant difference exists between the control and the consanguineous subsamples among both whites and nonwhites.

Our data are also classified according to coefficient of inbreeding (F) and mortality

(abortions, stillbirths, etc.) (tables 3 and 4). The large variation of mortality rates according to F may reflect, at least in part, some socioeconomic heterogeneity.

In table 5, estimates of the numbers of lethons (lethal equivalents per gamete) based on two approaches (MCM—Morton, Crow, and Muller [7], and FM—Freire-Maia and Freire-Maia [8]) are presented. These estimates are approximately equal in both ethnic groups.

TABLE 2

DATA ON PART OF CONTROL AND CONSANGUINEOUS SUBSAMPLES (CONTROL SUBSAMPLE COMPOSED OF ONLY COUSINS AND SIBS)

Comparison	Control	Consanguineous	t
Number of sibships:			
Whites	56	35	.....
Nonwhites	37	28	.....
Mean number of pregnancies per couple:			
Whites	7.20±0.56	9.00±0.82	1.82
Nonwhites	6.19±0.56	7.07±0.83	0.88
Mean number of births per couple:			
Whites	6.36±0.47	7.11±0.64	0.95
Nonwhites	5.84±0.52	5.86±0.59	0.02
Mean number of live births per couple:			
Whites	6.16±0.47	6.66±0.63	0.63
Nonwhites	5.46±0.50	5.50±0.57	0.05
Mean marriage age of husbands:			
Whites	26.36±1.02	25.11±0.71	1.00
Nonwhites	24.74±0.93	22.96±0.85	1.41
Mean marriage age of wives:			
Whites	20.71±0.64	19.03±0.58	1.94
Nonwhites	19.34±0.75	19.81±0.70	0.46
Mean age of husbands at the year of the survey:			
Whites	48.47±1.94	51.97±2.04	1.24
Nonwhites	44.45±2.78	45.64±2.68	0.31
Mean age of wives at the year of the survey:			
Whites	44.49±1.78	46.32±2.13	0.66
Nonwhites	38.66±2.26	43.92±2.42	1.59
Mean cohabitation time:			
Whites	22.18±1.76	26.37±2.12	1.52
Nonwhites	17.26±2.16	22.96±2.38	1.77

NOTE.—Differences not significant.

DISCUSSION

Because the wives in the consanguineous samples are older and have had more pregnancies than the controls (tables 1 and 2), our estimates of numbers of lethons (table 5) are to be considered as probable overestimates. This is the second investigation made in Brazil using controls belonging to the same families of the consanguineous spouses. The first one, of a white southern population (known to be of much more heterogeneous European origin than those from Minas Gerais, who were almost entirely of Portuguese descent), led to 2.08 ± 0.86 lethons [9].

TABLE 3

MORTALITY IN DIFFERENT LEVELS OF F (TOTAL DATA)

ABORTIONS			STILLBIRTHS			INFANT-JUVENILE MORTALITY			TOTAL FREQ.
F	N	Freq.	F	N	Freq.	F	N	Freq.	
				Whites					
0	756	.1111	0	679	.0221	0	664	.2003	.3069
.015625	107	.2897	.015625	76	.0789	.015625	70	.1000	.4112
.031960	66	.2424	.032169	51	.0784	.032247	47	.0851	.3636
.070731	280	.1500	.070639	239	.0586	.070868	225	.2533	.4036
.052066*	453	.1965	.053885*	366	.0656	.054253*	342	.1988	.3996*
				Nonwhites					
0	459	.1002	0	422	.0474	0	402	.1692	.2919
.018067	32	.1875	.028312	117	.0513	.018229	27	.1852	.3438
.031319	114	.2105	.064954	121	.1074	.031343	84	.2381	.4386
.065024	130	.0692	.046941*	238	.0798	.065104	108	.3056	.4231
.045658*	276	.1413	.....	.....	.....	.046376*	219	.2648	.4203*

NOTE.—For abortions, N = no. of pregnancies; for stillbirths, N = no. of children born; for infant-juvenile mortality, N = no. of children born alive. Infant-juvenile mortality is the mortality from birth up to and including age 20. The values of t for the comparison between the control and the total inbred subsample in each ethnic category are as follows: whites—abortions (3.90; $P < .001$), stillbirths (3.08; $P < .01$), infant-juvenile mortality (0.06), total (3.12; $P < .01$); nonwhites—1.75, 1.59, 2.72 ($P < .01$), and 3.52 ($P < .001$), respectively.

* Total of inbred subsamples.

TABLE 4

MORTALITY IN DIFFERENT LEVELS OF F (ONLY SITUATIONS WITH SIB AND COUSIN CONTROLS INCLUDED)

ABORTIONS			STILLBIRTHS			INFANT-JUVENILE MORTALITY			TOTAL FREQ.
F	N	Freq.	F	N	Freq.	F	N	Freq.	
				Whites					
0	403	.1191	0	356	.0309	0	345	.1623	.2854
.015625	32	.5625	.027945	52	.0385	.015625	14	.1429	.6250
.032169	51	.2745	.068330	197	.0711	.032552	36	.1111	.3922
.068056	232	.1509	.059896*	249	.0643	.068434	183	.2678	.4224
.056920*	315	.2127	.....	.....	.....	.059717*	233	.2361	.4381*
				Nonwhites					
0	229	.0699	0	216	.0648	0	202	.1832	.2926
.019176	22	.2727	.029498	107	.0561	.019761	17	.2941	.5000
.031319	114	.2105	.067708	57	.0702	.031343	84	.2381	.4386
.067792	62	.0806	.042778*	164	.0610	.067807	53	.3208	.4194
.041391*	198	.1768	.....	.....	.....	.042614*	154	.2727	.4394*

NOTE.—For abortions, N = no. of pregnancies; for stillbirths, N = no. of children born; for infant-juvenile mortality, N = no. of children born alive. The values of t for the comparison between the control and the total inbred subsample in each ethnic category are as follows: whites—abortions (3.85; $P < .001$), stillbirths (1.85), infant-juvenile mortality (2.16; $P < .05$), and total (4.26; $P < .001$); nonwhites—3.35 ($P < .001$), 0.15, 1.99 ($P < .05$), and 3.17 ($P < .01$), respectively.

* Total of inbred subsamples.

Other investigations, both on white and Negro Brazilian populations but with random control, gave the following estimates of lethons:

1. State of Bahia: whites, 1.31; Negroes, 1.21 [10].

2. State of Espírito Santo: whites, 2.54; nonwhites, 2.92 (A. Freire-Maia, personal communication).

3. State of Paraná: a predominantly white population, 2.30 [11]; the white fraction of this population, 3.34 [12].

4. A trihybrid migrant sample from the east and northeast: larger than 1 (without racial influence) [5].

5. State of Minas Gerais: whites, 1.29; nonwhites, 2.72 [6]. These data include those of [1, 2]. With a multiple regression analysis, the whole of these data led to a value somewhat larger than one lethon, *without racial effect* [6]. A previous analysis, using only the control subsample and the lowest values of F, led to 4.54 for whites and 5.56 for nonwhites, the difference being nonsignificant [3].

TABLE 5

ESTIMATES OF NUMBERS OF LETHONS ON BASIS OF DATA FROM TABLES 3 AND 4, USING TWO METHODS

Ethnic Group and Method	Abortions	Stillbirths	Infant-Juvenile Mortality	Total
Whites:*				
MCM....	0.66±0.38	0.56±0.18	0.87±0.51	2.09±0.70
FM.....	1.93±0.49	0.84±0.27	−0.03±0.60	2.74±0.84
Nonwhites:*				
MCM....	0.01±0.50	0.92±0.37	2.75±0.79	3.62±1.03
FM.....	1.02±0.62	0.73±0.46	2.62±0.96	4.36±1.24
Whites:†				
MCM....	0.33±0.48	0.62±0.26	1.91±0.62	2.90±0.85
FM.....	1.96±0.59	0.58±0.31	1.53±0.71	4.19±0.99
Nonwhites:†				
MCM....	1.06±0.63	0.02±0.55	2.65±1.12	3.69±1.45
FM.....	2.93±0.88	−0.10±0.62	2.71±1.36	5.59±1.76

NOTE.—MCM = Morton, Crow, and Muller [7]; FM = Freire-Maia and Freire-Maia [8]. For details, see text.
* Total data.
† Only sib and cousin control.

6. State of Minas Gerais: whites, 2.09 and 2.90; nonwhites, 3.62 and 3.69 (present investigation. The second estimates, 2.90 and 3.69, respectively, correspond to the data with sib and cousin controls).

In summary, the following estimates of numbers of lethons have been obtained: (1) A trihybrid population: >1 (without race effect); (2) a dihybrid population: >1 (without race effect); (3) a predominantly white population: 2.30; (4) whites: 1.29, 1.31, 2.08, 2.09, 2.54, 2.90, 3.34, 4.54; and (5) mulattoes and Negroes: 1.21, 2.72, 2.92. 3.62, 3.69, 5.56.

The range or variation is practically the same in both whites and nonwhites. It corresponds roughly to the range formed by investigations performed in other countries, where estimates both lower than 1 and higher than 4 have been obtained [3, 5, 13–15]. On the basis of all these data, it seems safe to assume that the number of

lethons acting from about the second month of pregnancy up to the age of 20 is about the same in all the human populations so far investigated (roughly 2), the differences being most probably due to methodology, extraneous variation, "incomplete" data (use of segments of "total mortality"), or pure sampling. Regarding the first aspect, we would like to comment on the uncritical use of methods widely known as leading to underestimates of lethons. Based on the hypothesis of a linear relation between inbreeding and mortality, some authors apply either the regression technique or simply the product of the difference between the mortality rate in inbred and outbred sibships by the reciprocal of F (see [16] for a discussion of this problem). With regard to extraneous concomitant variables that may bias the data, it seems important to consider that a group living under low socioeconomic level is expected to have a higher precocious mortality but may also present a larger proportion of underreported events. For instance, see [5] for an analysis of this possibility. In the use of different segments of "total mortality" to measure inbreeding effect, suffice it to mention that some studies only include small portions of the whole range (perinatal deaths, stillbirths plus infantile mortality, etc.) whereas others, such as our own, encompass a wider period (abortions, stillbirths, and mortality from birth up to the age of 20). For detailed references to this problem, see [13, 15]. As far as sampling is concerned, it is interesting to recall that some investigations led to either negative or too high numbers of lethons, at least one of the reasons for this being the small size of the samples. See [3, 5, 15] for some examples.

In connection with the above estimates, it is interesting that for a large Portuguese (white) population, the following estimates of numbers of lethons have been obtained: 1.48, 1.71, 2.12, and 2.31 [17]. The lowest and the highest are based on data with sib controls; the others, on all controls taken together (neighbors, cousins, and sibs). The two highest estimates are based on different types of consanguineous marriages, whereas the two lowest are based on first cousins only. These values may be described as representing roughly 2, as estimated for Brazilian whites and nonwhites.

SUMMARY

A new investigation using sib and cousin controls, made in the same Brazilian area where whites and nonwhites (mulattoes and Negroes) had before shown inbreeding loads of different magnitudes, failed to support these findings. Our present data show that the number of lethons is the same in both ethnic groups. A review of all investigations on Brazilian whites and nonwhites suggests that the number of lethons may be accepted as roughly 2 in both ethnic groups.

REFERENCES

1. Freire-Maia N, Freire-Maia A, Quelce-Salgado A: The load of lethal mutations in white and Negro Brazilian populations. I. First survey. *Hum Hered* (Basel) 13:185–198, 1963
2. Freire-Maia N: The load of lethal mutations in white and Negro Brazilian populations. II. Second survey. *Hum Hered* (Basel) 13:199–225, 1963
3. Freire-Maia N, Azevedo JBC: Extraneous variation in inbreeding studies. *Amer J Hum Genet* 19:686–689, 1967

4. AZEVEDO JBC, FREIRE-MAIA N: Uma reanálise do problema da carga genética em brancos e negros do sul de Minas. *Ciência e Cult* 17:156, 1965
5. KRIEGER H: Inbreeding effects in northeastern Brazil. Ph.D. thesis, Univ. Hawaii, 1966
6. KRIEGER H, FREIRE-MAIA N, AZEVEDO JBC: The inbreeding load in Brazilian whites and Negroes: further data and a reanalysis. *Amer J Hum Genet* 23:8–16, 1971
7. MORTON NE, CROW JF, MULLER HJ: An estimate of the mutational damage in man from data on consanguineous marriages. *Proc Nat Acad Sci USA* 42:855–863, 1956
8. FREIRE-MAIA N, FREIRE-MAIA A: Estimate of the genetic load disclosed by inbreeding. *Genetics* 50:527–529, 1964
9. MARÇALLO FA, FREIRE-MAIA N, AZEVEDO JBC, et al: Inbreeding effect on mortality and morbidity in south Brazilian populations. *Ann Hum Genet* 27:203–218, 1964
10. QUELCE-SALGADO A, MARTELLO N: Mortalidade e carga genética atuante em populações do interior do Estado da Bahia. *Ciência e Cult* 21:252–253, 1968
11. MARÇALLO FA, AZEVEDO JBC: Equivalentes letais em Caucasóides sul-brasileiros. *Bol Soc Brasil Genêt* 4:158, 1962
12. AZEVEDO JBC, MARÇALLO FA: Efeitos do endocruzamento sôbre a mortalidade e a morbidade em populações sul-brasileiras. *Ciência e Cult* 15:192, 1963
13. FREIRE-MAIA N: Deleterious mutations in man. *Soc Biol* 7:193–203, 1960
14. MORTON NE: Morbidity of children from consanguineous marriages, in *Progress in Medical Genetics*, vol 1, edited by STEINBERG A, New York, Grune & Stratton, 1961, pp 261–291
15. SCHULL WJ, NEEL JV: *The Effects of Inbreeding on Japanese Children.* New York, Harper & Row, 1965
16. FREIRE-MAIA N: On the methods available for estimating the load of mutations disclosed by inbreeding. *Cold Spring Harbor Sympos Quant Biol* 29:31–40, 1964
17. FREIRE-MAIA N, DE AZEVEDO-FIALHO MGM, FREIRE-MAIA FLN: Inbreeding load, as estimated with sib control, in a Portuguese population. *Hum Hered* (Basel)20:248–251, 1970