Estimating fertility for archaeological samples

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Abstract

The interpretation of age-at-death distributions for skeletal samples from archaeological sites is plagued by multiple problems. It is of central importance for us to develop approaches that allow the assessment of sample reliability and comparison of demographic parameters. This paper outlines a method by which obvious bias can be detected and samples can be compared on a key demographic parameter.

INTRODUCTION

In spite of using samples that can be shown to be very incomplete and biased, Angel (1971) made an important pioneering effort to use a comparative diachronic method for the study of burials. This was an essential step: without methods of comparison, we cannot interpret our data. Angel's suggestion was to use the proportions of juveniles to adults. This type of approach was also developed in France based on the realization that methods of adult age assessment are flawed and that we will have to be satisfied with the use of summary demographic parameters – estimators – in characterizing our samples. Bocquet-Appel and Masset (1977, 1982) developed what they called the index of juvenility, the ratio of subadults aged 5 to 14 years to adults aged 20 and over.

My own interest in this field began when I came to understand that Ontario Iroquoian samples from different periods, pre- and post-European incursions, could not be distinguished on their demographic values. This was a nonsensical result and led to work on why this should be so (Jackes, 1985) and on ways to compare sites in the face of this impediment to interpretation. An invited lecture at the University of Toronto proposed comparison of sites based on subadult mortality quotients and this was explained in papers submitted for publication, which were rejected but quite widely distributed in 1983 and 1984. Because subadult age estimates are more accurate than those for adults, the method concentrated on subadults. The focus was on the life table quotient (q) values for site comparison, and initially the mortality quotient curves were examined for deviations from the expected shape, as this would indicate errors of age assessment or sampling bias. Buikstra and Konigsberg (1985) initially used mortality quotients (q values) as a method of comparing across sites, but since they included adult q values their results were not informative.

A colleague pointed out to me that Bocquet-Appel and Masset were thinking along the same lines as I was, and I began to use their ratio of 5-14 year old juveniles to adults of 20 and over (the juvenile to adult ratio, abbreviated as J:A, Jackes, 1986) together with my proposed summary value of mean childhood mortality (the mean of ${}_5q_5$, ${}_5q_{10}$ and ${}_5q_{15}$, abbreviated as MCM). The reasoning was, in part, that the two values could be discrepant for some sites. Discrepancy, and the direction of the discrepancy, gives clues to problems. The initial focus of

my approach was on identifying sites in which the sample is unrepresentative, biased or incomplete, but the subsequent addition of fertility rate estimates added weight to the conclusions.

I will present here an example of this process. That example will be followed by details of the method and tests of the accuracy of the method based on some of the data from historical demography and demonstrations of the ways in which possible bias might be identified.

THE EXAMPLE

I was sent age-at-death distribution data for a Caribbean archaeological site by Mirjana Roksandic (*in litt*. 8th February 2011) with a query about bias: I reformulated the data as shown in Table 1.

TABLE 1. Caribbean data

Age categories	Frequency	Standard age units	Redistribution
0-3	85	0-4.99	91
4-9	36	5-9.99	30
10-14	4	10-14.99	4
15-19	13	15-19.99	13
20-24	24	20-24.99	24
25+	37	25+	37
Total	199		199

I responded by saying that the data were biased by under-representation of adults. There might have been selective burial or historical factors leading to a situation in which many adults were not given normal burial. It was not possible for this to be the full sample of the dead: I suggested that the addition of at least 100 adults was needed in order to make the sample biologically meaningful. Roksandic replied (*in litt* 10th February 2011): "I got the explanation. About 100 of the excavated skeletons were taken for a study on syphilis (and apparently lost)." Therefore, we could assume that many of the missing skeletons had visible syphilitic lesions.

THE METHOD

What was the method used to come to the conclusion that at least 100 adults were missing from the distribution? The method was to calculate MCM and J:A and to derive from them estimates of the total fertility rate. Another estimator, P, calculated from the age distribution numbers for 5-19/5+ years (Bocquet-Appel, 2002), is the near equivalent of MCM.

The total fertility rate (TFR) is the average rate for all females in a population, calculated here for 30 years of reproductive life from 15 years of age. With the Caribbean sample at n = 199 the 95% CI fertility (TFR) range is from 17 to 21. Not only is the range too broad, but it is impossible that the *average* woman would have 17 or more live-born children. Various background discussions about constraints on fertility (Jackes and Meiklejohn, 2008, Jackes et al., 2008, Jackes, 2009, 2011) have perhaps not given sufficient emphasis to the distinction between fecundity and fertility, between potential and actual. While total fecundity may average 15-16, an uncontrolled or natural total fertility rate would, with very few exceptions not exceed 8.5 (Wood, 1990:214, 222-223).

In the case of the Caribbean skeletal sample, the addition of 100 adults of age 25 and over, so that n = 299, results in a TFR 95% CI range of 6.1-7.5. Since TFR is a measure of live-born children, the likelihood of fetal loss and stillbirths in women with syphilis (Watson-Jones et al., 2002) suggests that this TFR estimate is still too high. Thus more than 100 individuals are probably missing from the sample. Syphilitic skeletal lesions will not be seen amongst those who died immediately following the initial infection. They only appear in the tertiary stage, so we can expect that most of the selected individuals were fully adult (Clark and Danbolt, 1955). While there is the question of congenital syphilis (see discussion in Mackey and Immerman, 2001), congenital syphilis will be seen most often among those who die at the very young ages excluded by the method used here. It is only after many pregnancies that syphilitic mothers are likely to give birth to children who survive to develop skeletal sequelae in late childhood/adolescence. We can, of course, continue to adjust the age-at-death distribution, easily bringing the TFR down to perhaps 5-6, but without knowing more about the sample, the historical setting and the basis for selection of the 100+ lost individuals, it is not possible to say that the excavated skeletons were ever in any way representative of a total group.

The method is based on 51 West model life tables (Coale and Demeny, 1983), as shown in Table 2: tables generating TFR estimates above 12.5 have been excluded. The estimator calculations are derived from the pooled sex model tables, and the table TF values are calculated for 30 years of reproductive life. The life table C_x values for females of 15-44.99 years and males of 15-44.99 years provide the male/female ratio figure used in the calculation for general fertility. All the West model tables used give a figure of 2.03, except for West 5. In the ten West 5 tables used, the value rises from 2.09 to 2.19. However the 2.03 value is used here for West 5: the total fertility rate rises to values out of line with the other tables if the C_x proportion of reproductive age women is reduced from 49% to 45-46%. The West 5 tables seem to be constructed so that TFR increases (as *r* – the rate of change in population size – increases) because there are proportionately fewer females. This would add undesirable noise to our calculations. It could be argued that 35 years of reproductive life, rather than 30, should be employed in the TFR calculations. At low levels of fertility the differences are trivial, but at higher levels of fertility (~8) the differences can reach at least 0.5. That the method chosen provides realistic estimates will be demonstrated below. The genesis of the West model tables is not relevant to the discussion here, nor is their validity as models for the demographic study of archaeological cemetery samples. They are simply the foundation of the method employed.

TABLE 2. Estimator values derived from West model life tables and estimates of total fertility rates.

West levels	Estimators from West tables			Table (C_x)	TFR estimated by quadratic regression			
	r	MCM	J:A	P	TFR	FIT MCM	FIT J:A	FIT P
1	-0.01	0.046	0.099	0.133	4.22	4.00	4.04	4.01
1	-0.005	0.055	0.121	0.156	4.78	4.57	4.58	4.56
1	0	0.064	0.146	0.181	5.48	5.21	5.23	5.24
1	0.005	0.075	0.176	0.208	6.33	6.09	6.03	6.09
1	0.01	0.086	0.211	0.237	7.38	7.07	7.02	7.13
1	0.015	0.099	0.251	0.268	8.67	8.37	8.22	8.37
1*	0.02	0.112	0.297	0.299	10.23	9.80	9.67	9.77
1*	0.025	0.126	0.35	0.332	12.13	11.52	11.45	11.42
2	-0.01	0.042	0.087	0.120	3.87	3.77	3.75	3.74
2	-0.005	0.05	0.107	0.142	4.35	4.25	4.23	4.21
2	0	0.059	0.131	0.166	4.95	4.85	4.84	4.82
2	0.005	0.069	0.159	0.193	5.69	5.60	5.57	5.61
2	0.01	0.08	0.192	0.221	6.61	6.52	6.48	6.54
2	0.015	0.092	0.23	0.251	7.73	7.65	7.58	7.67
3	-0.01	0.037	0.077	0.108	3.59	3.50	3.51	3.51
3	-0.005	0.045	0.096	0.129	4.01	3.94	3.96	3.92
3	0	0.054	0.118	0.152	4.53	4.51	4.51	4.46
3	0.005	0.063	0.144	0.178	5.18	5.14	5.17	5.16
3	0.01	0.074	0.175	0.206	5.99	6.01	6.01	6.03
3	0.015	0.086	0.21	0.236	6.98	7.07	6.99	7.09
4	-0.01	0.034	0.069	0.098	3.37	3.35	3.32	3.33
4	-0.005	0.041	0.086	0.117	3.74	3.72	3.72	3.68
4	0	0.049	0.106	0.14	4.20	4.19	4.21	4.17
4	0.005	0.058	0.131	0.165	4.77	4.78	4.84	4.79
4	0.01	0.068	0.159	0.192	5.48	5.52	5.57	5.58
4	0.015	0.08	0.193	0.221	6.36	6.52	6.51	6.54
5	-0.01	0.03	0.061	0.088	3.19	3.16	3.14	3.17
5	-0.005	0.037	0.077	0.107	3.51	3.50	3.51	3.49
5	0	0.045	0.096	0.128	3.91	3.94	3.96	3.90
5	0.005	0.053	0.119	0.152	4.42	4.44	4.53	4.46
5	0.01	0.063	0.145	0.178	5.06	5.14	5.20	5.16
5	0.015	0.075	0.177	0.207	5.85	6.09	6.06	6.06
5	0.02	0.086	0.214	0.238	6.82	7.07	7.11	7.16
5	0.025	0.1	0.258	0.27	8.03	8.47	8.43	8.46
5*	0.03	0.113	0.307	0.304	9.49	9.92	9.99	10.01
5*	0.035	0.128	0.364	0.338	11.28	11.77	11.94	11.73

6	-0.01	0.027	0.054	0.079	3.03	3.03	2.98	3.04
6	-0.005	0.033	0.069	0.097	3.32	3.30	3.32	3.31
6	0	0.041	0.086	0.117	3.68	3.72	3.72	3.68
6	0.005	0.049	0.107	0.14	4.13	4.19	4.23	4.17
6	0.01	0.059	0.133	0.166	4.70	4.85	4.89	4.82
6	0.015	0.069	0.163	0.194	5.41	5.60	5.68	5.64
8	-0.01	0.022	0.043	0.064	2.79	2.82	2.74	2.85
8	-0.005	0.027	0.055	0.08	3.01	3.03	3.00	3.05
8	0	0.034	0.07	0.098	3.30	3.35	3.35	3.33
8	0.005	0.041	0.088	0.119	3.66	3.72	3.77	3.72
8	0.01	0.05	0.11	0.143	4.12	4.25	4.31	4.24
8	0.015	0.06	0.137	0.169	4.70	4.92	4.99	4.90
10	-0.01	0.017	0.034	0.051	2.61	2.64	2.54	2.71
10	0	0.028	0.056	0.081	3.01	3.07	3.03	3.07
10	0.01	0.042	0.091	0.121	3.67	3.77	3.84	3.76

The data, i.e., the estimators and table TFR given in Table 2, are entered into SPSS (IBM, 2010). Curve estimation (quadratic) is selected under regression, total fertility is specified as the dependent variable, since that is what we are trying to predict. The constant (i.e., the intercept) is included. The independent variable will be successively MCM, J:A, and P (if that has been calculated rather than MCM). The quadratic curve is selected because, for each of the estimators, it accommodates all the data points in Table 2. The cubic equation is more complex, but is equivalent to the quadratic for MCM. It is generally consonant except at extreme values for J:A and fits well with P for all but the very lowest TFR. It is true that cubic regression would reduce extremely high predicted TFR values very slightly with J:A as the estimator, but extremely high TFR values are likely to arise only from biased data and cubic regression requires a more complex equation, so we will limit the details to quadratic regression.

An archaeological sample is added by simply appending the estimators to the SPSS file (i.e. to the estimators and TFR given in Table 2). Saving the fit (predicted value) and the 95% CI of the fit will provide the fertility estimates which can be used to: 1) assess the representativeness of the sample and 2) gain an idea of the fertility levels for that material.

How can we be sure that the method actually provides reasonable estimates of fertility?

CAN WE ESTIMATE FERTILITY WITH ANY ACCURACY?

Jackes and Meiklejohn (2008) established that it is possible to replicate the results of the method proposed here by using Brass relational (logit) tables, with a carefully chosen historical age-at-death distribution as seed data. But it is preferable that tests be made on examples for which we have life tables and fertility data. Here, we test the method first for middle level fertility by using the excellent historical data from Geneva (Perrenoud, 1978, 1984). The two sets of data differ slightly: we use the 1984 set to derive age-at-death distributions for eight separate periods between 1625 and 1825. Perrenoud's 1984 mortality figures are based on a sample of 3400

families for which the data are not fully complete: 11% of individuals known to have been born are not included among the dead and are believed to have emigrated from Geneva. The fertility figures come from Perrenoud (1990:249, Table 15.3 total progeny, adjusted age specific fertility rates) and encompass 2926 families representing varying marriage dates and very different numbers of families. For example, at 1770 only three years of marriages are included with an average of about 107 marriages per year. However, 11 years are included at 1800 with an average of 34 women marrying per year. The years 1625 to 1699 are represented by the longest time periods, more or less equivalent to the mortality data. Since the age-at-death distributions each represent periods of 20-26 years, the mortality data are much more representative of their periods than are the fertility data. This may explain the good fit of the fertility and mortality data in the mid 17th century. The 1700 and 1770 fertility fits from the two estimators are the most discrepant, based on the 95% CI (Jackes, 2011, Fig. 5.2). The 1770 period follows an influx of refugees and occurs at the time when Perrenoud (1990:251) discerns the beginning of contraception, especially among older women. We will discuss the 1700 and 1770 J:A and MCM discrepancies further below.

Despite the Geneva sample discrepancies between the mortality and fertility data, our estimations for the TFR when expressed as the 95% CI of each of the MCM and J:A values for the quadratic regression fit, are generally appropriate. It is clear from Figure 1 that the MCM and J:A fit values will converge and give an accurate estimation of the TFR when the mortality and fertility samples are equivalent, especially for the period 1650 to 1674. Figure 1 also suggests that an overall average TFR can be approximated even for imperfect data over a period of changing rates of population increase.

Bocquet-Appel and Naji (2006) have suggested that my TFR estimates are flawed. In fact, discrepancies between life table values and estimates indicate that the population represented by the sample is not stationary. That is, when *r*, the rate of change, is >0, the life table TFR (calculated from C_x) will be too low: this is illustrated by the values shown as stars in Figure 1. We can approximate the Perrenoud fertility values by altering the life table to accord with an appropriate rate of growth. The need to calculate life tables with rate of growth adjustments provides the answer to their discrepant findings with regard to fertility levels calculated from life tables (Bocquet-Appel and Naji, 2006:356, Fig. 6, Jackes, 2010:111, Fig. 5.2). The highest rate of growth, $r = 0.01225$, seems to have been in the 25 years from 1650, based on 1:1 sex ratio and 30 years of reproductive life from age 15.

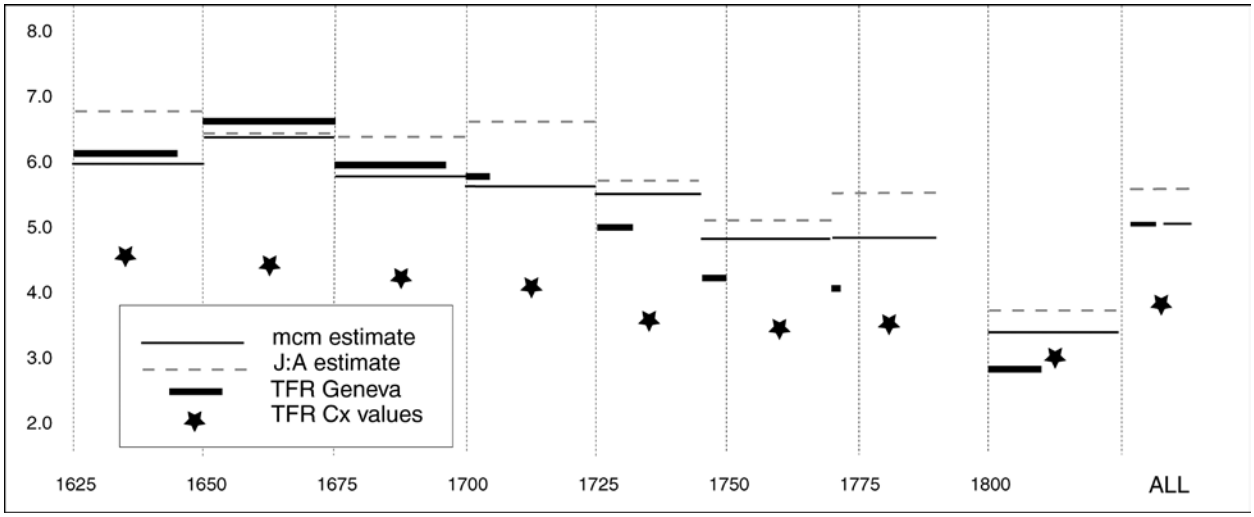

Fig. 1. TFR fit values derived by quadratic regression from MCM and J:A calculated from age-at-death distributions (Perrenoud 1984, 1990). "All" refers to the summed data. For "All" the estimates are 5.14 for MCM, 5.18 for P and 5.55 for J:A. The actual mean "all" TFR value from Perrenoud's 1990 data is 5.15.

It should not be assumed that Geneva went into a decline from that time onwards: infant mortality rates were reduced and the city had a substantial amount of in-migration. The rate of growth would have slowed again, so that by 1770 it is possible the rate of growth had dropped back to $r = 0.005$ (the data are, however, inadequate for proof of this). Nevertheless, by 1800, it would be necessary to calculate for a decline, based on life table C_x values, to reach the published TFR of 2.92. This suggests that the method of estimating fertility may provide discrepant results as r approaches 0.

Since the adjustment necessary to reach the 1800 Geneva TFR of 2.92 is $r = -0.002$, our low end fertility estimates might be considered flawed. However, this was tested (Jackes and Meiklejohn, 2008:235) using data on white urban Americans from 1905 to 1910. The TFR of 2.7 (Haines, 1989:142, table 2) can be approximated by estimates derived from white deaths, 1901 to 1910, in the ten original registration states (Glover 1921). The quadratic fits range from the J:A predicted TFR at 2.52, through the MCM at 2.64 to 2.7, the P quadratic TFR fit. Because r approaches 0, the life table TF value of 2.6, calculated here in the same way as the West model TF values, is more or less equivalent to the regression fit values.

We have discussed (Jackes, 1994; Jackes, 2009; Jackes et al., 2008; Jackes and Meiklejohn, 2008:255) the range of total fertility that can be expected, pointing out that a fertility rate (not for any particular woman but for the *average* woman) has limits, both biological and social/cultural. It is not necessary to restate the arguments here, but it should be noted that West model tables which produce calculated table TFR values much over 12.0 have been excluded. Even so, the tables which produce the highest fertility rates (marked with an asterisk in Table 2) are those

which emerge from the cloud of regression analysis residuals as marked outliers. Inclusion of high fertility tables is to satisfy suggestions that estimates of maximum fertility rates are too low (Jackes et al., 2008), but in fact removal of the model fertility rates for those four tables, thus excluding them from calculation of the TFR estimates, will make no significant differences. In none of the Geneva MCM derived fit estimates is there any change and the J:A predicted value would change only for the period beginning1675 – from 6.5 to 6.4.

Excessively high fertility estimates also raises the question of the regression equation selected. As noted above, only in extreme cases, such as the Caribbean data, could cubic regression be considered more suitable, generating lower TFRs (the cubic J:A fit is 16.7, compared with the quadratic J:A fit of 19.5). Nevertheless, over the entire 51 tables, the deviation of the cubic from the quadratic J:A fit is -0.0004 and the estimates are equivalent over the biologically plausible range of data, rising above 0.1 only in the two most extreme of our 51 tables. The best method of deriving high fertility values was tested by using what we could generally regard as the most reliable set of data available for high fertility. At this level, TFR ranges based on the 95% CI for cubic and quadratic regression predicted values are virtually identical (compound/growth regression was also tested). The test data used is that of American Hutterites dying from 1941 to 1950 (Eaton and Mayer, 1953:238 Table 16). We might expect a TFR of 8.7 or 8.8 (Nonaka et al., 1994:416 Table 2, see also Eaton and Mayer, 1953:221 Table 7 where the 1946-1950 TFR can be calculated from the total number of women as 8.8) and our best estimate for high fertility will derive from quadratic regression based on J:A. Table 3 demonstrates this, but also the way in which there can be significant discrepancies in the predictions from different estimators and this will be discussed below.

TABLE 3. Estimating Hutterite fertility from Hutterite deaths – 1941 to 1950.

Estimator	Value	Fit	95% CI low	95% CI high
MCM	0.093	7.75	7.33	8.17
J:A	0.278	9.06	8.55	9.56
P	0.255	7.83	7.39	8.28

HOW TO CALCULATE TFR

For those without access to SPSS, the fit can be calculated using the figures provided in Table 4. The first step is to find the proportions among the dead represented by J:A or P. For MCM, the *q* values are found using a standardized life table with age categories as in Table 1: the mean of the *q* values for those dying between ages 5 and 19.99 years is calculated. Ages 0 to 4.99 are excluded from all calculations because of the widely recognized under-representation of infants, and possibly young children, in many cemetery samples.

TABLE 4. Values to use in calculating predicted TFR values from the estimators.

Estimator	b0 (constant)	b1	b2
MCM	2.172	20.06	429.329
J:A	1.825	20.311	20.518
P	2.425	1.779	76.207

The formula for the quadratic fit ($\hat{Y}$, the predicted value) from x (the particular value for the estimator, whether MCM, J:A or P), using the values in Table 4, is as follows:

$$\hat{Y} = b0+(b1*x)+(b2*x^2)$$

The SPSS 95% confidence limits can be approximated within a rounding error by use of the following formula with figures for each predicted TFR ($\hat{Y}$)

$$95\%\ \text{CI low} = \hat{Y} - t_{.025}\ \sqrt{\text{MSE}(1+(1/n))}\ \text{and}\ 95\%\ \text{CI high} = \hat{Y} + t_{.025}\ \sqrt{\text{MSE}(1+(1/n))}$$

using the mean square error (MSE). The $t_{.025}$ value (2.01) is multiplied by $\sqrt{\text{MSE}(1+(1/n))}$ to arrive at the value for each estimator (given in Table 5). This value is then subtracted from and added to $\hat{Y}$ for the confidence interval of $\hat{Y}$.

TABLE 5. Values to be added or subtracted to find the 95% CI for each TFR predicted value from the relevant estimator.

Estimator	$t_{.025}\sqrt{\text{MSE}(1+(1/n))}$
MCM	0.411
J:A	0.489
P	0.435

It is not possible to replicate exactly the 95% CI generated by SPSS because the SPSS formulae have an additional term *h*, described as a "computational detail" in regression calculations (IBM 2010a:274). In fact, *h* is "leverage" and is used to examine whether the independent variable is suspect. The difference would be of no relevance, disappearing with rounding at several decimal places, except in the two cases in which the predicted TFR reaches 11. For West 1 at $r = 0.025$ and West 5 at $r = 0.035$, the formula will generate figures which differ by between 0.05 and 0.08 from the SPSS calculated values for confidence limits. The largest difference is between 11.36 (SPSS) and 11.45 (formula above) as the lower value of the CI for the West 5 at $r = 0.035$ J:A fit. The difference will be rounded away in reporting the TFR and all other differences are considerably more trivial. It does not seem necessary to complicate matters by introducing *h* into the calculations.

MORE ON BIAS

So far we have focused on fertility estimates and have no more than mentioned that they may indicate an under-representation of adults, such as could result from selective burial practices. At what point do we suspect an over-representation of children or an under-representation of adults in a sample? As noted above, we will not restate discussions on factors which limit actual fertility, as distinct from potential fecundity, but we should be suspicious of samples which indicate that the *average* woman, married or unmarried, whatever her state of health and nutrition, whatever the circumstances, actually had ten or more live-born children. A theoretical maximum fertility rate of 12.5 is reached when MCM = 0.1335, J:A = 0.380 and P = 0.3522 and values approaching or exceeding this range may indicate a biased sample. The TFR value of 12.5 is derived from 12.44, proposed as a maximum **marital** fertility rate (MFR) based on the summed age specific fertility of Hutterites, 1921-1930 (Coale, 1967), but criticized as downplaying the importance of fertility in the 15-19 age range (Wetherell, 2001). Whether the age-specific fertility rate of well-nourished married North American adolescents is relevant to other situations can be discussed. While we may note that 14 can be given as the maximum TMFR, 12.5 is a generous value for a maximum TFR.

The estimators themselves may give us some further information (Jackes, 2009:112 Fig. 5.3). I will illustrate this briefly by examining the age-at-death distributions already discussed, with the addition of one further source of information (see Jackes, 1993). Figure 2 shows the quadratic curve and 95% CI calculated excluding the West model tables marked by an asterisk in Table 2. All other data, excluding only the extreme outlier on Figure 2 (i.e., MM), are included in the calculation of the curve and 95% CI, so that the curve is pulled slightly to the left of the West model tables. Firstly, the samples falling within the 95% CI are important. It is noteworthy that the Caribbean data (Carib n = 299), despite all uncertainties, are now situated quite well within our data set, giving us some assurance that most missing skeletons were those of full adults. The US NE white urban American age-at-death data for the first decade of the 20th century fall firmly on the line at the low end of the curve and our best historical sample from Geneva, for the period from 1650 to 1674, also falls on the line: these two examples suggest that the West model tables are realistic. The Geneva samples from 1700 and 1770 lie just outside the 95% CI: this is to be expected since they have discrepant estimator values, as shown in Figure 1.

It is very unusual among well over 100 archaeological and historical samples, for an MCM value to fall far to the left of the line, and it seems to indicate a low number of late adolescents in the sample. Depending on circumstances, this can be interpreted as a consequence of emigration or of political unrest and war (see Jackes, 2011 for examples of this). Since each of the year ranges 1700-1724 and 1770-1790 saw severe subsistence and epidemic disease crises (Pfister, 1978, Appleby, 1980, Post, 1990), we might well expect some distortion of the Genevan age-at-death distributions.

What is most interesting is that the Hutterite estimators, which we might regard as very accurate, fall to the left of the 95% CI. As noted above (Table 3), the estimators gave markedly different fertility predictions. The data were collected by letters and interviews for most, but not all, of the 93 widely dispersed Hutterite colonies, the majority of which were in Canada. However, 20% of

the records were incomplete, and Eaton and Mayer (1953:217, 248) suggest the data may under-enumerate young males termed “deserters”. Lives were disrupted during the Second World War. Despite religious strictures against involvement, some few enlisted, others were sent away for Alternative Service in Canada (Willms, 1958:399-400) and the equivalent Civilian Public Service in the United States. Disruption and out-migration may explain those termed “forgotten” by Eaton and Mayer (1953:217). While Eaton and Mayer noted the apparent low rate of young male deaths, they did not refer back to their statements about the under-representation of young males in their data. Another source of error may be the age categories: the published Hutterite age-at-death categories are 5 to 14 and 15 to 24. While the 5-14 figures can be manipulated without alteration to the estimators, equal distribution across years within the 15 to 24 range will probably lead to inaccuracy in the standard age data. The suggestion is, then, that MCM falls too far to the left of the 95% CI and we should regard the most accurate age estimation as that given by J:A. This was the conclusion reached previously (Table 3). Adjusting the figures in the 15-19 and 20-24 age categories, simply increasing the number of individuals in the first by three at the expense of the second, will bring the data well within the CI and halve the discrepancies in the TFR estimates. The J:A and MCM predicted values are now 9.3 and 8.7. These fits may be more in line with what could be expected for the overall Hutterite TFR value at a time of a slightly increasing fertility rate (Nonaka et al., 1994), but the indications remain that the Hutterite data are less complete than generally acknowledged.

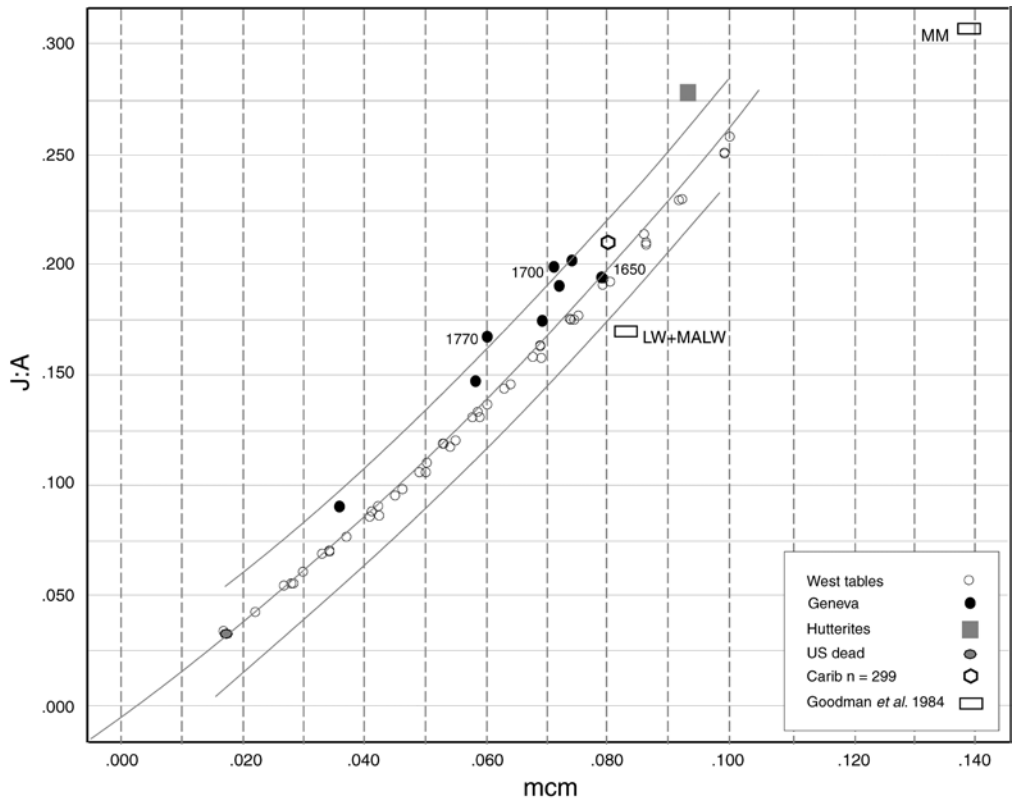

Fig. 2. Examining samples for signs of bias by looking at the relationship between mean childhood mortality (MCM) and the juvenile:adult ratio (J:A).

Redistributing across age categories, together with sample uncertainties (Jackes, 1993), has caused a sample to fall to the right of the 95% CI line, a more common feature among archaeological (not historical) age-at-death distributions (Jackes, 2011). This Late Woodland + Mississippian Acculturated Late Woodland sample (LW+MALW, Goodman et al., 1984:275 Table 11.1) requires redistribution of those individuals assessed broadly as 20-29 years of age, because the mortality quotients (*q*) used to calculate MCM derive in part from the 20-24 age category. Based on the estimators, it is almost certain that too many individuals were placed in the late adolescent age group. The value of using MCM, rather than P, is that it allows us to examine errors arising from the quite problematic age assessment of individuals in their late adolescence and early twenties. Figure 2 demonstrates that for the LW+MALW sample adjustments should be made in the two 5 year age categories from 15 to 24. It is a simple matter to propose a minor adjustment so that the J:A fit is 5.7 instead of 5.9: while no more than a guess and hardly significant in terms of TFR, this suggests that a researcher might usefully re-examine age assessments for individuals in late adolescence and early adulthood.

The Middle Mississippian sample (MM, Goodman et al., 1984: 275 table 11.2) presents an even more extreme example, clearly indicated by the discrepancy between the J:A TFR CI range of 9.5 to 10.5 compared with the MCM TFR CI range of 12.6 to 13.6. As stated above, this sample was not used in the analyses shown in Figure 2. Since there is no overlap in the TFR ranges, we can only assume that the data cannot be relied upon and, indeed, another researcher using the same material came to a very different conclusion regarding the distribution of ages, specifically in the adolescent and young adult age range (Jackes, 1993:436). Despite the clear possibility that these MM data are flawed, Bocquet-Appel and Naji (2006), with exactly the same distribution as used here (P = .362), include this and six other sites with higher P values in a comparative study of North American sites. Comparison is essential, but inclusion of sites in comparative studies without close examination of the data and of the nature of the sites must be avoided (Jackes, 2006, 2011).

CONCLUSION

The use of the estimator and TFR values provided in Table 2 allows the calculation of fertility estimates for age-at-death distributions for which MCM, J:A or P have been calculated. The estimators depend in various ways on the proportions of subadults over age 5 and adults over age 20 within a cemetery sample. It is inadvisable to use samples of less than 100 overall, but examining both the estimators and the estimated fertility rates will indicate whether a sample is inappropriate for use in palaeodemography. If the fertility estimates are very discrepant (if the estimators fall far to either side of the curve expressing the relationship of model table MCM and J:A figures) or if the fertility estimates fall above reasonable biological/cultural limits of the total fertility rate, then the sample may be unrepresentative of the group being studied. Any sample with a TFR above 10 must be re-examined carefully. Incompletely excavated cemeteries, faulty redistribution of published ages, exclusion of adults for whom satisfactory age assessment is impossible, problems of age assessment around age 5 and particularly in the 15-20 and 20-25 age ranges, can all bias results. Small samples covering either very long or very short periods of time can give an unrealistic picture, because of fluctuations. No doubt the rapidly changing situation in Geneva over a 200 year period is unlikely to be reflected in most archaeological samples, but

it has been demonstrated that predicted values will provide a general indication of TFR as long as the sample size is adequate, although fluctuations and in- and out-migration are always important considerations.

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