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DOUGLAS H. UBELAKER

WEIGHTING OF AGE INTERVAL VALUES IN LIFE TABLE CONSTRUCTION

ABTRACT: Accurate estimation of ages at death and adequate sampling represent two major concerns in palaeodemography. This paper addresses the relevant particular problem of the treatment of samples that include some individuals of incomplete preservation resulting in non-specific age estimates. A procedure of weighting the values in appropriate age intervals is recommended when ages at death can only be estimated generally for a limited number of individuals in the sample and more accurate estimates are available for other, better preserved individuals. This problem is usually encountered with adult individuals. In such cases, the weighting procedure is recommended over complete exclusion or use of the mean age value of the wide age estimate.

KEY WORDS: Palaeodemography – Life table – Weighting – Sampling

INTRODUCTION

Palaeodemography attempts to examine the demographic structure of past populations with a special emphasis on life expectancy and mortality issues. Aspects of this endeavour can include assessment of archaeological data, comparative studies of modern populations, and archival information on early historic populations. However, within the last three decades much of this research has focused on the skeletal remains of past populations and the direct evidence they present of the people they represent. Collectively, scholarly attempts to reconstruct past demographic profiles are complex and produce information relative to broad issues in anthropology (Brothwell 1971, Constandse-Westermann, Newell 1989, Cook 1972, Dublin, Spiegelman 1941, Hassan 1978, Howell 1976, Lovejoy 1971, Patterson 1974, Piontek 1990, Piontek, Kaczmarek 1987, Weiss 1976).

Within skeletal approaches to demographic reconstruction, the life table has emerged as a useful format to express research results (Acsádi, Nemeskéri 1970, Angel 1969). The life table offers summary information on the distribution of deaths, survivorship, age specific-probability of death, life expectancy, and other factors. This format also facilitates comparison with demographic information from modern populations.

Although the structure of the life table is relatively standard, palaeodemographers have utilized a variety of approaches to definitions of age intervals, largely driven by confidence in age-at-death estimates and the techniques employed. Many workers (e.g. Angel 1969, Brothwell 1972, Churcher, Kenyon 1960, Lovejoy 1977) have utilized a five-year age interval for construction of life tables or similar compilations of demographic data from ancient remains. In contrast, Blakely (1971) employed a ten-year interval. Hanáková (1979) utilized age intervals of variable magnitude below age 20 and a ten-year interval above age 20. Similarly, Prokopec (1979) utilized variable age intervals, reflecting ageing criteria. In their classic work, Acsádi and Nemeskéri (1970) utilized both single-year intervals and abridged five-year intervals.

Interpretations of life tables have varied as well. Whereas many authors use life table data to examine patterns of ancient mortality, others have argued that such data are heavily influenced by fertility and population growth rates (Johansson, Horowitz 1986, Sattenspiel, Harpending 1983). Comparison of ancient life table data with profiles from modern populations has proven stimulating as well (Henneberg 1977).

With the growing use of life tables in studies of past populations, procedures and underlying assumptions have received increasing scrutiny. The primary concern has been the extent to which the samples used in analysis are representative of the parent population. This constitutes not only a sample size problem (Hoppa, Saunders 1998, Masset, Parzysz 1985), but also consideration if an aspect of the sample has been excluded for cultural or taphonomic reasons. Mortuary customs may have precluded inclusion of some aspect of the deceased individuals from a population (Katzenberg, White 1979). Some particularly fragile infant and elderly remains may not have survived the burial environment to be included in the sample (Henneberg 1977, Moore, Swedlund, Armelagos 1975, Willey, Mann 1986). If detected, these problems can be addressed, but they remain significant concerns in palaeodemographic interpretation.

Articles by Bocquet-Appel and Masset (Bocquet 1978, Bocquet-Appel, Masset 1982, 1985, 1996, Masset 1974) offered sharp criticism of palaeodemographic reconstruction from skeletal samples, focusing mostly on the inaccuracy of estimations of age at death. These criticisms have been answered (Buikstra, Konigsberg 1985, Piontek, Weber 1986, Van Gerven, Armelagos 1983) but concerns remain, especially about sampling problems and the accuracy of age estimates. This concern has led to the development of new techniques (e.g. Lamendin *et al.* 1992), the use of multiple techniques to improve accuracy (e.g. Meindl *et al.* 1983) and greater awareness of the limitations of age estimation (Sjøvold 1978).

WEIGHTING PROCEDURE

Weighting of age interval values in life table construction has received comparatively little attention in the palaeodemography literature but relates to problems of age estimation and representation. Frequently, human remains from archaeological contexts are incomplete or otherwise altered by their burial environment. In the extreme, poor or incomplete preservation will preclude accurate age at death estimation and prevent life table construction altogether. In some samples, preservation is variable, both among and within individuals. Thus, while most skeletons within a given sample may be well-preserved, allowing all techniques to be employed, others may be incomplete or deteriorated to the point that only limited techniques can be utilized. This situation can result in age estimates of varied accuracy. Whereas it may be possible to assign a well-preserved, complete skeleton to a five-year age interval with a reasonable degree of accuracy, only a general age estimate may be possible for a poorly preserved one. The latter situation can lead to such assessments as "adult", "mature", or "likely between the ages of 20 and 50 years". With these samples, the problem for the palaeodemographer becomes whether to exclude the problematic remains or, if not, how to relate them to the age intervals chosen.

Exclusion may remove a significant segment from the distribution of ages at death and skew the statistics. The impact of removal would be to increase artificially the ratio of immature to mature remains in the sample and to decrease the life expectancy values, especially in the early immature years.

If the palaeodemographer decides to include them, the question becomes how to relate these general age estimates to the more precise ones in the sample, estimated from more completely preserved remains. One choice is simply to use the mean of the general age estimate. Thus, if the ages at death for 20 individuals in the sample had been generally estimated to be between the ages of 20 and 50, this approach would call for the addition of 20 individuals to the 35.0 to 39.9 age interval. However, while this addition would ensure that the correct proportion of mature and immature is maintained, it artificially swells the particular age interval into which the estimates fall.

The approach to this problem recommended here involves weighting of age interval values to accommodate the general age estimates or otherwise missing data. Such an approach calls for first calculating the distribution of deaths that can be estimated accurately and assigned to five-year age intervals. The age intervals impacted by the more general age estimates are then weighted proportionately so that the total number of individuals in the sample equals the number of individuals listed in the life table. Thus the 20 general age estimates discussed above would be distributed proportionately among the age intervals between 20 and 50, rather than all being assigned to the 35.0 to 39.9 interval. This approach assumes that the actual ages at death of these individuals would likely follow the documented age distribution of other adults in the sample within these age limits. The procedure ensures that the correct proportion of mature to immature is maintained. It also maintains the adult age distribution suggested by the more precise age estimates.

I first introduced this procedure in my 1974 demographic study of two ossuary samples from the mid-Atlantic area of the United States. For example, detailed inventories had suggested that 188 individuals were present in one of the ossuaries. However, the most accurate age estimates were available for only 173 individuals. These 173 individuals were assigned to their appropriate age intervals. To accommodate the other individuals for which specific ages were not known (all adults), each of the mature age intervals was increased by a factor of 1.18.

I have also used this approach to accommodate general age estimates in research with archeologically recovered samples from Ecuador (e.g. Ubelaker 1994). Use of the technique has generally been restricted in my research to those samples where some of the individuals, usually adults, have only very general estimates, whereas most others are sufficiently well-preserved to allow more precise estimates.

This weighting of age interval data to accommodate some general adult age estimates has also been employed by Klepinger (1979) in her study of a Valdivia III phase

TABLE 1. Life table reconstructed from the Bronze Age Tiszafüred sample from northeastern Hungary (from Ubelaker, Pap 1996).

X	Dx	dx	lx	qx	Lx	Tx	e^0x
0–0.9	27	4.55	100.00	0.0455	97.723	2409.275	24.09
1–4.9	67	11.30	95.45	0.1184	359.191	2311.551	24.22
5–9.9	59	9.95	84.15	0.1182	395.868	1952.361	23.20
10–14.9	24	4.05	74.20	0.0545	360.877	1556.492	20.98
15–19.9	32	5.40	70.15	0.0769	337.268	1195.615	17.04
20–24.9	38	6.41	64.76	0.0990	307.757	858.347	13.26
25–29.9	107	18.04	58.35	0.3092	246.627	550.590	9.44
30–34.9	110	18.55	40.30	0.4603	155.143	303.963	7.54
35–39.9	60	10.12	21.75	0.4651	83.474	148.819	6.84
40–44.9	38	6.41	11.64	0.5507	42.158	65.346	5.62
45–49.9	22	3.71	5.23	0.7097	16.863	23.187	4.44
50–54.9	7	1.18	1.52	0.7778	4.637	6.324	4.17
55–59.9	1	0.17	0.34	0.5000	1.265	1.686	5.00
60–64.9	1	0.17	0.17	1.0000	0.422	0.422	2.50

TABLE 2. Life table simulated using the mean value of all general adult age estimates.

x	Dx	dx	lx	qx	Lx	Tx	e^0x
0–0.9	27	3.79	100.00	0.0379	98.105	2718.320	27.18
1–4.9	67	9.40	96.21	0.0977	366.040	2620.215	27.23
5–9.9	59	8.27	86.81	0.0953	413.375	2254.175	25.97
10–14.9	24	3.37	78.54	0.0429	384.275	1840.800	23.44
15–19.9	32	4.49	75.17	0.0597	364.625	1456.525	19.38
20–24.9	38	5.33	70.68	0.0754	340.075	1091.900	15.45
25–29.9	107	15.01	65.35	0.2297	289.225	751.825	11.50
30–34.9	110	15.43	50.34	0.3065	213.125	462.600	9.19
35–39.9	60	8.42	34.91	0.2412	153.500	249.475	7.15
40–44.9	158	22.16	26.49	0.8365	77.050	95.975	3.62
45–49.9	22	3.09	4.33	0.7136	13.925	18.925	4.37
50–54.9	7	0.98	1.24	0.7903	3.750	5.000	4.03
55–59.9	1	0.14	0.26	0.5385	0.950	1.250	4.81
60–64.9	1	0.14	0.12	1.1667	0.300	0.300	2.50

TABLE 3. Life table simulated using adult age interval values weighted proportionately to accommodate the general adult age estimates.

x	Dx	dx	lx	qx	Lx	Tx	e^0x
0–0.9	27	3.79	100.00	0.0379	98.105	2562.520	25.63
1–4.9	67	9.40	96.21	0.0977	366.040	2464.415	25.61
5–9.9	59	8.27	86.81	0.0953	413.375	2098.375	24.17
10–14.9	24	3.37	78.54	0.0429	384.275	1685.000	21.45
15–19.9	32	4.49	75.17	0.0597	364.625	1300.725	17.30
20–24.9	49.88	7.00	70.68	0.0990	335.900	936.100	13.24
25–29.9	140.43	19.70	63.68	0.3094	269.150	600.200	9.43
30–34.9	144.38	20.25	43.98	0.4604	169.275	331.050	7.53
35–39.9	78.76	11.05	23.73	0.4657	91.025	161.775	6.82
40–44.9	49.88	7.00	12.68	0.5521	45.900	70.750	5.58
45–49.9	28.88	4.05	5.68	0.7130	18.275	24.850	4.38
50–54.9	9.18	1.29	1.63	0.7914	4.925	6.575	4.03
55–59.9	1.31	0.18	0.34	0.5294	1.250	1.650	4.85
60–64.9	1.31	0.18	0.16	1.1250	0.400	0.400	2.50

sample from Real Alto, Ecuador and the Mudar *et al.* (1998) study of the Hand Site Cemetery sample from Virginia. Use of the procedure usually can be detected in life tables because it frequently produces decimal values in the Dx column.

Table 1 presents a life table calculated for a Bronze Age sample from north-eastern Hungary (Ubelaker, Pap 1996). This table was constructed from the examination of 593 individuals from the Tiszafüred-Majoros sample, as part of a larger study of temporal trends of morbidity and mortality in north-eastern Hungary. Ages at death were estimated using standard procedures (Ubelaker 1989) and were all assigned to five-year age intervals (except for year one).

LIFE TABLE SIMULATIONS

For theoretical demonstration purposes, assume that 120 additional adult individual skeletons had been present, but so poorly preserved that specific age estimates were not possible. The general size of the bones and other factors indicated they were of adult origin but only a general estimate of between 20 and 65 years was possible. If a life table is desired for this theoretical sample, three options are available: 1. exclude these remains; 2. calculate the mean of the estimated ages and add them to the appropriate interval; or 3. distribute them proportionately to the existing age interval values.

The first option basically would leave *Table 1* intact. Theoretically, this option would exaggerate the actual ratio of immature to mature and artificially depress life expectancy in the lower age intervals.

The second option, as discussed above, would be to calculate the mean age of the 120 poorly preserved individuals (42.5 years) and add all 120 individuals to that age interval. This practice would artificially increase the number of deaths in that age interval from 39 to 158. The life table resulting from this practice is presented in *Table 2*. As predicted, life expectancy at birth increased from about 24 years to about 27 years. Life expectancy for all other age intervals below 40 increased as well. Life expectancy values declined in this theoretical table in age intervals 40 and higher. Similar changes are seen in the qx age-specific mortality column.

For the third option, values of the original Dx column were weighted proportionately to accommodate the additional 120 adult individuals. The life table resulting from the use of these weighted values is produced in *Table 3*. As in *Table 2, Table 3* shows an increase in life expectancy at birth and at other intervals below age 20, but the differences are smaller. In contrast to the *Tables 1* and *2* comparison, the life expectancy values are quite similar between *Tables 1* and *3* for age intervals 20 and higher. Similar patterns are seen in the age-specific mortality comparisons.

SUMMARY

To achieve the most accurate life table is possible when only general age estimates are available for a segment of the sample, weighting of age interval data is both desirable and appropriate. Use of this procedure should be guided by the relative numbers of individuals in this category and the size of the age range represented. Obviously, if the number of poorly preserved individuals is excessive, life table calculation may be precluded altogether. However, if calculation of a life table is judged suitable and some individuals with only general age estimates are present, the weighting procedure is preferable over exclusion of those individuals or the use of their individual mean ages.

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Douglas H. Ubelaker
Department of Anthropology
NMNH, MRC 112
Smithsonian Institution
Washington, D.C. 20560
U.S.A.
E-mail: ubelaker.doug@nmnh.si.edu