Current methodological issues in the study of prehistoric demography

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Resumen

Hay cuatro aspectos de actualidad en paleodemografía: 1) los avances en el conocimiento de la biología del esqueleto han mejorado significativamente nuestra habilidad para estimar los parámetros demográficos en poblaciones antiguas; 2) no todos los osarios deben utilizarse en la reconstrucción demográfica, ya que este tipo de series no siempre permite desarrollar investigación paleodemográfica; 3) la imposición de los patrones modernos de mortalidad en los estudios paleodemográficos es problemática, y 4) el mayor sesgo en paleodemografía puede estar relacionado con los efectos de la migración en poblaciones prehistóricas consideradas como estacionarias.

PALABRAS CLAVE: paleodemografía, muestra esquelética, tablas de vida modelo, tasa de crecimiento intrínseco.

Abstract

There are four current issues in paleodemography: 1) Recent advances in skeletal biology have significantly improved our ability to estimate the demographic parameters of extinct populations; 2) Some ossuaries should not be used for demographic reconstruction, and these collections have no bearing on the feasibility of paleodemographic research; 3) The imposition of modern mortality patterns on those of paleodemography is problematic, and 4) The greatest bias in paleodemography may involve the effects of departures from demographic stationarity during prehistoric times.

KEY WORDS: paleodemography, skeletal sampling, model life tables, intrinsic growth rate.

Two decades ago Bocquet-Appel and Masset (1982) raised a number of questions concerning the analysis of vital rates from skeleton-based demographies. Since that time the field of paleodemography has become almost as disputatious as some other areas of anthropology. However, this has resulted in constructive debates and timely re-examinations of models and assumptions. Further critical review and new research efforts in this area have increased dramatically, and have moved paleodemography from the periphery to the forefront of prehistoric studies (Roth, 1992).

Paleodemography is more than the study of mortality and fertility of archaeological populations. It also includes the estimation of the distribution, density, and age composition of prehistoric peoples. It considers intrinsic rates of growth or decline, and it includes migration and its age and sex structure as well. A comprehensive survey of all these areas is beyond the scope of this paper, which is limited to issues directly concerning the estimation of vital structures of extinct populations from cemeteries. This paper addresses some of the sampling problems in paleodemography and life table mortality schedules and fertility in the context of stable population theory. It also addresses the role of mortality models external to paleodemography and offers an approach to the problem of unknown intrinsic rates of growth in prehistory.

Space also precludes a discussion of recent views concerning morbidity patterns in skeletal populations (Wood *et al.*, 1992) or the health status surrounding the adoption of agricultural systems (Cohen, 1997). At present, there remain limits to the inferences that can be drawn from paleodemography, especially in the realm of rapid culture change. However, archaeological populations offer a special and important view of the biology, cultural evolution, and the basic demography of extinct peoples which is not available from other fields of anthropology.

SAMPLING PROBLEMS IN PALEODEMOGRAPHY

The demographic reconstruction of an extinct society is a sampling process which may involve several potential sources of error. Aboriginal inhumation practices, soil and other conditions of interment including subsequent disturbances of the burials, and the care and skill of the excavators may all affect the representativeness of a cemetery. It bears repeating that if "an unbiased, representative sample [...] cannot be assumed, further demographic analysis is not likely to be productive" (Weiss, 1973: 58).

Certainly, burial customs associated with infanticide have skewed many cemeteries (Scrimshaw, 1984; Saunders, 1992). Yet if the practice of infanticide was restricted to such uncommon situations as genetic defects, twinnings, and breach births there is little impact on mortality profiles. Conditions which predispose cultures toward (typically female) infanticide for less immediate reasons include very short interbirth intervals, high transport costs of infants over large distances, and perceptions of the need to limit family size. In instances of high reported frequencies of female infanticide, either the habitats are extremely marginal or the males have far greater value than females as economic providers or combatants (Divale & Harris, 1976; Scrimshaw, 1984). While it might be widely accepted that infanticides were usually not buried with the rest of the population (Saunders, 1992), it is important to note that skewed sex ratios resulting from frequent female infanticide would be archaeologically detectable.

In any case, such perinatal deaths may not be recovered even by the most meticulous excavators, usually took place within a matter of minutes of birth, and would suggest that paleodemographers alter their definition of the radix by that amount of time. The most general prevalences of infanticide in human populations, both living and extinct, have proved to be difficult demographic parameters to estimate. And although infanticide is by definition a condition of mortality, it should be regarded by anthropological demographers as a deliberate control over fertility. That is, removing it altogether from the calculation of life expectancy at birth would make the metric more reflective of the actual biological conditions of mortality, and therefore, more utilitarian to population scientists across the spectrum of human ecologies and cultures. In any event, paleodemographic reconstruction might include some provision for at least low infanticide levels, not recovered by archaeologists.

There is also ethnographic evidence of the occasional killing of the old and the infirm, but it is rare that these remains would have been treated in ways different from those of other adult decedents. Any graves containing crippled, injured, or malformed elderly would imply that efforts had been made to return all of that society's members to a common place of burial. Young adults, particularly males, may have died violently or otherwise some distance from the habitation/cemetery. A mixture of bundle burials (i.e., only crania and assorted long bones) with articulated ones are further evidence of such a general effort, since it indicates return of the kinsmen's "essential" remains to the cemetery.

There is little demography that can be inferred from scattered or poorly preserved remains. Nor is it possible to usefully estimate the levels of bias in preservation by age or sex for any given site, when it is clear that some differential loss of skeletons has occurred (Gordon & Buikstra, 1981). If a portion of a cemetery cannot be aged or sexed owing to dissolution of calcified tissues, or if there is evidence of carelessness in excavation and recovery, the value of that site to the study of human demography is diminished by an unknown extent.

However, the general claims about the effect of *differential* preservation by age or sex of bone remains on the field of paleodemography (Masset, 1973; Waldron, 1987; Walker *et al.*, 1988; Katzenberg, 1992; Jackes, 1992) are overstated. The potential for this kind of bias may be obvious at once by simple inspection of the integrity of the burial pits, articulations, and periosteal bone layers. Bone and tooth survival is a function of mechanical displacement, soil drainage, and especially pH (Gordon & Buikstra, 1981). Unfavorable conditions cause the destruction or agitation of hard tissue remains with such speed that sites of moderate antiquity primarily fall into two groups –those with demographically useful bone assemblages and those without. An intermediate site in which the human remains are actually in the process of disappearing would probably have such fragile contents that even the adult sample would be in poor condition. Both Sundick (1978) and Saunders (1992) argue that in such sites the hard evidence required to recognize and *age* a subadult (primarily teeth) is preserved at least as well as the bones of a robust adult skeleton. Nevertheless, there may be a need for some added provision in the wake of moderate mechanical disturbances, such as tree roots and rodents, so as to estimate accurately the proportion of infants and very young children (Lovejoy *et al.*, 1977). The issue of differential preservation of bone microstructure is no different. Although there are instances of age-related preservation bias in histomorphological data (Garland, 1987; Hanson & Buikstra, 1987), the potential for bias should be recognizable, and therefore any impact on the feasibility of paleodemographic inference is minor. In nearly all instances it should be readily apparent *from the archaeological data themselves* which sites are useful to paleodemographers, and which are not (but, see Jackes, 1992). Nor is the use of age distributions from modern reference populations likely to overcome the deficiencies of inadequate archaeological recovery.

MORTALITY MODELS AND REFERENCE POPULATIONS

A compelling mathematical consistency in the pattern of adult mortality by age has long been recognized, beginning with the work of Benjamin Gompertz. Subsequent adjustments to Gompertz' function by William Makeham and Wilfred Perks were also confined to death rates at higher ages. Karl Pearson offered a rather different family of curves through the combination of independent normal distributions pertaining to different periods of life. After World War II there was a shift in approach away from functional graduations toward reference sets of life tables (see Brass, 1971 for discussion). The primary purpose of these was to supplement incomplete demographic data from developing countries, especially those in tropical Africa.

Conventionally called "models" or "model life tables," such reference tables are based on the same basic assumption that governs mathematical models: that there is a limited number of dimensions of variation to the shape of the "curve of deaths". The best known reference-set was developed at Princeton's Office of Population Research (Coale and Demeny, 1966; Coale *et al.*, 1983), and was an extension of the earlier United Nations one-parameter series of the 1950's. From 326 two-sex life tables of the 19th and 20th centuries, there appeared to be four "families" of mortality profiles. For instance, life tables representing populations still in the grasp of the European tuberculosis epidemic, such as Sweden in the late 19th century, had distinctive patterns of adult mortality. These underlie the "North" series of models. An "East" and a "South" pattern also emerged, depending on the relationship between early childhood and late adult mortality. Finally, the "West" family took form as a residual collection after the three other regions were removed. It has become the regular choice in most anthropological applications.

Many anthropologists have used the Coale and Demeny models –accessible by a continuum of either intrinsic growth rates or gross reproductive rates– to examine and explain fundamental processes as they might apply to pre-modern human populations (Sattenspiel & Harpending, 1983; Gage, 1988; Horowitz *et al.*, 1988; Konigsberg *et al.*, 1994; Dumond, 1997; Sullivan, 1997). However, others have invoked the modern patterns of longevity in efforts to dismiss certain archaeological populations from the study of human demography altogether (Howell, 1982; Johansson & Horowitz, 1986; Milner *et al.*, 1989; Paine, 1989). Not only are the survivorship levels of most skeleton-based demographies extremely low, but also their *patterns* stand in marked contrast to the lowest survivorship levels of the West family. Since by modern standards the levels of childhood mortality in paleodemography are low relative to adult mortality levels, it has been inferred by some that paleodemographic tables must be incorrect. Whether such conclusions are appropriate depends upon the nature of the data on which the Coale and Demeny tables were based. The historical mortality profiles which were chosen met several criteria: 1) the data were derived from national populations with both accurate censuses and continuous vital registration; 2) sexes were treated separately; 3) no non-Europeans minorities were included in tables of industrial nations, and 4) the populations had experienced no major wars (Coale & Demeny, 1966). In this empirical collection very few populations (7%) pre-dated 1870, and of these not one was from outside Europe.

It is not generally appreciated that within this collection *frequent* and *large* deviations from average patterns were observed in the under-10 and over-60 age groups (Coale & Demeny, 1966: 12). This is especially true for the underrepresented areas of middle-19th century peasant Europe and in the underdeveloped countries in Asia, Africa, and Latin America. Brass (1971) also examines many of the profiles *not* used in the Regional set calculations, such as Mauritius 1942-1946 and Guyana 1945-1947, which had very high adult death rates compared to those in childhood. He notes that "social and mortality/high fertility (with high growth), and every gradation in between. The implications are important. From the archaeologist's point of view, what does the appearance of a "bottom-heavy" cemetery age pyramid from the period of early adoption of agriculture imply? A moderate increase in fertility signaling the success of a cultigen-based economy and a healthy population growth rate is one possibility. Another is exactly the opposite: a considerable increase in childhood mortality, population decline, and the nutritional limitations of undiversified agricultural products. By itself, the cemetery could be interpreted in either fashion, or more appropriately, in a whole range of fashions.

Bennett (1973), Weiss (1973), and Moore *et al.*, (1975) were the first to provide archaeologists the practical means under stable population theory for relating the age distribution of a cemetery to a mortality profile through an intrinsic growth rate (r, the "Malthusian parameter"). Weiss (1973) presented a means for calculating both an age-specific fertility function and the population's age proportions, or pyramid. Muller (1997) provided a series of clear applications. *The problem is that there is no direct cemetery evidence for fertility, age structure, or intrinsic growth rate.* Therefore, in the language of elementary algebra, paleodemography generally presents more unknowns than equations, and an exact solution is not possible without more information. That is, a given cemetery does not provide a solution in the sense of one demographic profile, but rather a continuum of solutions, each point of which contains a mortality level and a fertility level, with an associated growth level. Associated with each point on the mortality continuum is a life table, and although the levels are free to vary their *patterns* are common, and determined by the cemetery age distribution. Underlying the variation in fertility level is also a common *pattern*, which is the archetypal human fertility curve.

Sattenspiel & Harpending (1983) studied variation in life expectancy and birthrate within several of the Coale and Demeny West models and offered an interesting observation: For stable populations, the cemetery age distribution determines the birth rate but can make no prediction of mortality. That is, mean age at death predicts the reciprocal of the crude birth rate nearly exactly for all (humanly possible) values of the intrinsic rate of growth, *i.e.*, -1% < **r** < +4.0%

per year. However, life expectancy at birth varies directly with the growth rate. This means that the cemetery fixes the crude birth rate, but both mortality and growth are not determined. Johansson & Horowitz (1986) restated this and explore more closely the small departures from linearity of the relationships between mean age and life expectancy. Horowitz *et al.,* (1988) showed that the closeness of these approximations is limited to the kinds of conditions that only paleodemographers examine, i.e., very low life expectancies.

If fertility is fixed, how can demographers choose a specific mortality level on the continuum of solutions? Bennett's (1973) analysis of Point of Pines, Asch's (1976) approach to Middle Woodland groups in the Lower Illinois Valley, and Muller's (1997) models for the dynamics of late prehistoric populations in the Eastern Woodlands all argued for solutions –or ranges of solutions– based on an hypothesized growth rate. However, archaeological support for a single value is exceedingly difficult to find (Horowitz *et al.,* 1988).

Life expectancy at birth (E_0) is a function of mortality only. By contrast, the crude birth rate (**b**) depends on age-specific fertilities, the age structure of the population, and even the mortality function. Recent work suggests that an hypothesized fertility (or restricted range) be used to complete a demographic reconstruction whenever the use of a growth rate is not feasible (Meindl *et al.,* 2001). However, as Sattenspiel & Harpending (1983) pointed out, the regression of **b** on **r** or on any mortality variable is virtually horizontal. No numerical solution could emerge from an hypothesized crude birth rate; moreover, there is only one value of **b** possible for a given cemetery.

A different fertility measure, one that is stripped of any influence of maternal mortality or age structure, may be more appropriate. The total fertility rate (**TFR**) is a measure of completed fertility performance. The **TFR** represents the average number of live births to women who live to the end of the reproductive span (age 50 years), calculated as the sum of the age-specific fertility rates (see Weiss, 1973). While this measure is sometimes unchanging with **r**, this is only true in the vicinity of stationarity. It begins to increase geometrically after growth rates exceed about a percent. Therefore, one problem with this approach is that the only exact solutions possible are high-growth solutions. Another problem is that the variance of **TFR** values in natural fertility populations is very large (Wood, 1990).

An application of the above is an analysis of the Late-Archaic Ward site cemetery in Kentucky (15McL11) for which was found a mean age of death in the mid-20's (Meindl *et al.*, 1999). An hypothesized value of **TFR** = 6.5 children determined both a new life expectancy in the mid-30's and a nonzero growth rate of 2.5% (It was assumed that only the periods of growth were represented in the cemetery). A value of 2.5% per annum is high but not unusual for well-censused primitive Amerindian populations of this century (Weiss, 1975; Hill & Hurtado, 1996). It is of interest that this analysis corresponded to the consensus among Eastern Woodland archaeologists that the first population explosion in Kentucky took place in the Late Archaic (Griffin, 1967; Jefferies, 1996).

LITERATURE CITED

ASCH, D. L.
1976 *The Middle Woodland populations of the Lower Illinois Valley: A study in paleodemographic methods,* Northwestern University Archaeological Program, Scientific Papers, 1, 99 p.

BENNETT, K. A.
1973 On the estimation of some demographic characteristics on a prehistoric population from the American Southwest, *Am. J. Phys. Anthropol.*, 39: 223-232.

BOCQUET-APPEL, J. P., C. MASSET
1982 Farewell to paleodemography, *J. Hum. Evol.*, 11: 321-333.

BRASS, W.
1971 On the scale of mortality, *Biological aspects of demography,* W. Brass (ed.), Taylor and Francis London: 69-110.

COALE, A. J., P. DEMENY
1966 *Regional model life tables and stable populations,* Princeton University Press, Princeton, 871 p.

COALE, A. J., P. DEMENY WITH B. VAUGHAN
1983 *Regional model life tables and stable populations,* Academic Press, New York, 496 p.

COHEN, M. N.
1997 Does paleopathology measure community health? A rebuttal of "The osteological paradox" and its implications for world history, see R. R. Paine: 242-260.

DIVALE, W., M. HARRIS
1976 Population, warfare, and the male supremacist complex, *Amer. Anthropol.*, 78: 521-538.

DUMOND, D. E.
1997 Seeking demographic causes for changes in population growth rates, see R. R Paine: 175-190.

GAGE, T. B.
1988 Mathematical hazard models of mortality: An alternative to model life tables, *Am. J. Phys. Anthropol*, 76: 429-441.
1989 Bio-mathematical approaches to the study of human variation in mortality, *Yearb. Phys. Anthropol.*, 32: 185-214.
1990 Variation and classification of human age patterns of mortality: Analysis using competing hazards models, *Hum. Biol.*, 62: 589-617.

GARLAND, A. N.
1987 A histological study of archaeological bone decomposition, A. C. Garland, R. C. Janaway (eds.), *Death, Decay and Reconstruction: Approaches to Archaeology and Forensic Science,* A. Boddington, Manchester University Press, Manchester: 109-126.

GORDON, C. C., J. E. BUIKSTRA
1981 Soil pH, bone preservation, and sampling bias at mortuary sites, *Am. Antiq.*, 46: 566-571.

GRIFFIN, J. B.
1967 Eastern North American archaeology: A summary, *Science,* 156: 175-191.

HANSON, D. B., J. E. BUIKSTRA
1987 Histomorphological alteration in buried human bone from the Lower Illinois Valley: Implications for paleodietary research, *J. Archaeol. Sci.*, 14: 549-563.

HILL, K., A. M. HURTADO
1996 *Ache life history*, Aldine de Gruyter, New York, 561 p.

HOROWITZ, S., G. ARMELAGOS, K. WACHTER
1988 On generating birth rates from skeletal populations, *Am. J. Phys. Anthropol.*, 76: 189-196.

HOWELL, N.
1982 Village composition implied by a paleodemographic life table, *Am. J. Phys. Anthropol.*, 59: 263-269.

JACKES, M. K.
1992 Paleodemography: Problems and techniques, S. R. Saunders, M. A. Katzenberg, (eds.), *Skeletal Biology of Past Peoples: Research Methods*, Wiley-Liss, New York: 189-224.

JEFFERIES, R. W.
1996 Hunters and gatherers after the Ice Age, R. B. Lewis (ed.), *Kentucky Archaeology*, University Press of Kentucky, Lexington: 39-77.

JOHANSSON, S. R., S. HOROWITZ
1986 Estimating mortality in skeletal populations: Influence of the growth rate on the interpretation of levels and trends during the transition to agriculture, *Am. J. Phys. Anthropol.*, 71: 233-250.

KATZENBERG, M. A.
1992 Comment on: The osteological paradox, J. H. Wood *et al.* (eds.), *Curr. Anthropol.*, 33: 361.

KONIGSBERG, L. W., S. R. FRANKENBERG
1994 Paleodemography: "Not quite dead", *Evol. Anthropol.*, 3: 92-105.

LOVEJOY, C. O., R. S. MEINDL, T. R. PRYZBECK, T. S. BARTON, K. G. HEIPLE, D. KOTTING
1977 Paleodemography of the Libben site, *Science*, Ottawa County, Ohio, 198: 291-293.

MASSET, C.
1973 Influence du sexe et de l'âge sur la conservation des os humains, M. Sauter (ed.), *L'homme, hier et aujourd'hui: Recueil d'études en Hommage à André Leroi-Gourhan*, Cujas, Paris: 333-343.

MEINDL, R. S., R. P. MENSFORTH, H. YORK
1999 Estimates of age structure and mortality from the Ward site, a late-Archaic population, F. Peña Saint Martin, R. M. Ramos Rodríguez (eds.), *Estudios de Antropología Biológica*, volumen IX, Universidad Nacional Autónoma de México, México, 555 p.
2001 Mortality, fertility, and growth in the Kentucky Late Archaic: The paleodemography of the Ward site O. H. Prufer, S. E. Pedde, R. S. Meindl (eds.), *Archaic Transitions in Ohio and Kentucky Prehistory*, Kent State University Press, Kent, 359 p.

MILNER, G. R., D. A. HUMPF, H. C. HARPENDING
1989 Pattern matching of age-at-death distributions in paleodemographic analysis, *Am. J. Phys. Anthropol.*, 80: 49-58.

MOORE, J. A., A. C. SWEDLUND, G. J. ARMELAGOS
1975 The use of life tables in paleodemography, *Am. Antiq.*, 40: 57-70.

MULLER, J.
1997 Native Eastern American population continuity and stability, see Paine 1997: 343-364.

PAINE, R. R.
1989 Model life table fitting by maximum likelihood estimation: A procedure to reconstruct paleodemographic characteristics from skeletal age distributions, *Am. J. Phys. Anthropol.*, 79: 51-62.
1997 *Integrating archaeological demography: multidisciplinary approaches to prehistoric population*, Southern Illinois University, Carbondale.

ROTH, E. A.
1992 Applications of demographic models to paleodemography, S. R. Saunders & M.A. Katzenberg (eds.), *Skeletal biology of past peoples: research methods*, Wiley-Liss, New York: 175-188.

SATTENSPIEL, L., H. HARPENDING
1983 Stable populations and skeletal age, *Am. Antiq.*, 48: 489-498.

SAUNDERS, S. R.
1992 Subadult skeletons and growth related studies, S. R. Saunders, M. A. Katzenberg (eds.), *Skeletal biology of past peoples: research methods*, Wiley-Liss, New York: 1-20.

SCRIMSHAW, S. C. M.
1984 Infanticide in human populations: Societal and individual concerns, G. Hausfater, S. B. Hrdy (eds.), *Infanticide: Comparative and evolutionary perspectives*, Aldine, New York: 439-462.

SULLIVAN, N. C.
1997 Contact period Huron demography, see R. R. Paine 1997: 327-342.

SUNDICK, R. I.
1978 Human skeletal growth and age determination, *Homo,* 29: 228-249.

WALDRON, T.
1987 The relative survival of the human skeleton: Implications for paleopathology, A. Boddington, A. N. Garland, R. C. Janeway (eds.), *Death, decay, and reconstruction: approaches to archaeology and Forensic Science*, Manchester University Press, Manchester: 55-64.

WALKER, P. L., J. R. JOHNSON, P. M. LAMBERT
1988 Age and sex biases in the preservation of human skeletal remains, *Am. J. Phys. Anthropol.*, 76: 183-188.

WEISS, K. M.
1973 Demographic models for anthropology, *Mem. 27 Soc. Am. Archaeol.*; also *Am. Antiq.*, 38: 2, Part II, 186 p.
1975 The application of demographic models to anthropological data, *Hum. Ecol.*, 3: 87-103.

WOOD, J. W.
1990 Fertility in anthropological populations, *Annu. Rev. Anthropol.*, 19: 211-242.

WOOD, J. W., G. R. MILNER, H. C. HARPENDING, K. M. WEISS
1992 The osteological paradox, *Curr. Anthropol.*, 33: 343-370.