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Antiquity of Postreproductive Life: Are There Modern Impacts on Hunter-Gatherer Postreproductive Life Spans?

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ABSTRACT Female postreproductive life is a striking feature of human life history and there have been several recent attempts to account for its evolution. But archaeologists estimate that in the past, few individuals lived many postreproductive years. Is postreproductive life a phenotypic outcome of modern conditions, needing no evolutionary account? This article assesses effects of the modern world on hunter-gatherer adult mortality, with special reference to the Hadza. Evidence suggests that such effects are not sufficient to deny the existence of substantial life expectancy at the end of the childbearing career. Data from contemporary hunter-gatherers (Ache, !Kung, Hadza) match longevity extrapolated from regressions of lifespan on body and brain weight. Twenty or so vigorous years between the end of reproduction and the onset of significant senescence does require an explanation. Am. J. Hum. Biol. 14:184–205, 2002.

Almost alone among animals, modern humans live long after the age at which females cease to reproduce. Because this phenomenon seems at first sight to fly in the face of theoretical predictions about senescence (Hamilton, 1966), it has long attracted the attention of anthropologists and biologists who offer adaptationist accounts of its evolution (Williams, 1957; Kaplan, 1997; Kaplan et al., 2000; Hawkes et al., 1997). But what if there is really nothing to explain? What if postreproductive survival is so recent that we cannot believe it resulted from natural selection?

There are many critiques of the competing ideas about the evolution of post-reproductive life, for example, Packer et al. (1998) and Blurton Jones et al. (1999). But in this article we attend to the most basic criticism—that postreproductive life has characterized human life history for too short a time to require an evolutionary explanation. Some suggest it is a product of modern civilization, a novelty of the past 200 years or so (Washburn, 1981), whereas others suggest it is a product of agricultural or industrial subsistence. Austad (1997) presents the contrast between modern hunter-gatherers (!Kung and Ache), and earlier populations and challenges us to resolve the contradiction between estimates of postreproductive survivorship from paleodemography and from modern hunter-gatherers. Austad offers as representative of prehistoric populations the Weiss (1973) life tables for the paleolithic and the well-known report of Libben by Lovejoy et al. (1977). Libben is convenient to discuss because of Howell's (1982) examination of its demographic implications. Libben represents an agricultural population and some view early agricultural populations as having suffered more mortality than the populations of foragers they replaced (Cohen, 1989; but see Wood et al., 1992).

There is another family of arguments which suggest that postreproductive life needs no adaptationist explanation. These account for postreproductive life as a by-product of other processes. In an early example, Weiss (1981) suggests that since human lifespan falls within the range predicted for human body size, it requires no further explanation.

The idea that postreproductive life is a product of the modern world deserves attention, not only because paleodemography suggests very few survivors past the 40s, but

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TABLE 1. Published demographic values for !Kung, Hadza, and Ache

	!Kung	Hadza	Ache
Population size[a]	895/841/796->454	750/1000	550
TFR[b]	4.7	6.2	8.2
Rate of increase[c]	0.0026	0.013	0.025
% over 60[d]	8.5	8.8	5.5
Infant mortality[e]	0.20/0.15	0.21	0.12–0.18
Life expectancy at birth[f]	30.0	32.5	37.1
Life expectancy for female age 45[f]	20.0	21.3	22.1

[a]Population size. !Kung: Howell (1979) pp. 18, 30; Hadza: 750 in 1985 census, 1,000 ever recorded. Eastern Hadza only. Ache: Hill and Hurtado (1996) Fig. 3.1 Northern Ache in 1970.
[b]TFR: Howell (1979) table 6.1 and p 123. Hadza Dyson (1977). Ache, H&H p 253.
[c]Rate of increase: !Kung, Howell 1979:214 Table 11.1, pre-1950. Hadza Blurton Jones et al. 1992; Ache Hill and Hurtado (1996) p, 468.
[d]Percent over 60: !Kung 8.5 from Howell (1979), table 2.1. Hadza, Blurton Jones et al. table 1. Ache from p 141, table 4.4.
[e]Infant mortality: Howell (1979), table 4.1 from reproductive history interviews / table 4.6 for 1964–73. Hadza: from reproductive history interviews. Model North 6 gives 20.5 Ache; H&H p 187 and table 6.1.
[f]Life expectancy at birth and at 45: !Kung from Coale and Demeny (1983) Model West 5. Hadza from Coale and Demeny Model North 6. Ache: H&H table 6.1.

also because basing a species characteristic on modern hunter-gatherers may neglect the influence of the modern world upon these peoples. Perhaps modern hunter-gatherers have more access to modern medicine than is readily apparent, perhaps trade with their neighbors is strongly beneficial, and not disadvantageous and exploitative, as some have argued. Howell (1979) found lower mortality among !Kung born after 1950, when the herder population of the Dobe area increased, changing the economic opportunities available to !Kung. How general is such an effect? Can such changes have shaped mortality in the Ache or Hadza? Do the answers change our picture of the duration of postreproductive life?

Descriptions of characteristics of *H. sapiens* (or earlier forms) have been based on three main lines of evidence:

1) Characteristics of modern populations. Special attention is often given to contemporary foragers on the assumption that their economy more closely displays the costs, benefits, and trade-offs crucial to the period in which the species evolved its characteristics. In the case of demography and life history, it is clear that agriculture and industrialization had effects, so special attention should be given to hunters and gatherers. Here we add new data on Hadza mortality to two well-studied cases, the !Kung (Howell, 1979) and the Ache (Hill and Hurtado, 1996). Expectation of life of women age 45 is between 19 and 22 years in these populations (Table 1).

2) Quantitative comparative studies in which a character of interest is extrapolated from others less in question. Weiss and others (Weiss, 1981; Sacher, 1959, 1975; McHenry, 1994) showed a correlation between body size and longevity and extrapolated early human longevity from estimates of body size. Recently, Hammer and Foley (1996) assembled data from anthropoid primates and used regressions to predict lifespan of several hominids from body and brain weights. After examining the impact of modern conditions on contemporary hunter-gatherer mortality, we compare the figures with the results of Hammer and Foley (1996).

3) Archaeological data sometimes provide direct evidence about a trait. But in the case of postreproductive life archaeological reports have offered a striking contrast with the first two procedures. As yet, every paleodemographic account suggests a truncation of human lifespan close to the age at which reproduction ceases. Archaeologists and physical anthropologists actively investigate several limitations of these reconstructions. The distribution of age at death, the measure from which paleodemographers reconstruct demography, is more sensitive to fertility than to mortality (Milner et al., 1989) and is highly sensitive to rate of population change (Howell, 1979). Errors in age estimation, particularly of old and active people, are quite severe, for example, comparison of documented age with age assessed from the skeletons in the Spitalfields study (Molleson et al., 1993; Key et al., 1994). Extreme differential loss of skeletons of the young and old was shown when Walker et al. (1988; see also Walker, 1995) compared documentary and archaeological evidence from mission cemeteries in California. Analysis of 32 skeletons found two individuals of estimated age >45 (about

5%). This is similar to many paleodemography results. But written records showed that 539 individuals >45 had been buried there, 37% of the buried population. Walker et al. (1988) point out that conditions at the site did not favor good preservation of skeletons. State of preservation may be better at other sites, but sites relevant to the current topic are several orders of magnitude older. Claims of good preservation should be supported by objective evidence. Walker (1995) suggests a method for quantifying state of preservation and shows that if this is applied to the California skeletal sample the distribution of ages at death conforms to a pattern more in line with contemporary life tables and the written records. Paleodemographers and archaeologists continue to work on improving estimates of age at death, but apparently less on finding ways to assess the importance of differential preservation of the young and the old. In contrast to these tasks, this article attempts to evaluate ways in which the modern world could inflate the survivorship of modern hunter-gatherer adults.

Contemporary hunter-gatherers live in a world of farmers and herders who are in turn more or less effectively connected to a global economy and modern technology. Although it is easy to overemphasize these links, whose influence seems fleeting and tenuous when viewed from remote rural corners of developing countries, the situation of modern hunter-gatherers might be different in many ways from that of hunters in a world of hunters. Examining two sub-Saharan populations (!Kung and Hadza, with special emphasis on new data from the Hadza) and one south American population (Ache) we try to assess the extent and effects of 1) errors in estimates of individual ages; 2) access to modern medicine; 3) access to modern hygiene and facilities such as piped water, which are sometimes viewed as having greater effects than medicine; 4) law and order; 5) the possibility that old people take shelter with farmers, enabling them to live longer than they might among their more mobile kin; 6) the possibility that foragers may obtain food from farmers at critical times, and again escape mortality in this way; 7) reduction in predation as wild animals became more scarce; 8) outside ideological influences on leaving the sick or elderly behind; and 9) infant nutrition and adult mortality (Barker, 1997). We then attempt a crude "accounting," developing a "worst-case" scenario for Hadza survivorship into and during postreproductive life. We discuss the difficulty of estimating the effects of epidemics and warfare.

ETHNOGRAPHIC BACKGROUND

Hunters and gatherers

While our working category of "hunter-gatherer" is simply economic (people who during the period of observation acquire nearly all of their food by hunting wild animals and foraging for wild plant foods) it needs qualifying for !Kung and Hadza. !Kung increasingly used resources from Herero and Tswana herders during the period covered by Howell (1979), changing from apparently almost no people using these resources to perhaps more than half the !Kung using some unmeasured amount of food acquired from herders. Howell sets 1950 as a turning point in this process and presents data on mortality of children born before 1950 and those born in and after 1950.

Hadza have been closely surrounded by neighbors and traded with them for at least the last 100 years. Although most reports concern receipt of cloth, pots, and iron, Hadza could also have obtained food if they needed it. Today individual Hadza frequently work for farmers guarding maize fields, or harvesting sweet potatoes, and all Hadza sometimes beg off fanners and trade honey with herders. Hadza use of farm foods has varied greatly over the last 40 years. Intermittent imposed settlements included delivery of maize, irregularly and unreliably. Some Hadza have spent long periods living in a settlement or village, but most did not and few do today. Much of the time almost no food was provided to settlements. Hadza trying to modernize by living in larger, more stable communities still fed themselves from the bush. Some Hadza live near villagers (farmers) and others far from them. In 1985–1986, working in one of the most remote locations, Hawkes et al. (1997) and found that only 5% of food came from farmers (carried back from visits to villages). In 1995–1996, Marlowe (1997) worked in a variety of camps including some very near villages and farmers. About 11% of Hadza food came from agricultural, non-

wild resources. Among Hadza who lived in Munguli, some farmed successfully until they all left in 1990. Thus, there has been great variation in Hadza reliance on bush or farm food and there is some possibility that access to farm food has affected Hadza mortality. We examine data on this issue below.

Before peaceful contact and settlement in 1971, Ache obtained all their food from wild resources, except for whatever they got from the occasional and often fatal practice of raiding farmers' fields.

!Kung. The !Kung of northwestern Botswana and northeastern Namibia, and their lifestyle of the 1950s to 1970s, are well known to anthropologist readers. Howell's (1979) demographic study centered on a study population of some 454 individuals out of a Zhun/twa speaking population of some 800–900. Nearly 10% of the population were >60 years old, total fertility rate (TFR) was low, 4.7 (Table 1). The pre-1950 population was best represented by Coale and Demeny (1983) model West 5, but it was evident in the 1960s that both fertility and mortality were undergoing rapid change as !Kung interacted more closely with Herero and Tswana immigrants.

Ache. The Ache of Paraguay are also well known to anthropological readers (Hill and Hurtado, 1996). Their presettlement, full-time forager lifestyle was much more mobile than the life of the other populations discussed here. Small groups moved almost daily through the forest, clearing a new sleeping area each evening. Couples and their children shared a fire, but people lived in much greater proximity at these overnight camps than in a Hadza or !Kung camp. In some contrast to !Kung and Hadza, Ache men provided about 80% of the food by hunting animals of a wide variety of sizes and taxa. While !Kung are known to have practiced occasional infanticide and Hadza claim never to have heard of such a practice, Ache used to regularly kill one or more children upon the death of their father, and sometimes in other circumstances. Hill and Hurtado (1996) describe informants' interpretations of this practice.

Hill and Hurtado (1996) present data from "the forest period" before Ache were contacted by Westerners or educated Paraguayans, and during which they lived almost entirely off hunted and gathered foods, the contact period of rampant infections and deaths, and a settlement period during which the population recovered and medical care became available. Life expectancy at birth rose from 37.1 years for females in the forest period to 45.6 in the settlement. Life expectancy at age 45 rose only from 22 years in the forest period to 24 years in the settlement. During the contact period, mortality rose mostly among the young and old, including old females. "Only a handful of women over the age of fifty survived the contact period" (Hill and Hurtado, 1996, p. 189). These authors attributed the virulence of these epidemics to lack of previous exposure to the disease organisms. The northern Ache had kept themselves isolated from their neighbors. But a question of interest is whether many forager populations were so isolated in a world of foragers among foragers. It will be difficult to assess the effect of disease reservoir and population density upon forager mortality. In the forest period 5.5% of people were >60 years, TFR was 8.2, and the population was increasing rapidly (Table 1).

Hadza. The eastern Hadza are a group of 700–800 people who occupy an area of 2,500 km^2 in the Eastern Rift Valley, south and east of Lake Eyasi, in northern Tanzania. The climate is warm and dry. Annual rainfall is in the 300–600 mm range, most of it falling in the 6–7 month wet season (November–May). Vegetation is primarily mixed savanna woodland; medium/large animals are locally abundant. Ethnographic data on the eastern Hadza is most available in the publications of Woodburn (1964, 1968a, 1970, 1972, 1979, 1982, 1988). The western Hadza are about 250 people who speak the same language but live west of Lake Eyasi. Contact is sufficiently low for eastern Hadza informants to often comment that they do not know people in the west, although individuals and families do move between these areas. Eastern Hadza talk of themselves as living in three regions: Mangola-Balai, Siponga, and Tliika.

The language, Hadzane, has been studied by Woodburn and others and recently by Sands (1993, 1995). Linguists agree only that its connection to any other African language family is very remote. Hadza must have remained culturally distinct from their neighbors (who currently represent the

Bantu, Nilotic, and Cushitic language families) for many hundreds of years. At the beginning of this century, it appears that only the Hadza occupied this country (Baumann, 1894; Obst, 1912). They apparently lived entirely by hunting and gathering. Local incursions by non-Hadza pastoral and agricultural groups are recorded as early as the 1920s and have continued to the present (McDowell, 1981; Dar es Salaam; Woodburn, 1988). Archaeological evidence suggests that farmers and pastoralists have been present intermittently for several centuries, hunter-gatherers far longer (Mehlman, 1988). During the past 50 years various segments of the Hadza population have been subjected to a series of government- and mission-sponsored settlement schemes designed to encourage them to abandon the foraging life in favor of farming. None of these schemes has been successful and in every case most of the Hadza returned to the bush, usually within a few months. In each instance some Hadza avoided settlement and continued to live as full-time hunter-gatherers.

During the 1990s hunting became progressively more difficult as interference by outside agencies continued and incursions by people with other lifestyles increased and the habitat was degraded. The arrival of "ethno-tourism" in the late 1990s seemed likely to herald the imminent submersion of the Hadza into a new lower rung of Tanzanian rural society. But by the end of the century it appeared that this development might instead have positive outcomes in some localities.

Many have argued that anthropologists too readily separate people into assumedly isolated "tribes." This could lead to demographic study of populations that were not demographic units. This study included as members of the Hadza population anyone who claims Hadzane as his or her mother tongue. By and large this coincides with being regarded as Hadza by other Hadza, and by others who would regard themselves as not Hadza, and with residing in a fairly circumscribed area. It coincides less tightly with many other traits, characteristics, or habits: carrying a bow, knowing the footpaths, knowing how to hunt and gather, attending epeme dances, using one set of place names rather than another, and so on. It coincides with a sharp difference in probability of marriage—Hadza marry other Hadza much more often than they marry people who do not have Hadza as their mother tongue. But some Hadza do marry others (Stevens, 1977); Hadza may be more culturally separable than genetically separable from their neighbors.

The field method allowed Hadza to define themselves indirectly. The censuses and anthropometry was conducted from camp to camp, finding each camp by asking people in the current camp where there is another. Informants were also asked the whereabouts of each person listed in the population register ("where are they now" interviews). The register is a list of information about all the people encountered in our research, or who Lars Smith encountered in 1977, and others before him. We also tried to identify in this register everyone we saw in a census. These procedures give clues about the difficulty of "becoming a Hadza" and of ceasing to "be a Hadza." Only one adult was located, who our field assistant claimed was not born a Hadza but has "become one"; he speaks Hadza, his wife is Hadza, he lives as a Hadza and with Hadza, and has for a long time. There is also one other man who seems to be in the early steps of the same process. These are two, contrasting with some 200 adult men, who Hadza regard as having been born and raised Hadza. There are also a few people recorded earlier whom we have not met but who Hadza know to be alive. The assistant and others stated of some of them have "gone to the Swahilis," and although in some sense apparent to Hadza, they are still "really" Hadza, they should now be categorized differently from the majority.

HADZA DEMOGRAPHY

Blurton Jones et al. (1992) reported results of a census conducted in 1985 by Lars Smith and Blurton Jones. Age structure, survival from an earlier census conducted as part of the International Biological Program (IBP) by Barnicot, Bennett, and Woodburn, a capture-recapture calculation of population increase, and other measures were found to fit closely to Model North 6 chosen by Dyson (1977) to fit the 1966–1967 IBP data. The age structure was significantly younger than Model West 5 that Howell (1979) reported as the best fit to the !Kung. Middle-aged and older Hadza seemed to survive at a higher rate than expected from Model 6 North.

TABLE 2. Causes of death of Hadza 1985–1997

Hadza 1985–1997	Male	Female
Respiratory (TB, pneumonia)	5	6
"Oldness"	4	5
Measles	8	4
Other illness	15	10
Homicide	3	1
Childbirth	0	5
Fall from tree	1	0
In hospital or jail	2	1
"Poisoned" or bewitched	3	2
Total given a cause*	41	34

*Only 75 deaths out of a little more than 125 were ascribed a "cause" by informants.

We acquired new data on Hadza mortality from repeat censuses and reproductive history interviews conducted between 1990 and 1999. Some births, deaths, and camp compositions were recorded during behavioral and ecological observations conducted during 1985–1986, fall 1988, and winter 1989. At each census, informants are asked for news of everyone recorded in previous censuses. This is our main source of information about deaths. Information on cause of death is sought at the same time but is hard to elicit, vague, and often uninterpretable (Table 2). More than one report of a death is sought. Only rarely has a person reported as dead been seen or reported alive at a later date. The method of estimating individual ages is discussed below.

The fate of the 706 people censused in 1985 was tabulated. Fifty-seven individuals had died by 1990. Of the survivors to 1990, a further 68 died by 1995. Year of death was estimated for each individual who died by 1995. If year of death was not known, it was estimated as one-third of the time between the last report of the person alive and the first year in which they were reported dead. Many of these estimated years of death can be refined in further fieldwork. The number entering each year of life was then calculated and a life table was constructed (Table 3, Fig. 1). Number entering each year was computed as in the following examples. Child A was 5 years old at the time of the 1985 census and lived until 1988. He was recorded as entering the years 5, 6, 7, and 8, and dying by the end of year 8. Old lady B was calculated as 65 in 1985 and died in 1992. She was recorded as entering years 65, 66, 67, 68, 69, 70, 71, 72, and dying at the end of year 72. Her sister C was

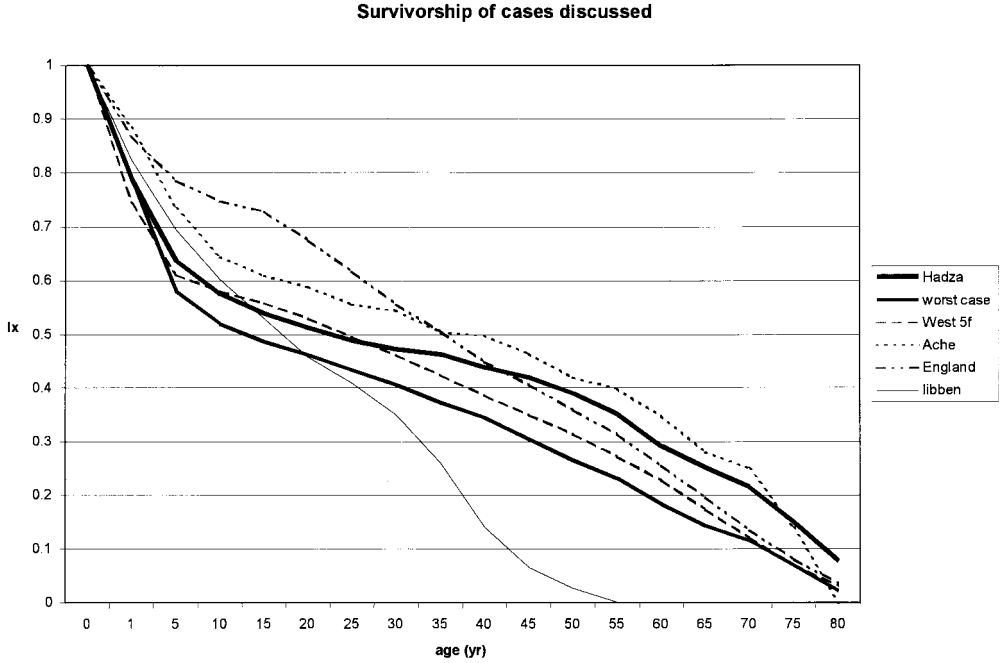

Fig. 1.

TABLE 3. Hadza lifetable 1985–1990

Age	Enter	Die	qx	lx probability
0	0	0	0.21	1
1	23	1	0.0435	0.79
2	54	3	0.0556	0.7556
3	77	5	0.0649	0.7137
4	92	4	0.0435	0.6673
5	105	7	0.0667	0.6383
6	117	1	0.0085	0.5958
7	133	1	0.0075	0.5907
8	149	2	0.0134	0.5862
9	163	1	0.0061	0.5784
10	177	1	0.0056	0.5748
11	193	5	0.0259	0.5716
12	191	3	0.0157	0.5568
13	176	3	0.0170	0.5480
14	168	0	0	0.5387
15	168	2	0.0119	0.5387
16	164	2	0.0122	0.5323
17	164	0	0	0.5258
18	161	2	0.0124	0.5258
19	156	2	0.0128	0.5192
20	151	2	0.0132	0.5126
21	145	1	0.0069	0.5058
22	140	3	0.0214	0.5023
23	133	1	0.0075	0.4915
24	132	0	0	0.4878
25	132	2	0.0151	0.4878
26	127	1	0.0079	0.4804
27	122	0	0	0.4767
28	115	0	0	0.4767
29	114	1	0.0088	0.4767
30	109	0	0	0.4725
31	109	0	0	0.4725
32	108	0	0	0.4725
33	106	0	0	0.4725
34	103	2	0.0194	0.4725
35	98	0	0	0.4633
36	94	1	0.0106	0.4633
37	91	2	0.0219	0.4584
38	88	1	0.0114	0.4483
39	90	1	0.0111	0.4432
40	85	1	0.0118	0.4383
41	85	3	0.0353	0.4331
42	79	0	0	0.4178
43	74	0	0	0.4178
44	72	0	0	0.4178
45	73	3	0.0411	0.4178
46	69	1	0.0145	0.4007
47	66	1	0.0152	0.3949
48	64	0	0	0.3889
49	64	0	0	0.3889
50	63	3	0.0476	0.3889
51	60	1	0.0167	0.3704
52	55	1	0.0182	0.3642
53	55	1	0.0182	0.3576
54	54	0	0	0.3511
55	52	3	0.0577	0.3511
56	47	2	0.0426	0.3308
57	46	2	0.0435	0.3167
58	46	0	0	0.3029
59	50	2	0.04	0.3029
60	46	2	0.0435	0.2908
61	41	3	0.0732	0.2782
62	38	1	0.0263	0.2578
63	39	0	0	0.2511
64	41	0	0	0.2511
65	41	1	0.0244	0.2511
66	42	1	0.0238	0.2449
67	40	2	0.05	0.2391

TABLE 3. (Continued)

Age	Enter	Die	qx	lx probability
68	38	2	0.0526	0.2271
69	36	0	0	0.2152
70	36	1	0.0278	0.2152
71	38	1	0.0263	0.2092
72	39	3	0.0769	0.2037
73	35	2	0.0571	0.1880
74	33	5	0.1515	0.1773
75	28	5	0.1786	0.1504
76	19	1	0.0526	0.1236
77	17	0	0	0.1171
78	15	4	0.2667	0.1171
79	11	1	0.0909	0.0858
80	8	1	0.125	0.0780
81	7	1	0.1429	0.0683
82	4	0	0	0.0585
83	3	1	0.3333	0.0585
84	1	0	0	0.0390

recorded as 55 in 1985 and survived throughout the study period. She was computed as entering every year of life from 55 to 65 and dying in none of them. Because the censuses may undercount the smallest babies, infant mortality is taken from the reproductive history interviews (proportion of babies born but dying before they could walk, age at walking appears to be close to the 1 year, as found in many populations, including African populations).

Hadza survivorship is close to that for Model North 6 and a little higher than Model 5 West (!Kung), and very close to precontact Ache. The Hadza data confirm the observation of high adult survivorship and an expectation of life just over 20 years for women 45 years of age. The data will support further analysis when a final census has been completed, the revised method of estimating ages has been compared with the original, and year of death has been established more closely.

Now we consider a series of ways in which these data (and the data on Ache and !Kung) might conceivably underestimate adult mortality. Most have to do with possible differences between the circumstances of hunter-gatherers in a world of hunters and hunter-gatherers as studied in the modern world.

Are the age estimates bad?

At the time of study very few !Kung, Ache, or Hadza knew their ages or had had them recorded. Could errors in age estimation exaggerate the survivorship of elderly contemporary hunter-gatherers and account for the difference between contemporary and archaeological populations?

Howell (1979) estimated ages of !Kung by first ranking everyone in order from oldest to youngest. There were two known age points and a figure for infant and child mortality that allowed her to choose a model from Coale and Demeny (1985). Howell then matched the age ranking to the age structure to obtain age estimates for every individual. Howell devised some checks on the age estimates, as well as several checks on the fit to West 5. Particularly useful is the age gap between mother and first, second, third children. The gap did not change with mother's age as it might have done if older women had their age grossly over- or underestimated.

Hill and Hurtado (1996) estimated Ache birth dates by a combination of ranking, and informants matching contemporary individuals to the developmental stage of other individuals at the time of significant events in the past. For example, A's mother was asked how large A was ("which child here was closest to A") when she bore his next younger sister. Many of the contemporary reference children were of known age. A's mother might also be asked who she most resembled when she bore A and all his siblings "which woman here is closest...?" Hill and Hurtado checked their estimates in several ways.

Hadza ages were calculated by an age ranking which originally included some 44 individuals of known age between 1 and

TABLE 4. Expectation of life at age 45 with different assumptions about age of oldest individuals

	e45 to Tmax	e45 to 70	e20 to Tmax	e20 to 70
!Kung west 5*	20.0	17.5	34.0	32.4
Ache forest period	22.1	19.6	39.8	37.8
Hadza 1985–1995	23.0	20.0	41.4	38.1
Hadza "worst case"	19.3	17.1	33.7	32.2

*From Coale and Demeny (1983) Model West 5. Expectancy to 70 calculated from (Tx-T70)/lx.54.

29 years. Ages of four older individuals were estimated by less direct and independent methods. Rank order and age were regressed and a polynomial equation used to calculate age of each individual in the ranking. These estimates also passed the test of the gap between mother and first child (Blurton Jones et al., 1992).

Subsequently, more age marks have been established. Three cases are particularly important for testing estimates of older ages. Dorothea Bleek's notebooks of her visit to the Hadza in 1930 (University of Capetown Library, Manuscripts and Archives Department) contain many partial genealogies. Most of the people named in them were remembered by informants in the 1990s; they include their parents, grandparents, and other kin. Two individuals were recognized by informants as still living in 1991. Bleek describes both as "boys," and says the youngest was aged about 8 and she reports his height as 116 cm, nearer the height of a 10–12 year-old Hadza child. Supposing this to indicate that both were around 10 in 1930 (born 1920) then they were around 71 years in 1991. Their position in the age ranking had given them calculated ages of 66 and 74, mean 69.5 in 1991, which agrees remarkably with the new estimate.

Most of the men and women named by Kohl-Larsen (1943, 1958) from his fieldwork at the other end of Hadza country between 1934–1937 are also recognized by contemporary Hadza and their descendants are well known. Most of those named were dead by 1985. If they were adult (>20) in the mid-1930s, thus born around 1915, then the youngest of these adults would have been 70 in 1985. Four men and four women were still alive in 1985, all ranked among those >60 years. Kohl-Larsen gave no indication of their ages. But he named a boy ("Der Knabe...") who informants claimed they could recognize and who had been known to Lars Smith in the 1970s. Though dead by 1985, "the boy" had an older brother alive (who had been estimated to be 2–5 years older). Suppose the boy was 5 (born, say 1930), and his brother 7–10 years old (born 1925–28), then the brother was 57–60 in 1985. His age calculated from his rank was 56 in 1985. This match is also extremely encouraging. The quest for more calendar marks and historical information continues.

While the estimates of age are reasonably reliable for older people, three ways in which inaccuracy could affect the conclusions about postreproductive life, need discussion.

Assumptions about maximum age. The figure obtained for life expectancy at 45 years (e45) is affected by the assumption about maximum age, particularly the decision about which will be the highest age tabulated. For example, Wood (1987) published a life table for the Gainj with the final age group as 60–65. If we assume that all !Kung in Howell's Table 4.6 had died by 60, instead of between 85 and 90, the estimate of e45 for !Kung in the 1960s declines from 27.31 to 16.57. Since estimates of the age of the older people are probably the least reliable in any sample we should take account of the effect of variation in estimated oldest age. The proportion surviving to the highest age group tabulated, or to any lower age, is not affected. We can replace e45 with, for example (25e45), the number of years lived between 45 and 70 by someone who reaches 45. Table 4 shows such life expectancy figures from age 45 and from age 20 (used below) for the three populations and for the eventual Hadza "worst case." In these populations the high expectation of life at age 45 is not dependent on a handful of very old individuals.

Difference between model life tables and Ache and Hadza. Among the Ache, and less so among the Hadza, more people age 50–65 years appear to survive than in the nearest

Coale and Demeny (1983) models. If the Hadza 50–70-year-olds were in fact 40–65-year-olds, the fit to the model might be close. But estimates of the age of these older women gave a similar gap between the woman and her oldest child as observed among younger women (Blurton Jones et al., 1992). If the age estimates were lowered for the older women this would no longer hold true. The effect on e45 would be quite small, as can be seen by comparing the observed Hadza e45 of 23.0 years, with that from Model 6 North 21.3.

Can the 76 Hadza women over 45 be explained away? It seems impossible that there are errors gross enough to remove the 76 Hadza women who are over 45 years of age. Two arguments can be given.

i) Many women calculated to be over 45 years have living daughters and grandchildren and a few have great-grandchildren. Ages of young women are quite well established and provide an age at first childbirth around 18–19 years. There are also a number of women born before a well-remembered 1964 earthquake, who are thus now in their mid-30s. Many of these have living mothers, who are thus likely to be women over 55 years unless age at first birth has recently increased markedly.

ii) If a population is decreasing it will have an older age pyramid than if it was growing. What if the old women are relics of a rapidly decreasing population? Even in a population with an age pyramid as shallow as Libben (Howell, 1982), not dissimilar to many archaeological populations, forager or nonforager, a few might survive beyond 45 years. But very few survive, 2% in Howell's calculation of the age structure implied by the Libben life table. If the 76 older Hadza women were the relics of such a population, it would have had to number 8,000 and exist sometime in the lifetime of these women. There are many previous accounts of the Hadza and none indicate a population any greater than 800 or so. There is good evidence that the Hadza population has been increasing for the past several decades at a rate that fits well with the few previous accounts (Blurton Jones et al., 1992).

It must be concluded that neither population decline, nor errors of age estimation are sufficient to do away with the large observed population of older people, or to greatly affect estimates of survivorship of those who reach age 45.

Modern medicine

Did researchers intervene enough to affect the mortality statistics? Researchers can have had no effect on Ache survival in the forest. The data were gathered in retrospective interviews. No researchers were with the northern Ache before the contact and settlement period (Hill and Hurtado, 1996). Howell (1979), discussing the low mortality of the !Kung between 1964 and 1973, considers migration of the less healthy to health care on the periphery of !Kung country and the possibility that the researchers had an effect by giving health care and emergency transport.

In fieldwork with the Hadza we responded to requests for help with sickness or injury in two ways: transporting individuals to rural health clinic or hospital, or giving medicines when available. We justified this by the extreme isolation of our field camps (by journey time if not miles) from professional help and the extremity of life in a bush camp. It seemed unethical to withhold help from Hadza that we gave, or would have given, to ourselves and each other. Did we transport enough sick people to affect the mortality statistics? Table 5 shows that the cases were not so obviously concentrated on accidental injuries as Howell indicates for the !Kung (Howell, 1979). Two facts stand out in Table 5. We mainly transported men, as also reported by Howell (1979). We only transported two women, one of them postreproductive. Most of the people that we transported died; our help was ineffective.

Did we treat enough people against genuinely threatening conditions successfully enough to affect the statistics? We tabulated the interventions of one of us. Most treatment was given to children. Ear infections were fairly common, as were cuts and scrapes, and we saw one serious burn. Only one treated child died (3 years later). But we suspect that the condition of only about two was sufficiently serious to make it possible that they might have died without our intervention. Older women asked for medicine for sore eyes and the occasional cough or abdominal pain. When eye infection was obvious and we were going to be in camp long enough, we offered treatment.

TABLE 5. Hadza transported by researchers in search of medical attention

ID	Sex	Age	Year	Request by	Illness	Outcome
SE	M	65	1985	Family	Sleeping sickness	Died in hospital
SM	M	58	1986	Family	Not diagnosed	Died
KS	M	23	1986	Community	Psychosis?	Died in hospital
GM	M	50	1986	Self	Injured leg	Survived >10 yrs
SG	F	2	1986	Parents	Skin lesions. Scabies	Alive
NS	F	7	1990	Observer and assistant, weight loss	TB	Alive
HW	M	45	1992	S asked return to camp after failed treatment.	TB?	Died
OP	M	43	1995	Observer and assistant	Clinic gave antibiotics	Alive
NI	F	34	1997	Family asked for medicine. Too ill	Acute pneumonia	Alive
MG	M	62	1997	Family	TB recurrence	Died
MM	M	65	1996	Fall from tree	Injuries	Died
NM	F	61	1998	Head wound from drunk son-in-law		Alive

How much access do Hadza (and others) have to modern medicine and do they make use of it? Throughout the study period, government clinics have been available no more than a day and one-half walk from any Hadza camp. Hadza seem extremely reluctant to go to these clinics. They are convinced that there will be no medicines and that if there were the attendant would say there were not, refusing to treat penniless Hadza. Our experience is that there is some truth, but only some, in these suspicions. When we have accompanied Hadza to these clinics they have been fairly well received and treated. The clinic attendants appear to be very competent but supply lines are long and very unreliable in the countryside.

Bennett et al. (1973) reported a very different picture from the 1960s. During the 1966 and 1967 IBP surveys, shortly after the establishment of the Yaeda and Munguli settlements (now long deserted by most Hadza), 242 out of 491 Hadza interviewed had at some time sought Western medical aid, 75% of the people in settlements but only 40% of eastern Hadza not in a settlement, and only 18% of western Hadza. This greater access to medicine may explain why, even though informants describe an unusual number of illnesses and deaths at the settlements, there was no trace in the 1985 age structure.

Towards the end of the recent period of demographic data collection there have been two improvements in access to modern medicine. Between 1994 and 1998 CUSO ("a Canadian organization for global social justice") field representatives have made more frequent visits to one previously isolated bush location and become more inclined to transport Hadza for medical care. Since 1995 a mission-supported doctor has been stationed in Mangola at the north end of Hadza country and he tries to be accessible to Hadza. In other respects medical care remains remote and forbidding to the Hadza. In towns such as Arusha, a wide variety of modern medicines (antibiotics, chloroquine, and variants) are available in shops without prescription, and increasingly in smaller towns. But Hadza still have no access to such sources.

Reservoir of disease. Modern hunter-gatherers try to isolate themselves from their farmer neighbors. This might make epidemics less frequent but may make them more severe. Contact die-offs confirm the potential severity. In a world of hunters among hunters isolation may have been less rigorous, with the result that diseases spread more easily but perhaps with less dire consequences.

The modern world differs in two other ways. The surrounding farmer populations are much more dense than previous forager neighbors would have been, perhaps implying a larger reservoir of disease. On the other hand, these dense modern farmer populations have the advantage of immunization programs and other public health efforts. While such efforts have led to the global extinction of smallpox, sleeping sickness returned to the Eyasi area after an absence. It may now be disappearing again. As a result of clearance by herders, the Tsetse fly vectors have become noticeably scarce. Hadza themselves have received few

successful immunizations (Bennett et al., 1973). We organized a measles immunization expedition from the Mbulu government hospital in 1992 and some may have been reached by the 1997 polio vaccination drive.

It is difficult to assess the relative importance of these counteracting factors. The Hadza may have avoided the 1917 flu pandemic, as it receives no mention in Bagshawe (1924–1925), Bleek (1931a, b), or Kohl-Larsen (1943, 1958), despite Bagshawe reporting Hadza as giving refuge to Isanzu during the 1918–1920 famine. But Hadza did not totally escape the polio epidemic of the mid-1960s. Bennett et al. (1973) imply that few Hadza were affected by a smallpox epidemic in Shinyanga Region, adjacent to the western Hadza. Many Hadza children succumbed to measles during a brief settlement attempt in 1986. Hadza claim that many died of disease during the 1964–1965 settlements. No case of AIDS is presently known among Hadza. The first case in the study area was reported in Mangola (a large village in the northern part of Hadza country) among non-Hadza in 1991 and the disease is abundant elsewhere in northern Tanzania. Meningococcal meningitis has had several small epidemics in northern Tanzania in recent years, including one near the northern end of Hadza country in which the mission doctor rapidly interceded, but we have heard of no Hadza deaths suggestive of this disease.

Before modern medicine existed? Modern medicine and public health interventions ("sanitary engineering" and immunization programs) are effective and avoiding food shortfall aids survival. In trying to assess their effect upon the three modern hunter-gatherer populations, another comparison may help. Figure 1 shows that Hadza adult and elder mortality was very similar to that of the English between 1640 and 1809. The English of that period had no access to modern, science-based medicine. It had not been invented. There seems no reason to suppose that English traditional folk medicine was any better than that of the Hadza, Ache, or !Kung. Thus modern hunter-gatherers show a level of mortality close to that of farming populations with no access to modern medicine. Similar data (Laslett, 1995) are available for France, Sweden, and other European countries. Absence of modern medicine did not lower European postreproductive survivorship below that observed among modern hunter-gatherers.

Sanitary engineering

Much of the 19–20th century improvement in life expectancy has been attributed to piped water, sewage disposal, and other improvements in hygiene. Does this contribute to survivorship of Hadza, !Kung or Ache in the forest period? We know only one Hadza who has access to piped water (he works in the house of a European farmer), and very few individuals among their farmer or herder neighbors have access to piped water. At three Hadza settlements in the 1960s an effort was made to provide piped water. All of these have been defunct since at least 1985. Relics can be seen and in one place (Endamagha) the source is used by farmers and herders. At some settlement attempts, pit latrines were dug. We have no data on their use or longevity. In Hadza camps people defecate a little outside camp, mostly during the hours of darkness. Each camp is surrounded by a band of drying feces some 20–40 yards from the houses. Camps are moved relatively frequently and large populations of flies do not accumulate. Water is obtained from a variety of natural sources. As described by Woodburn (1968a), many of these are also used by wild animals and Datoga livestock. Likewise, Ache in the forest period, and !Kung described by Howell (1979), had no access to piped water or sewage disposal. All three populations achieve their survival figures without the assistance of modern sanitary engineering.

Law and order; murder/homicide

Hadza are not noted in the literature for an unusual incidence of homicide. Their relationship with their herder neighbors, the Datoga, has been described as uneasy. It is said that sometimes a Datoga youth will attempt to enhance his status by killing a Hadza instead of a lion or a cattle thief. It is said that Hadza have made the occasional retaliatory killing. Murders of Hadza by Hadza are known but appear rare. Woodburn (1979) has described in some detail the ease with which Hadza men, all lethally armed with poison arrows, could ambush, kill, and remain undetected. He suggests that this is an important "equalizer" and restraint in Hadza social life.

Our records show four Hadza killed, three by Datoga (two men, one woman) a man killed by other Hadza in 10 years. These deaths come from a sample of 1,000 people followed in our "where are they now" interviews and known to have been alive at some time between 1985 and 1995. This is four deaths in 10,000 person-years (40/100,000). Lee (1979) gives a rate for the !Kung of 29.3 per 100,000 person-years. (Kim Hill, personal communication, suggests this figure is an underestimate because it includes the years after police began to intervene and because the people who lived in Namibia were included, while it is not clear that all homicides that occurred in Namibia would have been recorded). All these killings were of !Kung by !Kung. Thus, compared to !Kung, Hadza lose more people to homicide but themselves kill fewer.

Hill and Hurtado (1996) describe homicide as "by far the most common cause of death to forest-dwelling Ache" (p. 163), mostly at the hands of non-Ache raiding parties. Hill (personal communication) calculated homicides per person-year. Ache homicide rate is much higher than that of Hadza or !Kung. The difference appears partly due to the high rate of killings by non-Ache, and the practice of killing children under a variety of special circumstances. Nonetheless, adult Ache kill other adult Ache at a higher rate than Hadza or !Kung kill each other.

Although Lee (1979; see also Cashdan and Draper, 1992) reports police intervention as long ago as 1952, !Kung recognize they are "remote from any immediate authority figure to settle disputes." We have witnessed two large-scale disputes among Hadza, each reaching borderlines of deadly force. Each resulted in large delegations of people going from camp to camp debating the issue and apparently influencing a peaceful settlement. We have also seen communal discussion with a young woman and her suitors about the danger of her failure to chose between them.

Does knowledge that homicide is illegal and could bring trouble from the outside have no effect? Several observations suggest that knowledge of state law and the police may have had little effect among the Hadza until very recently.

1) Hadza recounting their versions of an ambush and murder (apparently the same incident as reported by Woodburn, 1979) show no indication that they believed external authority should have been involved.

2) Informants reporting the three killings of Hadza by Datoga made no mention of having sought outside intervention or punishment.

3) When asked whether any one had reported these cases to the police or other local authority, informants seemed surprised at the idea they could have done this.

4) Hadza seemed unsurprised when, sometime in the late 1980s or early 1990s, one of their own responded to villagers' pleas (because the police were 2 days away, so could not be called in time) to bring his arrows to deal with some young non-Hadza who had turned violent at the traveling market.

5) In 1995 one of the best-educated and most softly spoken Hadza was interviewed in the district capital by a Tanzanian economist from a government commission. Aiming for a "household budget" of the Hadza, the economist latched instantly onto the rationality of hunting—why hunt to provide a public good? "You get more women." And since most are married, the next question: "What if you catch another man with your wife?" "Arrows" was the unhesitating reply. Earlier authors have reported that Hadza regard a wronged husband as justified in killing his rival. The conversation implies that this idea is still accepted.

6) The police are 2 days walk away from the closest Hadza camps, and unlikely to have a functioning vehicle or want to chase miscreants through the bush.

Among the Hadza, understanding, belief in, and access to the rule of law has grown only slowly. But they have long had evidence of the power that outside authorities can wield. Bleek's 1930 field notebooks (University of Capetown Library, Manuscripts and Archives Department) show her informants had been impressed by the power of the Germans but it is not clear that they understood this as anything but randomly applied. But in 1934–1939, some requested Kohl-Larsen's intervention in a potentially deadly dispute (Kohl-Larsen, 1958). In 1964 many Hadza witnessed firsthand the power of the new postcolonial government when some 100 or more were rounded up at gunpoint and taken to the Yaeda settlement scheme. In 1985 Hadza reported the rapid and severe punishment visited upon Datoga after some bird trap-

pers had been killed in a remote location. But even by 1990, Hadza understanding of the legal system was not sufficient for them to recognize that a local official had no legal right to be sending groups of young men into the bush to round people up and beat them if they refused to join yet another settlement scheme. By 1995 Hadza were ready to have the ward secretary call police in response to a murder.

Our current impression is that externally imposed law and order had little influence upon Hadza homicide rates during most of our study period. The similarities between Hadza and !Kung methods of dealing with disputes and violence suggest a long-lasting condition of a low but recordable rate of homicide.

Note that among !Kung only three of the killings were of a woman, and only one among the Hadza. Ache, on the other hand, reported killing older women. Yet Hill and Hurtado (1996) cite very low mortality among women 45 to 65 years. We conclude that in the past mortality due to homicide within the ethnic group is unlikely to have accounted for much larger numbers of deaths to postreproductive women than were observed in the contemporary forager populations.

Do the elderly or infirm take refuge in villages?

Two possibilities are envisaged:

1) Elderly, sick, and infirm go to villages and thereby survive longer. Then, if they are included in our censuses, high elder survivals would be recorded.

2) Elderly sick, infirm go to villages, die nonetheless, but get left out of censuses because the villages were not visited. Thus, only the healthiest, toughest old people could be included in the census, and this might give an inflated estimate of elder survival (a possibility discussed for the !Kung by Howell, 1979).

Neither can have affected mortality estimates for the Ache in the forest period. Relations with villagers were too hostile for such an arrangement: 15 adult females age 15–59 were shot by Paraguayans and one was captured. Two females over 60 were shot by Paraguayans.

Do older Hadza take refuge near farmers? We rated all camps in the 1977 census by Lars Smith and in our 1985 and 1995 censuses for proximity to farmers. The rating scale of 0–7 was intended to reflect the effort required to be in a position to beg for farm foods: 0 being easiest, 7 hardest. The scale primarily reflects distance in walking time from a camp to the nearest farmers or fields. All camps named in the 1977, 1985, 1995 censuses were rated with respect to the distribution of farmers in those years. Farmers have expanded their range, and thus many locations have gained lower scores as time went on. Each individual received a score on these ratings, determined by the camp he or she was found in, for each of the censuses (1977, 1985, 1995). We calculated changes from 1977 to 1985 and from 1985 to 1995 and correlated these with age. There was no significant relationship for 1977–1985 (Pearson's $r = -0.026$, $n = 403$, $P = 0.601$), and apparently no great tendency for people in general to be camped nearer farmers in 1985 than 1977. Between 1985 and 1995 there was a different picture. More people were camped near farmers in 1995 than in 1985 (probably due to the encroachment by farmers) and there was a significant correlation between age and increased proximity to farmers. But it was young Hadza who were camped nearer to farmers, not older Hadza (Pearson's $r = 0.259$, $n = 367$, $P < 0.0001$). There is no significant tendency for older Hadza to move near to farmers. Taking shelter near farmers thus seems unlikely to account for Hadza elder survivorship.

Farmer or herder neighbors protect modern hunter-gatherers from food shortage?

Both !Kung and Hadza have been observed regularly trading with, working for, and begging from farmers. In a world of hunters among hunters, opportunities for long-distance exchange may have been present but the availability of food to beg may have been much reduced. But evaluating the difference between the modern and ancient circumstance is not easy. Farmers have occupied the locations with the highest rainfall or best groundwater supply, thus perhaps areas of greatest biomass productivity (see Foley, 1982). Farmers or herders have degraded the environment in parts of !Kung and Hadza country. We may be observing forager mortality in degraded versions of the least productive habitats. The question can be posed as: "Do farmers give more food than they, 'take' by removing and degrading wild

habitat?" The 11% of the Hadza diet obtained from farm foods (1995–1996) could be weighed against the measurable percentage of land lost to farmers and the less easily measured loss of game and other resources. The balance is likely to tip in the direction of greater hardship for Hadza in recent years. In contrast, Balee (1992) claims that long-departed, undocumented farmers had enriched the Ache habitat.

Anthropological literature comments on the reliability of foraging and chanciness of farming, citing striking instances of farmers seeking refuge among foragers to escape famine due to crop failure. Lee (1979) gives an instance among the !Kung. Bagshawe (1924; p. 126) reports an instance in Hadza country "during the 1918–1920 famine hundreds of natives belonging to other tribes took refuge in their [Hadza] country and lived on game which the Hadza assisted them to kill." "There are amongst the tribe a few foreign girls, mostly Anisanzu, who married Kangeju [Hadza] men during the famine." Bagshawe (1924) and Obst's (1912) Hadza informants, present-day Hadza, and Datoga informants of Borgerhoff-Mulder, Sellen and Sieff (personal communication) in the 1990s report Datoga herders taking to the forager lifestyle after losing their cattle to the Maasai in the 19th century. They soon returned to herding but their clan are still remembered as the people who once lived among the Hadza as hunters. Opportunities for foragers to benefit from farmers are also quite evident. Might these opportunities have had significant affects on mortality or lifespan? How great could these effects be?

Among Ache in the forest period, the effect was surely minimal, or even negative. Stealing from farmers' fields was a very dangerous occupation, many Ache were shot by Paraguayans, and others were captured and enslaved. Trying to benefit from farm produce may thus have increased mortality! Howell (1979) dates the arrival in the Dobe area of a substantial number of herders to the 1950s and reports the lower mortality of !Kung born after 1950. In the 1960s and 1970s, many !Kung spent time at cattle posts, working for and begging off herd owners.

Hadza are so mobile and opportunistic that it might be hard to directly assess an effect of farm food. Marlowe's recent observation that even in 1995, in a sample of camps that included many close to farmers, the proportion of food of agricultural origin was only 11%, suggests the effect may be small (Marlowe, 1997). We tested for an effect of proximity to farmers upon Hadza mortality, using the ratings of camps by proximity to farmers. The proximity rating was entered as an independent variable to predict survival or death across the 5 years, 1985–1990, after controlling for age (age+age^2). There was no significant effect of proximity to farmers (P = 0.9350). This result is to be expected if Hadza are free to move to where food is most available to them. But with so few deaths this cannot be a very powerful test.

Predation

Hill and Hurtado (1996) begin their account of Ache demography with an informant's chilling story of the loss of a friend to a jaguar. Predation has loomed large in the evolutionary anthropologist's imagination, from Bowlby's (1969) account of the origins of the child's attachment to its caregiver, to contemporary discussions of the effectiveness of scavenging. Yet data on modern hunter-gatherers show few losses to predators. Ache greatly fear jaguars, and nine adults were reported killed by them but these contributed only .0235% of deaths. Snakebites contributed only .0548%. Hadza respect lions, and !Kung fear them, and deaths or serious injuries inflicted by lions have been reported. Yet in neither population is there a single death in the demographic data attributed to a large predator. Hadza and !Kung also regard buffalo as dangerous, and Hadza greatly fear elephants. Rhinoceros were abundant, and much feared by Hadza for their unpredictability during fieldwork in 1959–1961 by Woodburn (1964) but disappeared by the time Lars Smith was in the field in the mid-1970s. We have heard of no deaths of Hadza attributed to Rhinoceros. Bennett et al. (1973) report a number of injuries inflicted by wild animals, or sustained while running away from them. Such accidents continue. Falls from trees were a more common cause of injury and still are.

Is this low predation rate because modern foragers (but only men, not women) are well-armed (with bows and poison arrows, none had guns during the study periods), or because predators have become scarce? Li-

ons cannot be described as scarce in either sub-Saharan habitat during the main periods of data collection. !Kung researchers often saw lion tracks near their camps, often heard lions and hyenas at night. Between 1984 and 1992 in Hadza bush camps it was very unusual not to hear lions at night, and extraordinary not to hear hyenas. Numbers of these predators are likely to vary with numbers of prey, which is in turn closely linked to rainfall (Coe et al., 1976). In 1995 lions were noticeably scarce in Hadza country and they remain less often heard than before that time.

Perhaps lions took more foragers when there were no herders conducting a vendetta on lions. Blurton Jones and Konner (1976) linked the reportedly more cautious scavenging practices of !Kung as contrasted with Hadza to a difference in the behavior of lions in the two regions, which might result from the different practices of Herero pastoralists in Ngamiland (see also Howell, 1979), and Maasai and Datoga in northern Tanzania. Different abundance of prey might also account for the difference in lion behavior.

GETTING LEFT BEHIND

Walking was the only means of transport available to Hadza, !Kung, or Ache during the study periods. In each population, there are accounts of old and infirm people being left behind to die while camp mates moved. Such observations are well ingrained in the paleontological imagination and may well exemplify the final exit of many of the very old. But did mobility cause many deaths among the 45–65-year-olds? Would the recoverably sick 50-year-old who falls behind be left to die, or would they live to catch up another day? Has the penalty of mobility ameliorated in the world of hunters among farmers? Have outside ethics been imposed? Informant accounts seem to imply ambivalence, people were not easily abandoned. This might imply that it would be easy to persuade people to cease this practice, or alternatively that the "new" ethic would readily be acknowledged but the tough choices imposed by the forager lifestyle might nonetheless prevail.

Among the Hadza there are some cases of long survival and travel by the very infirm. A man who could barely walk (G.M. in Table 5) asked to be driven to a village. We obliged but years later found him many miles away, and he survived about another 10 years unable to walk without the aid of a pole. We also visited an old woman badly afflicted with leprosy, barely able to see or walk, and apparently confined to her house at Mongo wa Mono, site of a recent settlement effort. A couple of years later we found her 55 km away at her son's house. She had walked there and stayed until her death a year or so later. The case of desertion discussed by Woodburn in Lee and DeVore (1968) begins with the parents carrying the paralyzed boy from camp to camp for some years. Likewise, from at least 1985 to 1995 a blind youth's parents led him and fed him into their own late 70s. There are also reports of blind adults surviving for long periods among the !Kung. Hill and Hurtado (1996) report 11 deaths under their category "left behind" but also describe the case of an abandoned man who recovered and rejoined his band.

The significance of mobility for adult mortality must have always been quite variable. When !Kung move from one dry season waterhole to another they may cover some 20–30 miles in a day, across waterless and nearly shadeless country. Someone who embarked on such a journey and failed to complete it would have to spend a cold and dangerous night in the bush, with or without a helper. Among the Ache, with apparently daily trekking, anyone unable to keep up, or recruit help, must have been at considerable risk. Journeys accomplished by Eskimos and other northern foragers might be even more challenging. However, except among the Ache, little is known about the option of not embarking on the journey. Did it always mean staying alone in a totally exhausted habitat? Many camp movements involve camp fission. The infirm elder might be left with a less than optimal faction but nonetheless not alone.

If the goal is to estimate an average risk of a prehistoric African forager dying by being left behind, then Foley's (1982) argument is relevant. He points out that in Africa, contemporary foragers inhabit areas of lowest biomass productivity. Savanna areas of high productivity are now occupied by herders or farmers. This might imply that the !Kung situation is extreme and the Hadza situation is a more typical representation of prehistoric mobility. Hadza country is well-supplied with small water

sources. Although camp moves are frequent, the distances are often quite small. Woodburn (1968a) has described Hadza country as relatively rich in food resources. We think there may always have been only few fatal desertions among the Hadza, mainly because of the short distances traveled on most moves. Perhaps the "paleontological imagination" misunderstood the variability, extent, and nature of savanna hunter-gatherer mobility.

Changes in infant nutrition affect adult survivorship

Barker (1997) has shown that impaired fetal growth predicts higher adult mortality, suggesting that the fetus adjusts to impaired nutrition in ways that exert costs later in life. Impaired fetal growth leads to greater risk of several diseases of adult life, particularly coronary heart disease and diabetes. These "diseases of civilization" have little relevance to the adult mortality of contemporary hunter-gatherers (Barnicot et al., 1972, Truswell and Hanson, 1976). But if poor fetal nutrition were also to impair the immune system, forager mortality could be strongly affected by changes in maternal nutrition. There is no evidence for significant secular changes in maternal nutrition. Adult Hadza heights and weights do not differ between 1966–1967 (Hiernaux and Hartono 1980) and today. Both resemble the figures given by Obst (1912). It is also not clear whether the effects described by Barker are due to shortfall in mother's nutritional intake, or due to problems with pregnancy that might be related to stress, or genetic variation in response to stress, or parent–offspring conflict (Haig, 1993).

Accounting: the Hadza "worst case"

The investigations reported above give a better feel for possible variation in Hadza mortality. Here we attempt a crude "accounting" to show how Hadza survivorship would be affected by increases in the effects examined above. Researcher intervention probably saved one boy, no men, two girls, and two women in 10 years. Let us add deaths of three children and two adult women. Let us double the number of homicides, despite our having argued that policing had not held down the homicide rate. Thus, we add another four deaths of adults. We will count nothing for older people moving nearer farmers, they do not do it. We found no significant effect of proximity to farmers and we will ignore this. But we will assume that the opportunity to seek out medical help from government clinics saves one death per 5 years in each adult 5-year age class (12 classes, 12 deaths added for each 5 years for each sex, 48 added deaths). We add these 57 "deaths" to the life table. The deaths of the three children were added at the age they were when we intervened. The deaths of adults were added to any age for which zero deaths had been recorded. The deaths represent a 46% increase in the number of deaths used to calculate Qx and Ix. But the effect on the Ix curve is quite small, moving the Hadza down from near the Ache to near the !Kung, leaving a life expectancy at 45 of 19.3 years. We conclude that these features, or possible features, of the modern world have only a slight effect on the picture of adult survivorship obtained from contemporary hunter-gatherer populations and are not sufficient to suggest that postreproductive life is a product of the modern world.

How do the data from hunter-gatherers match the extrapolations from brain weight and body weight?

Comparative studies have extrapolated human life spans that are nearly as long as are observed in living populations. In the most recent comparative study, using 13 anthropoid subfamilies Hammer and Foley (1996) extrapolate *H. sapiens* maximum lifespan as between 66 and 78 years. Lifespan in the contemporary populations, defined as the age of the oldest individuals, is very vulnerable to sampling error and the difficulty of allotting ages to older individuals. The comparative method may smooth out some of this variation, being based on large numbers of species. A better way to compare the two sets of observations is to compare average adult lifespan, the expectation of life at onset of reproduction. The extrapolated maximum lifespans, converted by Charnov's (1993) formula, correspond to average adult life spans for *H. sapiens* of 26.2–30.9 years. If reproduction begins at 20 years, Hammer and Foley's, extrapolations can be compared with modern hunter-gatherer life tables and with Coale and Demeny (1983) life tables for other modern populations. Table 6 shows that Hammer and Foley's (1996) results are not far out of

TABLE 6. Maximum lifespan (Tmax), average adult lifespan (assuming first birth at 20, e20), for modern hunter-gatherers

	Tmax	Average adult lifespan (e20) from 0.4 Tmax–0.1	Observed average adult lifespan (e20)	Nearest model
!Kung	88	35.1	33.9	West 5 f.
Ache (forest)	77	30.7	39.8	
Hadza	84	33.5	41.4	North 6 f.
Hadza "worst case"			33.7	
H. sapiens upper estimate	77.6	30.9		West 3 f. North 1 f.
H. sapiens lower estimate	65.9	26.2		<West 1
Gainj			26.8	~West 1
Libben			16.2	

Hammer and Foley (1996) estimates for *H. sapiens* from body size and brain size, compared with Gainj (Wood, 1987), and Libben (Lovejoy et al., 1977).

line with observed life tables of modern hunter-gatherers, and are far from the reports of archaeological populations. The extrapolated average adult lifespan is close to that for the !Kung and the Hadza "worst case," and greater than that estimated for the Gainj horticulturalists in New Guinea by Wood (1987).

DISCUSSION

Ways in which mortality of adult contemporary hunter-gatherers might underestimate adult mortality of prehistoric hunter-gatherers were considered. "Modern influence" can be shown in the comparison of !Kung before and after 1950. Several potential modern influences were suggested, tested, and mostly discarded among the Hadza, and are barely imaginable for the Ache in the forest period. Such underestimation was not sufficient to explain away the 20-year life expectation of hunter-gatherers who reach 45 years of age. Comparative studies such as Hammer and Foley (1996) predict a human lifespan of 66–78 years from regressions of lifespan on brain and body weight. Converted to average adult lifespan, these results overlap with the figures from contemporary populations. These two sources support the conclusion that the evolved average adult lifespan for *Homo sapiens* includes a lengthy postreproductive period. Postreproductive life is not a product of civilization and modern circumstances, nor of agricultural or industrial economies.

Of course, confirming the existence of a postreproductive lifespan does not permit a choice between alternative explanations of this phenomenon. For example, we have given no attention to "by-product" accounts. For instance, if hunter-gatherer adult mortality remained constant throughout adult life (as apparently observed in some birds, see Stearns 1992), one could regard postreproductive individuals as the chance residuum of a constant rate of attrition of the adult population. Whether this situation truly applies to birds is disputed, and it would pose some interesting problems for life history evolution. Ache, Hadza, and !Kung show very similar adult mortality (Table 4). Each population also shows the usual Gompertz-like increase in probability of death in the late 60s and 70s. (These populations are too small to show the small "non-Gompertz" tail that currently interests both demographers and biologists, e.g., Partridge and Mangel, 2000.) The picture is compatible with Hamilton's (1966) picture of evolution of senescence, but only if we assume that individuals age 45–65 have reproductive value.

Two other possible lines of argument which seem likely to support our conclusion were omitted:

1) Demonstrating the comparative vigor of older adults. Whatever the mortality levels, hunter-gatherers appear to maintain physical ability at a similar level to, or better than observed in other active modern humans (Finch, 1990; see also Barnicot, 1972; Truswell and Hanson, 1976). For example, postreproductive Hadza women work longer hours and as effectively as younger women (Hawkes et al, 1997) and Hadza men aged 60 are about as good at target archery as men in their 30s (unpublished data collected by Marlowe and Blurton Jones). Kaplan (1994) plotted food production against age for Piro and Machiguenga horticulturalists and showed productivity continuing at a high level into the

60s. More systematic data on physical capacities of older foragers are needed in order to make a quantitative comparison of senescence.

2) Examining data from other Third World and historical populations. Many populations may show adult survivorship similar to contemporary hunter-gatherers (child mortality may vary much more), suggesting a life history that is almost universal, found everywhere except under industrialization, ad lib food, and advanced infrastructure and health services. However, published after the tabulations for this article were completed, Early and Headland (1998) may provide a contrary example from the Agta. Agta economy, with extensive trading of meat for rice and long-standing if limited horticulture, falls outside our economic definition of hunter-gatherer. But the existence of such a high-mortality population anywhere, and especially with a postreproductive survivorship somewhat worse than the !Kung and the Hadza "worst case," is important. From the figures available, an Agta 40-year-old can expect only about 16–17 more years. Because of the low maximum age apparently attributed, this figure should be compared to the years of expected life to age 70 in Table 4. Headland and Headland (1997) report the high mortality of the Agta as evidence of the progressive loss of their livelihood by a well-documented series of deprivations by outside forces. But without better understanding of the reported rates of death among 30-, 40-, and 50-year-olds, which exceed the highest mortality models in Coale and Demeny (1983), and among the 60-year-olds where mortality is lower than in the models, we cannot claim to have closed all argument about the extent of human postreproductive life.

Archaeological accounts do not agree with comparative extrapolations, or with the hunter-gatherer data; few describe individuals living beyond their 40s. The agreement between the comparative extrapolations and the modern data supports Howell's (1976) proposition that "the uniformitarian assumption" (that the overall pattern of age-specific fertility and mortality is similar for any human population) be employed by archaeological demography. To discard the uniformitarian assumption and support the view that few lived past 45 would require the following: a) to discard the comparative findings, and therefore require us to show why human life span should be so much shorter than predicted by patterns of correlation found among other taxa; b) to find some significant modern influence; and c) to show why the Ache, to whom none of the modern influences proposed and examined in this article can have applied, had adult survivorship so close to that of the other populations.

Hill and Hurtado (1996) discuss the unreality of excluding warfare from demographic models. It is excluded because it is often very extreme and very sporadic, and thus cannot be encompassed by stable population models. But many societies have existed in which warfare was frequent, if small-scaled. Among Ache, risk of homicide seems to have been constant, and high. We have seen no accounts of mortality due to warfare among !Kung. Data on the Hadza cover no period of warfare. Colonial and postcolonial governments may have reduced traditional indigenous warfare. Even today Hadza talk of a time when Hadza were killed in some numbers by Maasai. Early written accounts (Obst, 1912; Bagshawe, 1924–1925; Jaeger, 191l) suggest they are referring to a period sometime in the mid-to-late 19th century when Maasai expanded into Ngorongoro crater and other areas around Hadza country. Indeed, Blurton Jones et al. (1992) argued that Hadza population was still increasing from a low produced by these attacks. Had German colonization and Rinderpest not weakened the Maasai it is doubtful that Hadza would have survived into the 20th century.

The sparse historical information about epidemics and the Hadza was discussed earlier. Modern foragers have tended to isolate themselves from their densely populated neighbors. The isolation might have increased the intensity of epidemics but perhaps reduced their frequency. The dense population and connections to the larger world might have increased the frequency of epidemics among their neighbors. It is possible that in a world of hunters among hunters, diseases flowed more steadily and epidemics were less frequent and less severe, or that populations were simply too small to support certain diseases. As with the history of warfare, feeling runs so intensely in historical research on Africa and South America that we may be excused for

reserving judgment until less passionately overinterpreted data become available.

Discussing the very low adult mortality of the Ache, Hill and Hurtado (1996) suggested that a "sawtooth" pattern of rapid increase and sudden crash may not have been unusual in human population history. Their argument goes beyond the Ache illustration of such a pattern. Hill and Hurtado point out that rapid increase seems built in to human life history parameters. While Malthus suggested that human fertility must outrun available land, and Darwin modified this view to point out that populations must grow rapidly unless curbed by mortality (which then exerts selection), Hill and Hurtado (1996, p. 471) imply that perhaps human mortality could rarely have kept up with fertility: "foragers not affected by STDs do show completed family sizes of around six live births. Most also show survivorship to adulthood around 50%. This leads to a very high population growth that would be impossible to sustain. ...then juvenile mortality must have been around 67% during most of human history. Such high mortality has never been observed in any traditional population... An alternative view on human life history is that rapid growth has been a common characteristic of our species." Hill and Hurtado further point out that if human mortality levels were other than observed, we would be a very different animal. Higher adult or preadult mortality would lead to an earlier age at maturity, thus an earlier age at cessation of growth: we would be a smaller animal than we are.

Hill and Hurtado's suggestion needs to be approached cautiously. Fertility varies as well as child mortality, and the !Kung case shows that an approximation to zero population growth is possible in a hard environment. But if a sawtooth history does characterize the human species, its implications should be considered. Life history theory based on stationary populations may be inadequate [although there are some indications that selection due to rapid increase and selection at density dependence have similar effects on life history (Charlesworth, summarized in Stearns, 1992)]. Life history effects of repeated population crashes have not been explored theoretically, although population bottlenecks are expected to leave genetic traces (Harpending et al., 1993) and empirical study long ago recorded changes in gene frequency following a population crash. A key question is whether genotypes adapted to survive the rare disaster can prevail over those adapted to make the most of the longer periods during which rapid multiplication is possible.

The Hadza data support Hill and Hurtado's suggestion. Perhaps zero population growth cannot be regarded as the primitive condition of mankind. Would our attitudes to, and interventions with, population growth be different if we thought of rapid increase as the natural state of affairs, instead of as an annoying aberration of people in developing countries? As evolutionary anthropologists we should also continue to wonder about how such a life history came about.

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