AMERICAN JOURNAL OF PHYSICAL ANTHROPOLOGY 124:315–329 (2004)

Has the Transition to Agriculture Reshaped the Demographic Structure of Prehistoric Populations? New Evidence From the Levant

Vered Eshed,[1]* Avi Gopher,[2] Timothy B. Gage,[3] and Israel Hershkovitz[1,4]

[1]*Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv 69978, Israel*
[2]*Institute of Archaeology, Tel Aviv University, Tel Aviv 69978, Israel*
[3]*Department of Anthropology, University at Albany-SUNY, Albany, New York 12222*
[4]*Cleveland Museum of Natural History, Cleveland, Ohio 44106-1767*

KEY WORDS paleodemography; agricultural revolution; Natufian; Neolithic; skeletal populations

ABSTRACT This paper presents the demographic changes that followed the transition from a hunting-gathering way of life (Natufian) to an agricultural, food-producing economy (Neolithic) in the southern Levant. The study is based on 217 Natufian (10,500–8,300 BC) skeletons and 262 Neolithic (8,300–5,500 BC) skeletons. Age and sex identification were carried out, and life tables were constructed. A five-parameter competing hazard model developed by Siler ([1979] Ecology *60:*750–757) was used to smooth life-table data. No indication of increased mortality with the advent of agriculture was noted. On the contrary, both life expectancy at birth (24.6 vs. 25.5 years) and adults' mean age at death (31.2 vs. 32.1 years) increased slightly from the Natufian to the Neolithic period (assuming stationary populations). Yet the transition to agriculture affected males and females differently: mean age at death in the Natufian was higher for adult females compared to adult males, while in the Neolithic, it was the reverse. One interpretation given to the distribution of female ages at death is that with the onset of the Neolithic period, maternal mortality increased as a result of a concomitant increase in fertility. If the adoption of agriculture in the Levant increased the rate of population growth at the beginning of the Neolithic, expectation of life may have increased dramatically. Am J Phys Anthropol 124: 315–329, 2004.

At the end of the Pleistocene and beginning of the Holocene, the eastern Mediterranean region witnessed one of the greatest revolutions of mankind, the abandonment of the long-time traditional economy of hunting and gathering in favor of agriculture. This transition had an impact on all aspects of human life, including demography. Greater control over food resources might have improved human health, leading to greater life expectancy and increasing fertility. Yet farming creates dense, permanent settlements (infectious diseases), daily contact with livestock (zoonoses), and changes in diet that could increase the risks to human health. The effect of the transition to agriculture on the demography of human populations is still an unanswered question, over which anthropologists' opinions remain strongly divided. Cohen and Armelagos (1984) summarized the major changes following the transition to agriculture in various parts of the world as follows: higher rates of infection; declines in overall quality of nutrition; reduction in physical stress; and declines in mean age at death (and/or life expectancy at various ages). Yet not all studies agree with these conclusions. For example, lower mean age at death among agriculturalists compared to hunter-gathers was interpreted to reflect an increase in mortality and declining life expectancy with the shift to agriculture (Cohen and Armelagos, 1984; Kennedy, 1984). However, mean age at death is related to fertility and birth rate, and not mortality (Sattenspiel and Harpending, 1983). Human populations experiencing growth will have a greater number of younger individuals, resulting in a larger proportion of juvenile relative to adult skeletons. In many parts of the world, birth rate increased during the adoption of agriculture, and mortality showed no change over the same period (e.g., Buikstra et al., 1986). Johansson and Horowitz (1986) claimed that when one considers the wide variety of ecological conditions under which local populations adopted agricul-

Grant sponsor: CARE; Grant sponsor: MAFCAF; Grant sponsor: Leakey Foundation.

*Correspondence to: Vered Eshed, Department of Anatomy and Anthropology, Sackler Faculty of Medicine, Tel Aviv University, Tel Aviv 69978, Israel. E-mail: veredes@post.tau.ac.il

Received 7 June 2002; accepted 3 April 2003

DOI 10.1002/ajpa.10332
Published online 19 November 2003 in Wiley InterScience (www.interscience.wiley.com).

ture, it is reasonable to expect a wide variety of demographic responses to the adoption and intensification of agriculture.

PEOPLE IN CHANGE IN THE SOUTHERN LEVANT

The Natufian culture is dated to ca. 10,500–8300 BC (all dates in this paper are uncalibrated C-14 years BC), and is generally divided into three major chronological phases Early (12,500–11,500 BC), Middle (11,500–10,700 BC), and Final (10,700–10,250 BC). Natufian sites are found throughout the Levant, yet the center of this culture was in the southern Levant. Natufian economy was intensive and diverse, based largely on hunting (mainly gazelles) and gathering (mainly cereals). Natufian sites include relatively large base camps (up to 0.2 hectares), sedentary or semisedentary sites, and ephemeral, task-specific sites, small in area. Base camps constitute stone structures and usually contain onsite human burials. Most burials are primary and of a single individual, although secondary and multiple burials are also observed. Burial offerings are sometimes found on or around the interred.

The early (prepottery) Neolithic (PPN) period in the southern Levant is dated to ca. 8250–5500 BC, and is divided into three major phases: PPNA (the earliest; 8250–7400 BC), PPNB (7400–6100 BC), and the PPNC (the latest; 6100–5500 BC). Prepottery Neolithic sites are found throughout the Levant in a variety of environments. Prepottery Neolithic economy shows the earliest evidence for plant domestication in the 8th millennium BC. Domesticated animals appear in the southern Levant later in the 7th millennium BC, yet hunting continues throughout the PPN period. Neolithic sites vary largely in size. There are "megasize" sites of 10–15 hectares, usually built in stone and mud bricks, creating a whole new anthropogenic landscape, as well as small temporary sites of a few huts. Burial in the PPN is on-site and is spread everywhere, i.e., in houses (under floors) or courtyards. It includes primary and secondary burials, mostly of single individuals, but group burials are also evident (Hershkovitz and Gopher, 1988). A conspicuous trait of PPN burial customs is the detachment of adult skulls and their burial in a separate context.

DEMOGRAPHIC CONSEQUENCES OF THE AGRICULTURAL REVOLUTION IN THE LEVANT

Three major factors must be considered when the demographic profile of a prehistoric population is being constructed and analyzed: subsistence, social customs, and health. The first two are discussed in details along the paper. As for the health status of the two populations, very little is known. Neolithic populations were exposed to two major life-risk factors: first, there were infectious diseases (habitation in sedentary dense sites and domestication of animals). Indeed, Eshed (2001) demonstrated a high increase in inflammatory diseases from the Natufian (10%) to the Neolithic (39%) population. Second, there were ecological diseases (cultivating low-land marshy areas). Angel (1973) and Hershkovitz and Edelson (1991) showed that *Falciparum malaria* posed a great risk to human life during the Neolithic, as the first farmers preferred to settle along year-round body water.

In what way has the change in economic strategies in the Levant affected the demographic profile of Neolithic populations? The demographic characteristics of southern Levant populations before and after the transition to agriculture are poorly known due to the small Neolithic sample sizes available to previous studies. Hassan (1981), who was the only one to construct life tables for the Natufian population (from Hayonim Cave), calculated a life expectancy of 23.6 years. Hershkovitz and Gopher (1990), based on the skeletal sample available at the time, claimed that the demographic profile of Neolithic populations differed significantly from that of their predecessors, the Natufians. Among their major findings were: a decrease in mean age at death from Natufian hunter-gatherers to Neolithic farmers; an increase in the child/adult ratio from the Natufian (23.1/100) to the Neolithic (32.3/100) period; and an increase in the number of adult females, from 31.8% in the Natufian to 48.1% in the Neolithic. Based on their findings, Hershkovitz and Gopher (1990) suggested a demographic shift in the Neolithic (due to cultural as well as economical changes), which ultimately resulted in population growth. Belfer-Cohen et al. (1991), in a study of Natufian populations, reported similar trends: low proportions (23.0%) of children (<12 years), ranging from 16.3% in Eynan to 37.8% in Shukba (with the largest sites, e.g., El-Wad and Eynan, yielding the lowest proportion of children compared to smaller sites); representation of children decreasing throughout (from Early to Late and Final Natufian); scarcity (ca. 7%) of elderly Natufians (>45 years); and number of adult (>13 years) males much greater than number of females (68.6% vs. 31.4%). However, the proportion of females increases from the Early to Late and Final Natufian.

Hershkovitz and Gopher (1990) were unsure of how well the available skeletal sample reflected the real mortality of the populations studied, and stated that "the age at death distribution in both Natufian and Pre-Pottery Neolithic sites may be a reflection of a variety of extraneous . . . rather than a picture of the actual age at death pyramid of the populations". . ."moreover, 40% of the total skeletal sample could not be sexed confidently" (Hershkovitz and Gopher, 1990, p. 23, 26). In addition, their analysis included the skeletal material from Jericho (Kurt and Rohrer-Ertl, 1981), which has since proved to be unreliable, since sex and age identification was carried out in the field in the early 1950s.

The quantity and quality of Natufian and particularly Neolithic skeletal assemblages have increased considerably, due to extensive excavations of old and new sites since Hershkovitz and Gopher (1990). Two newly excavated large Neolithic sites, Atlit-Yam, a submerged site off the Carmel coast (Galili et al., 1993), and Kfar Hahoresh in the Lower Galilee (Goring-Morris et al., 1998; Goring-Morris, 2000), yield, for the first time, large enough skeletal samples for single-site analysis. Furthermore, the establishment of the prehistoric skeletal collection at Tel Aviv University enabled us to study all the skeletal material included in this paper, and to apply new analytical methods ourselves. All previous large-scale studies (Smith et al., 1984; Hershkovitz and Gopher, 1990; Belfer-Cohen et al., 1991) were partially based on data gathered from published reports.

The aim of this paper is to reconstruct the demographic profile of Natufian and prepottery Neolithic populations using Hazard analysis, and to reveal the major demographic changes that accompanied the transition from a hunting and gathering to an agricultural economy in the Levant. The present study will tell us if and in what way human demography changed course with the adoption of food-producing strategies at the beginning of the Holocene in the Levant. The adoption of agriculture was a no-return point in human history, and changed radically the relationship between man and his environment. In less than a few centuries, a million of years of the hunting and gathering way of life were replaced by a new mode of subsistence, consequently leading to a change in all aspects (biological and social) of human life.

MATERIALS

The Natufian sample consisted of 217 individuals (66 immature, and 151 adults). The prepottery Neolithic sample comprised 262 individuals (66 immature, and 196 adults). The Natufian and Neolithic samples are listed in Table 1, and site locations are shown in Figure 1. All skeletal material presented in this study, except the three PPN sites from south Sinai and the Natufian Mugharet el Wad site, are part of the collection of the Sackler Faculty of Medicine, Tel Aviv University.

The combined Natufian sample is composed of skeletal material obtained from three sites: Ain Mallahah (Eynan), Hayonim Cave and Terrace, and Nahal Oren (see Table 1). Ain Mallaha is located in the Hula basin, Upper Galilee, and is a major open-air, multilayer Natufian site in which major parts of the Natufian sequence are represented (Valla et al., 1998). The site of Hayonim Cave and Terrace is located in the Western Galilee, including both Early and Late Natufian. Skeletal remains were found in unpaved pits, excluding two that were constructed of limestone slabs. Nahal Oren, in the Carmel ridge, is an open-air terrace/slope site of the Late/Final Natufian. Human skeletal remains were mostly found in a restricted burial ground within the site. Graves are simple pits dug into the ground, with stones on the skeletons. Generally, most of the Natufian skeletons were found in flexed positions and in a clear archaeological context.

TABLE 1. Natufian and Neolithic sample used in this study

Natufian sites	Immature	Adults	Total
Ain Mallaha[1–3]	28	74	102
Erq el Ahmar[4]	0	6	6
Et Tin[5]	1	4	5
Hayonim Cave[6]	16	32	48
Mugharet el Wad[7]	0	11	11
Nahal Oren[8,9]	10	31	41
Rakefet[9]	2	2	4
Total	57	160	217
Neolithic sites			
Abu Gosh[10]	3	27	30
Abu Madi[11]	0	1	1
Atlit Yam[9]	22	38	60
Beisamoun[10]	7	12	19
Gilgal[9]	2	1	3
Hatoula[12]	0	10	10
Horvat Galil[13]	1	3	4
Kfar Hahoresh[9]	17	35	52
Nahal Hemar[14]	1	17	18
Nahal Oren[9]	1	10	11
Netiv Hagdud[15]	9	18	27
Ujrat el Mehed[11]	0	17	17
Wadi Tbeik[11]	0	2	2
Yiftahel[9,16]	3	5	8
Total	66	196	262

[1]Soliveres-Massei, 1988.
[2] Bocquentin et al., 2001.
[3] Valla et al., 1998.
[4] Vallois 1936.
[5] Lahr and Haydenblit, 1995.
[6] Belfer Cohen, 1988.
[7] McCown, 1939.
[8] Crognier and Dupouy Madre, 1974.
[9] Unpublished new material.
[10] Arensburg, 1978.
[11] Hershkovitz et al., 1994.
[12] Le Mort, 1989; Le Mort et al., 1994.
[13] Hershkovitz and Gopher, 1988.
[14] Arensburg and Hershkovitz, 1988.
[15] Belfer-Cohen et al., 1990.
[16] Hershkovitz et al., 1986.

The Neolithic samples include finds from PPNA-PPNB and PPNC sites. The PPNA sample originates from four sites, with two major samples from Netiv Hagdud and Hatoula. Netiv Hagdud is a large tell site (1.5 hectares) in the Lower Jordan Valley (Bar-Yosef and Gopher, 1997), while Hatoula is a small slope site (0.1–0.2 hectare) in the Judean Hills. Burials were found on-site in intra- or extramural contexts. The two other PPNA samples, from Gilgal I and Abu Maadi, are small. None of the PPNA sites showed domesticated animals (hunting continued as the only meat procurement method). Cereals were consumed in the PPNA sites of Netiv Hagdud and Gilgal, and may have been cultivated. The PPNB sample includes all parts of the PPNB (Early, Middle, and Late). The Early PPNB sample is small, coming from one large tell site (Horvat Galil) in the Upper Galilee, and one small slope site (Nahal Oren). The major PPNB sample is that of the Middle PPNB, coming mainly from Kefar Hahoresh and Abu Gosh. Kefar Hahoresh is a medium-sized site

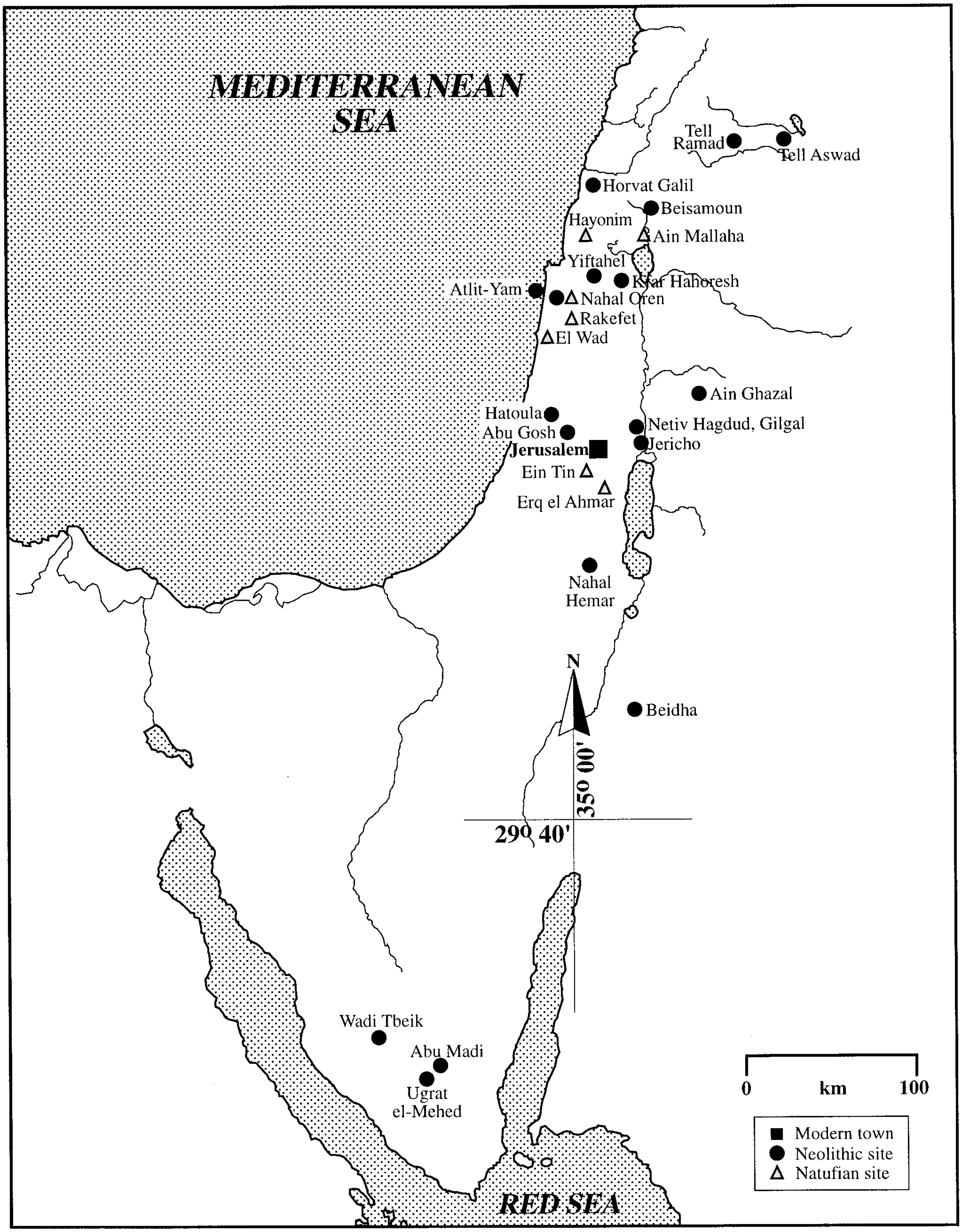

Fig. 1. Map of main Natufian and Neolithic sites in Levant.

(0.8 hectare), recently excavated and interpreted as a burial site (Goring-Morris et al., 1998; Goring-Morris, 2000). Abu Gosh is a small slope site (0.5 hectare) where burials were associated with houses and courtyards (Lechevallier, 1978). The sample from the Nahal Hemar Cave is very special, a small and isolated cave in which a rich inventory of paraphernalia and skeletal remains was found, including uniquely treated skulls (Arensburg and Hershkovitz, 1988). The Late PPNB sample is restricted to Beisamoun, a large open-air site in the Hula basin. Burials were found in association with houses including treated (plastered) skulls (Lechevallier, 1978). The PPNC sample comes from Atlit-Yam, and is unique in being retrieved from the bottom of the sea in the Atlit Bay, some 8–12 m below sea level (Galili et al., 1993).

Considering the nature of the Natufian and Neolithic cultures, we can assume that burials on-site represent a repository of individuals who, during their lifetimes, were socially related. Furthermore, there are no indications for nonrandom interments due to social, economic, or religious factors in these periods. Knowing the burial customs in the Natufian and Neolithic, we can assume that most of the deceased were buried on-site. The fact that many burials in these periods were protected (e.g., under plastered floors, in constructed pits) allows the assumption that most skeletons (including females and children) are represented in the sample. There is no archaeological and anthropological evidence to believe that only selected members of the community were buried within the geographical boundaries of the site. Finally, as none of the sites were completely excavated and sampling techniques are difficult to apply (people were buried within living quarters rather than in organized cemeteries), the sample obtained from each site may not ultimately reflect the composition of the population. Yet, by combining neighboring samples from several sites, we partially overcome this problem.

METHODS

Minimum number of individuals (MNI)

This parameter was calculated using the greatest number of same age-range-related diagnostic and indicative bones. The sample included all individuals recovered from what were interpreted as intended burial contexts, whether primary or secondary. Isolated skulls were not included in the count, since it is possible that the postcranial bones of the same individuals were recovered from other parts of the site. Scattered bones of children were taken into consideration only if their ages were not represented in the sample.

Sex determination for the adult population

Sex identification for all individuals over 15 years of age was based on the following methods: morphology of the skull and long bones (Bass, 1987), morphology of the innominate (Bass, 1987; Segebarth-Orban,1980; Washburn, 1948), and the vertical diameter of the femoral head (Bass, 1987). For 63 Neolithic individuals (24.0%) and 64 Natufian individuals (29.5%), sex could not be determined.

Age determination

Adults were defined as individuals over 15 years of age. Ages were determined using the following criteria: metamorphosis of the auricular surface of the ilium (Lovejoy et al., 1985a), metamorphosis of the pubic symphysis (Brooks and Suchey, 1990), stages of tooth attrition (using standards modified from Hillson, 1986; Lovejoy, 1985), metamorphosis of the sternal end of the ribs (Loth and Iscan, 1989), and the presence of osteophytes and arthritic lesions on the vertebra (Nathan, 1962). For young adults, i.e., 15–25 years, the following additional criteria were used: closure of epiphyses on the long bones (Johnston and Zimmer, 1989), and closure of the sternal ends of the clavicles (Szlivassy, 1980). For the subadult class (under 15 years), we used the following criteria: the length of long bones without the epiphyses (Bass, 1987), stages of tooth eruption and development (Ubelaker, 1989), and closure of the epiphyses of long bones (Johnston and Zimmer, 1989).

A final estimated age for each skeleton was computed by averaging the data obtained from the different aging methods. For 88 Neolithic individuals (33.5%) and 55 Natufian individuals (25.3%), age could not be determined. The age and sex of each individual were determined by one of the authors (V.E.).

Life-table construction

Calculating life tables is the most useful technique for dealing with mortality. Life tables were constructed using 5-year age intervals to age 20, and 10-year age intervals at older ages. Final life tables are presented in 10-year intervals (Ubelaker, 1974). All adult individuals for whom age could not be determined were divided into adult age categories according to the relative frequency of individuals found in each age group. This was based on the assumption that the observed percentage of the age groups represents the real mortality pattern of the population. We also smoothed the life tables using a five-parameter competing Hazard model developed by Siler (1979), using the methods described in Gage (1988). This model facilitates life-table construction without imposing a particular age pattern of mortality on the data. It can be applied to small populations and can "correct" defective data and smooth random variation in age-specific mortality resulting from small sample sizes (Gage, 1988). Using the model by Siler (1979), we constructed life tables assuming stationary populations and assuming stable populations with a 1% growth rate.

In general, we expect stationary or very low population growth rates for hunter-gathers just prior to

TABLE 2. Age and sex distribution in Neolithic populations

Site	N	Sex: M	F	?	C	Age: 0–5	5–10	10–15	15–20	20–30	30–40	40–50	>50	>15
Gilgal	3	1			2	1	1			1				
Hatoula	10	3	5	2					1	2	1	1	2	3
Abu Gosh	30	7	3	17	3	3 (5–10)		4	4		2			17
Abu Madi 1	1		1						1					
Beisamoun	19	3	4	5	7	6	1							12
Horvat Galil	4	1	2		1		1			1				2
Kfar-Hahoresh	52	17	5	13	17	11	4	2	2	11	5	5	0	12[2]
Nahal Hemar	18	14		3	1	1				1	1	2	1	9
Nahal Oren	11	1	1	9	0		1		1	1	4		2	2[1]
Netiv-Hagdud	27	8	3	7	9	6 +2 (0–10)	1	7 (10–20)						11
Ujrat El Mehed	17	9	6	1	1		1(<15)		1					15
Wadi Tbeik	2	2												2
Yftahel	8	2	3		3	3			2	1		1		1
Atlit Yam	60	19	13	6	22	11	7	4	5	6	5	4	5	13[3]
Total	262	87	46	63	66	39	16	10 +1 (<15) +5 (<10)	17 +7 (10–20)	24 +7 (>20)	18 +5(>30)	13 +2 (>40)	10	88
After adding individuals aged specifically unknown														
Sum	262	87	46	63	66	43	18	12	38	50	42	33	26	
%	262	33	18	24	25	16.5	6.8	4.5	14.5	19.3	16.1	12.7	9.7	

[1] 1 individual from this group is >20 years old.
[2] 1 individual is >40 years, 4 individuals are >30 years, 4 individuals are >20 years.
[3] 1 individual is >30 years, 2 individuals are >20 years.
N, total number of individuals; M, male; F, female; ?, sex could not be determined; C, children (years < 15 years).

TABLE 3. Age and sex distribution in Natufian population by site

Site	N	Sex: M	F	?	C	Age: 0–5	5–10	10–15	15–20	20–30	30–40	40–50	>50	>15
Ain Mallaha	102	24	14	36	28	17	9	2	9	12	11	10	3	29
Hayonim	48	20	5	7	16	8	5	1	6	8	3	4	0	11[1]
						+1 (5–15) + 1(0–15)								
Nahal Oren	41	10	6	15	10	4	6	0	1	6	6	5	1	12[2]
Rakefet	4	1	1	0	2	0	0	2	0	0	2	0	0	0
Et Tin	5	0	0	4	1	0	1	0	0	0	0	0	0	4
Erq El Ahmar	6	3	1	2	0	0	0	0	0	2	0	0	0	4[3]
El Wad	11	8	3							4	7			
Total	217	66	30	64	57	29	21	5	16	32	29	19	4	55
						+1 (5–15) + 1 (0–15)				+2 (>20)	+2 (<30)	+1 (>40)		
After adding the individuals aged specifically unknown														
Sum	217	66	30	64	57	30	22	5	25	52	45	31	7	
%	100	30.4	13.8	29.5	26.3	13.6	10.2	2.4	11.7	24.0	20.8	14.2	3.0	

[1] 1 individuals from this group is >20 years, and 1 individual is >40 years old.
[2] 1 individual from this group is >20 years old.
[3] 2 individuals are 15–30 years old.
N, total number of individuals; M, male; F, female; ?, sex could not be determined; C, children (years < 15 years).

the advent of agriculture (Carneiro and Hilse, 1966; Hassan, 1981; Hershkovitz and Gopher, 1990). Natufian site analysis by subperiod (Early, Late, and Final) bears out the above anticipation, and it is even possible that a decline in population took place towards the Late and Final Natufian (Belfer-Chosen, 1991; Bar Yosef, 1998, 2001). However, with the advent of agriculture, populations expanding into the new "cultural" habitat might display substantial population growth.

Statistics

All statistical analyses were carried out using StatView for Macintosh.

RESULTS

Minimum number of individuals

The combined Neolithic sample included 262 individuals, 66 of whom were children. This includes 87 adult males and 46 adult females (Table 2). The Natufian sample consisted of 217 individuals, 57 of whom were children. Of the adult population, 66 individuals were males, and 30 were females (Table 3).

Adult age ratio

Sex ratio (males/females) $\times$ 100 is similar in both populations: 189 in the Neolithic, and 220 in

TABLE 4. Life tables for Neolithic population

Age group	Number of deaths	Percentage of deaths	Survivors entering	Probability of death	Total years lived between age X and X + 5	Years lived beyond age X	Life expectancy
Raw data stationary population							
(X)	(Dx)	(dx)	(Ix)	(qx)	(Lx)	(Tx)	(e^0x)
0–9	61	23.2	100.0	0.2	883.9	2,552.9	25.5
10–19	50	19.0	76.8	0.2	673.0	1,668.9	21.7
20–29	50	19.3	57.8	0.3	481.8	996.0	17.2
30–39	42	16.1	38.5	0.4	304.7	514.2	13.3
40–49	33	12.7	22.4	0.6	160.7	209.5	9.3
50<	26	9.7	9.7	1.0	48.7	48.7	5.0
Sum	262	100			2,552.9		
Smoothed life tables using the Siler (1979) model stationary population							
(X)			(lx)	(qx)	(Lx)	(Tx)	(e^0x)
1			100.0	0.9	951.9	2,550.4	25.5
10			78.5	0.2	777.7	1,782.5	22.6
20			61.0	0.3	601.5	1,081.9	17.7
30			41.8	0.4	409.4	566.5	13.5
40			23.8	0.6	230.9	240.3	10.0
50			10.2	0.9	09.7	74.8	7.3
Sum					2981.1		
Smoothed life tables assuming 1% rate of population growth							
(X)			(lx)	(qx)	(Lx)	(Tx)	(e^0x)
1			100.0	0.8	956.5	3,106.4	31.0
10			85.9	0.1	855.2	2,299.2	26.7
20			73.8	0.2	730.9	1,494.7	20.2
30			55.9	0.3	549.8	514.2	15.0
40			35.1	0.5	341.6	209.5	10.9
50			16.7	0.9	159.4	48.7	7.7
Sum					3,593.4		

TABLE 5. Life tables for Natufian population

Age group	Number of deaths	Percentage of deaths	Survivors entering	Probability of death	Total years lived between age X and X + 5	Years lived beyond age X	Life expectancy
Raw data, stationary population							
(X)	(Dx)	(Dx)	(Ix)	(qx)	(Lx)	(Tx)	(e^0x)
0–9	52	23.8	100.0	0.2	880.9	2,465.3	24.7
10–19	30	14.1	76.2	0.2	691.0	1,584.4	20.8
20–29	52	23.9	62.0	0.4	500.5	893.4	14.4
30–39	45	20.8	38.1	0.5	276.6	392.8	10.3
40–49	31	14.2	17.2	0.8	101.2	116.2	6.7
50<	7	3.0	3.0	1.0	15.0	15.0	5.0
Sum	217	100			2,465.3		
Smoothed life tables using the Siler (1979) stationary population							
(X)			(Ix)	(qx)	(Lx)	(Tx)	(e^0x)
1			100.0	0.4	976.7	2,466.5	24.6
10			79.9	0.1	792.5	1,678.7	21.0
20			63.9	0.3	630.2	954.3	14.9
30			42.0	0.5	408.4	419.9	9.9
40			18.7	1.0	158.0	100.8	6.3
50			3.9	1.9	35.9	15.1	3.7
Sum					3,001.7		

the Natufian ($\chi^2 = 0.280$, df = 1, $P = 0.596$). This means that for every adult female, in both populations, there were approximately two adult males.

Assuming stationary conditions, life expectancy at birth ($e^o x$) for the Neolithic population is 25.5 years (Table 4), similar to that of the Natufians at 24.6 years (Table 5). The mean age at death for adults is 32.1 years in the Neolithic population and 31.2 years in the Natufian population. Finally, the percentage of deaths in the 15–20 years cohort is similar in both periods: 14.5% in the Neolithic, and 11.5% in the Natufian period ($\chi^2 = 0.925$, df = 1, $P = 0.336$) (Tables 2 and 3, and Fig. 2).

Demographic comparison between the Natufian and the Neolithic samples, however, revealed sev-

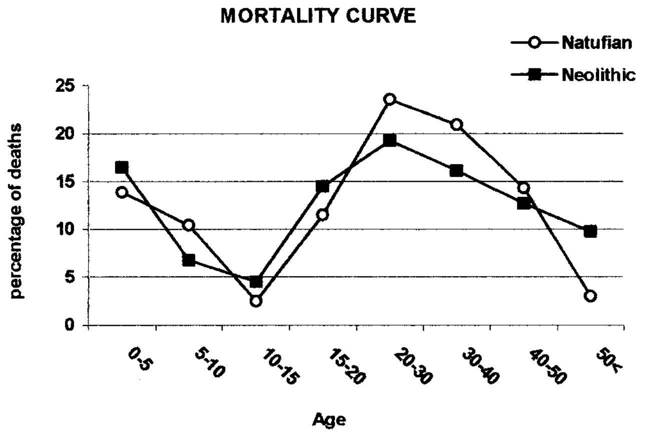

Fig. 2. Mortality curve for Natufian and Neolithic populations.

eral interesting differences: 1) when gender is considered, mean age at death for Neolithic males is 37.6 years, and for females, 30.1 years, while for Natufians males it is 32.2 years, and for females, 35.5 years; 2) between 20–50 years, a higher percentage of deaths occurred in the Natufian (58.9%) compared to the Neolithic (48.1%) (χ^2 = 5.656, df = 1, P = 0.0174). In older adults (>50 years), the trend reverses, with more deaths in the Natufian population (9.7% vs. 3%; Tables 2 and 3 and Fig. 2) (χ^2 = 8.301, df = 1, P = 0.004). This clearly indicates that more people reached old age (>50 years) in the Neolithic period. Life expectancy ($e^o x$) at age 40 years is therefore lower for the Natufian population compared to the Neolithic: 6.7 years vs. 9.3 years, respectively (Tables 4 and 5). Similar results (Figs. 3, 4) are obtained when the data are smoothed by the model of Siler (1979), assuming that both populations are stationary (6.3 years vs. 10.1; Tables 5 and 4, respectively). If the Natufian population was stationary while the Neolithic population was growing at 1% rate, expectation of life in the Neolithic would increase to 31.1 years (Table 4).

Mortality by sex for the three first adult age cohorts (15–20, 20–30, and 30–40 years old) is different between the Natufian and Neolithic populations (Tables 6 and 7; Figs. 5, 6). In the Natufian population until age 40 years, male mortality is higher than female mortality, although this difference is not significant (χ^2 = 2.105, df = 1, P = 0.146; 81% vs. 64%). The trend is reversed for adults over age 40 years, where male mortality was 19%, compared to females at 36% (Fig. 5). In the Neolithic period (Fig. 6), female mortality is higher than male mortality in the younger-adult age category of 15–40 years old: 78% vs. 58.3%, and more males are found over 40 years of age (χ^2 = 3.710, df = 1, P = 0.054). This indicates a higher mortality rate among Neolithic females of childbearing age (15–20 years) compared to Natufian females, i.e., 24.4% in the Neolithic vs. 3.3% in the Natufians (χ^2 = 5.960, df = 1, P = 0.014; Table 7). These mortality rates by sex and age should be viewed cautiously, however, as only 60% of the Natufian and 67.9% of the Neolithic adult skeletons could be sexed.

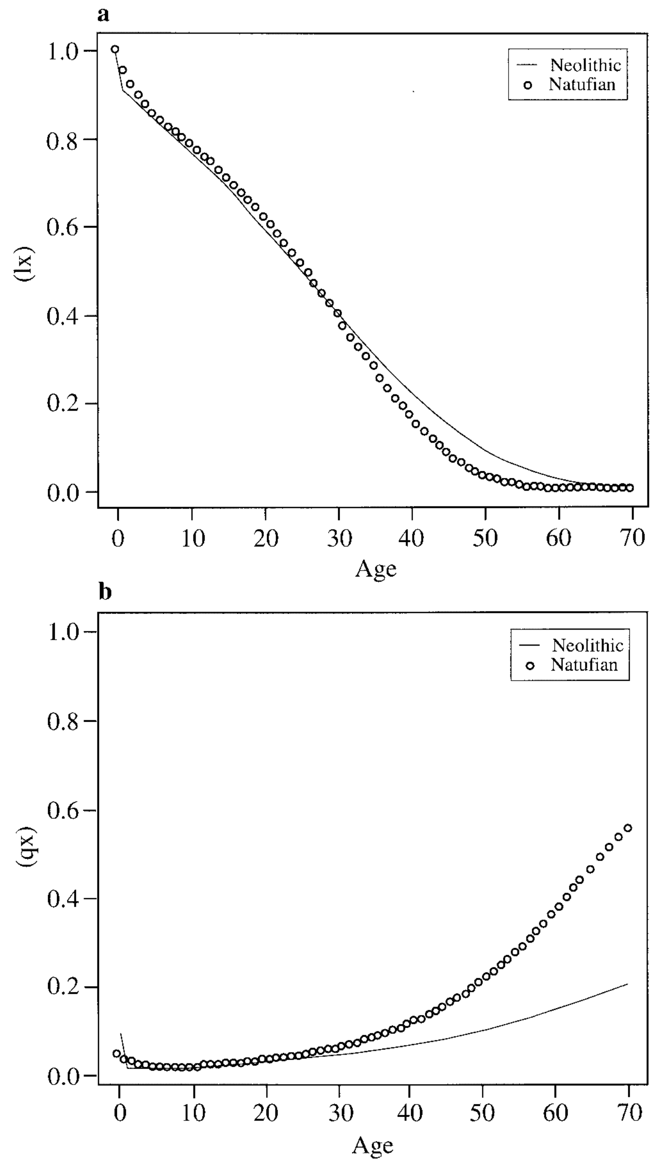

Fig. 3. Comparison of (**a**) survivorship curve (lx) and (**b**) mortality curve (qx) for Neolithic and Natufian populations, assuming both populations are stationary (data smoothed; model of Siler, 1979).

Childhood mortality

The child/adult ratios are similar in both populations: 0.29 for the Neolithic, and 0.28 for the Natufian (χ^2 = 0.072, df = 1, P = 0.788). Childhood mortality was highest among infants and young children (0–5 years) in both populations: 16.5% in the Neolithic, and 13.9% in the Natufian (Fig. 2). After age 5 years, mortality decreases steadily until age 15 years: 6.8% and 4.5% in the Neolithic and 10.4% and 2.5% in the Natufian, for the age cohorts 5–10 and 10–15 years, respectively (Tables 2 and 3, and Fig. 2). The relative proportion of child death

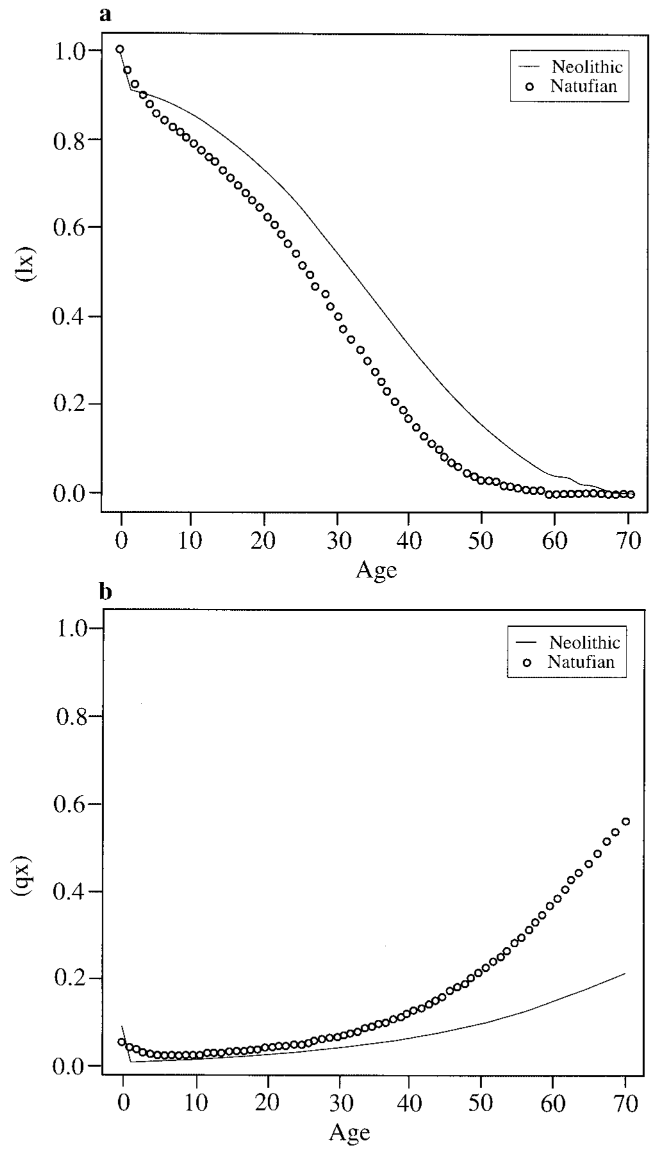

Fig. 4. Comparison of (**a**) survivorship curve (lx) and (**b**) mortality curve (qx) for Neolithic and Natufian populations, assuming stationary Natufian population and stable Neolithic population with 1% growth rate.

(0–20 years) in 5-year intervals, for both the Natufian and Neolithic, appear in Figure 7a,b. The weight of child mortality, measured as (N_{0-5}/N_{0-20}), was similar in both periods: 36.5% vs. 38.7%, respectively ($\chi^2 = 0.093$, df = 1, $P = 0.760$).

A true or false difference?

The main difference between Natufian and Neolithic mortality curves lies in the higher mortality rate among the Natufian people between age 20–40 years (Fig. 2). The difference appears to be almost entirely collapsible into change in young adult females. Is this difference real, or simply the result of bias due to nondemographic factors such as methodological deficiencies, sampling problems, or cultural differences in burial practices? To answer this question, we separately analyzed three large base-camp Natufian sites: Ain Mallaha, Nahal Oren, and Hayonim (Table 3). When the three Natufian sites are compared (Fig. 8), results show only one exception in the 30–40-year cohort: while the Hayonim population displays a low mortality rate at 9.2%, the two other populations, Ain Mallaha and Nahal Oren, display considerably higher mortality rates at 17.7% and 23.9%, respectively.

DISCUSSION

As there is very little agreement among anthropologists regarding the degree of validity of paleodemographic analysis, we chose to open our discussion by presenting the limitations of the present study. There are two sources of error in the paleodemographic methodology: 1) sampling and preservation problems, and 2) problems associated with the assumption of stationary populations. Constructing life tables for archaeological populations is problematic due mainly to inadequate sampling and problems with sex and age determination (Hassan, 1981; Konigsberg and Frankenberg, 1992; Hoppa and Vaupel, 2002). Estimated average age based on various methods introduces bias into adult ages (Lovejoy et al., 1985b; Paine and Harpending, 1998), and is likely to affect the results of a demographic study. Nevertheless, considering the fragmentary nature of many of the skeletons studied, the method used in the present study (average age) will yield the best results (Bedford et al., 1993). Considering the nature of the evidence used to obtain vital statistics for the dead precludes the attainment of the degree of reliability and accuracy possible for living populations. In most cases, it is impossible to obtain a representative group of skeletons for a given population, due to the fact that most Levantine prehistoric sites contain relatively small numbers of skeletons. Furthermore, burial customs may introduce additional bias to our material (e.g., dead infants may not be disposed of in the same fashion as adults; Hershkovitz and Gopher, 1990), and the fragmented nature of most bones makes the identification of age and sex in many cases difficult, if at all possible. Proper sampling and preservation, however, are not the only problems that introduce bias to paleodemographic analyses. Another problem concerns sex and age determination methods (e.g., error in age estimation is much greater for adults than for children). Considering the nature of the material we were working with in the present study, it is clear that intrinsic sampling problems could not all be overridden. Another crucial issue is the status of the populations, i.e., stationary, declining, or growing. Population growth is an important issue in the interpretation of paleodemographic life tables, since the resulting expectations of life will be biased if the population studied is not stationary (Sattenspiel and Harpending, 1983; Johansson and Horowitz, 1986). A growing population will appear to have a lower expectation of life and lower mean age at

TABLE 6. The Natufian population studied, by sex and age (N = 96)

Sex	N	Age group 15–20	20–30	30–40	40–50	50<	Adult >15[2]
Male							
Real sample	66	4	20	19	8	2	13
Adjusted sample[1]	66	5	25	24	10	2	
Relative frequency (%)[3]	100	7.4	37.8	35.9	15.1	3.8	
Female							
Real sample	30	1	8	7	7	2	5
Adjusted sample[1]	30	1	10	8	8	3	
Relative frequency (%)[3]	100	4	32	28	28	8.0	

[1] After adding individuals aged specifically unknown (>15).
[2] Individuals over age 15 years. Specific age is not known.
[3] Relative frequency (%) was calculated as follows: [number of individuals in specific age group after adjustment/total number of individuals (N)] × 100.

TABLE 7. The Neolithic population studied, by sex and age (N = 131)

Sex	N	Age group 15–20	20–30	30–40	40–50	50<	Adult >15[2]
Male							
Real sample	88	2	14 + 1 (>20)	9 + 5 (>30)	7 + 1 (>40)	8	40
Adjusted sample	88	4	27	21	17	19	
Relative frequency (%)[3]	100	4.3	30.5	23.5	19.5	22.3	
Female							
Real sample	45[4]	6	7 + 1 (>20)	5		1	21
Adjusted sample[1]	45	11	14	10	8	2	
Relative frequency (%)[3]	100	25.0	30.9	22.1	17.6	4.4	

[1] After adding individuals aged specifically unknown (>15).
[2] Individuals over age 15 years. Specific age is not known.
[3] Relative frequency (%) was calculated as follows [number of individuals in specific age group after adjustment/total number of individuals (N)] × 100.
[4] Not including one individual (female) age 10–15 years old.

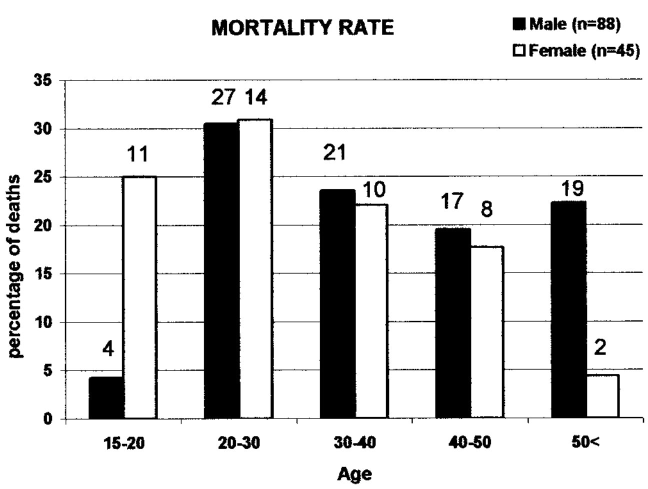

Fig. 5. Mortality rates by sex and age in Neolithic population.

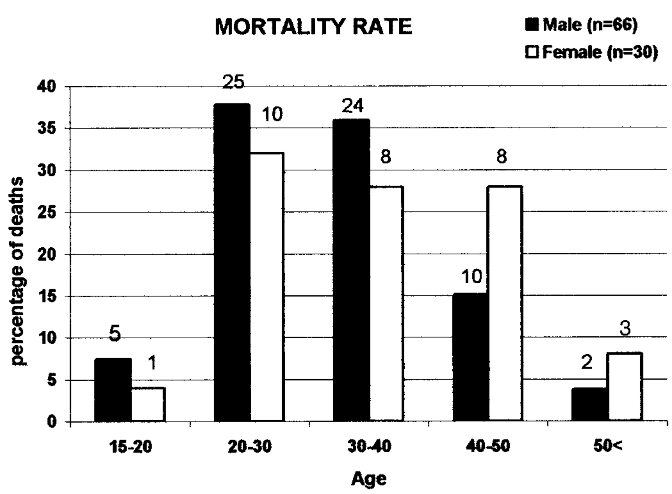

Fig. 6. Mortality rates by sex and age in Natufian population.

death (MAAD), while a declining population will appear to have a higher expectation of life and a higher MAAD. The proportion of children is also affected. A growing population will have a larger proportion of children, and a declining population will have a smaller proportion of children.

All these difficulties do not necessarily mean that we should give up our efforts to reconstruct life as it was in prehistoric times. Hassan (1981, p. 96) stated very convincingly that "it would be unfair to dwell on the difficulties involved in paleodemographic analysis, for it is our only means of developing some understanding of the vital statistics of prehistoric populations." It is true, however, that Hassan (1981) wrote before anthropologists were aware of the many critical obstacles associated with paleodemo-

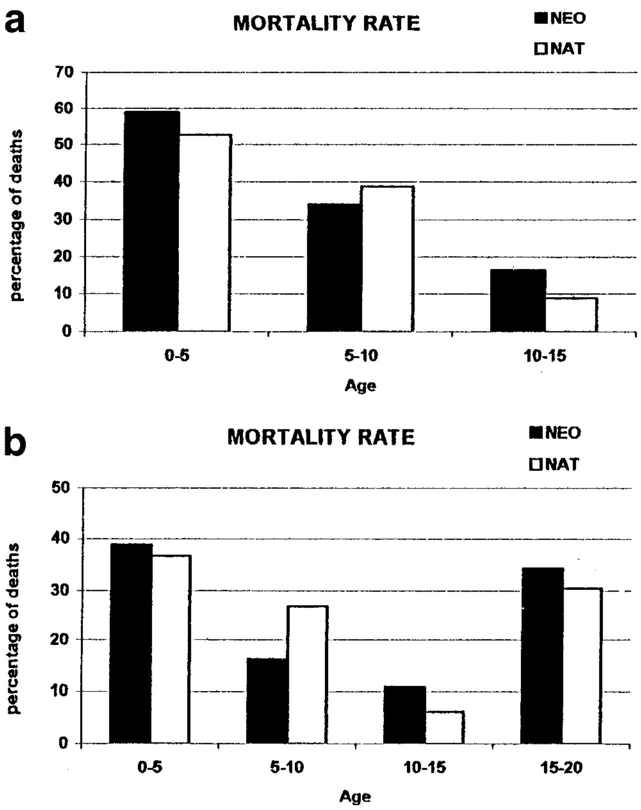

Fig. 7. Comparison of proportion of child deaths for Natufian and Neolithic populations, based on cumulative of death (**a**) until age of 15 years and (**b**) 20 years.

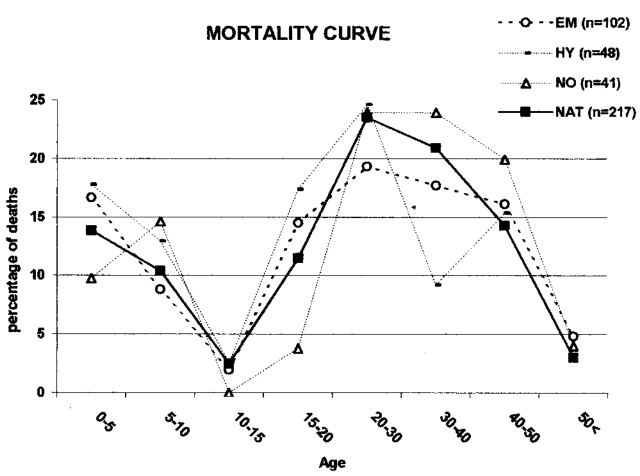

Fig. 8. Mortality curve of three Natufian populations (Ain-Mallaha, Hayonim, and Nahal Oren) compared to entire Natufian sample.

graphic analyses. The critics of paleodemographic studies, however, provided the driving force in the search for new, better, more reliable methods, resulting in a plethora of new paleodemographic studies (e.g., Hoppa and Vaupel, 2002; Paine, 1989, 2000; Konigsberg and Frankenberg, 1992; Gage, 1988, 1990). Assuming a stationary population, life expectancy (sex-combined) at birth (25.5 years for the Neolithic population, and 24.6 years for the Natufians) and adult mean age at death (31.2 vs. 32.1 years) increase slightly (ca. 1 year) from the Natufian to the Neolithic period. These trends were identified by previous studies (Arensburg, 1973; Smith et al., 1984; Hershkovitz and Gopher, 1990). If Neolithic populations were growing at a faster rate, then the differential in expectation of life is underestimated.

When males and females are analyzed separately, however, the trend is not consistent: while adult mean age at death (AMAAD) increases for Neolithic males by 2 years (from 35.5 years in the Natufian to 37.6 in the Neolithic), it decreases for females by ca. 2 years (from 32.2 years in the Natufian to 30.1 years in the Neolithic). Although sex differences in adult mortality are known from Old World prehistoric populations (Boldsen and Paine, 1995), does the opposite trend in the two populations need an explanation? Based on the above results, we can argue that adult female Neolithic mortality in the younger adult age cohorts is higher than adult male Neolithic mortality (these two populations must have had the same growth rate, regardless of infanticide, selective parental investment, etc). Therefore, this finding is not due to the assumption of stationary populations. The reverse phenomenon was found in the Natufian. This suggests a change in the ratio of adult male to female mortality (barring sampling problems) that could be due to maternal mortality as a result of greater fertility in the Neolithic (implying a faster growing rate).

Adult female mortality with the onset of the Neolithic period could have increased due to an increasing number of births and earlier onset of pregnancy. Indeed, 24.4% of all Neolithic females are in the age cohort of 15–20 years, while only 3.3% of Natufian females fall within this age group (P = 0.014). Further, if we consider the fertile period of females to be between 15–40 years, the relative frequency of Neolithic females in this age cohort is greater than in the Natufian population (78.0% vs. 58.3%). One obstacle in the above suggestion is that the proportion of children in the Natufian is similar to that in the Neolithic. Yet, if only large Neolithic sites are considered (that were meticulately excavated in the last decade), the proportion of children rises to 32.6% in Kfar Hahoresh (PPNB) and 36.6% in Atlit-Yam (PPNC), while in the Natufian site of Ain Mallaha, the rate is only 27.6%. These numbers are supported by Hershkovitz and Gopher (1990). Boldsen and Paine (1995) found a similar trend in adult mortality between Mesolithic and Neolithic populations of Europe. They demonstrated that during the Neolithic and subsequent periods, female conditional survivorship through the reproductive years declined vis à vis male condition survivorship through the same ages. Changes in birth rates associated with the adoption of agriculture, and changes in the level of maternal risk associated with childbirth, were offered as explanations.

The correlation between female mortality and births was broguht up previously (e.g., Friedlander, 1996). Many ethnographical studies on recent hunter-gatherer populations indicate that female fertility is low (Hitchcock, 1982; Howell, 1979), mainly due to widely spaced intervals between births, averaging 3–4 years (Howell, 1979, 1986). A few factors are known to lower the number of births for females: 1) workload, much in the same manner that athletics seem to lower the fertility of Western females and cause irregular cycles (Bentley, 1985); 2) inadequate food supply (Hausman and Wilmsen, 1984; Cohen, 1989); 3) seasonal weight fluctuations, that can reduce fertility even if the basic level of nutrition is not low (Lager and Ellison, 1987); and 4) prolonged nursing (Lee, 1980; Konner and Worthman, 1980).

We therefore suggest that the higher AMAAD for Natufian females is due to a lower death rate (deriving from low numbers of births per female) during their reproductive period. The Natufians mainly practiced a hunter-gatherer way of life, and even if mobility decreased, the traditional long birth intervals persisted and were longer than in the Neolithic population. Hausman and Wilmsen (1984) argued that !Kung traditional lifestyles show a seasonal peak of birth, resulting from a tendency for conception to occur in periods of dietary abundance. They note that when the !Kung become sedentary, they are fatter and show less seasonal weight fluctuation, which results in higher fertility and shorter birth intervals.

Male populations present the opposite picture, i.e., an increase in adult mean age at death from the Natufian to the Neolithic period, assuming stationary populations. Why does this increase occur? Better living conditions and a better quality and larger quantity of food could be part of the answer (although there is no direct evidence to support such claims). Reduced physical stress due to lower hunting activity may be an additional explanation. Hunting is almost exclusively a male activity (Murdock and Provost, 1973), and was an important subsistence activity in the Natufian (e.g., Belfer-Cohen, 1991; Bar Yosef, 1998). It is also possible that social conflicts under conditions of growing stress (environmental or economical) could have promoted intra- and intergroup violence. The much higher frequency of skull trauma among Natufian males compared to Neolithic malse (16.6% vs. 6.6%) (Eshed, 2001) may indirectly support such a suggestion.

Child mortality presents another interesting issue. An abundance of demographic studies show that mortality rate (ca. 40% until age 10 years) did not change dramatically until the 18th century (Bourgeois-Pichat, 1951; Brothwell, 1986–1987; Alesan et al., 1999; Gage, 1990, 1994; Ublaker, 1974). The issue is therefore the children/adult ratio and the relative proportions of children in the age cohorts. Assuming stationary populations, children between age 0–5 years composed 13.6% of the Natufian sample, and 16.5% of the total Neolithic sample. From age 5 onwards, mortality rates in both populations decrease until age 15 years. In the early years, infants are at greater risk, probably due to exogenous factors, related to the development of the immunological system and the response capacity to environmental stressors. These consist mainly of infections, parasites, and gastrointestinal disorders (Alesan et al., 1999). The general child-mortality curve follows the model given by Weiss (1973) for ancient populations: a high mortality rate for infancy, reducing but still high until age 5 years, and from this age onwards, progressively declining, reaching a minimum in the last age category (10–15 years old). Baker and Dutt (1972), who gathered demographic data from 20th century high-altitude human populations, reported on very high mortality rates during the first year of life (death rate, 192/1,000), dropping rapidly during the next 4 years. The lowest rates appear from age 5–14 years (for age group 10–14 years, the death rate was found to be 3/1,000), after which time they begin to climb gradually until old age. Mortality data (death before 15 years) obtained for American Indian populations (data collected between 1934–1970), divided by mode of subsistence (hunter and gatherers vs. agriculturalists), varied considerably: from 15–62% in the former, to 21–61% in the latter (Salzano, 1972). The author emphasized that the two ranges overlap.

Assuming stationary populations, the relative number of children (0–15 years) per adult was similar in both Natufian (26.3%) and Neolithic (25.0%) populations. Yet large variability in child/adult (child = 12 years and younger) proportions in various Natufian sites exists, e.g., 16.3% in Eynan to 37.8% in Shukba, according to Belfer-Cohen et al. (1991). Their most interesting find is the decrease in child representation from Early (29.1%) to Late (23.0%) Natufian. Following this and our data, it may well be that the demographic change already started in the Natufian, a time that faced in its Late and Final stages a climatological change (the Younger Dryas) that may have effected a population decline (hence the lower proportion of children and the higher MAAD in the Late and Final Natufian compared to the Early Natufian). The demographic profile of the Natufian clearly showed a gradual decline rather than a population crash, e.g., a plague episode (Paine, 2000). The population slowly recovered in the PPNA, and growth was accelerated during the PPNB period. The abundance of PPNB sites supports the above approach.

Paine and Boldsen (2002) demonstrated that the proportion of late childhood (5–18 years) to early childhood (2–5 years) death changed between the Mesolithic period and the Neolithic in Europe, i.e., an increased death rate among older children. This trend reversed after the Iron Age, and child death again became concentrated in earlier ages. The authors suggested that epidemic events (interval below 18 years) could have been associated with the changing pattern of childhood mortality. In the present study, no shift towards later childhood death (15 years) in the Neolithic was found (Fig. 7). This indirectly implies that the transition to agriculture in the Levant was not followed by an increase in the risk of more frequent epidemic cycles.

In the classic work by Acsadi and Nemeskeri (1970) on "The History of Life Span and Mortality," age at death for Old World preagricultural skeletal populations was found to be much lower compared to postagricultural populations (ca. 10 years). Acsadi and Nemeskeri (1970) argued that agriculture promoted a rapid population growth (due to improvement of food supply). They ignored, however, a significant increase in risk factors such as infectious diseases or zoonoses. The present study clearly shows that post- and preagricultural populations in the Levant had a mean age at death around 25 years (slightly greater in the Neolithic). The Natufian population with a life expectancy at birth of 25 years needs only about five births per women to maintain itself. With the onset of agriculture, as our study showed, fertility rose.

The sex ratio was slightly lower in the Neolithic (187) than in the Natufian (220) population. Yet in both populations, the number of adult males was twice as high as the number of females. This unusual sex ratio for the two populations is confirmed by cross-investigators and across sites. Belfer-Cohen et al. (1991), who summarized all the Natufian data till 1990, reported on 68.6% of adult males in the Natufian population (with the proportion of females increasing in the later part of the Natufian). Similar results were reported by Hershkovitz and Gopher (1990). Furthermore, from the six large Natufian sites studied, in five, the number of adult males was much greater than of adult females (Belfer-Cohen et al., 1991; Soliveres-Massei, 1988; Crognier and Dupouy-Madre, 1974; Arensburg, 1973). A similarly biased sex ratio was found for various Neolithic sites (Eshed, 2001).

How can we explain the overrepresentation of males in these two prehistoric populations? Two major approaches can be adopted: A) The observed sex ratio does not represent the real past situation, and was probably distorted due to various factors such as: 1) taphonomic, i.e., the high rate of unidentified (unsexed) skeletons due to the fragmentary nature of many skeletons and differential preservation (female skeletons are less robust than male skeletons, and possibly were more damaged); 2) burial practices, i.e., it may well be that females were treated differently at death than males; and 3) methodological, i.e., our analytical tools (based on modern samples) are inappropriate or not sensitive enough to carry out proper sex identification on prehistoric populations. B) The sex ratio, as seen, does represent past reality. Such an excess of males over females could be the result of social behavior, such as selective infanticide (parental differential investment), a practice considered common among hunter-gatherer societies. Henry (1989) claimed that the excess of males over females in most Natufian sites is the result of selective female infanticide or neglect, and that it expresses their attempt to control a dramatic growth in their population. Contributing factors could be the dramatic reduction in food resources (mainly in variety and quantity of hunting animals) due to increasing environmental stress.

The fact that the sex ratio started rising from the Late and Final Natufian towards the final stage of the prepottery Neolithic (146 in Atlit-Yam) may indicate that even if the magnitude is somewhat biased (due to the extraneous factors mentioned above), the sex ratio in these periods was certainly in favor of males. Yet there was a shift towards an equal proportion of males to females in the later parts of the Neolithic.

In the present study, we tried to present the demographic processes that accompanied the Agricultural Revolution in the Levant. Our results indicate an increase in fertility and decrease in mortality, resulting in fairly rapid population growth. Finally, the data of the present study can be used as a reference data, on the border between prehistoric populations (of zero growth rate) and historic populations (of 0.1–1.5% growth rate).

Swendlund and Armelagos (1976) stated that the accuracy of paleodemographic analysis is proportional to the degree to which the subject population is sedentary, the size of the site, and the number of skeletons excavated. Considering the above, paleodemographic analyses based on sedentary prehistoric populations like those from Atlit-Yam (AY) and Ketar Hahoresh (KHH), where considerable numbers of skeletons were found, are therefore reliable.

CONCLUSIONS

The transition from a hunter-gatherer way of life to a food-producing economy in the Levant is probably not associated with a demographic "crisis," as previously claimed. Contrary to the statement of Cohen and Armelagos (1984, p. 592) that "mean age at death (and/or life expectancy at various ages) declined with the adoption of farming," our study shows no such decline. Life expectancy at birth in the Neolithic period probably increased, and so did adult mean age at death. The transition to agriculture, however, affected males and females differently: while females experienced a decrease in mean age at death in the Neolithic period, males experienced an increase. Natufian women lived longer, probably because of less frequent births, while Natufian males were more likely to die earlier, possibly because of their hunting activities and intersocial conflict. The present study provides good evidence that in the Levant, mortality declined with the introduction of agriculture, and fertility increased. This suggests population growth (ca. $r = 0.5$–1%) at the advent of agriculture.

ACKNOWLEDGMENTS

We thank Anna Behar for drawing the map, and Janet Padiak and Charles M. FitzGerald for reading and correcting the manuscript.

LITERATURE CITED

Acsadi GY, Nemeskeri J. 1970. History of human life span and mortality. Budapest: Akademiai Kiado.
Alesan A, Malgosa A, Simo C. 1999. Looking into the demography of an Iron Age population in the western Mediterranean, I. Mortality. Am J Phys Anthropol 110:285–301.
Angel JL. 1973. Early Neolithic people of Nea Nikomedeia. In: Schwidetzky I, editor. Die Anfange des Neolithikums vom Orient bis Nordeuropa. Volume III. Köln: Bohlan Verlag. p 103–112.
Arensburg B. 1973. The people in the land of Israel from the Epipaleolithic to present times. Ph.D. thesis, Tel Aviv University.
Arensburg B, Hershkovitz I. 1988. Nahal Hemar Cave, Neolithic human remains. Atiqot 18:50–58.
Arensburg B, Smith P, Yakar R. 1978. The human remains from Abou Gosh. Mem Trav Centre Recherches Prehist Fr Jerusalem 2:107–120.
Baker PT, Dutt JS.1972. Demographic variables as measures of biological adaptation: a case study of high-altitude human populations. In: Harrison GA, Boyce AJ, editors. The structure of human populations. Oxford: Clarendon Press. p 352–378.
Bar-Yosef O. 1998. The Natufian culture in the Levant, threshold to the origins of agriculture. Evol Anthropol 6:159–177.
Bar-Yosef O. 2001. From sedentary foragers to village hierarchies: the emergence of social institutions. Proc Br Acad 110: 1–38.
Bar-Yosef O, Gopher A. 1997. An Early Neolithic village in the Jordan Valley. Part I: the archaeology of Netiv Hagdud. American School of Prehistoric Research bulletin 43. Cambridge, MA: Peabody Museum, Harvard University.
Bass WM. 1987. Human osteology. A laboratory and field manual. 3rd ed. Columbia, MO: Missouri Archaeological Society.
Bedford MA, Russel KF, Lovejoy CO, Meindl RS, Simpson SW, Stuart-Macadam PL. 1993. Test of the multifactorial aging method using skeletons with known age-at-death from the grant collection Am J Phys Antropol 91:287–297.
Belfer-Cohen A. 1988. The Natufian graveyard in Hayonim Cave. Paleorient 14:297–308.
Belfer-Cohen A. 1991. The Natufian in the Levant. Annu Rev Anthropol 20:167–186.
Belfer-Cohen A, Arensburg B, Bar-Yosef O, Gopher A. 1990. Human remains from Netiv Hagdud—a PPNA site in the Jordan Valley. J Isr Prehist Soc Mitekufat Haeven 23:79–85.
Belfer-Cohen A, Schepartz LA, Bar-Yosef O. 1991. New biological data for the Natufian populations in Israel. In: Bar-Yosef O, Valla FR, editors. The Naufian culture in the Levant. p 411–424. Ann Arbor, Michigan: International Monographs in Prehistory.
Bentley G. 1985. Hunter-gatherer energetics and fertility: a reassessment of the !Kung San. Hum Evol 13:79–110.
Bocquentin F, Sellier P, Murail P. 2001. La population Natoufienne de Mallaha (Eynan, Israël): dénombrement, âge au décès at recrutement funéraire. Paleorient 27:89–106.
Boldsen JL, Paine RR. 1995. Defining extreme longevity from the Mesolithic to the Middle Ages: estimates based on skeletal data. In: Jeune B, Vaupel JW, editors. Exceptional longevity from prehistory to present. Odense: Odense University Press. p 25–36.
Bourgeois-Pichat L. 1951. La mesure de la mortalite infantile. II. Le causes de deces. Population 6:459–480.
Brooks S, Suchey JM. 1990. Skeletal age determination based on the os pubis: a comparison of Acsadi-Nemeskeri and Suchey-Brooks methods. Hum Evol 5:227–238.
Brothwell DR. 1986–1987. The problem of the interpretation of child mortality in earlier populations. Antropol Port 4–5:135–143.
Buikstra JE, Konigsberg LW, Bullington J. 1986. Fertility and the development of agriculture in the prehistoric Midwest. Am Antiq 51:528–546.
Carneiro RL, Hilse D. 1966. On determining the probable rate of population growth during the Neolithic. Am Anthropol 68:179–181.
Cohen M. 1989. Health and the rise of civilization. New Haven: Yale University Press.
Cohen M, Armelagos G. 1984. Paleopathology at the origins of agriculture. Orlando: Academic Press.
Crognier E, Dupouy-Madre M. 1974. Les Natoufiens du Nahal Oren (Israel étude anthropologique). Paleorient 1:103–121.
Eshed V. 2001. From foraging to farming in the Holocene (the pre-pottery Neolithic period 8,300–6,000 B.C.) in the southern Levant: the skeletal evidence. Unpublished Ph.D. thesis, Tel Aviv University.
Friedlander NJ. 1996. The relation of lifetime reproduction to survivorship in women and men: a retrospective study. Am J Hum Biol 8:771–783.
Gage TB. 1988. Mathematical Hazard models of mortality: an alternative to model life tables. Am J Phys Anthropol 76:429–441.
Gage TB. 1990. Variation and classification of human age patterns of mortality. Analysis using competing Hazards models. Hum Biol 62:589–617.
Gage TB. 1994. Population variation in cause of death: level, gender and period effect. Demography 31:271–296.
Galili E, Weinstein-Evron M, Hershkovitz I, Gopher A, Kislev M, Lernau O, Kolska-Horowitz l, Lernau H. 1993. Atlit-Yam: a prehistoric site on the sea floor off the Israeli Coast J Field Archaeol 20:133–157.
Goring-Morris AN. 2000. The quick and the dead: the social context of aceramic Neolithic mortuary practices as seen from Kfar Hahoresh. In: Kuijt I, editor. Life in Neolithic farming communities. New York: Kluwer Academic. p 103–136.
Goring-Morris AN, Burns R, Davidxon A, Eshed V, Goren Y, Hershkovitz I, Kangas S, Kelecevic J. 1998. The 1997 season of excavations at the mortuary site of Kfar HaHoresh, Galilee, Israel. Neolithics 3:1–4.
Hassan FA. 1981. Demographic archaeology. New York: Academic Press.
Hausman AJ, Wilmsen EN. 1984. Impact of seasonality of foods on growth and fertility. Am J Phys Anthropol 63:169.
Henry OD. 1989. From foraging to agriculture. The Levant at the end of the Ice Age. Philadelphia: University of Pennsylvania Press.
Hershkovitz I, Edelson G. 1991. The first identified case of thalassemia? Hum Evol 6:49–54.
Hershkovitz I, Gopher A. 1988. Human remains from Horvat Galil. A pre-pottery Neolithic site in the Upper Galilee, Israel. Paleorient 14:119–123.
Hershkovitz I, Gopher A. 1990. Paleodemography, burial customs, and food-producing economy at the beginning of the Holocene: a perspective from the southern Levant. J Isr Prehist Soc Mitekufat Haeven 23:9–47.
Hershkovitz I, Garfinkel Y, Arensburg B. 1986. Neolithic skeletal remains at Yiftahel, area C, Israel. Paleorient 12:73–81.
Hershkovitz I, Bar-Yosef O, Arensburg B. 1994. The pre-pottery Neolithic populations of south Sinai and their relations to other circum-Mediterranean groups: an anthropological study. Paleorient 20:59–84.
Hillson S. 1986. Teeth. Cambridge: Cambridge University Press.
Hitchcock RK. 1982. Patterns of sedentism among the Besarwa of eastern Botswana. In: Leacock E, Lee RB, editors. Politics and history in band societies. Cambridge: Cambridge University Press. p 223–268.
Hoppa RD, Vaupel JW. 2002. The Rostock manifesto for paleodemography: the way from stage to age. In: Hoppa RD, Vaupel JW, editors. Paleodemography: age distribution from skeletal samples. Cambridge: Cambridge University Press. p 1–8.
Howell N. 1979. Demography of the Dobe !Kung. New York: Academic Press.
Howell N. 1986. Feedback and buffers in relation to scarcity and abundance: Studies of hunter-gatherer populations In:

Coleman D, Schofield RS, editors. State of population theory. London: Blackwell.
Johansson SR, Horowitz S. 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.
Johnston FE, Zimmer LO. 1989. Assessment of growth and age in the immature skeleton: In: Iscan MY, Kenneth AR, editors. Reconstruction of life from the skeleton. New York: Alan R. Liss. p 11–21.
Kennedy KAR. 1984. Growth, nutrition, and pathology in changing paleodemographic settings in south Asia. In: Cohen MN, Armelagos GJ, editors. Paleopathology at the origin of agriculture. London: Academic Press. p 169–192.
Konigsberg LW, Frankenberg SR. 1992. Estimation of age structure in anthropological demography. Am J Phys Anthropol 89:235–256.
Konner M, Worthman C. 1980. Nursing frequency. Gonad function and birth spacing among !Kung hunter-gatherers. Science 235:436.
Kurt G, Rohrer-Ertl O. 1981. On the anthropology of Mesolithic to Chalcolithic human remains from the Tell es-Sultan in Jericho, Jordan. In: Kenyon KM, editor. Excavations at Jericho III. London: British School of Archaeology in Jerusalem. p 407–499.
Lager C, Ellison PT. 1987. Effects of moderate weight loss on ovulatory frequency and luteal function in adult women. Am J Phys Anthropol 72:221–222.
Lahr MM, Haydenblit R. 1995. The human remains from the site of Et-Tin, Israel. Paleorient 21:97–111.
Lechevallier M. 1978. Abou Gosh et Beisamoun. Deux gisements du Vll[e] millénaire avant l'ère Chrétienne en Israël. Mémoires et travaux du Centre de Recherches Préhistoriques Français de Jerusalem. Paris: Association Paléorient.
Lee RB. 1980. Lactation, ovulation, infanticide and women's work: a study of hunter-gatherer population regulation. In: Cohen MN, Armelagos GJ, editors. Paleopathology at the origins of agriculture. New York: Academic Press. p 321–348.
Le Mort F. 1989. PPNA burials from Hatoula (Israel). BAR Int Ser 508:133–140.
Le Mort F, Hershkovitz I, Spiers M. 1994. Les restes humains. Mem Trav Centre Recherche Fr Jerusalem 8:59–72.
Loth SR, Iscan MY. 1989. Morphological assessment of age in the adult: the thoracic region. In: Iscan, MY, editor. Age markers in the human skeleton. Springfield, IL: Charles C. Thomas. p 105–136.
Lovejoy CO. 1985. Dental wear in the Libben population: its functional pattern and role in the determination of adult skeletal age at death. Am J Phys Anthropol 68:47–56.
Lovejoy CO, Meindl RS, Prysbeck TR, Mensforth RP. 1985a. Chronological metamorphosis of the auricular surface of the ilium: a new method for the determination of adult skeletal age at death. Am J Phys Anthropol 68:15–28.
Lovejoy CO, Meindl RS, Mensforth RP. 1985b. Multifactorial determination of skeletal age at death: a method and blind tests of its accuracy. Am J Phys Anthropol 68:1–14.
McCown T. 1939. The Natufian crania from Mount Carmel (Palestine) and their interrelationship. Ph.D. thesis, University of California at Berkeley.
Murdock GP, Provost C. 1973. Factors in the division of labor by sex: a cross-cultural analysis. Ethnology 12:203–225.
Nathan H. 1962. Osteophytes of the vertebral column. An anatomical study of their development according to age, races and sex with considerations as to their etiology and significance. J Bone Joint Surg [Br] 44:243–268.
Paine RR. 1989. Model life table fitting by maximum likelihood estimation: a procedure to reconstruct paleodemogrphic characteristics from skeletal age distribution. Am J Phys Anthropol 80:49–58.
Paine RR. 2000. Population crashes in prehistory, and there is no paleodemographer there to hear it: does it make a sound? Am J Phys Anthropol 112:181–190.
Paine RR, Boldsen JL. 2002. Linking age-at-death distributions and ancient population dynamics. In: Hoppa RD, Vaupel JW, editors. Paleodemography: age distribution from skeletal samples. Cambridge: Cambridge University Press. p 169–180.
Paine RR, Harpending HC. 1998. Effect of sample bias on paleodemographic fertility estimates. Am J Phys Anthropol 105: 231–240.
Salzano FM. 1972. Genetic aspects of the demography of American Indians and Eskimos. In: Harrison GA, Boyce AJ, editors. The structure of human populations. Oxford: Clarendon Press. p 234–251.
Sattenspiel L, Harpending HC. 1983. Stable populations and skeletal age. Am Antiq 48:389–498.
Segebarth-Orban R. 1980. An evaluation of the skeletal dimorphism of the human innominate bone. J Hum Evol 9:601–607.
Siler W. 1979. A competing-risk model for animal mortality. Ecology 60:750–757.
Smith P, Bar-Yosef O, Sillen A. 1984. Archaeological and skeletal evidence for dietary change during the late Pleistocene/early Holocene in the Levant. In: Cohen MN, Armelagos GJ, editors. Paleopathology at the origins of agriculture. New York: Academic Press. p 101–136.
Soliveres-Massei O. 1988. Etude anthropologique. Mem Trav Centre Recherche Fr Jerusalem 7:106–208
Swendlund AC, Armelagos GJ. 1976. Demographic anthropology. Iowa: W.M.C. Brown Co. Publishers.
Szilvassy J. 1980. Age determination on the sternal articular faces of the clavicula. J Hum Evol 9:609–610.
Ubelaker DH. 1974. Reconstruction of demographic profiles from ossuary skeletal samples. A case study from the Tidewater Potomac. Washington, DC: Smithsonian Institution Press.
Ubelaker DH. 1989. Human skeletal remains: excavation, analysis, interpretation, 2nd ed. Washington, DC: Taraxacum.
Valla FR, Khalaily H, Samuelian N, Bocquentin F, Delange C, Valentin B, Plisson H, Rabinovitch R, Belfer-Cohen A. 1998. Le Natoufien final et les nouvelles fouilles à Mallaha (Eynan), Israël, 1996–1997. J Isr Prehist Soc 28:105–176.
Vallois HV. 1936. Les ossements Natoufiens d'Erq el-Ahmar (Palestine). Anthropologie 46:529–539.
Washburn SL.1948. Sex differences in the pubic bone. Am J Phys Antropol 6:199–208.
Weiss KM. 1973. Demographic models for anthropology. Am Antiq 39:2.