AMERICAN JOURNAL OF HUMAN BIOLOGY 13:733–743 (2001)

Diachronic Patterns of Dental Hypoplasias and Vault Porosities During the Predynastic in the Naqada Region, Upper Egypt

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ABSTRACT The diachronic pattern of the frequencies of linear enamel hypoplasias and porotic hyperostosis was studied in temporally separated samples of adult predynastic Egyptian remains from the Naqada region, Upper Egypt. The samples covered a period of increasing population density and social complexity as well as decreasing Nile flooding in Egypt. First and second molars were evaluated for hypoplasias in material from the Naqada I, II, and III periods; sample sizes were 13, 30, and 25, respectively, for the first molar, and 11, 28, and 24 for the second molar. Cranial vaults were examined for porotic hyperostosis using several approaches; sample sizes were 26, 66, and 51 for Naqada I, II and III, respectively. Linear regression showed a decreasing trend for several variables: for the individual frequency of first molar hypoplasias ($\rho = 0.025$), the vault porosity score, which indicates the severity of the lesions ($\rho < 0.001$), and the extent score, which indicates the number of superior vault bones having porosities ($\rho < 0.001$). Logistic regression showed a temporal decline in the percentage of crania per sample having any vault porosities and only higher grade lesions ($\rho < 0.012$ and $\rho < 0.003$, respectively). Lesions of the second molar showed no directional trend. The results contrast with the common observation that these skeletal markers usually increase in contexts of increasing population density and social complexity. Am. J. Hum. Biol. 13:733–743, 2001.

Studies of palaeopathological skeletal markers have had as one goal the exploration of disease patterns over time in relationship to change in subsistence strategy and/or social complexity (Cohen and Armelagos, 1984; Larsen, 1995). Results of such studies for several locales have usually shown an increase in lesions in these contexts and been interpreted as suggesting that health generally declined during and after the transition to farming until more recent times (Cohen and Armelagos, 1984, editors' summary). ''Health'' in these studies is based primarily on the assessment of lesions that occur in childhood. The higher frequencies of skeletal lesions have variously been explained in terms of disease caused by the secondary effects of increased population aggregation (Kent, 1986), or intensified reliance on single crops (Goodman and Rose, 1980), i.e., agricultural intensification. Social relationships have also been implicated in health changes, in situations where there may have been exploitation of food producers by elites (Martin et al., 1984; Goodman et al., 1988). Such exploitation is usually viewed as being concomitant with increasing social complexity and social inequality (Cohen, 1978).

This report presents the results of research on predynastic remains of different dates from cemeteries in the region near Naqada Upper Egypt (Fig. 1). The goal was to determine for a geographically restricted and historically important locale the pattern of diachronic frequencies of skeletal markers to see how they compare with results from similar studies. The majority of studies of pathology in ancient Egyptians have been performed on dynastic period remains (Davies and Walker, 1993). The predynastic period is less well known and has not been fully explored to assess disease patterns associated with diachronic changes in socioecology and subsistence, as has been done for Nubia (Rudney, 1983; Martin et al., 1984; Goodman et al., 1988; Van Gerven et al., 1995) and the Aegean (Angel, 1971). The Naqada region is one site of documented continuous predynastic culture spanning nearly 10 centuries and is postulated to have been the locale of a proto-kingdom called Nubt in the latter part of the predynastic (Kemp, 1991). Hence, it is

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Received 24 April 2000; Revision received 13 March 2001; Accepted 3 April 2001

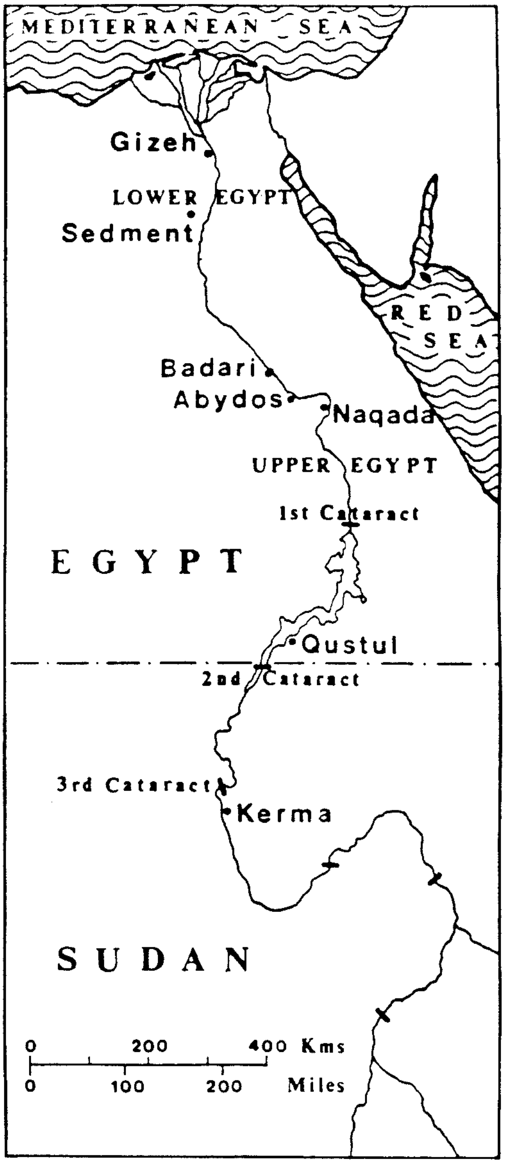

Fig. 1.

an ideal place to study pathological skeletal lesions over time and to consider their health connotations. Unfortunately, the remains used here do not represent a true demographic sample. This study is limited to adult individuals with recoverable graves, which means that they were not likely to represent those most economically challenged (Baines, personal communication).

It should also be noted that the 19th-century excavation of Naqada region cemeteries did not follow the canons of modern bioarchaeology, which aim to capture demographically accurate samples. The remains of infants and juveniles were not systematically preserved and curated. However, the lesions studied here in adults occur in childhood and the overall observations are about the childhood challenges of the studied adults. In spite of different excavation and curation concerns of earlier workers, it is worthwhile to examine older skeletal collections with new questions because they are frequently a sole source of relevant data. Although the remains from the Naqada cemeteries number in the hundreds, only a fraction of these can be reasonably dated to recognized cultural phases.

In addition to being the site of an ancient settlement and cemetery, the term Naqada (Nagada, Nakada) refers to successive cultural phases (Hendrickx, 1996) or "archaeologic-time units" (Hassan, 1988). The phrase "cultural phase" must be used with reservation because it may be taken to imply the existence within a chronological unit of a level of cultural homogeneity which does not exist. For example, Holmes (1989) has demonstrated geographical variability of lithic assemblages within time units which merge seamlessly into each other. The "units" of predynastic Egyptian culture recognized at Naqada occupy important chronological and cultural spaces. Temporally, these phases are broadly between the Badarian and First Dynasty, a period of approximately 1,000 years (~3,900–3,050 BC). The units currently recognized are Naqada I (~3,900–3,650 BC), Naqada II (~3,650–3,300 BC), and Naqada III (~3,300–3,050 BC) (Hassan, 1988). The boundaries between each are blurred. Chronologically, Naqada I roughly corresponds to what older literature designates the Amratian, Naqada II, the Gerzean, and Naqada III, the Semainean. However, the Semainean is not the cultural equivalent of Naqada III, because the former term is connected to a theory of external origins, which is now recognized as being false. These units were defined by a relative dating method based on ceramic seriation, called sequence dating (Petrie 1899), which has been further refined (Kaiser, 1957;

Hendrickx, 1996). By the beginning of Naqada III, Upper (southern) Egyptian culture had expanded northward either by conquest, peaceful migration, the spread of ideas, or a combination of these (Adams 1988; Hassan, 1988; Bard, 1989, 1994b; Köhler, 1995). Culturally and politically, the "phases" provide continuity between the Badarian (the earliest recognized southern specifically *predynastic* culture), which merges with Nagada I, and Dynasty I, which emerges directly from Naqada III.

Naqada I contrasts with the Badarian in evincing greater dependence on food production, increased population aggregation and sedentism, and greater social inequality especially near its end (Hoffman, 1988; Bard, 1989). Trade was also important. The Naqada II and III periods are characterized by sociocultural developments which may be said to provide the foundation for the ancient dynastic Egyptian state and society. Naqada II marks a time of increased trade, craft specialization, production, urbanization, and the rise of permanent elites (Case and Payne, 1962; Arkell and Ucko, 1965; Hoffman, 1988; Bard, 1994b; Köhler, 1995; Friedman, 1996). Naqada III, which is also called the Terminal Predynastic and protodynastic, is the more proximate link to Dynasty I since the first "kings" in Egypt seem to emerge at this time (Kemp, 1991; Dreyer, 1992). Hence, the period is designated politically as Dynasty O. Dynasty I kings would seem to owe the beginnings of their political lineage and conceptions of kingship to southern Egyptian Dynasty O rulers from either Abydos (Dreyer, 1992), Naqada, or Hierakonpolis (Kemp, 1991).

Palaeopathology

Skeletal markers which are used most often in other regional diachronic studies of palaeopathology are linear enamel hypoplasias and cranial vault or orbital porosities (Cohen and Armelagos, 1984; Larsen, 1995). These lesions represent defects which can be termed as indicators of *episodic* stress (linear hypoplasias) or of stress likely associated with *specific* diseases (vault porosities) (Goodman et al., 1984). These particular pathologies are reflective of growth and disease stress caused by biological insults during childhood (Stuart-MacAdam, 1985; Goodman and Rose, 1990). The stress experienced and manifested by children can be viewed as an index of the "environmental quality" of the population (Harrison and Brush, 1991).

Examination of the frequency and nature of childhood health indicators in those who attained adulthood is one way of assessing the physical and social environments, when considered with other data in earlier societies. Childhood stress may reflect aspects of the biosocial matrix of nutritional availability, infectious disease burden and exposure, and social factors which have an impact on life history or lifestyle. Studies of diachronic samples from a region whose sociohistorical trajectory is known may help elucidate the biological dimensions of the social and physical ecology of the changes over time.

Linear enamel hypoplasias are non-remodeling defects of the dental crown that indicate the arrest or slowing of ameloblast activity responsible for enamel deposition (Goodman and Rose, 1990). This process is likely modulated by insulin-like growth factor I (Cohick and Clemmons, 1993; Adamo, 1995). These defects correlate frequently (but not always) with recalled [childhood] disease episodes, which are interpreted as being severe enough to cause general growth perturbation. Lesser insults, those not recalled as specific disease episodes, could also decrease ameloblast activity. It is reasonable to assume that a severe compromise in ameloblast secretion resulting in an observable defect is more likely to have occurred as an acute event against a background of general physiological challenge, after a certain threshold has been reached (Goodman and Rose, 1990). Such a scenario would describe the early Nile Valley where chronic parasitic infection was common along with other health compromising conditions, such as poor protein and caloric intakes (see below). Such a general background of stress raises catecholamine levels which in turn may increase susceptibility to episodes of infectious disease (Gruchow, 1979).

The maxillary central incisors and mandibular canines are most sensitive to such generalized but episodic growth disruptions (Goodman and Rose, 1990). Less sensitive teeth (e.g., molars) would reflect only the more severe events of physiological stress.

Porosities of the superior vault, especially when associated with diploic thickening, have generally been interpreted as indicative of acquired anemia-causing conditions (as have been orbital porosities, which are not assessed here) (Steinbock, 1976; Ortner and Putscha, 1981; Stuart-MacAdam, 1987). The classic condition is characterized by symmetrical porosities on obviously thickened parietals and called porotic hyperostosis. The vault bone thickening and porosities are most likely secondary to marrow hypertrophy (a response to lowered hemoglobin), which widens the diploic space and causes cortical destruction by pressure necrosis. Dietary iron deficiency is believed to be the most common etiological factor, which is a reasonable assumption given its widespread prevalence (see UNICEF, 1989), although it may be better to subsume it under a more general category of hypoferrmic states. Genetic anemias (Angel, 1964) are not likely to be represented in great frequency (or at all) due to their rarity and lessened likelihood of being captured in samples of adults, because of early mortality (Ortner and Putschar, 1981).

Vault porosities can be the result of scalp infections or injuries; such lesions would likely be recognized by their asymmetry and localization and can be called primary (cranial) periostitis (Ortner and Putschar, 1981) or pericranitis. More widespread porous changes in the vault may be associated with general infections (secondary periostitis) or with deficiencies of vitamin C or D (Ortner and Putschar, 1981). The lesions of periostitis and vitamin C are confined only to the periosteum without marrow cavity expansion and cortical destruction. Vitamin D deficiency may produce lesions with diploic expansion, but it is generally distinguishable by having finer porosities than the classically described vault lesions. However, vitamin D deficiency is unlikely to be an issue in the Nile Valley because of the high levels of solar radiation.

Although vault porosities are lesions of childhood, they persist to adulthood with varying degrees of remodeling in evidence. It is generally assumed that lesions remodel in proportion to their severity so that degrees of childhood differences are accurately preserved in adult remains, making meaningful comparisons possible. This is reason able since new lesions do not form in adulthood (Stuart-MacAdam, 1985). However, there is the possibility that variability in ongoing physiological strain could cause differences in the level of remodeling, thus theoretically confounding the interpretation of inter-group differences in the severity of lesions observed in adult crania.

In addition to dietary iron deficiency, other acquired etiologies of anemia include poor nutrition and diseases causing chronic inflammation. A diet limited in protein and energy could contribute to an anemic state. Fasting and protein restriction have been shown to decrease insulin-like growth factor 1 (IGF-1), which in addition to other roles "functions as an erythropoetic growth factor" (Erickson and Quesenberry, 1992, pp. 745–755). Poor intakes would contribute to an anemia of chronic disease. An anaemia of inflammation has been reported in children with a number of illnesses which provoke the inflammatory response (Abshire, 1996). The common parasitic diseases of the Nile Valley bilharzia and hookworm would provoke the inflammatory response as well as cause blood loss, dietary iron deficiency, general debilitation, and immunocompromise (Stephenson and Holland, 1987; Cline, 1989; Farid, 1989; Tanaka, 1989; Pearce and Simpson, 1994). Autopsy and immunologic methods indicate the presence of schistosomiasis in predynastic and dynastic Egyptian remains (Ruffer, 1910; Sandison, 1980; Miller et al., 1993), but prevalences not known. Serum iron levels may also be lowered in response to active iron using pathogens (Weinburg, 1984; Stuart-MacAdam, 1992). This may trigger a marrow response. In short there are many pathways and factors related to environmental quality which could incite bone marrow expansion and potentially lead to lesions. These would also provide a background of increased susceptibility to episodic disease and other biological insults.

Not all challenged individuals develop enamel hypoplasias or vault porosities (Stuart-MacAdam, 1987; Goodman and Rose, 1990). The skeletal markers are thus imperfect indicators of biological stress. Nevertheless, they provide insights into episodic and chronic disease levels in a population.

The predynastic Egyptians over the period covered in this study were increasingly dependent on food production, specifically agriculture (Hassan, 1988). Emmer wheat and barley were the staples. Cattle and ovacaprids, although domesticated, were apparently rarely consumed; some wild re-sources (both plant and animal) were also utilized (Wetterstrom, 1993). The amount of cereal production was dependent on the level of Nile flooding, with decreased inundation resulting in less yield (Butzer, 1976). During the period from Naqada I to Naqada III, annual Nile flooding steadily declined, producing circumstances that perhaps encouraged changes in social organization. The lowest levels occurred in Naqada III, conceivably placing a strain on resources which contributed to war between local communities (Hassan, 1988) or between the "proto-kingdoms" of Upper Egypt as postulated by Kemp (1991).

The disease ecology of the ancient Naqada region, in addition to issues of food supply, social organization and exposure to Nile alluvium, also included increased population aggregation (Hassan, 1988) and an environment within settlements which contained the debris from animals and households (Dixon, 1972). All of these factors would have been constraints on childhood well-being (Wood, 1983).

Material

The material from the Naqada region consists of adult crania (male and female) designated as Naqada, which are part of the Duckworth collection at Cambridge University. The material is derived from excavations carried out by Petrie and Quibell (Petrie, 1896). The Naqada I (NI) and II (NII) series are those used by Berry et al. (1967), with Naqada II being augmented with material from Ballas (also in the Naqada region). The Naqada III (NIII) material is primarily from Ballas.

Due to post-mortem loss and incomplete skulls, there were insufficient numbers of upper central incisors and lower canines. Upper first and second molars (M^1 and M^2) had to be used. This is unfortunate because these teeth are relatively insensitive to growth disturbance, as evidenced by intertooth comparisons of the occurrence of gross linear enamel hypoplasias (Goodman et al., 1984; Goodman and Rose, 1990). However, there may be a hidden benefit in using these teeth because any defects are likely to connote a serious growth disturbance. Hence, this study examines the diachronic frequency of severe childhood health events in surviving adults.

The number of cranial vaults (orbits not used) and first and second molars were as follows:

	Values	M^1	M^2
NI	26	13	11
NII	66	30	28
NIII	51	25	24

Sample sizes are not equal for each structure because of postmortem tooth loss and/or missing maxillae. The same individuals are not represented in each category. The sample sizes are problematic, but not unusable (Angel, 1971; Rudney, 1983). The absolute sizes and numerical inequality of samples are generally problems in studies of remains excavated by expeditions in the late 19th and early 20th centuries. The second molars, being the least sensitive teeth and having the smallest sample sizes foreach time period, are least likely to provide valid information.

Methods

The growth disturbance (episodic) variables were the frequency of hypoplasias in a sample, designated PresM^1 and PresM^2 , and the number of hypoplasias per tooth (one per individual), designated HyponoM^1 and HyponoM^2. Teeth were included if less than an estimated one-third of the occlusal surface was worn. If only one tooth of a class was available, the individual was included because in all cases where lesions were present on an antimere one was observed (although in varying degrees) on the other (when both existed). Lesion counts were based on the most affected tooth of each class per individual. These inclusion criteria were developed to minimize overlooking any evidence of growth disturbance (Berti and Mahaney, 1995).

The porosity-defined vault variables were designed to specify the frequency of affected individuals in the sample and the average severity and anatomical extent of porosities in individuals. Severity was indicated by a vault porosity score (VPS), an ordinal level variable, based on Hillson's (1978) adaptation for the vault of Nathan and Haas' (1966) grading system applied to cribra or-bitalia:

0 No porosities
1 Scattered fine foramina

2 Larger foramina
3 Some foramina linked
4 More connections between foramina, "canal-like" structures
5 Small trabecular outgrowths from the outer table
6 Marked trabecular structures on outer table

Grade 2 is usually associated with some thickening (personal observation), and in this scale begins the approach to the more classic lesion described ("porotic hyperostosis"). The variables VPP1 and VPP2, respectively, indicate the frequency of lesions with VPS of 1 or better, or 2 or more. Using VPP2 helps to exclude those with possibly only periostitis. The extent score (ES) measures how many of the external superior vault bones (frontal, parietal, and occipital) were involved and is scored 0–3. (Cribra was not counted as frontal involvement; the parietals were counted only once.)

The variables $HyponoM^1$, $HyponoM^2$, VPS, and ES were evaluated with ANOVA, multiple comparison procedures, and regression. Non-parametric approaches were also employed because the data did not meet all of the requirements for parametric procedures (specifically, normality, equality of variances, and measurement in the interval level). However, it is usually argued that parametric methods are robust to violation of the assumptions in the case of interval data (Toothaker, 1993). It is also argued that "latent continuous variables" underlie ordinal variables (Borgatta and Bohrnstedt, 1980; Weisberg, 1992), so that parametric techniques are often used for their analysis. Contingency tables were used to evaluate the binary variables: $PresM^1$, $PresM^2$, VPP1, and VPP2.

The statistical techniques form an analytical approach designed to (1) assess the existence of heterogeneity in samples, (2) locate the sources of heterogeneity, i.e., identify the pairs of groups which are different, (3) determine the diachronic pattern of the assessed central tendencies or ranks, and (4) assess the pattern for the existence of an overall trend which is significant. The levels of probability include 0.10, 0.05, 0.01, and 0.001. Presenting results with the 0.10 level of probability is justifiable for small samples (Bernard, 1995), and if these data are considered from a clinical medical perspective, in which a false-positive assessment is usually less costly than a false-negative one. However, greater emphasis is placed on results with p levels less than 0.05.

The multiple comparison procedure was the least-significant difference (LSD) test, sometimes called the protected *t*-test (Klockars and Sax, 1986; Toothaker, 1993), which, if calculated correctly, uses the *t*-test for pairwise comparisons only after general heterogeneity is detected by the ANOVA. The LSD has been criticized for being too powerful a test and, therefore, for having a high risk for making Type I errors if the number of comparisons is greater than 3. Here, that stricture was met. The results of pairwise comparisons using the nonparametric Mann–Whitney test are presented if the Kruskal–Wallis statistic, the nonparametric equivalent of ANOVA (Gibbons, 1993), indicates heterogeneity at the 0.10 level of probability. The analyses were carried out using the Statistical Package for the Social Sciences (SPSS).

RESULTS

The observations were made using traditional macroscopic techniques and without radiographs. None of the crania exhibited the extreme Grade 6 lesions or the altered maxilla often associated with thalassemia.

The results indicated temporal variation for the lesions of growth arrest and probable anemia. Overall there was a diachronic decline in marker levels in these samples from the Naqada region. Analyses of second molar lesions did not reveal a temporal trend for NI through NIII, but there was a decline from NI to NII. It is of interest that none of the indicators showed a consistent increase in frequency.

The standard deviations were generally large in relation to the means (Table 1). Bartlett's Box F test evinced equality of variances for $HyponoM^2$, VPS, and ES. A two-way ANOVA revealed no sex effects.

The percentages of individuals with hypoplasias or vault lesions showed some differences (Table 2). Contingency table analyses indicated temporal heterogeneity for VPP1 and VPP2.

The Kruskal–Wallis test and one-way ANOVA indicated heterogeneity ($P < 0.10$) for all variables (Table 3). If only $P < 0.05$ or less was accepted, then VPS and ES can be considered based on both approaches. $HyponoM^1$ reached significance by the parametric ANOVA.

TABLE 1. Means and standard deviations

	Naqada I		Naqada II		Naqada III	
	Mean	SD	Mean	SD	Mean	SD
M^1 hypoplasias	1.23	1.17	0.70	0.65	0.48	0.71
M^2 hypoplasias	1.27	1.01	0.61	0.74	0.88	0.74
Vault porosity score	1.86	0.98	1.15	0.99	0.82	0.77
Extent score	2.36	0.76	1.41	1.01	1.09	0.98

TABLE 2. Frequencies of binary variables by periods; χ^2 and ρ values from contingency table analyses for each variable

	M^1	M^2	Vault (score ≥ 1)	Vault (score ≥ 2)
Naqada I	61.5	81.8	92.3	61.5
Naqada II	60.0	50.0	69.7	31.8
NaqadaII	36.0	66.7	62.7	17.6
χ^2	3.80	3.76	7.52	15.2
ρ	0.15	0.15	0.02	0.00005

TABLE 3. Probabilities for temporal heterogeneity of variables, nonparametric and parametric methods

	χ^2	ρ	*F* ratio	*P*
M^1 hypoplasias	5.02	0.08	3.85	0.03
M^2 hypoplasias	5.32	0.07	2.88	0.06
Vault porosity score	18.08	0.0001	11.18	<0.0001
Extent score	26.45	<0.0001	14.66	<0.0001

The results of the multiple comparison tests showed the sources of temporal heterogeneity of the variables (Table 4). Differences were observed for the NII–NIII comparison for VPS and ES at $P < 0.05$ and $P < 0.10$, respectively. NI and III were different at $P < 0.05$ for all variables except the number of lesions on M^2.

The means and ranks indicated values that formed decreasing arrays from NI to NIII for all variables except $HyponoM^2$ (Table 5). The data suggested, overall, directional changes from NI to NIII, with differences between the endpoint series being dif ferent at more standard probability levels.

The patterns observed were further examined for linearity. Results of regression analyses indicated significant trends of decrease for all continuous variables except $HyponoM^2$ (Table 6). $HyponoM^2$ showed no overall trend over time. Logistic regression showed decreases in frequencies of VPP1, VPP2 at notable probability levels, and for $PresM^1$ at $P < 0.10$. In summary, the regression analyses indicated an overall diachronic decline of stress markers in the samples from the Naqada region.

TABLE 4. Comparisons using LSD and Mann–Whitney for variables found heterogenous by analysis of variance (P < 0.05)

	$HyponoM^1$		VPS		ES	
	MW	LSD	MW	LSD	MW	LSD
I–II	—	—	0.09	<0.10	0.0007	<0.10
II–III	0.04	—	0.02	<0.01	0.07	<0.10
I–III	0.04	<0.05	<0.001	<0.001	0.0001	<0.001

DISCUSSION

The most conservative and valid statement that can be made is that the incidence of the most stable studied markers decreases in the earlier to later samples and is likely most valid for the porosity defined lesions. The findings are suggestive but not conclusive. However, several possible explanations can be explored. The interest here is in the diachronic pattern, and what is note-worthy is that the markers did not increase over time. More material is needed to confirm this impression.

A major problem with attempts at interpretation is the lack of secure broad mortality statistics. The osteological paradox must be considered (Wood et al., 1992). It has been argued that because many individuals die in childhood without any skeletal lesions, a false impression of general *population* health could be gained. Further, without early childhood mortality statistics it would not be possible to accurately infer the meaning, for a population, of changes in lesion frequency in diachronic samples of *adults* beyond the samples themselves. Fewer lesions could mean only that a hardy few survived to adulthood to be counted, and that the sick, even relatively mildly ill, had died as infants or children, thus remaining invisible to analyses of adult remains. In some instances, samples with greater lesion prevalence may indicate that a greater range and number of people survived to adulthood, because more individuals survived childhood and a variety of

TABLE 5. Means and ranks by cultural phase

	HyponoM^1		HyponoM^1		VPS		ES	
	Mean	Rank	Mean	Rank	Mean	Rank	Mean	Rank
NI	1.23	42.77	1.27	40.14	1.86	99.42	2.36	103.36
NII	0.70	35.45	0.61	27.18	1.15	71.26	1.41	67.77
NIII	0.48	29.06	0.88	33.90	0.82	58.98	1.09	56.40

TABLE 6. Summary of linear and logistic regression analyses

Means	Adj. R^2	B	SE B	Beta	T	Sig T
M^1 hypoplasias	0.80	−0.368	0.159	−0.314	−2.320	0.025
M^2 hypoplasias	−0.016	−0.077	0.161	−0.068	−0.480	0.633
Vault porosity score	0.286	−0.756	0.164	−0.548	−4.589	<0.001
Extent score	0.313	−0.803	0.165	−0.571	−4.874	<0.001
		LOGISTIC				
Dichatomous variables		B	SE	Sig		
Vault (score ≥ 1)		−0.708	0.283	0.012		
Vault (score ≥ 2)		−0.997	0.275	0.0003		
M^1 lesion		−0.596	0.319	0.088		
M^2 lesion		−0.138	0.364	0.705		

insults. The lesion frequency could make the population appear to be less "healthy" compared to another if interpreted in an empiricist manner. This would be the case if "health" was based only on the presence of lesions and not the survival of children. However, a decrease in infant mortality is an improvement in population health at some fundamental level.

How health is defined influences interpretation. The health of adults and children could be worse in some sense even though the population "health" in terms of sheer growth is improved. Class, cultural, or occupational differences could also result in different frequencies of lesions from the same population. Thus, there are many possible "osteological paradoxes" which must be considered.

The samples used here are comparable, being those of individuals who survived to adulthood and who received a recoverable burial. Intact, large, demographically broader osteological samples of the Naqada region for these periods do not exist. However, circumstantial evidence exists that allows for some confidence to be placed in the ability to interpret the results presented here. Castillos (1982) provides an extensive review of archeological reports from nearly all published Upper Egyptian sites, including Naqada, of Badarian through Early Dynastic graves/tombs. Shape, size, orientation, contents ("wealth"), gender, and age of the graves/tombs, were assessed. Note that representative samples of remains were not generally brought back for curation in earlier years and hence are not available, although they are mentioned in site reports. An approximate composite picture of mortality is gained for early Upper Egypt, at least for those with recoverable burials. The pattern suggests that there was a slight decrease or more likely no change in infant and childhood mortality throughout the predynastic. Although no formal statistical support is provided (e.g., contingency table analysis), the large sample sizes reported and the similarity to diachronic patterns in Bard (1989) are grounds for accepting the basic validity of Castillos' (1982) assessment, at least from the perspective of exploratory data analysis (Tukey, 1977) . Also, although the samples used here are small in absolute terms, they represent a respectable percentage of the population likely to be resident in Naqada, estimated to be perhaps 900 individuals (Hassan, 1993).

The issue of infant and childhood mortality rates is of relevance to this study. If infant and childhood mortality had increased markedly over time, the results obtained here would likely be an example of the osteological paradox from the view of whole population "health." If lesion frequency had increased and mortality for children collectively had decreased, this would suggest non-adaptation, either social or biological, to the matrix of insults. Health would be "worse" in terms of disease frequency but "better" in the sense of greater childhood survival. Given that childhood and infant mortality remained unchanged or decreased slightly, with equal numbers or more surviving to adulthood, the improvement or no change in lesion burden is noteworthy.

The results suggest that there was a trend of improvement or no change in aspects of childhood health in the Naqada region, coinciding with the period of increasing social complexity, increasing population and aggregation, and lowering Nile floods. These Egyptian data do not show the more common pattern of increasing skeletal pathologies over time in these contexts. The percentage of any lesion per period does not systematically increase, and in the case of vault lesions, notably decreases over time. The lack of a decreasing trend for M^2 lesions may reflect sampling bias due to the relatively small numbers of available teeth and/or the intrinsic quality of the second molar.

The M^2 is not likely to have the same reliability as M^1 as an indicator. However the M^2 crown matures at a later time, and it is possible that differential timing of the stress is a factor. If this is so then it may mean that NIII was more stressful for children between the ages of 3 and 8 years of age.

The overall findings might be explained by a biocultural approach, which is admittedly based mainly on theoretical considerations. The general improvement in childhood health of those reaching adulthood subsequent to Naqada I may represent microadaptation to the previously described biosocial environment, in which ongoing crowding was probably a factor. The Nile levels showed gradual decline from NI to NIII (Butzer, 1976), theoretically causing food stress, but this may have been ameliorated by the social organization. A decline in disease parameters could be the result of either or both factors—biological and/or social adaptation. It is also possible that there was simply less exposure to background insults. Declining Nile levels could have decreased the general exposure to schistosomiasis, because the drop in the number of post-flood natural eddies and pools would not favor the snail hosts. However those children involved in farming would still have been exposed.

The Nile levels were lowest in Naqada III, and perhaps this encouraged political activity which caused the coalescence of communities (Hassan, 1988). In terms of cereal production, levels would have theoretically been at their lowest; yet, "health" improved (lesions declined) for the sampled adults as children. The social reorganization postulated by Hassan (1988) was conceivably beneficial to children. Perhaps the increase in social complexity was not initially marked by an increase in social inequality which affected the health of children. Castillos (1982) suggests that it was not. Some models of state formation do not postulate a necessary inequality (Cohen, 1978). Paynter (1989) calls into question the well-known construct that the transition to more social complexity is essentially defined by a recognizable absolute social inequality.

There is positive evidence, if mortuary data can be used, that in *some* regions of Upper Egypt, "social inequality" seems to have *decreased* overall from Naqada I to Naqada III (Griswold, 1992). However, in the Naqada region, social heterogeneity (a proxy for complexity) apparently increased from Naqada I to Naqada II and then subsequently *decreased* in the Naqada III period (Bard, 1989). This is of interest given that kings are known to have emerged during Naqada III. It suggests that the emergence of kingship is not necessarily accompanied by marked general social heterogeneity. It illustrates that within an emerging widespread cultural and political system that change in spatial terms can be uneven.

The site which shows the overall continuous decline from Naqada I to Naqada III in social heterogeneity is in Armant (Griswold, 1992), which was not a region of major sociopolitical development, unlike Naqada. However, the mortuary changes may reflect a more general process, specifically relative impoverishment. Bard (1989, 1994a) suggests that the general decrease in social heterogeneity and tomb wealth at Naqada during Naqada III may be related to economic disruption, perhaps due to warfare. A more beneficial social structure, given the low Nile levels in Naqada III, must also be considered in explaining the lesion improvement. It is noteworthy that the Naqada III period, when early "kingdoms" emerged, shows less overall mortuary differentiation between individuals in multiple locales (Armant and Naqada). This may mean that the fit between some kinds of mortuary data and increasing social stratification deserves a reexamination.

In summary, diachronic samples from predynastic Egypt at Naqada do not show an overall increase in skeletal lesions indicative of childhood biological stress during the period over which there is increasing environmental challenge: lower Nile floods, population aggregation, agricultural intensification, and sociopolitical complexity. This is counter to what has usually, but not always, been found in similar situations. It is difficult to derive biosocial health generalizations from paleopathological studies of societies in transition, to more complexity or "statehood." Each case needs to be treated as a historical particularism, with its own unique circumstances.

ACKNOWLEDGMENTS

We thank Dr. R. Foley and M. Bellati for the use of material in the Duckworth collection. Dr. H. Whitehouse, of the Ashmolean, made it possible to evaluate the material from Ballas, by providing necessary advice and access to notes made from Quibell's records and those of Mrs. J. Payne, whose contributions to knowledge of the Egyptian predynastic have enriched the field. Thanks also go to Mrs. B. Adams who answered a query in such a way as to help identify the Ballas records. Professor J. Baines provided invaluable input in this project. Dr. C. Berry kindly provided the data of previous work. Comments by the editor and referees helped to improve the manuscript. This research was supported by the Boise and Griffith Funds, Oxford University. The final manuscript was typed by Maytiller Evans.

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