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Population Continuity or Population Change: Formation of the Ancient Egyptian State

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ABSTRACT The origins of the ancient Egyptian state and its formation have received much attention through analysis of mortuary contexts, skeletal material, and trade. Genetic diversity was analyzed by studying craniometric variation within a series of six time-successive Egyptian populations in order to investigate the evidence for migration over the period of the development of social hierarchy and the Egyptian state. Craniometric variation, based upon 16 measurements, was assessed through principal components analysis, discriminant function analysis, and Mahalanobis D^2 matrix computation. Spatial and temporal relationships were assessed by Mantel and Partial Mantel tests. The results indicate overall population continuity over the Predynastic and early Dynastic, and high levels of genetic heterogeneity, thereby suggesting that state formation occurred as a mainly indigenous process. Nevertheless, significant differences were found in morphology between both geographically-pooled and cemetery-specific temporal groups, indicating that some migration occurred along the Egyptian Nile Valley over the periods studied. Am J Phys Anthropol 132:501–509, 2007. ©2007 Wiley-Liss, Inc.

The origins of the Egyptian state have long been debated, with, as a result of the prevailing diffusionist paradigms of the time (Armelagos and Mills, 1993), much early attention focusing on the ethnic affiliation or biological similarities of the early Dynastic (EDyn) groups. Purported changes in the archaeological sequence associated with the formation of the state were attributed to the population replacement as a result of the arrival of a "Dynastic Race" of invaders (Petrie, 1920, 1939; Winkler, 1938, 1939; Emery, 1961). More recently, Egyptologists have proposed a model for indigenous state formation, whereby three protostates developed and merged through military or other expansion (Trigger, 1983; Hassan, 1988; Bard, 1989, 1994; Kemp, 1989), while others have taken a more Afrocentrist approach (Diop, 1974; Bernal, 1987, 1991).

The invasion model for state formation usually involved the migration of a foreign population along the Wadi Hammamat from Asia (Winkler, 1938, 1939; Derry, 1956; Kantor, 1965), or along a northern Egyptian delta route (Bard, 1994). Evidence to support this hypothesis consists of pottery from regions such as Palestine (Kantor, 1965), and Near Eastern turquoise and shells (Arkell, 1975) found within Predynastic Egyptian sites. Furthermore, Uruk cultural markers are found at sites in the delta (Bard, 1994). The process of State formation, therefore, has considered to have been affected, or even caused by new populations entering the Nile Valley (as proposed by Petrie and Winkler). This new group was considered to be either a small immigration (following Kantor, 1965) or a large-scale population replacement (following Petrie, 1920, 1939).

The later model of indigenous development is based upon both agriculture and warfare, with the Upper Egyptian nomes or districts conquering the Northern nomes in Lower Egypt. This model of state formation avoids population migrations along the Nile Valley, and is reliant only on *in situ* development by the indigenous population.

The current article assesses the biological affinities of a large sample of EDyn Egyptian crania and compares these with local preceding samples to establish whether any diachronic or synchronic morphological variation is found.

PREVIOUS CRANIOMETRIC STUDIES

A summary of the results of major previous studies is presented here; for further details see Keita (1995, 2004). The earliest morphological studies of Egyptian crania were chiefly concerned with the shape of certain anatomical complexes. These complexes, defined by extreme variants as geographic groups, were considered to be "racial types" (Warren, 1897; Fawcett and Lee, 1902; Giuffrida-Ruggeri, 1915; Pearson and Davin, 1924; Stoessiger, 1927; Woo, 1930; Morant, 1925, 1935, 1937; Jackson and Cave, 1937; Risdon, 1939; Derry, 1956; Nutter, 1958). For example, Randall-MacIver (1901), and Thomson and Randall-MacIver (1905), employing morphological observations, concluded that southern Predynastic Egyptians were a hybrid population, consisting of "Negroid" and non-"Negroid" (Semitic) elements. The pattern of variation in facial and nasal indices was similar for both sexes through all periods from the Predynastic to the Roman period. This, they argued, meant that the distribution could not be considered simply a result of normal varia-

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tion of a single type; rather they suggested the juxtaposition of two groups based upon the correlation between facial and nasal indices as the sole criterion for distinguishing these two racial groups. The first group were short or broad-faced and platyrhine, while the second group was long or narrow-faced and leptorhine. Morant (1925, 1935) argued that the Lower Egyptian type remained relatively unchanged from EDyn times to the Ptolemaic period, but that during this time the Upper Egyptian type changed, and as the vast majority of southern Dynastic crania fell between the two extremes of the "types", some form of transition must have occurred. Morant considered both types to represent very closely related populations; the differences between them could be due to evolution through selection or differing environments, or through the slow mingling of two different races. Risdon (1939) argued that the population of Upper Egypt underwent gradual change from the Badarian through to the 18th Dynasty, and that by the New Kingdom, one group had almost entirely replaced the other in Upper Egypt. Elliot-Smith (1915–1916) defined as a "Brown Race" the autochthonous population of the Nile Valley, although Giuffrida-Ruggeri (1922) considered this confusing as it blurred Caucasian and African "types". Elliot-Smith considered the Brown Race to have been modified by "Negroes" in the south and by Near Eastern populations in the north. By contrast, Giuffrida-Ruggeri (1922) concluded that the Lower Egyptians were a Mediterranean white population while the Upper Egyptians were Ethiopians.

Falkenburger (1947), Strouhal (1971), and Angel (1972) all considered the southern Egyptian populations to be "Negroid" or hybrid in character, while the northern populations were more European-like. Wiercinski (1965) defined the basic or indigenous Egyptian type as being Badarian-like, but then said that this group was of Near Eastern origin. Other authors considered the Badarian to be a "Negroid" group (Morant, 1935, 1937; Nutter, 1958; Strouhal, 1971; Angel, 1972). Coon (1939) considered a Delta Predynastic sample to be less "Negroid" in character than southern populations.

Although there was some criticism of the racial typology underlying these studies (Myers, 1905, 1908; Batrawi, 1945, 1946), most morphometric studies continued to employ the concept of two populations in Egypt, such as the Upper and Lower Egyptian types of Morant (1925) and Risdon (1939). Most authors suggested that the Upper Egyptian type (i.e. southern) had more "Negroid" traits that were gradually lost through time (Morant, 1925, 1935; Risdon, 1939; Batrawi, 1946). These studies also found that the southern populations tended to cluster with more southerly groups, e.g. Crichton (1966) found Naqada crania to be more "Negroid" than a later period sample from Gizeh, while Bräuer (1976) found that Nubian and early Egyptian series tended to cluster with more southern African groups.

Recent craniometric studies continue to note morphological differences between northern and southern Egyptian samples. Hillson (1978) referred to this as two distinct trends within his data set:

1. a northern and lower Egyptian tendency
2. a southern Egyptian and southern African trend.

In his work, the Upper Egyptians overlapped with southern African populations. Billy (1977) noted, from Penrose's C analyses, that the homogeneity of her Lower Egypt series contrasted with greater dispersion in Upper Egypt with a constant morphological type being conserved through Dynastic times in the north. Keita (1990, 1992), through the use of discriminant function analysis (DFA), noted the overlap of southern Egyptians and some southern African series.

The earliest sample, the Badarian, frequently appears to be relatively distinct. This could be due to their very gracile nature (Gaballah et al., 1972), with very little development of the muscular relief; hence they have often been considered to have a generally "feminine" character (Strouhal, 1971). In early studies the Badarian sample were usually also described as having rather small absolute dimensions, especially in terms of breadth, horizontal circumference, and cranial capacity (Stoessiger, 1927; Morant, 1935). Stoessinger (1927) described the group as being distinct from Later Predynastic (LPD) populations through being more dolichocephalic and prognathic, somewhat narrower in the parietal region, and having shorter faces (and a lower nasal index). In contrast, Strouhal (1971) considered them to have high nasal indices. He also summarized them as being dolichocranial, orthocranial, mesenic to leptic, and chamaerrhine, i.e. having narrow, average height skulls with average to narrow upper faces, and a rather broad nose with marked prognathism. It is interesting to note that these biometrical studies led the investigators to consider the Badarian to be homogeneous, while the excavators (Brunton and Caton-Thompson) considered them to be heterogeneous (Strouhal, 1971). When Mahalanobis D^2 was used, the Naqadan and Badarian Predynastic samples exhibited more similarity to Nubian, Tigrean, and some more southern series than to some mid- to late Dynastic series from northern Egypt (Mukherjee et al., 1955). The Badarian have been found to be very similar to a Kerma sample (Kushite Sudanese), using both the Penrose statistic (Nutter, 1958) and DFA of males alone (Keita, 1990). Furthermore, Keita considered that Badarian males had a southern modal phenotype, and that together with a Naqada sample, they formed a southern Egyptian cluster as tropical variants together with a sample from Kerma.

Although the Badarian material is considered by biometricians to be homogeneous, this homogeneity may break down by the LPD period, and has certainly broken down by the EDyn period, e.g. the cranial material from the Royal Tombs sample at Abydos has a markedly heterogeneous appearance (Keita, 1992). Billy (1975) found little similarity between Predynastic samples, and even found that 1st Dynasty material from Abydos and El Amrah failed to cluster, and that the Royal Tombs material was morphologically distinct from all other EDyn period samples (Batrawi, 1946; Billy, 1975, 1977). Rösing (1990) also analyzed a large series of Upper Egyptian crania, and found greater morphological separation between Predynastic and historic Egyptian than between Predynastic Egyptian and Nubian groups.

In summary, most early craniometric studies concluded that there were two population groups inhabiting Egypt throughout the Predynastic period, and that the northern group (the Lower Egyptian type) replaced the more "Negroid" southern type during the Dynastic period. Most modern Egyptologists adopt a different view, who (even when arguing for a conquest of the country as the prime mover in the formation of the State (argue that the southern populations conquered the northern groups. More recent studies continue to show a geographic variation in morphology within Egyptian samples (as opposed to

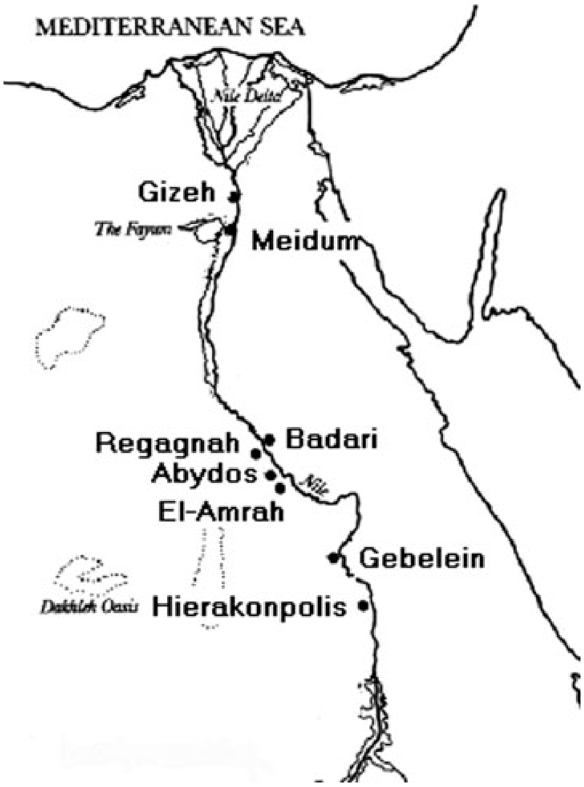

Fig. 1. Map of Egyptian sites sampled.

TABLE 1. Spatial distance between the archaeological sites (km)

	Bad	AEA	Hrk	Med	Reg	Giz	Geb
Bad	–						
AEA	106	–					
Hrk	253	147	–				
Med	267	369	507	–			
Reg	84	23	170	349	–		
Giz	333	433	569	65	413	–	
Geb	200	94	54	455	116	518	–

Bad refers to El-Badari, AEA to Abydos El-Amrah, Hrk to Hierakonpolis, Med to Meidum, Reg to Regagnah, Giz to Gizeh, and Geb to Gebelein.

Nubian material). This variation may be due to migrations of people or to other local factors.

The current article aims to ascertain whether any trend-like or distinct change is seen in craniometric measurements over the period of state formation, as the former would suggest indigenous state development, whereas the latter would suggest a greater role for migration in the process. The current study concentrates upon the Predynastic and EDyn periods, but also includes assessment of the Badarian and Middle Kingdom (MK) populations for comparison purposes.

MATERIALS AND METHODS

Skeletal sampling was mainly restricted to sites from Middle and Upper Egypt so that all individuals would have experienced reasonably similar geographical and climatic conditions. Due to the lack of Old Kingdom (OK), skeletal remains from Upper Egypt and one series from Lower Egypt were also analyzed (Gizeh). Site locations are shown in Figure 1. Distances between sites are shown in Table 1.

The selection of skeletal material was mainly pragmatic. For most periods, all available material was assessed, although complete skeletons were preferred over crania alone, and complete crania were selected in preference to fragmentary material. Care was taken to maximize samples from all available time periods. The sampling was also limited by the selection of the material that had been removed from Egypt and thus available for study in museum and university collections. Many collections derive from early excavations, with only individuals of interest being shipped back to the European collector funding the excavation, and hence the material studied may not be completely representative of the cemetery population. Four collections were studied; the Duckworth Collection of the Department of Biological Anthropology in Cambridge, the Egyptian collection of the Natural History Museum in London, the Marro Collection of the Department of Anthropology and Biology in Turin, and the Reisner Collection of the Natural History Museum in Vienna.

A series of six time-period groups were studied, dating from the Badarian (c. 4000 BC) to the MK (c. 1900 BC). The periods studied were the Badarian, the Early Predynastic (EPD), the LPD, the EDyn, the OK, and MK. Samples (Table 2) were studied only if they could be reliably dated to one of the six periods. The dates in Table 2 are midpoint time period dates and generate a temporal distance matrix. For further details regarding the cemeteries, see Zakrzewski (2003). Analysis was limited to adult individuals, with maturity being determined on the basis of sphenooccipital fusion, full epiphyseal fusion, and complete eruption of the third molars.

Following Howells (1973, 1989), all individuals were assigned a sex, rather than being classified as 'sex unknown'. The sex of each individual was primarily determined from analysis of the pelvic region, by assessing the size of the pubic angle, the size of the greater sciatic notch, the curvature of the sacrum, noting the presence or absence of ventral arc and subpubic concavity, the relative lengths of the inferior ramus of the pubis, and the distance from the pubic tubercle to the acetabulum. Postcranial sex was compared with the cranially determined sex. Cranial sex was assessed from the degree of supraorbital and glabellar projection, the squareness of the anterior portion of the mandible, the flaring of the gonial region, the robustness and level of muscle development in the nuchal region, and other features, such as the general size of the cranium with respect to others in the sample. The size of the mastoids was considered, but all the Egyptian cranial material studied has relatively inflated mastoids as compared to other populations. For individuals for whom cranial material alone was available, comparisons were made with individuals of known sex to increase the reliability of the sexing method.

The techniques described by Howells (1973, 1989) and Lahr (1996) were employed in this study. A spreading caliper was used to take the measurements where both landmarks for a single measurement such as maximum cranial breadth (XCB) had to be instrumentally determined. A digital sliding caliper, with direct data entry to a portable computer, was used to measure directly from one landmark to another, e.g. upper facial height (NPH).

TABLE 2. Sample information

Time period	Date	N	Cemetery site	Collection	n
Badari	4000 BC	27	El-Badari	Duckworth	27
EPD	3750 BC	53	Abydos El-Amrah	London	8
			Gebelein	Marro	45
LPD	3300 BC	41	El-Amrah	London	4
			Hierakonpolis	Duckworth	37
EDyn	2900 BC	48	Abdyos El-Amrah	Duckworth and London	48
OK	2600 BC	56	Meidum	London	2
			Regagnah	London	14
			Gizeh	Reisner	40
MK	1900 BC	22	Gebelein	Marro	22

Dates for time periods are mid-point time dates for the samples studied. N refers to the time period group sample size included in the current study, whereas n refers to the cemetery sample size in the current study (i.e. n is the breakdown of each time period group by cemetery).

Data analysis

SPSS 12.0 and PASSAGE 1.0 were used for statistical analysis. All variables were tested for normality using P–P and Q–Q plots, with a normal distribution being observed in all the variables selected for analysis. All data was then Z-scored within sexes (in order to adjust for sex-related size differences). Due to the rather small sample sizes of some time periods under consideration and the relatively fragmentary nature of the crania during these periods, analyses were performed on the pooled Z-scores. Given the fragmentary nature of the remains, to maximize the sample size (as crania lacking one measurement are removed from analyses), analysis of variance (ANOVA) was used to determine which variables exhibited significant differences between at least two of the time periods. Cut off-points from the ANOVA for variables for inclusion into further analyses were set at $P < 0.001$ and $N \geq 300$ (thereby reducing the cranial sample size of the current study to 247). Details of measurements selected are provided in Table 3.

TABLE 3. Description of variables selected for analysis

Variable	Description
NOL	Maximum cranial length, measured from nasion
BNL	Basion-nasion length (subnasal prognathism)
BBH	Basion-bregma height
XCB	Maximum cranial breadth
XFB	Maximum frontal breadth
STB	Bistephanic breadth
AUB	Biauricular breadth
ASB	Biasterionic breadth
NPH	Upper facial height
NLH	Nasal height
FMB	Fronto-malar breadth (midfacial breadth)
NAS	Nasion subtense (midfacial prognathism)
EKB	Biorbital breadth
DKB	Interorbital breadth
WMH	Cheek height
SOS	Supraorbital projection

All variables measured to nearest mm.

Principal components analysis (PCA) and DFA were undertaken. PCA is a form of factor analysis that aims to identify the underlying factors (variables) explaining the pattern within the set of observed variables, and is employed to ascertain which combination of variables best explain the variance seen within the ellipsoid of data points in multidimensional space. The importance of PCA in this study is to ascertain the morphological mapping of individuals, as overlap between temporal sample groups would therefore show morphological similarity. By contrast, the concept of DFA is to assign group membership from a number of predictors; thus in this study it has been used to assess whether craniometric variables can be used to predict the time period group membership of the cranial sample. The main aim is, therefore, to find the dimension or dimensions by which the groups differ and then derive classification functions from this to predict group membership. Successful development of these functions indicates that a degree of morphological differentiation exists between the samples.

The second part of the analysis was undertaken both on the time-period groups (where cemetery samples within each time period are pooled), and, where possible, on cemetery groups labeled by time period (such as the OK assemblage from Regagnah and the OK assemblage from Gizeh). Mahalanobis D^2 distances were calculated between the time-period groups and between the cemetery-sample groups. The Mahalanobis D^2 value between samples is used as a proxy for the genetic or biological distance between those samples. Due to their proximity (less than 10 km apart), material from Abydos and El-Amrah were pooled to form one "cemetery" sample. In addition, due to low cemetery sample sizes, the LPD material from Abydos El-Amrah and the OK material from Meidum were not analyzed as separate cemeteries. The pattern of temporal separation and geographic distance or isolation may affect the pattern of between-sample D^2 distances. If an isolation by distance model applies to the Egyptian samples studied, the expectation is that genetic or phenetic distance (in this case D^2 values) and spatial distance should be positively correlated, whereas genetic distance and temporal distance should be negatively correlated, as described and observed by Konigsberg (1990). Due to the internal structure of the biological distance, temporal distance and spatial distance matrices (because they are distance matrices, their elements are nonindependent), regression testing of one on another requires modification to simple linear regression, such as through the use of Mantel and Partial Mantel Tests. The latter test permits testing of two matrices, while controlling for the third. The potential correlations tested were the relationship between biological distance and time period (for the pooled time period samples), and between biological distance and both temporal distance and geographic distance for the cemetery samples. The Partial Mantel Test tests for correlations between biological distance (D^2) and temporal distance while controlling for geographic distance between the cemetery samples. A second Partial Mantel

TABLE 4. Component loadings from principal components analysis

Variable	PC 1	PC 2	PC 3	PC 4
FMB	0.759	0.368	0.305	−0.036
AUB	0.737	−0.137	0.125	0.245
NOL	0.732	0.037	−0.054	−0.330
NLH	0.691	0.015	−0.527	0.271
XFB	0.675	−0.568	0.223	−0.056
EKB	0.674	0.378	0.378	−0.024
NPH	0.654	0.046	−0.547	0.299
BNL	0.631	0.281	−0.245	−0.460
ASB	0.553	−0.195	0.188	0.124
WMH	0.533	0.228	−0.225	0.340
BBH	0.492	−0.186	−0.328	−0.430
STB	0.572	−0.593	0.268	−0.071
XCB	0.583	−0.593	0.043	0.049
NAS	0.437	0.536	−0.060	−0.239
DKB	0.350	0.402	0.463	0.086
SOS	0.305	0.302	0.167	0.317

Test was used to test for correlations between biological distance and geographical distance while controlling for temporal distance (between the same cemetery samples). These analyses were undertaken using PASSAGE 1.0. This software program was developed by Dr M Rosenberg and is kindly made available by him (http://www.passagesoftware.net/) (Rosenberg, 2001).

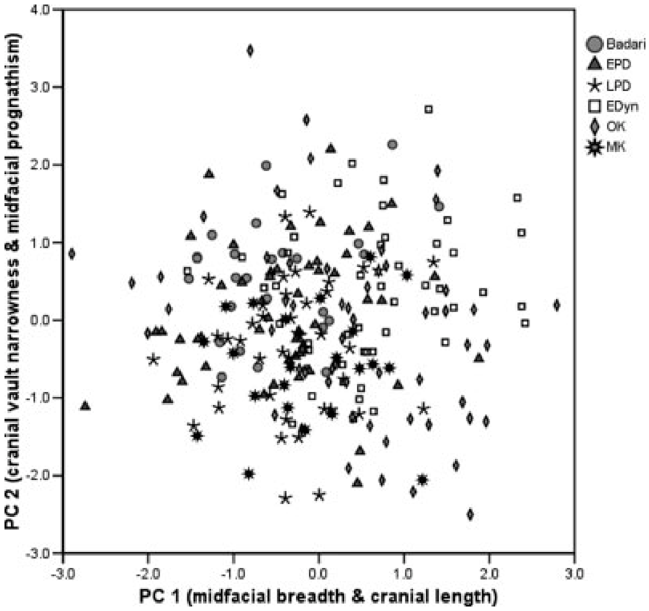

Fig. 2. Plot of the first two components derived, explaining 36.1% and 12.9% of the variance seen within the crania.

TABLE 5. Percentage classification of crania from DFA

Original period	Predicted time period group membership (%)						
	Badari	EPD	LPD	EDyn	OK	MK	Total
Badari	**40.7**	40.7	7.4	3.7	7.4	0	100.0
EPD	9.4	**54.7**	15.1	7.5	11.3	1.9	100.0
LPD	0	24.4	**43.9**	4.9	22.0	4.9	100.0
EDyn	2.1	8.3	4.2	**72.9**	10.4	2.1	100.0
OK	7.1	16.1	16.1	19.6	**37.5**	3.6	100.0
MK	0	22.7	4.5	0	63.6	**9.1**	100.0

Correct classifications are marked in bold. Each row indicates the original time period group to which the crania belong, whereas each column indicates the group to which they have been classified by DFA on the basis of their morphology.

RESULTS

PCA derived four components, cumulatively explaining 64.6% of the variance seen within the craniometric measurements (Table 4 for component loadings). Although no clear separation between the samples was seen (Fig. 2, plotting out the first two components), the EDyn and OK samples were generally longer vaulted with broader midfaces than the earlier samples (indicated by their position relatively high on PC1). The Badarian generally exhibit the greatest facial prognathism of the samples studied (demonstrated by their relatively high position on PC2). Despite their small sample size, and general lack in facial prognathism, the MK appear very morphologically heterogeneous (as indicated by their location in all quadrants of the plot). All individuals located at the extremes of the axes derive from the OK, suggesting morphological heterogeneity in this period.

Despite the overall morphological similarity (as determined from the overlapping nature) of these Egyptian samples (Fig. 2), morphological differences do exist between the time periods. DFA derived five functions, which together correctly classified 44.5% of the crania into their temporal group (Table 5). Importantly, although only 45% of crania were correctly classified by DFA, where misclassification occurred, the crania were generally misclassified into temporally adjacent samples (e.g. the Badarian misclassified as EPD). This implies some degree of morphological continuity across successive time periods. Most correct classifications were of the EDyn and most misclassifications were of the MK sample, suggesting some morphological homogeneity within the first sample and more heterogeneity in the later sample.

Mahalanobis D^2 distances were calculated between all the time periods (Table 6) and used as a proxy for genetic or biological distance between time periods. Most of the D^2 values were significant (that is, significantly greater than 0), with all those relating to the Badarian, EPD, and EDyn time periods demonstrating significance at $P < 0.001$. There is no significant genetic (phenetic) distance between the pooled OK and MK samples. No significant correlation was found between temporal distance and the D^2 values (biological–temporal correlation = 0.0715, n.s.).

Mahalanobis D^2 distances were also calculated between the cemetery groups by time period (Table 7). Again, most of the D^2 values were significant, with all those relating to the Badarian, from El-Badari, and the EDyn, from Abydos El-Amrah, demonstrating significance at $P < 0.001$. The partial correlation between biological distance and geographic distance between the cemeteries, controlling for time difference, is −0.3674 (n.s.). Controlling for geographic distance, the correlation between biological distance and time is −0.1692 (n.s.). A positive spatial–biological distance correlation would be expected under an isolation by distance model. Genetic distances between samples, as estimated here through D^2 distances, show no relationship with spatial distances between samples. A negative temporal correlation with genetic distance would also be expected under an isolation by distance model. Although this has been found within these samples, the correlation is very small and not statistically significant.

TABLE 6. Mahalanobis D^2 distances between time periods (cemeteries pooled)

	Badari	EPD	LPD	EDyn	OK	MK
Badari	–					
EPD	2.6720***	–				
LPD	4.7414***	2.0598***	–			
EDyn	6.1368***	3.6136***	4.8140***	–		
OK	3.2288***	2.0806***	1.4898**	2.7859***	–	
MK	3.9096***	2.6124***	1.9551*	5.2559***	1.5156 n.s.	–

*Mahalanobis D^2 difference is significantly different at $P < 0.05$, **significant at $P < 0.01$, ***significant at $P < 0.001$.

TABLE 7. Mahalanobis D^2 distances between cemeteries by time periods

	BadariBad	EPDAEA	EPDGeb	LPDHrk	EDynAEA	OKReg	OKGiz	MKGeb
BadariBad	–							
EPDAEA	4.9300***	–						
EPDGeb	3.1307***	5.6983**	–					
LPDHrk	5.2093***	6.6072***	2.4495***	–				
EDynAEA	6.1368***	8.3303***	3.6352***	4.8724***	–			
OKReg	4.5089***	6.3718*	4.0244***	5.2922***	4.3267***	–		
OKGiz	4.1670***	7.0585***	2.8394***	1.4803*	3.8032***	5.3168***	–	
MKGeb	3.9096***	5.1111*	3.0283***	1.9295 n.s.	5.2559***	5.7951***	1.4408 n.s.	–

*Mahalanobis D^2 difference is significantly different at $P < 0.05$, **significant at $P < 0.01$, ***significant at $P < 0.001$.

DISCUSSION

The development of the Egyptian state and the associated formation of hierarchical social organization occurred very rapidly within Egypt over the LPD and EDyn (Bard, 1989). If this process occurred as an entirely indigenous development with total population continuity, then little increase in morphological heterogeneity would be expected. In accordance with previous studies (Keita, 1990; Prowse and Lovell, 1996), the current study has shown the ancient Egyptians to exhibit both genetic heterogeneity and morphological similarity. The former is demonstrated by the significant D^2 values between the time period samples and the misclassification of the crania to groups by the DFA, while the latter is demonstrated by the overlapping nature of the data points in Figure 2.

Despite significant pairwise D^2 values between the time periods groups, no significant relationship was seen between these D^2 values and time for the pooled cemetery samples (Table 6). Furthermore, no significant relationship was found between the D^2 values and either temporal or geographic distance (when controlling for the other matrix) for the individual cemetery samples (Table 7). These results suggest that distinct morphological differences occur between the various samples, but that these differences are not patterned in either space or time. This implies that an isolation by distance model may not be appropriate for these groups (although isolation by distance on a smaller distance scale would be undetectable in this data). This result is in contrast with earlier craniometric studies that found some evidence for distinct northern and southern morphological patterns (Hillson, 1978; Keita, 1990, 1992). This lack of biological patterning by geographic distance between the cemetery sites may result from the large scale of geographic distance between the cemeteries in this study (Table 1). Isolation by distance may therefore operate at shorter distances than the geographic distances between these cemeteries and hence would be undetectable in the current data set.

The Badarian population

The Badarian crania have been characterized by their small and gracile nature (Stoessiger, 1927; Morant, 1935; Strouhal, 1971; Gaballah et al., 1972), and their relatively high degree of facial prognathism (Stoessiger, 1927). The current study supports this description (being placed low on PC1 in Fig. 2, as a result of their short cranial vaults and narrow faces). Furthermore, their phenotypic homogeneity (Fig. 2, Table 5) has been demonstrated. As a result of their facial prognathism, the Badarian sample has been described as forming a morphological cluster with Nubian, Tigrean, and other southern (or "Negroid") groups (Morant, 1935, 1937; Mukherjee et al., 1955; Nutter, 1958, Strouhal, 1971; Angel, 1972; Keita, 1990). Cranial nonmetric trait studies have found this group to be similar to other Egyptians, including much later material (Berry and Berry, 1967, 1972), but also to be significantly different from LPD material (Berry et al., 1967). Similarly, the study of dental nonmetric traits has suggested that the Badarian population is at the centroid of Egyptian dental samples (Irish, 2006), thereby suggesting similarity and hence continuity across Egyptian time periods. From the central location of the Badarian samples in Figure 2, the current study finds the Badarian to be relatively morphologically close to the centroid of all the Egyptian samples. The Badarian have been shown to exhibit greatest morphological similarity with the temporally successive EPD (Table 5). Finally, the biological distinctiveness of the Badarian from other Egyptian samples has also been demonstrated (Tables 6 and 7).

Formation of the Egyptian state

Contra early Egyptologists (Petrie, 1920, 1939; Emery, 1961; Kantor, 1965), archaeological continuity is currently postulated between the Predynastic periods and the EDyn (Hassan, 1988; Kemp, 1989; Bard, 1989, 1994; Midant-Reynes, 2000a). Although the EDyn samples (both EDyn and OK) show morphological similarities with the preceding populations (Fig. 2), each sample does exhibit certain distinct characteristics. Lying high on PC1 in Figure 2, the EDyn sample and OK samples have relatively longer and broader cranial vaults. Furthermore the EDyn sample is characterized by their relatively broad faces, thereby allowing successful group delineation by DFA (Table 5). In concordance with Keita (1990), the EDyn crania studied also demonstrated morphological heterogeneity, with the small number of crania that are misclassified, being misclassified by DFA into all potential time periods. Significant genetic pairwise differences are found not only between the EDyn and all other pooled cemetery time periods (Table 6), but also between the EDyn sample and all single cemetery samples (Table 7). These results suggest that the EDyn do form a distinct morphological pattern. Their overlap with other Egyptian samples (in PC space, Fig. 2) suggests that although their morphology is distinctive, the pattern does overlap with the other time periods. These results therefore do not support the Petrie concept of a "Dynastic race" (Petrie, 1939; Derry, 1956). Instead, the results suggest that the Egyptian state was not the product of mass movement of populations into the Egyptian Nile region, but rather that it was the result of primarily indigenous development combined with prolonged small-scale migration, potentially from trade, military, or other contacts.

The Middle Kingdom

The MK sample was studied as a potential out-group for comparison with the Predynastic and EDyn periods. With the increased size of the Egyptian population by this period (Butzer, 1976; Brewer and Teeter, 1999), greater morphological heterogeneity was predicted to be found. Figure 2 indicates that, despite the small sample size, craniometric heterogeneity is found as the MK individuals are placed in all quadrants of the plot. Furthermore, discriminant functions were not successful at morphologically proscribing this sample (Table 5). In concordance with this, the MK sample exhibited fewest significant pairwise biological distances with other samples (Tables 6 and 7). The sample studied originates from Gebelein in Upper Egypt. Interestingly, the only other sample deriving from Gebelein, an EPD sample, was found to be significantly biologically distant to the MK sample (Table 7). This result suggests that there is no simple biological population continuity at Gebelein. Stele indicate that Nubian mercenaries lived, married, died, and were buried at this site over the MK period (Fischer, 1961). Previous research has suggested that this sample may include some of these Nubians (Zakrzewski, 2003). If Nubians had been integrated into the Egyptian population in the MK but not in preceding periods, then one would expect to see higher phenotypic variance in the MK than in the EDyn and OK. This cannot be ascertained from the current analysis, but must remain a topic for future research.

Social context of the samples

This study concentrated upon the period of state formation. The region at the center of this process was the Abydos region (Wilkinson, 1999) and the samples selected derive mainly from this area. Due to its geographic location, Abydos was able to control trade and raw material resources over the LPD and EDyn periods (Bard, 1994).

Like Abydos, during the OK, Gizeh was also in an area of greater control of trade, and therefore formed a potential magnet area for rural to urban migration. The OK material from Gizeh may therefore have greater internal social differentiation than the OK material from the more rural sites of Regagnah and Meidum. Unfortunately the OK sample from Meidum was poorly preserved and so most was unsuitable for the current analysis. The OK cemetery samples were found to be biologically distant from each other (Table 7). This may represent social differences between the samples. This hypothesis has been used to account for differences between other Egyptian samples, such as the apparent distinctiveness of samples from Predynastic Naqada (Johnson and Lovell, 1994; Prowse and Lovell, 1996), and from MK Lisht (Irish, 2006).

Social diversity and hierarchy, demonstrated from funerary contexts, increases through the Predynastic periods (Bard, 1989). During the EPD, an increase in social diversity is suggested from the graves and funerary offerings (Midant-Reynes, 2000b). Social hierarchy, as characterized by a dramatic increase in the number of funerary offerings, developed during the LPD (Castillos, 1983; Midant-Reynes, 2000a). It is thus possible that in the straight time period analysis, despite pooling samples from several sites, the low levels of morphological diversity noted in the EPD and LPD samples may result from sampling selection of individuals from limited segments of society. By contrast, postcranial analysis of these same samples demonstrated the greatest sexual dimorphism and thus greatest potential social ranking difference over the EPD and LPD (Zakrzewski, 2003).

The cranial material studied originated from a variety of funerary contexts (for detailed descriptions of the cemeteries, see Zakrzewski, 2003; Keita and Boyce, 2006). Pooling material in this manner reduces the likelihood of bias due to selection of only individuals from certain social groups. The only temporal samples to derive from only one cemetery are the Badarian and the MK. Periods of key interest to the current study, i.e. those over the period of state formation (EPD, LPD, EDyn, and OK), derived from more than one cemetery and hence may include individuals from across social ranks. The current study has shown this approach to be problematic as significant biological distance was found between cemeteries from the same time period (Table 7). Greater distance was found between the OK material from Regagnah and Gizeh than between the EPD material from Abydos El-Amrah and Gebelein. This may reflect differences in internal social organization and social ranking (as discussed above), the greater geographic distance between the later period sites, or it may reflect changes in the Egyptian population within the Dynastic period resulting from migration.

CONCLUSIONS

The analyses of the crania studied suggest that genetic continuity occurs over the Egyptian Predynastic and EDyn periods. The study also indicates that a relatively high level of genetic differentiation was sustained over this time period. This evidence suggests that the process of state formation itself may have been mainly an indigenous process, but that it may have occurred in association with in-migration to the Abydos region of the Nile Valley. This potential in-migration may have occurred particularly during the EDyn and OK. A possible explanation is that the Egyptian state formed through increasing control of trade and raw materials, or due to military actions, potentially associated with the use of the Nile Valley as a corridor for prolonged small scale movements through the desert environment.

Using Mahalanobis D^2 values as a proxy for genetic or phenetic distance, significant genetic distances were found between time period groups and between cemetery groups. No conclusive linear relationship was found from any of the regressions of genetic distance on temporal distance (for the pooled time period groups), genetic distance on temporal distance (controlling for spatial distance), or genetic distance on spatial distance (controlling for time) for the cemetery groups. These results indicate that the biological patterning of the Egyptian population varied across time, but that no simple and consistent temporal or spatial trends could be discerned.

The Badarian is shown to be a genetically homogeneous sample, characterized by short cranial vaults and significant subnasal prognathism. The homogeneity of the Badarian mirrors previous cranial (Stoessiger, 1927; Morant, 1935; Strouhal, 1971; Gaballah et al., 1972) and postcranial studies (Zakrzewski, 2003). Due to their placement in all sectors of Figure 2, later groups are shown as being more phenotypically heterogeneous. Furthermore, as a result of its long broad vaults and broad faces, the EDyn sample appears morphologically distinct relative to the other temporal groups.

Due to the relatively small sample sizes arising from the fragmentary nature of some of the crania and the lack of skeletal material that cross-cuts all social ranks within each time period, these results must remain provisional and indicative. Further research on recently excavated material, especially from the Delta area, is therefore required in order to further address the issues raised.

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