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Neolithic skull shapes and demic diffusion: a bioarchaeological investigation into the nature of the Neolithic transition

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ABSTRACT – *There is a growing body of evidence that the spread of farming in Europe was not a single uniform process, but that it involved a complex set of processes such as demic diffusion, folk migration, frontier mobility, and leapfrog colonisation. Archaeogenetic studies, which examine contemporary geographical variations in the frequencies of various genetic markers have not succeeded in addressing the complex Neolithisation process at the required level of spatial and temporal resolution. Moreover, these studies are based on modern populations, and their interpretive genetic maps are often affected by post-Neolithic dispersals, migrations, and population movements in Eurasia. Craniometric studies may provide a solid link between the archaeological analysis of past events and their complex relationship to changes and fluctuations in corresponding morphological and thus biological variations. This paper focuses on the study of craniometric variations between and within Pre-Pottery Neolithic, Pottery Neolithic, and Early Neolithic specimens from the Near East, Anatolia and Europe. It addresses the meaning of the observed multivariate morphometric variations in the context of the spread of farming in Europe.*

IZVLEČEK – *Vedno več je dokazov, da širjenje poljedelstva v Evropi ni bil enkraten, enoten proces, temveč je obsegal kompleksen niz procesov, kot so demska difuzija, migracije ljudstev, mobilnost meja in kolonizacija na način žabjega skoka. Arheogenetske študije, ki preučujejo sodobne geografske variacije in pogostost različnih genskih označevalcev, niso uspele pojasniti kompleksnost prostorske in časovne strukturiranosti procesa neolitizacije. Ker te študije temeljijo na modernih populacijah, na njihove interpretativne genetske zemljevide pogosto vplivajo post-neolitske razpršitve, migracije in premiki prebivalstva v Evraziji. Kraniometrične študije lahko preskrbijo trden člen med arheološkimi analizami preteklih dogodkov in njihovimi kompleksnimi razmerji s spremembami in nestalnostmi v ustreznih morfoloških in bioloških variacijah. Ta članek se osredotoča na preučevanje kraniometričnih variacij med in znotraj predkeramičnih in keramičnih neolitskih ter zgodnje neolitskih populacij na Bližnjem vzhodu, v Anatoliji in v Evropi. Loteva se pomena opazovanih multivariantnih morfometričnih variacij v kontekstu širitve poljedelstva v Evropi.*

KEY WORDS – *neolithisation of Europe; Early Neolithic; craniometric analysis; multivariate statistical methods; sex-specific variability*

Introduction

The Neolithic period in the Near East and Anatolia was a period of experimentation, innovation and change. It was particularly demarcated by the 'cultural explosion' during the pre-pottery Neolithic B period (*Aurenche and Kozłowski 1999*) in the Levant, Mesopotamia, Iran and Anatolia. Preliminary analyses of the space-time dynamics of these cultures indicate that observed changes in the Levant's settlement patterns, population density and size, and cultural aspects such as architectural style, lithic typological attributes, etc. are possibly associated with a diffusive process to island and mainland Greece during this period (*Perlès 2001*). It is not clear, however, whether this process was for the most part cultural, demic, or a combination of both, and nor if it combined with a process of overland dispersal from western Anatolia to southeast Europe (*Özdoğan 1997*).

It is clear that the Neolithisation process in Europe varied by region/culture and that it comprised a series of complex processes involving population fusion, fission, leapfrog colonisation, dispersals and migrations. Analyses of radiocarbon dates (*Pinhasi et al. 2005*), and craniometric data (*Pinhasi & Pluciennik 2004; Pinhasi 2003*), highlight the complexity of the Neolithic transition in the various regions, and stress the need to examine its spatiotemporal, archaeological and biological aspects in greater scope and resolution.

Some analyses of the craniometric data set, utilising skeletons from Pre-Pottery and Early Neolithic occupational phases from Near Eastern, Anatolian and European sites, have demonstrated a high degree of morphological heterogeneity between and within populations. In particular, a high degree of morphometric heterogeneity has been detected and reported for the Near Eastern/Anatolian Pre-Pottery Neolithic specimens (*Pinhasi 2003*). This heterogeneity contrasts with the morphological homogeneity among the Central Anatolian Çatalhöyük skeletal population and that of mainland Greece, the Balkans and southern Hungary.

But what does this observed craniometric pattern tell us about the nature of the Neolithisation process in the various regions of the Near East, Anatolia, and Europe?

Ammerman & Cavalli-Sforza (*1971*) suggested that the 'Wave of Advance' (WOA) of the Neolithic farmers progressed at an averege speed of 1 km/yr, but that it was twice as rapid along the coasts of the Mediterranean (Cardial Neolithic and associated cultures). At present, however, the mosaic chronometric pattern of the Neolithisation of Italy (*Skeates 2003; Forenbaher and Miracle 2005*) does not support a straightforward linear demic diffusion, but points to the involvement of other processes, specifically the maritime colonisation of certain parts of the peninsula.

A recent analysis of the wave of advance, using radiocarbon dates from 735 early Neolithic sites in Europe, the Near East, and Anatolian sites (*Pinhasi et al. 2005*), has demonstrated high correlation coefficients ($R > 0.8$) for some of the Mesopotamian, southeast Anatolian and Levantine Probable Centres of Diffusion (POAs) and thus supports both in magnitude and average speed (km/year) the original approximation of Ammerman & Cavalli-Sforza (*1971*). In fact, the obtained average rate of the Neolithic spread over Europe was 0.3–0.6 km/yr, which is consistent with the prediction of the demic diffusion model. Pinhasi et al. (*2005*) examined whether the chronometric correlations between early Neolithic occupation in Europe and the Near East/Anatolian zone allow the interpolation of a best-fit geographic region in the Near Eastern/Anatolian from which a WOA probably originated. They reported that the most likely region was the northern Levant/Mesopotamia. This observation is in disagreement with results obtained from the craniomentric study, which suggests a centre of dispersal in Central Anatolia (*Pinhasi & Pluciennik 2004*).

At this stage, it is not clear whether or not the slow rate of overall spread and its essentially linear character, as shown by the above-mentioned analysis, is a true reflection of a single historical process which was for the most part demic in nature, or perhaps is merely an artefact – possibly the outcome of a series of movements and transitions that, when combined (i.e. when examining pan-continental trends), appear to be linear. Another possibility is that the chronological cline reported by Ammerman & Cavalli Sforza (*1971*) is the outcome of cultural diffusion, and thus that the Neolithisation process involved for the most part an economic/cultural transformation of in situ Mesolithic populations. It is therefore evident that we are now entering a new phase in the study of the Neolithic transition, one that requires greater attention to details and a finer focus on the application of specific archaeological and morphometric methods to tackle the process of Neolithisation on a regional-level.

It appears that a Neolithic dispersal from the Near East/Anatolia to Europe may have occurred at least twice: once as a PPN maritime expansion from the Levant/southern Anatolia, and later on during the Pottery Neolithic period as an overland dispersal from Central/Western Anatolia to southeast Europe (*Perlés 2001; Özdoğan 1997*). This means that more than one founder Neolithic population dispersed out of the Near East/Anatolia to Europe, and that each dispersal event must have left certain demographic and genetic signatures on modern Europeans. At the same time, the rise of regional variations in cultural aspects, as one can deduce from the certain differences in artefact styles, and the like, may have been the outcome of a period of fragmentation and isolation of certain communities, possibly associated with the severing of existing trade and exchange networks. Processes of fission, fusion, consolidation and isolation should therefore leave biological traces that to a certain extent correspond to those that can be read from the material record.

A demic diffusion process involves gene flow, which in general reduces the genetic and morphological difference between populations. In contrast, cultural diffusion will not have a direct effect on the morphological attributes of these populations, so that new artefacts, domesticates, and architectural features may appear in a given period in a certain region without any apparent change in the morphology of the skeletons from this period.

Genetic studies have not provided the required resolution to address this question (*Pluciennik 1996*). In particular, the time resolution applied in most genetic studies is too vast to recognise archaeological/historical processes of the scale involved in Neolithic studies (*Brown & Pluciennik 2001*). Craniometric studies may provide the 'missing link' between genetic studies, which for the most part examine geographically-based variations in a given marker among modern populations, and the Neolithic archaeological record. But can craniometric studies 'translate' observed biological affinities and variability among skeletal populations from various archaeological sites to corresponding historically-based population variations between archaeological cultures? The answer to this question requires examination of the relationship between 'archaeological cultures' and past human populations, whereas the latter is assumed to correspond to past ethnicity. Thus, the question may be rephrased, and one should ask whether the appearance of specific 'archaeological cultures' defined according to certain non-functional characteristic elements of their archaeological toolkit (such as pottery style) is directly associated with a corresponding biological process such as population differentiation, admixture, isolation and the like.

This paper will attempt to take an initial step towards furthering our current understanding of this complex polemic by systematically examining morphometric relationships and variations between Near Eastern, Anatolian and European Neolithic populations from specific sites that were allocated to a specific group on the basis of their archaeological attributes (e.g. Cardial, Starčevo-Körös-Çris, etc.). Morphometric variations and similarities between the groups should therefore shed some light on the relationship between archaeological entities and the corresponding biological attributes of past populations.

Materials and Methods

The skeletal sample is described in Table 1. It consists of Pre-Pottery Neolithic specimens from the sites of Zawi Chemi, Hotu, Abu Hureyra, and Çayönü in the Near East and Anatolia; Pottery Neolithic specimens from Çatalhöyük-Turkey; Early Neolithic specimens from Nea Nikomedeia-Greece, Vlasac and Lepenski Vir-Danube Gorge; various specimens from the Cardial Neolithic, Starčevo-Körös-Çris (SKC) complex; and the Linienbandkermik (LBK) sites of Visenhauser Hof, Sonderhausen and Schwetzingen. The sample is first analysed by groups (Tab. 1) which are defined according to either specific archaeological cultural entities (e.g. "Cardial") or site/culture (e.g. "Sondehausen-LBK").

The following set of standard craniometric variables that best define the gross moprphological shape and dimensions of the craniofacial complex are utilised:

- Vault height: BBH;
- Vault length: GOL;
- Vault breadth: minimal- MFB and maximal- XPB;
- Facial dimensions:
  Nasal height- NLH and breadth- NLB;
- Orbital height- OBH;
- Upper face height-NPH;
- Bizygomatic breadth- ZYB.

Three statistical methods are then applied to the samples:

1. Squared Mahalanobis Distances

The generalised distance, D^2 is a statistic that is often applied in the estimation of group differences between biological populations. It has been extensively applied in craniometric studies of prehistoric populations (see, for example, *Howells 1973; Keita 1990; 1992*).

2. Discriminant Function Analysis

The method is used in order to discriminate between groups, and to derive posterior probabilities for the correct classification of cases to one of the existing groups (thus indicating the degree to which it is possible to correctly assign a give case to a given group on the basis of the derived discriminant functions).

Another important use of discriminant function analysis is the actual positioning of populations and the interpretation of functions (*Howells 1973*). The b coefficients of each function can be interpreted in a similar manner to factor loadings – that is, the larger the coefficient, the greater the contribution of the respective variable to the discrimination between groups. However, these coefficients do not tell us between which of the groups the respective functions discriminate. This can be quite effectively achieved, however, by plotting group centroids and individual discriminant function scores (per case for the first two discriminant functions).

Location	Latitude	Longitude	N	M	F	Period	Group code
Abri De Pendimoun	43.48	7.30	1			Cardial	6
Arene Candide	38.33	16.12	1			Cardial	6
Arma Dell'aguila	42.37	13.37	2	1	1	Cardial	6
Castellar	43.48	7.30	1	1		Cardial	6
Chateau neuf	43.24	5.12	1	1		Cardial	6
Condeixa	40.06	8.30	26	11	15	Cardial	6
Finale Ligure	44.12	8.18	2	1	1	Cardial	6
Grotte Sicard	43.24	5.12	1	1		Cardial	6
Sabassona	41.38	2.18	1		1	Cardial	6
Salces	42.54	2.54	2	1	1	Cardial	6
Çatalhöyük	37.10	32.13	16	7	9	Pottery Neolithic	2
Lepenski Vir	44.33	22.03	5	4	1	Danube Gorge	5
Vinča	44.48	20.36	3	2	1	Danube Gorge	5
Schwetzingen	49.38	8.58	10	7	3	LBK	7
Sonderhausen	51.12	10.54	12	5	7	LBK	8
Viesenhäuser Hof	48.50	9.13	17	9	8	LBK	9
Nea Nikomedeia	40.65	22.30	10	3	7	Greek Neolithic	3
Abu Hureyra	35.87	38.40	2		2	PPN	1
Çayönü	38.23	39.65	3	2	1	PPN	1
Hotu	35.81	53.90				PPN	1
Zawi Chemi	37.08	43.87	1	1		PPN	1
Deszk	46.22	20.25	2	1	1	SKC	4
Devetaškata Peštera	43.23	24.95	1	1		SKC	4
Endröd	46.94	20.78	1	1		SKC	4
Gura Bacului	46.48	23.36	1		1	SKC	4
Kasanlak	42.36	25.24	1		1	SKC	4
Vészto-Mágori	46.94	20.23	6	6		SKC	4

Tab. 1. Samples analysed by location and archaeological period.

3. Principal Components Analysis

Principal Components Analysis (PCA) is a data reduction technique. It reduces dimensionality by calculating a series of uncorrelated factors, or PCs, whose total number should be significantly less than the total number of variables. PCA is for the most part an exploratory method, which is therefore to a certain extent subjective. However, its strength lies in the fact that it can be applied directly to the data set without the need to assign each case to a given group.

The first PC explains the largest amount of the total variation, and in most biological studies it mostly covers size-related variation. The second PC explains even less of the variation, and so on in descending percentages. It is therefore usually sufficient to examine only the first few PCs (depending on the percentage of variation that each one explains). Each case has a set of factor scores corresponding to each PC. By plotting bivariate graphs of the factor's scores (usually for the first vs. second component) it is then possible to assess any detectable relationship between the cases (in this specific case, Neolithic specimens). Furthermore, each PC contains a set of factor loadings for each variable, and it is therefore possible to examine which specific variables have the maximum positive or negative loadings on a given PC. It is then possible to interpret the relationship between the reduced set of variables and the obtained PCs, or in other words, to see if there is a meaningful biometric relationship between the variable set and the obtained PCs.

Results

The following is a description of the results obtained by analysing the same set utilising each of the above methods.

a. Squared Mahalanobis Distances

Results of the analysis are provided in Table 2. The largest Square Mahalanobis Distances (D^2) between a single site/culture, and the remainder are detected in the case of the Pre-Pottery Neolithic set and the rest with the exception of the Starčevo-Körös-Çris (SKC) and the Cardial Neolithic complexes. The second cultural complex with large D^2 distances is the Danube Gorge Neolithic (comprising specimens from the sites of Lepenski Vir and Vlasac). The group has large D^2 distances from all other sites/complexes. The third site with large D^2 distances from the remainder is the south-western LBK site of Viesenhauser Hof. Surprisingly, the specimens from this site have large D^2 distances not only from most other Neolithic complexes, but also from the two other LBK sites of Schwetzingen and Sonderhausen.

Small D^2 distances (< 4.0) are observed in the case of three sites/complexes: Çatalhöyük, Nea Nikomedeia and SKC. The D^2 distances between the three complexes are all below 3. Furthermore, Çatalhöyük shows small distances from all other complexes except PPN, Danube Gorge and Viesenhauser Hof. Exactly the same trend is noticed in the case of Nea Nikomedeia. The SKC complex differs from the other two only by having a slightly lower D^2 value for its distance from Viesenhauser Hof (3.98). In sum, the following trend is apparent from the Square Mahalanobis Distances analysis of the sites/complexes: the largest distances between a given complex/site and the remainder is indicated in the case of the PPN complex, the Danube Gorge complex and the site of Viesenhauser Hof. Small D^2 distances are observed between Çatalhöyük, Nea Nikomedeia and SKC, Cardial Neolithic and two out of the three LBK sites. The small distances point to minimal morphometric differences between the crania from each of these sites/complexes. It therefore suggests minimal morphological differentiation between these groups. The sharp contrast in D^2 distance trends between the LBK site of Viesenhauser Hof and the LBK sites of Schwetzingen and Sonderhausen is intriguing.

b. Discriminant Function Analysis

i.) Discrimination

In general poor discrimination is achieved between the various groups (Tabs. 3a–b). The lack of discrimination between most groups does not indicate a flaw in the data, but points to the fact that there are minimal inter-group morphometric differences and maximal intra-group differences. In other words, the selected groups are not biometrically (and hence biologically) distinct enough on the basis of the utilised craniometric set to facilitate group-based discrimination. This leads us to the next question, which is why there is no sufficient difference between these groups. And what does the lack of difference indicate? It is now necessary to focus on the range of variability in each group by looking at the contours that delimit some of the groups in relation to the centroids for each group (numbered black squares, Fig. 1). It is evident that the second discriminant function (the Y axis in Fig. 1) in fact manages to differentiate between the PPN group and the others. It therefore indicates that differences in the morphometric dimensions of the PPN specimens and the rest of the groups allow one to discriminate between them. It also suggests that if we apply this function to new specimens, it will allow us to successfully discriminate and classify PPN and "non-PPN" specimens on the basis of their craniometric dimensions. It therefore follows that the PPN specimens as a group share a distinct set of craniometric dimensions, reflecting a distinct skull vault/face shape. The position of Çatalhöyük within the Nea Nikomedeia group boundaries further point to the lack of biometric differentiation between them. A great degree of variability is evident in the case of the Cardial Neolithic complex, and the LBK groups. The latter show a pronounced degree of differentiation. Two of the Danube Gorge specimens fall near the PPN centroid, while the other one falls near the Sonderhausen

	Code	PPN	Çatalhöyük	Nea Nikomedeia	SKC	Danube G.	Cardial	Schwetzingen	Sonderhausen
PPN	1								
Çatalhöyük	2	**6.14**							
Nea Nikomedeia	3	**7.02**	1.32						
SKC	4	3.67	1.31	2.65					
Danube Gorge N.	5	**6.88**	**6.72**	**5.67**	**5.66**				
Cardial	6	3.61	2.87	1.55	2.12	**4.98**			
LBK- Schwetzingen	7	**5.00**	1.91	1.84	1.51	**4.95**	2.00		
LBK- Sonderhausen	8	**6.01**	2.88	2.62	3.74	**8.00**	2.44	**5.96**	
LBK-Viesenhäuser Hof	9	**8.07**	**6.30**	**5.43**	3.98	**7.20**	4.62	**5.16**	**6.71**

Tab. 2. Squared Mahalanobis distances between the samples. Distances greater than 4 D^2 units are in bold.

centroid. As only three specimens from this group were included (due to missing data), it is not possible to draw any conclusions based on the sample.

The large degree of morphometric variability within the Cardial Neolithic group suggests that it may in fact include several biological populations. Thus, both the PPN and the Cardial groups comprise specimens from various sites that span a large geographical range (see Tab. 1).

a. Structure Matrix

Function	1	2
BBH	0.35	0.50
NLB	0.19	0.34
OBH	0.14	–0.01
XPB	0.12	–0.01
NLH	0.33	0.22
NPH	–0.27	0.44
MFB	0.10	–0.18
ZYB	–0.01	–0.11
GOL	0.02	0.21

b. Summary of canonical discriminant functions

Function	Eigenvalue	% of Variance	Cumulative %
1	0.455	30.268	30.268
2	0.326	21.700	51.969
3	0.305	20.316	72.285
4	0.190	12.638	84.923
5	0.149	9.924	94.847
6	0.063	4.214	99.061
7	0.010	0.674	99.735
8	0.004	0.265	100.000

Tabs. 3a–b. Discriminant Function Analysis

ii) Classification

Table 4 provides the results of the classification of the various specimens for each group. Only 44.6% of the cases were correctly classified. The highest percentage of correct classification was in the case of Sonderhausen (75%), Viesenhauser Hof (66.67%), and PPN (60%). Poor classification was noted for the SKC, Danube Gorge, Cardial Neolithic and LBK-Viesenhauser Hof.

C. Principal Components Analysis

i.) Total sample (pooled sexes)

The principle components analysis examined the specimens from the above-mentioned groups using the same craniometric variable set. However, the method does not require the assignment of specimens to groups, thus allowing a 'natural' pattern of group differentiation to appear. The analysis shows no clear differentiation between the groups (Tabs. 5a–c). Figure 2 is a scatterplot of the factors scores values of the various skulls on the first and second principal components. The SKC, Cardial and LBK complexes display the most extensive range of variability. It therefore appears that it is not possible to detect clear morphometric differences between groups on the basis of this method when using the craniometric set provided. Also, note that most of the variability is accounted for by PC1 (55.67%), while only 12.29% of the variability is accounted for by PC2. It therefore seems that as PC1 is unipolar (factors loadings of all variables are positive), it mainly accounts for size-related variability. The positive factor loadings of the second component are for facial height measurements – more specifically, upper facial height, nasal height, and orbital height load positively on PC2, while the other variables have negative loadings. It therefore appears that the Danube Gorge Neolithic specimens have particularly low faces, while some of the SKC, LBK and Cardial specimens have long faces.

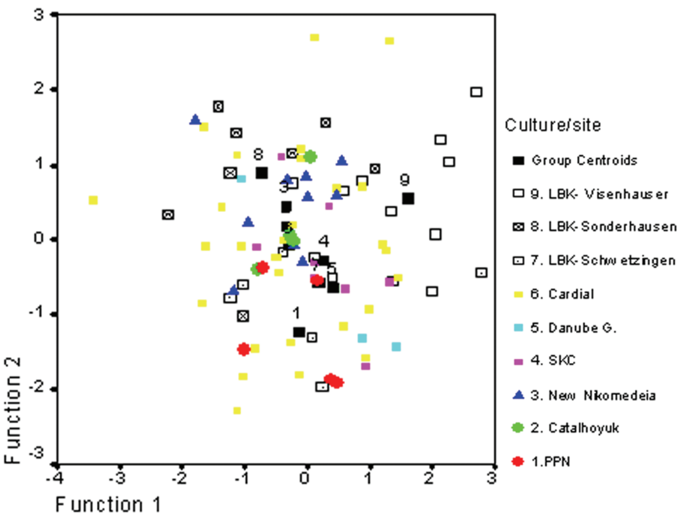

Fig. 1. Discriminant function analysis of craniometric measurements of skulls from 9 Early Neolithic cultures/sites.

ii.) Sex-specific patterns

A fair degree of overlap is expected when running a PCA on pooled rather than sexed samples (i.e. when male and females of each group are combined). A sex-specific analysis may allow one to differentiate between some of these groups. Figure 3 is a scatterplot of the same PCs, but indicating the values of each case (i.e. skull) by sex. Good separation is indicated between male and females: female specimens for PC1 < –0.8 values and male specimens for PC1 > 1. However, males and females overlap for –0.8 < PC1 < 1. About 2/3 of the males and 2/3 of the females fall on the overlapping range. It therefore means that a sexed analysis of the same set will only partially reduce the overlap between the groups, as only a third or so of the overlap is directly related to sexual dimorphism.

Discussion

The Squared Mahalanobis Distance analysis clearly indicates that D^2 distances between Çatalhöyük, Nea Nikomedeia, SKC, Cardial Neolithic, and two out of the three LBK sites are small. These distances indicate minimal inter-group morphometric differences in crania from each of these sites/complexes. The sites/cultures with the largest distances from the rest are PPN, Danube Gorge, and the LBK site of Viesenhauser Hof. The large D^2 distance between the LBK sites of Viesenhauser Hof and the LBK sites of Schwetzingen and Sonderhausen shows extensive craniometric variation between these LBK populations. The LBK culture dispersed across Central Europe in less than 500 years (*Bogucki 2003*). Considering the rapid speed of this dispersal and the extensive gene flow between LBK communities (as there were no major geographic barriers to prevent it), it is necessary to rule out the possibility that the observed morphological differences between the LBK populations analysed were the outcome of selection and/or stochastic changes to the genetic structure of these populations due to drift. It therefore appears that the only plausible explanation is that one or more of these populations either mixed with local Mesolithic hunters, or even that some of these populations were indigenous hunters that adopted farming. However, these hypotheses can only be tested with the analysis of Mesolithic populations, which is beyond the scope of this article (see *Pinhasi 2003*).The Discriminant Function analysis did not discriminate well between the groups. However, discrimination was achieved between PPN on the one hand and Nea Nikomedeia and Çatalhöyük on the other. Moreover, the function discriminated between Sondehausen, Viesenhauser Hof and Schwetizngen. The Principal Components Analysis (PCA) did not provide any additional information about the relationship between the specimens in relation to their archaeological cultures. However, it has been shown that differentiation between populations is hindered to a fair extent by the pooling of male and female samples. It is possible that sex-specific PCA will result in better differentiation between the groups. Furthermore, it is evident that specimens from some of the archaeological cultures, such as LBK and Cardial Neolithic, vary greatly in their morphologies, while others, such as the Danube Gorge Neolithic, are more tightly clustered and thus are morphologically more similar.

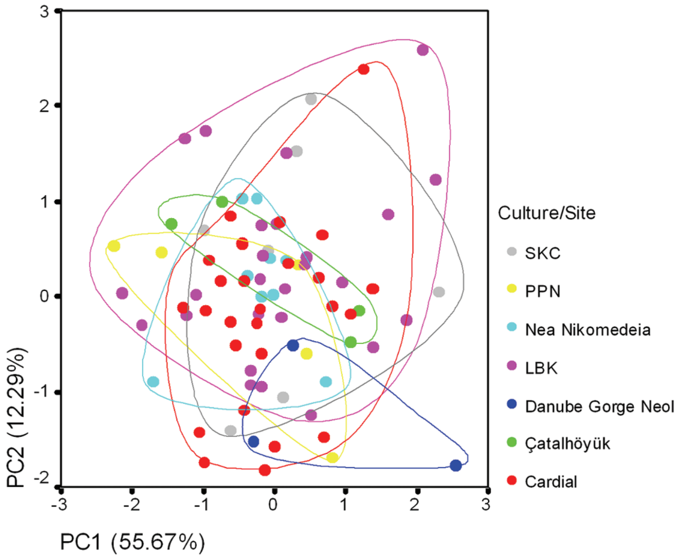

Fig. 2. Principal components analysis of craniometric measurements of skulls from Early Neolithic sites.

Özdoğan (*1997*) points out that the Neolithic communities of the Central Anatolian plateau form a distinct entity which differs from the south-eastern Anatolian, Levantine and Mesopotamian contemporaneous cultures in settlement pattern, architecture, lithic technology, bone tools, and other archaeological aspects. There is no simple corollary between specific cultural-archaeological entities and biological populations. However, in the case of the above analyses, the population of Çatahöyük differed biologically from the populations of the Near East and southeast Anatolia and were similar to the SKC and Nea Neikomediea cultures. Indeed in a previous publication (*Pinhasi 2003*), it was demonstrated that the Squared Mahalanobis Distance between Çatalhöyük and Çayönü is twice to three times the average distance between the former and any of the Early Neolithic southeast or central European Early Neolithic populations. The above analysis therefore confirms the archaeological observations made by Özdoğan (*1997*) and reaffirms in this specific case a correspondence between cultural boundaries that define a prehistoric culture and its biological basis.

A similar factor may explain the position of the Danube Gorge specimens. Pinhasi and Pluciennik (*2004*) pointed out that the craniometric analysis of the Danube Gorge Mesolithic and Neolithic specimens indicate a possible continuity in cranial morphology in this micro-region that contrasted with the Mesolithic-Neolithic morphometric discontinuity in the case of other regions in southeast Europe. This observation is also in accord with that made by Tringham (*2000*), who asserts that it is "*...unjustifiable to assume that the complexities of hunter-gathering society and the scenarios of their contact with agriculturalists that have been developed in the Danube Gorges sites also apply to southeast Europe outside the Danube Gorges*".

Group	1	2	3	4	5	6	7	8	9	Total
1	60				20	20				100
2		50					25	25		100
3			50	10			10	30		100
4	14.29	14.29		28.57	14.29	14.29	14.29			100
5					33.33		33.33	33.33		100
6	10.71		17.86	7.14	3.57	32.14	0.00	7.14	21.43	100
7		11.11	11.11		11.11	11.11	33.33	0.00	22.22	100
8	12.5							75	12.5	100
9					11.11	22.22			66.67	100

*Group codes legend: 1 – PPN, 2 – Çatalhöyük, 3 – Nea Nikomedeia, 4 – SKC, 5 – Danube Gorge Neolithic, 6 – Cardial Neolithic, 7 – LBK– Schwetzingen, 8 – LBK- Sonderhausen, 9 – LBK-Viesenhäuser Hof.

Tab. 4. Results of the classification of cases to each of the nine groups* (in percentages) on the basis of the discriminant functions.

According to Perlès (*2001; 2003*) the first pioneer colonisers of Greece were Near Eastern PPNB farmers who brought with them the 'Neolithic package', minus pottery. She then asserts that Nea Nikomedeia and other mainland Early Neolithic Greek sites are not associated with a westward 'wave of advance' of Anatolian populations

There are no grounds for believing that the settlement of mainland Greece, either by land or sea, can be compared with the slow movements of populations characteristic of the Cardial or Danubian 'waves of advance'. On the contrary, it seems to relate to these long-distance expeditions, well exemplified in the Mediterranean by the colonisation of Crete, Corsica and the Balearic Iislands, for instance" (*Perlès 2001*).

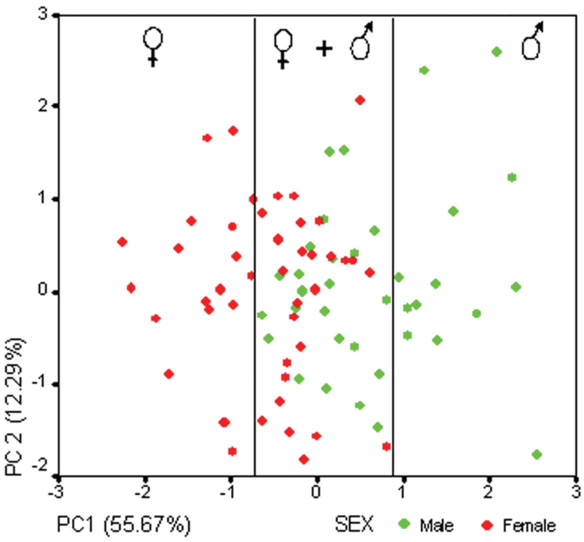

Fig. 3. Sexual dimorphism in craniometric measurements. The left and right sections comprise females and males only, respectively, while the middle section shows the range of PC1 scores in which the two sexes overlap.

However, the craniometric analysis indicates no morphological differences between Nea Nikomedeia and the Çatalhöyük populations, which contrasts with the differences between these and the PPN Levantine/ Anatolian samples.

The morphometric relationship between the LBK populations and those of southeast Europe and Anatolia appear to be complex. The separation between the sites of Viesenhauser Hof, Sonderhausen and Schwetzingen (Fig. 1) points to pronounced morphometric differences between these populations. This finding is in accord with Jochim's assertion (*2000*) that new archaeological evidence indicates greater regional differentiation within the LBK area than was previously assumed. It also supports the observation made by Bentley et al. (*2002*) using strontium isotope analysis which indicated that about 25% of the Schwetzingen individuals were non-local migrants, thus pointing to extensive mobility and mate exchange among LBK populations, possibly also involving local Late Mesolithic hunters.

The position of the Cardial Neolithic in the abovementioned analyses is unclear. Perhaps the large range of variability observed in the sample utilised reflects the fact that we are dealing with several biological populations spread across a vast geographical region. Only more analyses with a finer geographical and archaeological resolution will allow one to examine the biological nature of this cultural entity.

Conclusions

This work attempted to investigate the biological relationship between skeletal specimens from various Pre-Pottery and Early Neolithic sites from the Near

a. Descriptive statistics

	Mean	Std. Deviation
GOL	181.43	7.24
XPB	137.40	5.25
MFB	95.21	4.82
BBH	136.14	6.52
ZYB	124.59	7.82
NPH	66.32	4.76
OBH	31.67	2.05
NLB	24.28	2.03
NLH	48.03	3.65

b. Total variance explained (of first 4 Principal Components)

Function	Eigenvalue	% of Variance	Cumulative %
1	3.909	43.436	43.436
2	1.475	16.391	59.827
3	0.815	9.056	68.883
4	0.740	8.221	77.105

c. Factor loadings

	1	2
GOL	0.82	–0.03
XPB	0.45	–0.45
MFB	0.70	–0.02
BBH	0.69	–0.29
ZYB	0.80	–0.21
NPH	0.76	0.35
OBH	0.22	0.78
NLB	0.57	–0.34
NLH	0.69	0.54

Tabs. 5a–c. Principal Components Analysis of the total (unsexed) sample.

East, Anatolia, southeast Europe, Danube Gorge, Mediterranean Europe and Central Europe. By applying three specific methods to the same set of specimens, it investigated not only the affinities and differences between these specimens, but also the type of answers that one may obtain from the interpretation of biometric data. Furthermore, some specimens were categorised according to archaeological units of vast spatiotemporal scope, such as 'Cardial Neolithic', while others had a much narrower spatio-temporal scope (such as LBK- Viesenhauser Hof). This categorisation scheme was applied in order to see whether groups that share a given archaeological culture and are from a relatively narrow spatio-temporal range (LBK sites) are biologically more similar to each other than to other groups from different archaeological contexts. The results show that this was not the case, and therefore reaffirmed the previous observations (*Pinhasi 2003; Pinhasi and Pluciennik 2004*) that while biological differences between specimens relate to the specific archaeological culture-specific context, the relationship is complex. Nevertheless, the similarities between SKC, Nea Nikomedeia and Çatahöyük, and the differentiation between the PPN and other Early Neolithic groups show that craniometric studies can shed more light on the nature of the Neolithisation process in various regions, and provide an essential link between genetic studies and archaeology.

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