Human remains

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Earlier anthropological examinations

Earlier anthropological examination was made by Dzierżykray-Rogalski and Promińska in the course of excavations carried out at Kadero in 1972-1980. Fifty one inhumations were excavated. Of them, 36 were of the Neolithic chronology, 14 from the Late Meroitic period and 1 from the Medieval period. The authors focused on the Neolithic skeletal remains whose overall poor state of preservation made it impossible to complete metric data. The authors determined the sex and age of skeletal individuals and made observations that enabled them to arrive at several conclusions (Dzierżykray-Rogalski 1977, 1978, 1984, Dzierżykray-Rogalski and Krzyżaniak 1978, Dzierżykray-Rogalski and Promińska 1976, Promińska 1984, 1987). In the first place, they maintained that the Neolithic people in Kadero were very different from the contemporary inhabitants of the Khartoum region, but similar to those of the more southern part of Africa. They exhibited the prominent facial prognathism characteristic of some groups of the Black variety (Dzierżykray-Rogalski 1978:407, Dzierżykray-Rogalski and Krzyżaniak 1978, Promińska 1987:13).

Authors analyzed the mortuary ritual and noted an extremely contracted position of the corpses. They associated this with the corresponding beliefs about life after death (Dzierżykray-Rogalski and Promińska 1976, Dzierżykray-Rogalski 1984). Owing to further excavations carried out at Kadero and the discovery of a larger part of the burial grounds, the material of skeletons available for anthropological examinations significantly increased.

Characteristics of the skeletal assemblage

The present author examined a total of 195 burials in the course of excavation seasons between 1987 and 2001. The study was aimed at providing data on demographic structure and biological characteristics of human skeletal remains from the Neolithic cultural period, including mortality rate, variation in metric and non-metric anatomical traits, and evidence of paleopathological conditions.

The material available for anthropological examination consisted of bones and teeth. All examinations were carried out on site during archeological excavations. Anatomical and morphological details on bones and teeth were examined macroscopically and, where necessary, with the aid of a 10 x magnifying glass for identification purposes.

Altogether, the series of skeletons buried in Kadero consisted of 251 individuals deposited in 247 graves. Of them, 221 (88%) were of the Neolithic chronology, 26 (10.4%) from the Late Meroitic period, 4 (1.6%) were of Post-Meroitic/Christian period.

All but four Neolithic individuals were buried single. In three of the double burials, a female with a child were buried (graves 46, 97, 196). Two adults, male and female, were buried in the fourth double burial (grave 210).

The condition of the bone recovered from all the graves was assessed macroscopically and recorded according to the categories and descriptions referred to by Buikstra and Ubelaker (1994). The skeletal remains were significantly depleted by heavy calcium carbonate content of the soil and the erosive processes that led to the cracking and flaking of the bone surfaces. The type of soil is believed to be the most influential extrinsic factor in bone diagenesis, once all the soft tissue has been lost (Garland and Janaway, 1989). Gordon and Buikstra (1981) found a significant correlation existing between the pH of soil and bone preservation, with preservation generally better in soils with a neutral or slightly alkaline pH. Acidic, free draining soils such as sand and or gravel result in bad preservation level of bone. This may be so extreme that skeletal remains are only detectable as shadows in the sand as in the burial from grave 7. Such skeletons are beyond an actual anthropological examination.

Other factors, both intrinsic and extrinsic, including the chemistry, size (associated with the sex and age at death), shape, structure and density of bone, along with pathological changes to bone structure as well as ground water, soil type – mentioned above, temperature and air, along with the nature of local flora and fauna, and human activity – all these factors play a synergistic role in the diagenesis of inhumations (Henderson 1987; Galloway et al. 1995; Gill-King 1997). Of all the intrinsic factors, the bone mineral density is considered to be the most significant (Grupe 2007). And of all the extrinsic factors, the soil chemistry is believed to be the most effective in bone diagenesis.

The majority of the bone recovered at Kadero Neolithic graves was extremely friable and often crumbled into small pieces. In many adults only diaphyses of long bones were preserved making the measurement of bone length impossible. The condition of 13 (5.1% of the total sample) remains was so bad that their anatomical traits were hardly noticed, as was the case with skeletal remains from graves 91, 92, 109 or others. Neither sex nor age could be determined for these remains.

Unlike bones, teeth were much better preserved and often were the only remains to be examined anthropologically. Teeth were also used for analyses of ancient DNA.

Three categories of preservation level: poor, fair and good were distinguished in the Kadero sample. Each level reflects the degree of fragmentation, the completeness of a skeleton and dentition and the degree of post-mortem damage. Poor level of preservation reflects a high degree of fragmentation and post-mortem damage, with a high degree of surface erosion, where less than 25% of the components are present. Fair preservation level refers to remains with preservation rate ranging between 25% and 50%, with limited fragmentation and a small degree of surface erosion. Good level of preservation relates to specimens with 50% to 80% of components conserved and minimal fragmentation.

The majority of the remains from the Neolithic graves at Kadero fall into the category of poor preservation level (62.5%), 26% fall into the category of fair preservation level, and only 11.4% were assessed to be well preserved. None of the skeletons recovered fell into the category of excellent preservation level. The latter refers to those remains where over 75% of components are present and where a vast majority of a skeleton is intact.

The catalogue of burials provides an outline of the bones and dentition present for each skeleton. The inventories reflect the poor bone condition and an overall poor preservation level of the remains, as mentioned above. It is obvious that the degree of preservation has connotations for any succeeding analysis of the remains. The more fragmented remains the more limitations on the amount of information that can be obtained. Therefore, the results obtained in the present study should be interpreted very cautiously.

Methods of anthropological examinations

The pattern of mortality was assessed using biological attributes such as estimates of sex and age at death. Sex determination was limited to individuals who had survived past adolescence to manifest changes in the skeleton reflective of sex. While there have been several studies investigating morphological traits that might be sexually dimorphic in infants and juveniles with sufficient levels of accuracy to warrant their application in osteological analyses (among many others Schutkowski

1993), morphological standards for diagnosing sex in subadult[1] skeletons that would be acceptable to most osteologists have yet to be developed. Analysis of ancient DNA (SRY, amelogenin) by means of modern molecular techniques seems to be very promising for its precision in sex determination (Cunha et al. 2000).

Sex determination The distinction between males and females was determined mainly on the basis of observation of the anatomical traits on the pelvis and skull, but due to bone fragmentation and overall poor level of preservation, scoring covered nearly all bones of the skeleton known for its dimorphic distinction. Several sexually dimorphic skeletal features of the cranial and postcranial skeleton, such as nuchal crest, processus occipitalia externa, processus mastoideus, shape of mandible, mandible angle and mental eminence, supraorbital parts and shape of orbit, prominence of glabella, os coxae, subpubic region including: ventral arc, subpubic concavity, ischiopubic ramus ridge, greater sciatic notch, and preauricular sulcus, were observed (Buikstra, Ubelaker 1994:328). Sex determination criteria also included measurements of dimorphic dimensions, such as the maximum diameter of the femur head, maximum facial breadth (bizygomatic diameter) or the size of the processus mastoideus. Eventually, the bones of the skeleton and extremities in particular, are more robust with males than females. Fragmented bones and overall poor level of skeletal remains preservation prevented us from using a multivariate method of sexing skeletons.

The sex-determination of the skeletons is known to be difficult as some sex indicators may be unequally developed within the individual population. Taking this into account, a scoring system was established based on observed variation in morphological traits associated with either male or female sex and dimorphic dimensions of a study population. For example, measurements of the processus mastoideus were taken and then the cut off point for either male or female sex was established using discriminant functions. Such algorithms served the purpose of "population-adjusted" sex determination. The importance of the researcher's training and experience in collecting data should be emphasized at this point. The first impression of being brought in contact with such badly preserved skeletal remains is very depressing.

In the Kadero sample, sex of 11 individuals was determined using both methods, macroscopic observation of morphological traits indicative of sex and sex determination based on aDNA analysis. The molecular techniques used for sex determination based on aDNA were explained elsewhere (Witas et al. 2002).

Age determination The skeletons were first divided into two groups, subadults and adults.

The closure of the *synostosis spheno-occipitalis* was used as the main criterion for distinguishing subadults (fetuses, newborns, infants, children and juveniles) from those who survived above the age of 18 and died in adulthood.

Age-at-death of subadult skeletons was determined based on physiological-age criteria (developmental changes in tissues correlated to chronological age) such as, in order of precision, dental growth and development, the appearance and fusion of bony epiphyses, and diaphyseal length of bones of the upper and lower extremities.

The tooth formation and eruption timing was described against reference standards developed by Moorreess et al. (1963) and improved by Ubelaker (1989). Standards for epiphysis closure timing were taken from Buikstra and Ubelaker (1994:40). The maximum right and/or left diaphyseal lengths of the long bones (humerus, radius, ulna, femur and tibia), when available, were measured to the nearest half-millimeter following procedures recommended by Buikstra and Ubelaker and using standardized equipment (1994:46).

With regard to adult individuals, age determination is based on observation of morphological changes on the articulatory surfaces of the symphysis ossis pubis and condition of the sutures. Changes in the morphology of the pubic symphysis for both females and males are usually checked against the Suchey-Brooks standards (Brooks, Suchey 1990) but too few pelvic bones were preserved in the Kadero sample for this method to form the basis of age determination. Therefore, the

1 The term "subadult" refers to individuals who had not reached biological maturity at the time of death, including fetuses, newborns, infants, children and youngsters.

condition of the cranial suture, well knowing that it is an uncertain basis of age determination, was used in this study. The suture closure was scored based on a system adopted from Buikstra and Ubelaker (Buikstra, Ubelaker 1994). Consequently, the age of adult individuals in this study was determined in ten-year interval age categories, from 20 to 60 years. Considerable variability in the age of cranial sutures closure has been claimed to reduce their importance for age estimation (Masset 1989). Since the criterion is regarded as uncertain in age determination of an adult skeleton, one has to confine oneself to distinguish between three age groups: young, middle-aged and old adult. Young adult (adultus) refers to individuals between 20 and 35 years of age; in this group, the three major sutures on the skull are all open or have just started to close. Individuals with cranial sutures in various stages of closing form an age group of 35 to 50 years, designated as middle adult (matures). Finally, old adult (senilis) describes individuals over 50 years with all the sutures completely or almost completely closed.

All skeletons were first divided into two groups, subadults and adults using the closing of the *synostosis spheno-occipitalis* as the criterion of adulthood. Then, based on the dental age, children and juveniles were assigned to the following age categories: 0-3 years, 3-7 years, 7-11 years, 11-15 and 15-18 years. In skeletal remains being studied, it was extremely difficult to distinguish between prenatal and perinatal periods, therefore these periods in conjunction with the neonatal one were grouped together in the age group 0-3 years. Adults were assigned to three age groups: young adult-*adultus* (20-35 years), middle-aged adult-*maturus* (35-50 years) and old adult-*senilis* (50+ years).

The morphometric variables of the skull and the postcranial skeleton were scored after Buikstra and Ubelaker (1994). It should be mentioned that the overall poor level of bone preservation and in particular extremely flattened skulls and distorted bones of extremities made measurements difficult and sometimes even impossible.

Dental inventory consisted of dental measurements and descriptive morphological traits of the permanent dentition. Measurements were taken of the length (mesiodistal $M\text{-}D_{cor}$) and breadth (buccolingual $B\text{-}L_{cor}$) of crowns of permanent teeth relatively unaffected by attrition using a vernier caliper with a helios dial giving an accuracy of 0.01 mm (Kaczmarek 1980; Mayhall 1992). Preference was made for maximum diameters, which tend to be more easily and consistently measured, thereby helping to reduce the number of intra-observer errors. All measurements were taken twice and the mean of the two measurements was calculated and rounded off to the nearest 0.1 mm. Overall tooth size was expressed in terms of cross-sectional area calculated by multiplying the mesiodistal and buccolingual tooth crown diameters.

Dental morphological traits were collected using the standardized Arizona State University dental anthropology system (ASUDAS) on all teeth that were not heavily worn (Turner et al. 1991). Inventory protocol included 36 traits, however, many of them were impossible to score due to the low preservation level of the skeleton and its contracted position in the grave. Following traits were not observed: winging UI1, midline diastema UI1. The scoring procedure, described in terms of the rank scale was reduced to overall presence or absence of particular conditions, included both antimeres and, allowing for asymmetry, counted the side with the highest expression or else. If only one side was present, that side was assumed to represent the highest degree of trait expression. Dichotomization was based on each trait's morphological threshold as determined by Scott (1979) and Nichol (1990) according to standard ASUDAS procedure (Turner 1987; Scott and Turner 1997).

Ante-mortem tooth loss, severe dental attrition and chipping, and occasionally dental agenesis were scored, aiming to assess dental health in the study series. The occlusal surface of permanent molars was assessed according to Scott's system for scoring surface wear (Scott 1979). The surface wear of incisors, canines and premolars was estimated according to the scoring system proposed by Smith (1984).

Data analysis The quantitative data for craniometric and odontometric variations within the sample and between males and females were assessed by means of the coefficient of variation (CV),which is defined as the ratio of the standard deviation to the arithmetic mean and multiplied by

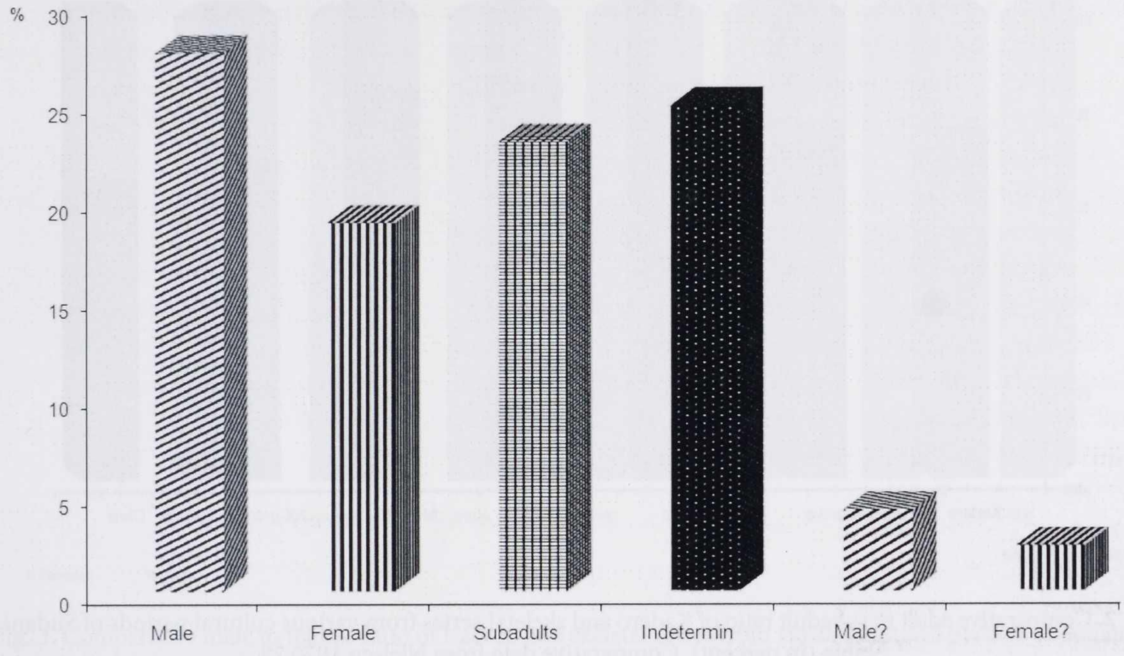

Fig. 1. Distribution of the adult and subadult individuals in the Kadero skeletal sample (in percent).

100. The difference between two mean values was tested with the *t*-Student test. A *chi-square* test was used for the qualitative study (frequency of non-metric dental traits). All statistical computations were performed using STATISTICA data analysis software system, version 8.0 (2008) www.statsoft.com. The level of significance was set at $p \leq 0.05$.

Mortality pattern

The distribution of subadults, adult males and females in the Kadero skeletal sample is shown in Fig.1.

From Fig. 1 it appears that out of the total of 219 individuals, 157 (75.4%) were adults and 51 (24.6%) were subadults. This gives a subadult to adult ratio of 1:3. Paleodemographic studies have shown that expected number of subadult component should constitute 50% of the total sample (Acsádi and Nemeskéri 1970, Hoppa and Vaupel 2002). In the light of this statement, the corresponding mortality rate of subadults was significantly lower than expected. The share of subadults in various skeletal series varies significantly. For the purposes of this study, comparative data were taken from Nielsen's diachronic analysis of skeletal remains from Sudanese Nubia (Nielsen 1970:28). The comparative picture is shown in Fig. 2.

The subadult mortality rate in the comparative skeletal series from Sudanese Nubia varies from 14.3% in the series from the Pharaonic period to 35.1% in the series dated to the Christian period. Results of the chi-square test revealed that the subadult-adult ratio in the Kadero series was significantly different from all but the A-group skeletal series ($p<0.05$). This skeleton series is dated to c. 3300-2800 B.C. and as Nielsen states "…the greater part is extremely fragmentary…" (Nielsen 1970:26).

Similarly low child mortality has been reported in Egyptian Nubia. The rate of child mortality ranged from 12.3% in the Predynastic period, through 16.2% in the Old and Middle Kingdoms, 11.4% in the Ptolemaic period, and 27.4% in the Christian period (Elliot-Smith and Wood Jones 1910).

Elsewhere, the share of children in the mortality rate was found to be higher, e.g., in the cemetery inside and around the ruined mastaba of Ptahshepses at Abusir, Egypt, used between the 7th century B.C. and 1st century A.D., the ratio between subadult and adult skeletons was almost 1:1, with 49.7% of subadults versus 50.3% of adults (Strouhal and Bareš 1993). Similar findings were shown by Armelagos for the skeletal sample from a Christian cemetery near Meinarti, Sudan, dated to 1050-1150 A.D. where subadult individuals consisted of 40% of the entire sample (Armelagos 1969).

The above shown bias in the population demographic profile in favour of adults has been a subject

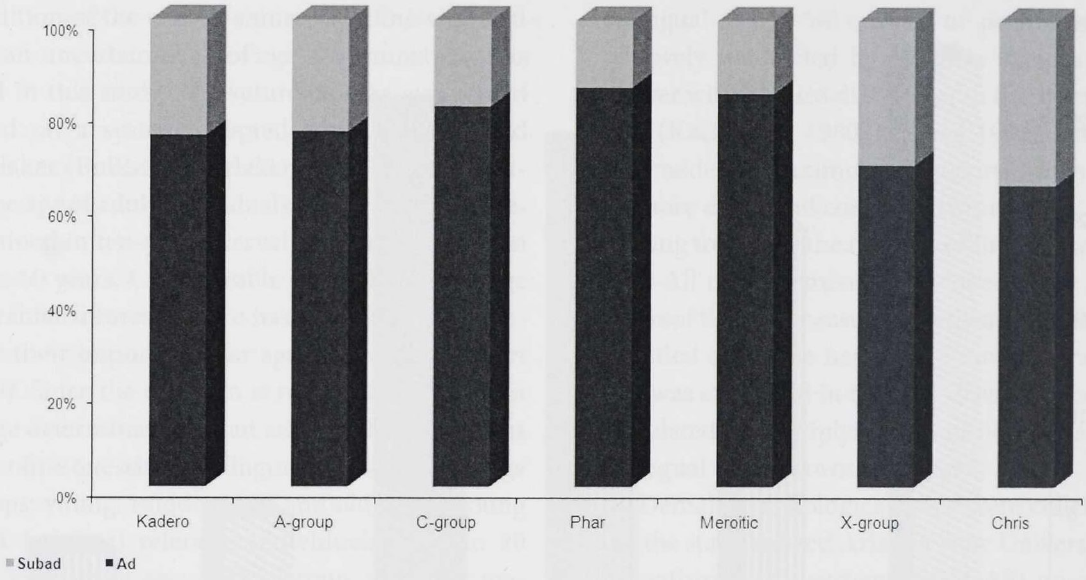

Fig. 2. Comparative adult to subadult ratio of Kadero and skeletal series from various cultural periods of Sudanese Nubia (in percent). Comparative data from Nielsen 1970:28.

of lively discussion. It is believed that the phenomenon is caused by a combination of factors. This may be attributed to cultural and socio-economic factors that may have influenced burial locations, whereof infants and children were buried differently and/or not in the same places as adults (Kamp 2001). The mortuary practice of burying stillborn/infants in jars is known from the A-group in Nubia (Nordström 1996). Verlinden (2008) found subadults buried in pots, these include both Nubian and Egyptian cemeteries from the Middle Kingdom. Britton summarizes subadult jar burials not only in Egypt and Nubia but also in other parts of the world (Britton 2009:Table 11:78-79).

Furthermore taphonomic factors such as the greater susceptibility to decay of the remains of children and shallow depth of burial have also been suggested as possible explanations for this phenomenon (Pfeiffer and Crowder 2004).

The sex distribution, illustrated in Fig. 1, is characterized by an excess of males over females (63.1% vs. 37.9%). The sex ratio of the Kadero individuals set at 1.7:1 male to female, revealed a considerable imbalance in favour of males. A similar overrepresentation of males was found in the comparative series from Sudanese Nubia (Nielsen 1970). See Fig.3.

In all but the Meroitic and Christian groups, males were in majority. The fact that in the skeletal samples males usually outnumber females is said to be due to the fragility of female skeletons which tend not to be preserved as well as the male ones. It is evident that small, porous bones, and those with high collagen contents, which are characteristics of juvenile and female bone, are particularly prone to decay. It can be taken for granted that a dominant part of the highly fragmented, sex undetermined skeletons might be either subadults or females. In the Kadero sample, 25% of all recovered skeletons could not be subjected to sex or age determination. However, since the remains of women sometimes survive in much greater quantity than remains of men (see the above mentioned groups from the Meroitic and Christian periods), preservation rates may not be the only explanation which can entirely resolve the problem. Some other factors should be considered as well.

For methodological purposes, aDNA extracted from teeth was used to determine genetic sex of 11 individuals whose sex was previously determined based on morphological criteria. An overall good agreement was found between morphological and genetic assignment to either sex. With regard to remains from grave 164 and 175, the product of amplification could not be identified nor sex determined. Two other cases, an individual from grave 154 was determined to be a male based on morphological criteria and a female based on aDNA analysis. Inversely, an individual from grave

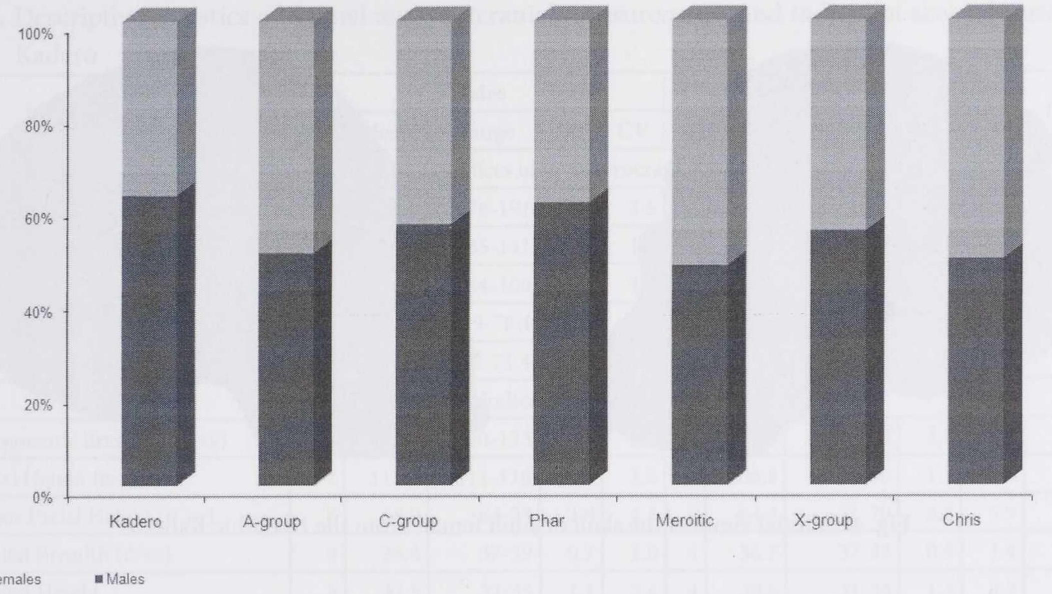

Fig. 3. Comparative male to female ratio of Kadero and skeletal series from various cultural periods of Sudanese Nubia (in percent). Comparative data from Nielsen 1970:30.

170 was morphologically determined as a female and aDNA analysis indicated a male sex. The sex assignment of these two individuals was then revised. In case of remains from grave 244, morphological evidences of sex were inconclusive. Analysis of aDNA enabled us to solve this problem. The sex of this individual was determined as being a male. Further analysis of aDNA enabled us to determine a male sex of a 7-14 year old child from grave No. 181 whose sex was not expressed in skeletal morphology. Table 1 summarizes the overall sex and age distribution in the Kadero sample.

When analyzing mortality rate among subadults, the highest death rate was found among the children in the age group 3-7 years, some 50.9% of all subadults. This rate was almost twice higher than the percentage of infants (29.4%) dying at the age between 0-3 years. It was 11.8% of children dying at the age between 7-11 years. The even distribution, 3.9%, was noted as to adolescents dying at the age from 11-14 years and 14-18 years. The highest mortality rate among children within the age group 3-7 years also applies to comparative skeletal samples from Sudanese Nubia. The respective figures are as follows: the A-group - 35.7%, the C-group - 26.5%, the X-group - 33.3%, Christian - 41.1% (Nielsen 1970:32-33).

The phenomenon of highest mortality rate within age 3-7 years is believed to be the result of weaning. In human species weaning usually occurs at the age of 2.5-3 years (Kennedy 2005). Weaning a nursing infant places him/her at a variety of risks related to parasites and microbes which cause acute infectious diseases and death. Consequently, the morbidity and mortality rate significantly increase. After this critical period, the mortality rate falls as demonstrated by the adolescent age group in the study series. Similar mortality rate of adolescents has been found in modern living populations. Adolescence is the period when individuals can acquire food by themselves, become

Table 1. Distribution of individuals from the Kadero skeletal sample according to sex and age-at-death

Age group (years)	Number of individuals Sex			% Popul
	Indeterminate	Male	Female	
0 - 3	15			6.8
3 - 7	26			11.9
7 - 11	6			2.7
11 - 15	2			0.9
15 - 18	2			0.9
Sudadult	2			0.9
20 - 35	6	40	32	35.6
35 - 50	1	15	3	8.7
50+		5		2.3
Adult	55			25.1
Indeterminate	9			4.1
Total	124	60	35	100

Fig. 4. Laterial views of the skull of adult female from the Neolithic Kadero

independent from adults care and support. Their immune systems protect them against infectious diseases. This allows survivorship until adulthood (Bogin and Smith 1996).

As for the adults, the mortality pattern revealed that women did not survive above the age of 50 years. Frequent childbirth with potentially deadly complications is thought to be the most likely explanation of this phenomenon.

Both male and female mortality rate was the highest in the age group 20-35 years, yielding 66% among males and 93% among females. This finding corroborates well with the statement that in prehistoric time the mortality in the age group 20-35 was substantially higher among women than among men.

The average adult age at death, calculated from the age-at-death data for adult individuals, turned out to be 30.8 years for men, SD=2.4 years and 27.7 years, SD=1.7 years for women.

These figures fit well with life expectancy data known for that time from paleodemographic literature. Quoting Angel's data on life expectancy for various populations, an average age at death in the Early Neolithic times at Greece was assessed at 33.6 years for men and 29.8 years for women, and for the Classical period it was 44.1 years for men and 36.8 years for women (Angel 1969; Morris 1994:476, Table 4).

It should be mentioned that the average age at death thus provided assumes a significantly shorter survivorship of people from Kadero than that estimated by Dzierżykray-Rogalski and Promińska in their unpublished manuscript from 1982 and the paper published by Promińska (1984; 1987:11). According to their calculations, the average age at death for males was 42.6 years (SD=8.47 years) and for females 33.4 years (SD=10.27 years). It seems that the source of discrepancies between two estimations lies in the sample size.

In summary, it should be stated that the skeletal remains available for examination in the Kadero sample may represent a biased sample of the population rather than reflect the actual demographic situation. Therefore, any final conclusions on mortality pattern should be drawn cautiously.

Variation in metric and non-metric anatomical traits of skull and postcranial skeleton

General macroscopic description of morphological and metric traits and indices of skull revealed that Kadero skulls were mesocranial and mesotopic, having prominent facial prognathism, robust mandible and at the second molar level marked muscular impressions and everted gonial area.

The morphometric variables of the skull, mandible and lower and upper limb bones are summarized in Table 2.

When interpreting data one should consider several limitations – first and foremost, a poor preservation state of skeletal remains that limited sample size for particular statistical computations. Statistical samples vary from 4 to 10 individuals. This should be borne in mind while interpreting data.

Table 2. Descriptive statistics of cranial and postcranial measurements and indices of skeletal series from Kadero

No Measurement	Males					Females					t-test
	n	Mean	Range	SD	CV	n	Mean	Range	SD	CV	
Measurements and indices of the neurocranial skeleton											
1 Maximum Cranial Lenght (g-op)	10	184.0	176-191	4.6	2.5	7	179.7	173-185	4.1	2.2	*
8 Maximum Cranial Breadth (eu-eu)	10	138.4	135-141	1.8	1.3	7	135.1	131-139	3.1	2.3	*
9 Minimum Frontal Breadth (ft-ft)	10	95.5	84-100	4.6	4.7	7	94	89-98	3.6	3.9	NS
8/1 Length-Breadth Index	10	75.2	71.9-78.4	2.0	2.6	7	75.1	72.3-76.9	1.5	2.0	
9/8 Transversal Fronto-Parietal Index	10	68.9	62.2-71.4	2.8	4.1	7	69.5	67.9-71.5	1.5	2.2	
Measurements and indices of the facial skeleton											
45 Bizygomatic Breadth (zy-zy)	9	127.5	120-133	4.7	3.7	5	121.2	116-124	3.3	2.7	*
47 Facial Height (n-gn)	7	113.6	111-116	1.7	1.5	5	108.4	107-110	1.1	1.0	*
48 Upper Facial Height (n-pr)	8	68.9	64-73	2.8	4.1	5	64.4	61-70	3.8	5.9	**
51 Orbital Breadth (d-ec)	8	38.4	37-39	0.7	1.8	4	36.7	37-38	0.5	1.4	*
52 Orbital Height	8	32.5	32-35	1.1	3.4	4	33.5	31-34	1.3	3.9	NS
66 Bigonial Width (go-go)	5	94.8	81-101	7.8	8.4	6	90.3	84-103	6.8	7.6	*
70 Maximum Ramus Height	5	56.8	53-57	1.9	3.3	6	52.9	49-55	2.8	5.3	**
71 Minimum Ramus Breadth	5	35.9	32-38	1.9	5.3	6	32.9	28-37	1.4	4.2	**
47/45 Facial Index	7	88.8	83.4-94.2	3.4	3.8	5	86.8	84.5-89.4	2.2	2.5	
48/45 Upper Facial Index, Kollmann	8	54.6	49.6-59.0	2.9	5.4	5	52.3	49.6-56.9	2.9	5.6	
52/51 Orbital Index	8	86.9	82.0-89.7	2.3	2.7	4	86.1	81.6-91.9	4.4	5.1	
Maximum length of long bones											
Femur	13	459.5	440-479	12.2	2.6	9	419.8	398-429	9.6	2.3	**
Tibia	8	379.5	357-409	15.4	4.1	8	365.9	351-390	13.1	3.6	**
Humerus	8	319.1	291-335	16.6	5.2	3	296.8	279-308	15.5	5.2	**

Explanation of parameters used in the table: No – number of measurement according to Martin and Saller (1957); n – number of cases; Mean – arithmetic mean; Range – values of the smallest and the largest items in the sample; SD – standard deviation; CV – percentage coefficient of variation; *t*-test - the difference between two mean values tested with *t* (Student's) test; * and ** - difference between two values statistically significant at $^{*}p<0.05$; and at $^{**}p<0.01$; NS - difference between two values statistically non-significant; all measurements in mm.

Figures shown in Table 2 confirmed what was obvious, namely that males had larger cranial dimensions as compared to females, and most of the male-female differences were statistically significant ($p<0.01$). Looking at the variability within gender and between males and females, it may be seen that the overall dispersion of metric traits is moderate. It seems evident as judged from the coefficient of variation (CV). Its average value is equal for males and females with regard to metric traits of neurocranium (an overall CV calculated as average of 3 neucranial diameters was 2.8 for males and females) as well as for measurements of the facial skeleton (an overall CV calculated of 8 facial diameters was 4.1 for males and 4 for females). The overall CV values for long bones were significantly higher for males than for females (4.7 and 3.7, respectively). This finding revealed that males were likely to be more heterogeneous than females in respect to their stature.

Beside cranial measurements, which express the size of various anatomical parts of the skull, cranial indices were calculated. An index in anthropometrics means a percent relation of two measurements, of which the smaller measurement is used as the numerator and the larger measurement as the denominator, so that its value is smaller than 100. The cranial index (length-breadth index), which is by far the best examined and most frequently used index value in anthropometrics, describes the shape of the skull, ranging from ex-

Table 3. Comparative mean values of selected cranial measurements in prehistoric skeletal series from Sudan

No Measurement	Site						
	Kadero		Site 117 Females	Site 6-B-36 M+F	Saggai 1 Females	A-group	
	Males	Females				Males	Females
1 Maximum Cranial Lenght (g-op)	184.0 (10)	179.7 (7)	186.0 (13)	185.8 (12)	179.0 (1)	186.3 (7)	178.2 (11)
8 Maximum Cranial Breadth (eu-eu)	138.4 (10)	135.1 (7)	131.7 (12)	127.5 (7)	136.0 (1)	136.3 (6)	131.0 (10)
9 Minimum Frontal Breadth (ft-ft)	95.5 (10)	94.0 (7)				95.8 (6)	89.2 (10)
45 Bizygomatic Breadth (zy-zy)	127.5 (9)	121.2 (5)				126.0 (3)	124.0 (3)
47 Facial Height (n-gn)	113.6 (7)	108.4 (5)	110.0 (6)	109.2 (7)	115.4 (2)	108.7 (3)	106.0 (1)
48 Upper Facial Height (n-pr)	68.9 (8)	64.4 (5)	65.6 (6)	66.3 (7)	67.5 (3)	67.5 (4)	64.0 (5)
51 Orbital Breadth (d-ec)	38.4 (8)	37.7 (4)				38.5 (4)	37.0 (6)
52 Orbital Height	33.4 (8)	32.5 (4)				31.2 (4)	31.0 (6)

Explanations: No – number of measurement according to Martin and Saller (1957); ( ) – number of cases in parentheses; M – Males; F – Females; Site 117 (Late Paleolithic) - Andersen 1968; Site 6-B-36 (Mesolithic 9000 and 6000 B.C.) – Carlson and van Gerven 1977; Saggai 1 (Mesolithic 6000 B.C.) – Coppa and Macchiarelli 1983; A-group (3300-2800 B.C.) – Nielsen 1970; all measurements shown in mm.

tremely long (*ultradolichocranial*), with a cranial index value below 64.9, to extremely short (*ultrabrachycranial*), with a cranial index value above 90.0. Kadero specimens featured a medium-length skull (*mesocranial*) with cranial index mean values equal to 75.2 in males and 75.1 in females.

The shape of the forehead, which was assessed as the minimum frontal breadth in relation to the biparietal breadth, revealed that males from the Kadero series had foreheads of medium breadth (*metrometopic*), that is, mean index value of 68.9. Whereas females' foreheads were broad (*eurymetopic*) as suggested by their index value of 69.5. Both male and female groups from the study series were described as having a medium-high face (*mesoprosopic*) with facial index values of 88.8 for males and 86.8 for females. As to the shape of eye-sockets, determined by orbital index, 86.9 in males and 86.1 in females, that is, featuring large-high orbits (hypsiconchic).

The analysis of the intra-group homogeneity of the skeletal material was extended to the rate of sexual dimorphism demonstrated both in the cranial and postcranial skeleton of the studied series and compared samples. Changes in sexual dimorphism through time are of special interest for anthropologists as it is believed that sexual dimorphism plays an important role in human adaptation. In reference to this problem, the amount of sexual dimorphism was presented in terms of index of dimorphism. The index of dimorphism was determined as female mean expressed as a percentage of male mean (Smith and Spencer 1984). On the basis of nine cranial measurements, Smith (1999) calculated the mean percent of dimorphism for Neanderthal as 93.06%, Upper Paleolithic 93.17%, Mesolithic 94.52%, Neolithic 95.35%. The mean percent of cranial dimorphism for Kadero was assessed on the basis of 11 cranial traits and was 95.2%. This figure is surprisingly similar to those mentioned above.

According to Trinkaus, the dimorphism in modern *Homo sapiens*' long bone length varies between 89.4% and 93.9% with an average of 91.4% (Trinkaus 1980). The mean percent of dimorphism for three long bone length of Kadero individuals was 93.9%. This figure reflects a modest degree of sexual dimorphism.

The comparative values reported in Table 3 place individuals from the Kadero sample between findings from the Mesolithic site of 6-B-36 and Saggai 1 and the A-group. However, any further conclusion is limited by small sample size of all series presented in Table 3. This also accounts for our restraining from discussing the racial "types", as was widely done in earlier anthropological studies on the Kadero skeletal series.

Maximum length of the femur was used as a proxy for stature and compared with selected skeletal series taken from Nielsen's diachronic study of skeletal remains from Sudanese Nubia (Nielsen 1970a). Data are shown in Table 4. Overall, it appears that the Kadero individuals both males (45.1

Table 4. Comparative average values of femur maximum length in various skeletal series from Sudanese Nubia

Site	Femur length (cm)				Dimorphism
	Males		Females		
	n	Mean	n	Mean	%
Kadero	13	45.9	9	41.9	91.3
A-group	3	47.6	7	42.5	89.2
C-group	55	45.5	47	42.1	92.5
Meroitic	28	45.0	36	41.9	93.1
X-group	36	44.5	27	41.8	93.9
Christian	13	45.0	12	41.4	91.5

Explanations: Data for comparative skeletal series taken from Nielsen 1970a:86; A-group – 3300-2800 B.C.; C-group 2300-1800 B.C.; Meroitic – 350 B.C. measurements shown in cm.

cm) and females (41.9 cm) were likely to be substantially shorter than individuals from A-group (47.6 cm males and 42.5 cm females). When compared with people representing various degrees of intensive agriculture (the Meroitic, X-group and Christians), males were likely to be slightly taller, whereas females were of similar stature. The rate of sexual dimorphism in maximum femoral length was smaller than in the A-group but oscillated around values of other compared samples from successive cultural periods.

It has widely been known that variation in stature (size of bones) has both genetic and environmental components (Falconer 1960). Accordingly, reduced adult stature may be in part caused by lasting nutritional deprivation and diseases in childhood (Saunders 1992, Saunders and Hoppa 1993). This phenomenon is well known in living societies where the social gradient in stature reflects socioeconomic inequality in access to nutrition and healthcare (Bogin and MacVean 1982). Martin et al. (1984) determined the impact of agricultural development on the biology of earlier populations from Lower Nubia. They found a number of indicators suggestive of serious nutritional deficiencies in subadults resulting in premature osteoporosis and growth retardation.

Zakrzewski (2003) also found an association between the Egyptian stature and the intensification of agriculture and social ranking. She demonstrated that the intensification of agriculture offered greater consistency of food production and the formation of social ranking. She stated that the greater social ranking differentiated an access to nutrition leading to possible diminished growth in childhood and shorter stature in adulthood. She also found that males showed a greater negative physiological response to harmful environmental conditions, which is an obvious phenomenon in the living human populations. The values shown in Table 4 seem to follow this pattern.

Dental morphology and odontometrics

Preliminary analysis of descriptive traits on tooth crowns of the Kadero odontological sample showed no significant dimorphism and so data on males and females were pooled for further study. The results are shown in Table 5.

The upper incisors were generally smooth in outline, with only trace of shovelling (10% of a second grade of shovelling) and no instances of marked shovelling. Labial surface of upper second incisors usually had tuberculum dentale (50%) although mostly of a third or fourth grade of trait expression. None of the upper second incisors was peg-shaped although these teeth were subject to size reduction. Upper first molars generally had all four cusps present. Hypocone reduction was usually observed on the upper second molars. The degree of reduction was relatively greater than in the compared series. The small cusp (grade 3) was present in 81.5%. In the Egyptian samples, the frequency of this trait ranged from 86.7% to 91.9%, and in the Nubian samples 72.7% to 92.7%. First upper molars generally showed some representation of Carabelli's cusp (56.5%), but it was significantly less common than in the Egyptian samples where the frequency of this trait reached 88% in the Gebel Ramlah series (Irish 2005). None of the upper molars was 5-cusped. In lower premolars there was a relatively high incidence of lingual cusp (61.8%), like in Egyptian series being compared. Mandibular torus was not observed in the sample. None of the lower first molars was 7-cusped and the incidence of 6-cusped form was 3.7%. Only a few lower second molars were 5-cusped (13.8%).

Table 5. Dental morphological trait percentages (%) and number of individuals scored (n) for Kadero and comparative prehistoric skeletal series from Nubia and Upper Egypt

Trait		KAD	Nubian samples*				Upper Egyptian samples**		
		KAD	PL	ME	X	CHR	GRM	BAD	NAQ
Labial curvature UI1	n	0/19					31	20	8
(+ = ASU 2 - 4)	%	0.0					0.0	5.6	0.0
Shoveling UI1	n	3/30	13/22	14/33	2/6	0/7	28	16	7
(+ = ASU 2 - 6)	%	10.0	59.1	42.4	32.3	0.0	42.9	25.0	14.3
Double Shoveling UI1	n	0/30	0/20	2/41	1/8	1/8	33	16	7
(+ = ASU 2 - 6)	%	0.0	0.0	4.9	12.5	12.5	6.1	0.0	0.0
Interruption groove UI2	n	0/24					27	20	11
(+ = ASU 2 - 6)	%	0.0					18.5	10.0	9.1
Tuberculum dentale UI2	n	12/24	7/18	16/39	3/6	1/8	27	22	11
(+ = ASU 2 - 6)	%	50.0	38.9	41.0	50.0	12.5	59.3	36.4	27.3
Hypocone UM2	n	31/38	25/27	60/77	14/16	8/11	37	30	44
(+ = ASU 3 - 5)	%	81.5	92.7	77.9	87.5	72.7	91.9	86.7	90.9
Cusp 5 UM1	n	0/46	4/14	7/63	4/18	2/12	19	20	40
(+ = ASU 2 - 5)	%	0.0	28.6	11.1	22.2	16.7	10.5	10.0	17.5
Carabelli's trait UM1	n	26/46	6/13	33/56	6/13	7/925	25	17	38
(+ = ASU 2 - 7)	%	56.5	46.2	58.9	46.2	77.8	88.0	64.7	68.4
Enamel extension UM1	n	2/46					32	31	46
(+ = ASU 1-3)	%	4.3					9.4	6.5	15.2
Peg-reduced UI2	n	0/24					38	39	60
(+ = ASU P or L)	%	0.0					5.3	10.3	0.0
Lingual cusp LP2	n	21/34					21	24	23
(+ = ASU 2-9)	%	61.8					61.9	79.2	95.7
Mandibular torus	n	0/11					41	40	58
(+ = ASU 2-3)	%	0.0					2.4	0.0	1.7
Groove pattern LM2	n	11/32	16/27	8/75	2/20	3/9	36	34	48
(+ = ASU Y)	%	34.4	59.3	10.7	10.0	33.3	66.7	35.3	45.8
Cusp number LM1	n	2/53					26	24	38
(+ = ASU 6+)	%	3.7					7.7	0.0	7.9
Cusp number LM2	n	5/36					32	21	36
(+ = ASU 5+)	%	13.8					78.1	19.1	27.8
Deflecting wrinkle LM1	n	0/23					16	21	33
(+ = ASU 2-3)	%	0.0					31.3	9.5	15.2
Protostylid	n	5/53	6/21	34/69	7/22	3/10	25	24	36
(+ = ASU 1-6)	%	9.4	28.6	49.3	31.8	30.0	36.0	12.5	22.2
Cusp 7 LM1	n	0/53	1/28	2/83	4/28	0/9	34	30	46
(+ = ASU 2-4)	%	0.0	3.6	2.4	14.3	0.0	5.9	13.3	10.9

Explanations: n – means number on individuals scored/sample size; for the Upper Egyptian samples percentage of individual scored and sample size is shown; Abbreviations: KAD – Kadero; PL – Pleistocene (18,000-12,000 B.C.); ME – Meroitic period (350 B.C.-350 A.D.); X – X-group (350-550 A.D.); CHR – Christian (550-1350 A.D.); GRM- Gebel Ramlah (4600-4400 B.C.); BAD – Badarian (4400-4000 B.C.0; NAQ – Naqada (4000-3200 B.C.)

* Chronology and dental traits for Nubian samples cited after Carlson and Van Gerven 1977:499;

** Chronology and dental traits for Upper Egyptian samples taken from Irish 2006:531-532.

Table 6. Descriptive statistics of the permanent tooth measurements in the Kadero dental sample

Tooth	I1	I2	C	P1	P2	M1	M2	M3
Maxilla								
Males								
M-Dcor n	17	14	19	17	16	26	22	18
Mean	8.96	7.52	8.38	7.55	6.98	10.82	10.53	9.52
SD	0.35	0.37	0.31	0.34	0.42	0.42	0.54	0.55
CV (%)	3.9	4.9	3,7	4.5	6.0	3.9	5.1	5.8
Females								
M-Dcor n	14	12	15	14	13	23	17	16
Mean	8.61	7.29	7.90	7.27	6.78	10.63	10.1	9.21
SD	0.39	0.40	0.30	0.32	0.41	0.30	0.68	0.64
CV (%)	4.5	5.6	3.8	4.4	6.0	2.8	6.7	6.9
t - test	p<0.01	p<0.05	p<0.01	p<0.01	NS	p<0.05	p<0.05	NS
Males								
B-Lcor n	17	14	19	17	16	26	22	18
Mean	7.92	7.36	9.14	9.32	9.12	12.02	11.82	11.57
SD	0.34	0.48	0.42	0.49	0.51	0.62	0.67	0.57
CV (%)	4.7	6.5	4.6	5.1	5.6	5.1	5.7	4.9
Females								
B-Lcor n	14	12	15	14	13	23	17	16
Mean	7.67	7.12	8.55	9.16	9.04	11.82	11.39	11.25
SD	0.39	0.42	0.44	0.41	0.40	0.56	0.61	0.62
CV (%)	5.1	6.3	5.1	4.5	4.4	4.7	5.3	5.5
t - test	p<0.05	p<0.01	p<0.01	p<0.05	NS	NS	p<0.01	NS
Mandible								
Males								
M-Dcor n	10	12	15	20	18	29	20	16
Mean	5.56	6.32	7.42	7.46	7.63	11.87	11.57	11.34
SD	0.21	0.44	0.69	0.33	0.51	0.62	0.74	0.65
CV (%)	3.8	6.9	9.3	4.4	6.7	5.2	6.4	5.7
Females								
M-Dcor n	8	8	14	18	17	25	16	14
Mean	5.25	5.95	7.25	7.27	7.37	11.27	11.18	11.06
SD	0.27	0.56	0.57	0.37	0.31	0.57	0.65	0.70
CV (%)	5.1	9.6	7.9	5.1	4.2	5.1	5.8	6.3
t - Test	p<0.01	NS	NS	p<0.05	p<0.01	p<0.01	NS	NS
Males								
B-Lcor n	10	12	15	20	18	29	20	16
Mean	6.01	6.32	8.12	8.04	8.42	11.52	11.0	10.64
SD	0.26	0.52	0.55	0.33	0.44	0.57	0.61	0.57
CV (%)	4.3	8.2	6,8	4.1	5.2	4.9	5.5	5.3
Females								
B-Lcor n	8	8	14	18	17	25	16	14
Mean	5.55	6.32	7.87	7.97	8.34	11.11	10.80	10.48
SD	0.27	0.56	0.51	0.38	0.53	0.74	0.81	0.79
CV (%)	4.9	8.9	6.5	4.8	6.3	6.7	7.5	7.5
t - test	p<0.01	NS	NS	NS	NS	p<0.01	NS	NS

Explanations: M-Dcor – mesiodistal diameter measured as maximum length of tooth crown; B-Lcor – buccolingual diameter measured as maximum breadth of tooth crown; n – sample size; SD – standard deviation; CV – coefficient of variation; all measurements shown in mm; *t*-Test – the Student's *t*- test; NS – differences were not statistically significant

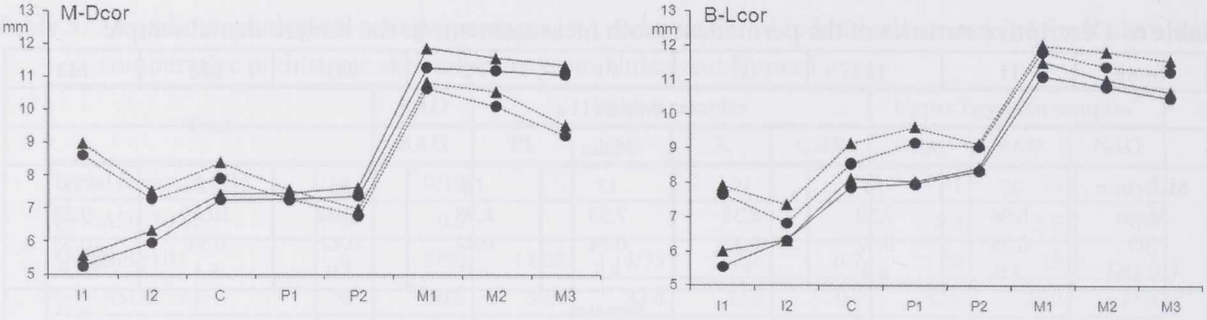

Fig. 5. Profiles of the mesiodistal (left) and buccolingual (right) diameters in the Kadeo sample. Dotted line is for maxillary teeth, solid line is for mandibular teeth, triangle marker is for men and circle marker is for women

Y-shape groove on these teeth was relatively less frequent (34.3%) than in Egyptian samples. There was no deflecting wrinkle present on the lower first molars. Little expression of the protostylid was present on the lower molars (9.4%). Only a faint extension of enamel along the roots of upper first molars was observed in a few cases (4.3%).

The overall pattern of dental morphology in Kadero revealed a characteristic picture. The dentition was characterized by showing very low frequency of shovelling, a moderate frequency of Carabelli's cusp, high frequency of reduced hypocone of upper second molars, very low frequency of protostylid, the absence of 7th cusps and substantially low incidence of 6th cusps on lower molars. This pattern differs slightly from the Nubian dentition in the presence of more reduced forms of upper and lower molars (absence of 7-cusped teeth, relatively high hypocone reduction of upper second molars, and moderate frequency of Carabelli's trait).

Odontometric descriptive statistics for the skeletal samples of Kadero are presented in Table 6. Genders are separated.

Aiming to estimate the degree of reduction of postcanine teeth, the Step Index developed by Selmer-Olsen (1949) was calculated in which the cheek teeth are each related to the first molar.

The estimation of the variability of the measurements was based on the calculation of the coefficient of variation (CV). Generally, the mesiodistal tooth crown length diameter had greater dispersion than the buccolingual tooth crown breadth. The same was observed in relation to the mandibular teeth, which had greater dispersion of both diameters than the maxillary teeth. It was also characteristic for the group that the males generally had greater dispersions than the females. The maxillary third molar gave the Step Index of 87.9 for males and 86.5 for females showing a considerable tooth reduction in the study sample. Maxillary cheek teeth were likely to be more strongly reduced than their mandibular counterparts (95.5 for males and 98.1 for females). The size of maxillary second incisor was reduced to a lesser degree than the size of cheek teeth.

As to the question of the degree of sexual dimorphism in tooth size, it was observed that generally males had larger teeth than females. Maxillary teeth were more sexually dimorphic than their mandibular counterparts. Of 16 tooth measurements, males had 11 maxillary and 6 mandibular measurements significantly larger than females. Sexual dimorphism in tooth size may be seen from dental profiles plotted for mesiodistal length and buccolingual breadth of tooth and presented in Fig. 5.

Analysis of the metric values revealed sexual dimorphism in tooth size, with the canine teeth playing the most significant role in differentiating males and females. Differences were found to be moderate, as 17 (53%) of the total of 32 measurements were statistically significant.

Low to medium values of the coefficient of variation indicated biological homogeneity of the group. Larger dispersion found in males than females was observed in other human groups and reported by others (Nielsen op. cit).

Comparison of profiles of cross-sectional area of maxillary and mandibular teeth in females from the Neolithic Kadero and the Mesolithic Saggai 1 samples are shown in Fig. 6.

A striking similarity was found in the mean values of the cross-sectional areas of mandibular teeth between the two compared series, Kadero and Saggai 1. Their tooth size was different in respect to maxillary teeth. The latter were smaller in the Kadero sample as compared to Saggai 1. A considerable reduction of cheek teeth was seen in both series. Thereby, as might be expected, trends in cross-sectional areas of maxillary and mandibular teeth largely conform to those of either dental dimension.

Of two dental dimensions reported in this study, the buccolingual diameter appears to be a better measure of the underlying genetic component of tooth size. Mesiodistal diameter is vulnerable to measurement error. It has been found that when maximum dimensions are recorded, occlusal and interproximal wear significantly diminish mesiodistal length (Frayer 1978, Biggerstaff 1979). The amount of attrition does not affect the maximum buccolingual breadths, which are measured below the original occlusal surface. Of all teeth, incisors are especially vulnerable to the decreasing reliability of mesiodistal metrics, because their maximum length is measured essentially at the unworn occlusal surface, which when erupted is sharp but then tends to be rapidly worn down. Indeed, the amount of attrition within a given specimen varies with each tooth class, depending upon such factors as size, morphology, and location of the tooth in the jaws (Van Reenen 1982). In an attempt to alleviate this problem, cross-sectional area of maxillary and mandibular teeth was used for comparison between the Kadero and Saggai 1 subsamples of females (Saggai 1 data comprises only females). Overall, the Kadero teeth were likely to be smaller as compared to teeth from the Saggai 1 sample. It was found especially with respect to the maxillary teeth. They were likely to be more vulnerable to diachronic changes than their mandibular counterparts.

Permanent teeth revealed severe attrition with common variant of the stage 6 and 7 observed in the upper and lower molars and 5 and 6 observed in upper incisors through the canines. Dental caries was not observed in the sample. Relevant data for the frequency of carious lesions for the Nubian series from Wadi Halfa provided by Armelagos (1969) was very low in the Mesolithic sample (1.0%) and increased to 18% in the Christian phase. Similar data for the earlier Egyptian populations indicated a 2.3% caries prevalence in Predynastic Egypt (Brothwell 1963:177) and 2.5% in the Late Period (Strouhal, Bares 1993). The frequency of ante-mortem tooth loss was assessed at 7.5% for upper molars and some 6.8% for lower molars, following the frequency given by Brothwell (1963:177) -- 8.6% in Predynastic Egypt and 14.1% in the Late Period.

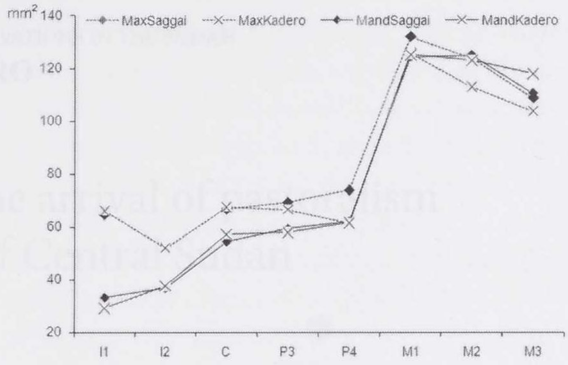

Fig. 6. Profiles of the female cross-sectional tooth areas (in mm2). Dotted line is for maxillary teeth, solid line is for mandibular teeth. Romboid marker is for Saggai 1, cross marker is for Kadero.

Conclusion

The present study aimed to summarize data on variation in metric and non-metric skeletal (cranial and postcranial), and dental morphological traits of the Neolithic population from Kadero. The sample appeared to be dentally homogenous showing a moderate rate of sexual dimorphism in cranial, post-cranial and dental morphological traits. The sample shared with earlier human groups a low frequency of shoveling, a moderate expression of Carabelli's cusp and a low frequency of protostylid. But the Kadero sample was characterized by specific traits attributed of biological variation, such as the lack of 7-cusped lower molars and greater hypocone reduction of the upper second molars.

This study provides the missing data on biological variation of prehistoric people living in the area of Central Sudan.