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Craniofacial Variation Between Southern and Northern Neolithic and Modern Chinese

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ABSTRACT Previous studies propose that the Yangtze River is the geographic boundary separating northern and southern Chinese populations. In order to test this hypothesis, 19 Neolithic and 15 Modern human cranial samples from north of the Qinling Mountain Range, south of the Yangtze River and in between were chosen for morphometric analysis. Our results indicate that cranial variation exists in Holocene Neolithic and Modern northern and southern Chinese. In the Neolithic sample, the northern Chinese crania are characterised by greater upper face height and orbit height, while the southern Chinese skulls are depicted by a wider nose. The morphology of the crania between the Qinling Mountain range and the Yangtze River feature a mosaic of characters that suggest affiliation with both north and south groups. In the Modern day sample, northern crania are characterised by a broad and wide face, and a tall nose. From the Neolithic to Modern day, a series of microevolutionary processes that apply to both the northern and southern samples can be discerned. Overall, the head gets lower, the face and nose become narrower and the orbits tend to be narrower and higher. Our results support the suggestion that the Qinling Mountain Range and the Yangtze River represent a natural barrier to the movement of Chinese populations. Climatic variation and the transition to an agricultural lifestyle are proposed as the primary factors influencing human craniofacial morphologies. Copyright © 2010 John Wiley & Sons, Ltd.

Key words: craniometric variation; Modern day; Neolithic age; northern Chinese; southern Chinese

Introduction

The Holocene is the primary epoch for the formation, differentiation and migratory patterning of Modern human populations throughout the world. Many changes in *Homo sapiens'* lifestyle, culture, technology, behaviour and economic patterning occurred. Analysis of Holocene human remains is very important to understand the development of Modern human populations and how this development was influenced by environmental and/or cultural processes. Research conducted on Holocene human remains from different spatio-temporal contexts indicates that the physical characters of Modern humans are still changing (Henneberg, 1988). For instance, 70% of the cranial features of northern populations from Chile show distinct temporal changes (Rothhammer *et al.*, 1982). In certain American populations from the mid-19th century to the 1970s the cranium became more dolichocephalic, and the face became narrower and higher (Jantz & Jantz, 2000). Studies of northeast African Nubian populations show that cranial robustness decreased, and head shape became more brachycephalic, while tooth and mandible size decreased (Carlson, 1976; Carlson & Van Gerven, 1977).

Few of these studies have focused on China despite rich human skeletal collections for this region, although many Holocene archaeological sites and human remains have been identified in China (Zhang, 1999). Some previous studies on anatomical and genetic data proposed that nearly all human populations living in China for the past 10 000 years are 'Mongoloids', except for a few minority groups in northwest China that have some European features in their genetic makeup (Han & Pan, 1984; Du, 2004). Other research has shown that craniometric diversity is

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present within local Chinese groups (e.g. Howells, 1983; Han & Pan, 1984; Wang, 1986; Zhang, 1999; Hanihara, 1994, 1996). There is growing evidence that the physical characteristics of Modern Chinese have undergone secular change and vary geographically (e.g. Wang, 1986; Zhang, 1999; Wu *et al.*, 2007). Studies of human dentition, archaeological assemblage composition, linguistics, familial surnames, anatomical and genetic systems provide justification for dividing Holocene Chinese populations into northern and southern groups (Turner, 1987; Zhang, 1988a; Ruhlen, 1994; Chu *et al.*, 1998; Su *et al.*, 1999; Yuan *et al.*, 2000; Ke *et al.*, 2001; Du, 2004; but see Ding *et al.*, 2000 for alternative interpretation). The Qinling Mountain Range, located in the middle of China, constitutes a natural barrier for many flora and fauna (Xie *et al.*, 2004). The Yellow River and Yangtze River are the major river systems in North and South China. Some scientists (e.g. Zhang, 1988a; Liu *et al.*, 1991) propose that the geographic boundary separating northern and southern Chinese populations is the Yangtze River, though others (e.g. Han & Pan, 1984; Pan, 2000) prefer the Yellow River.

Previous studies of Chinese Holocene human populations have traditionally focused on distinguishing 'racial features' among subgroups (e.g. Zhang, 1996; Pan, 2000; Zhu, 2002; Han, 2005). In this study, we present a new, comprehensive dataset comprised of Chinese male adult crania from Neolithic and Modern times. With this dataset we document spatio-temporal variation and develop some working hypotheses to explain whether the Qinling Mountain Range and/or the Yangtze River is a natural barrier to separate the northern and southern Chinese cranial samples.

Materials and methods

Materials

The database ($N = 309$) is comprised of 19 Neolithic and 15 Modern human crania groups from 34 archaeological sites (see Figure 1 and Table 1). In the Neolithic sample, Miaozigou, Yangshan, Liuwan, Banpo, Huaxian, Jiangjialiang, Xishan, Dawenkou, Xixiahou, Chengzi and Wangyin (Number symbols 1–11) are located north of the Qinling Mountain Range; Weidun, Hemudu, Tanshishan, Zhenpiyan and Hedang (Number symbols 15–19) are situated south of the Yangtze River; Diaolongbei, Yuchisi and Longqiuzhuang (Number symbols 12–14) are located between the Qinling Mountain Range and the Yangtze River. In the Modern sample, the North groups are Zhenzishan, Changchun, Lamadong, Shangsunjia,

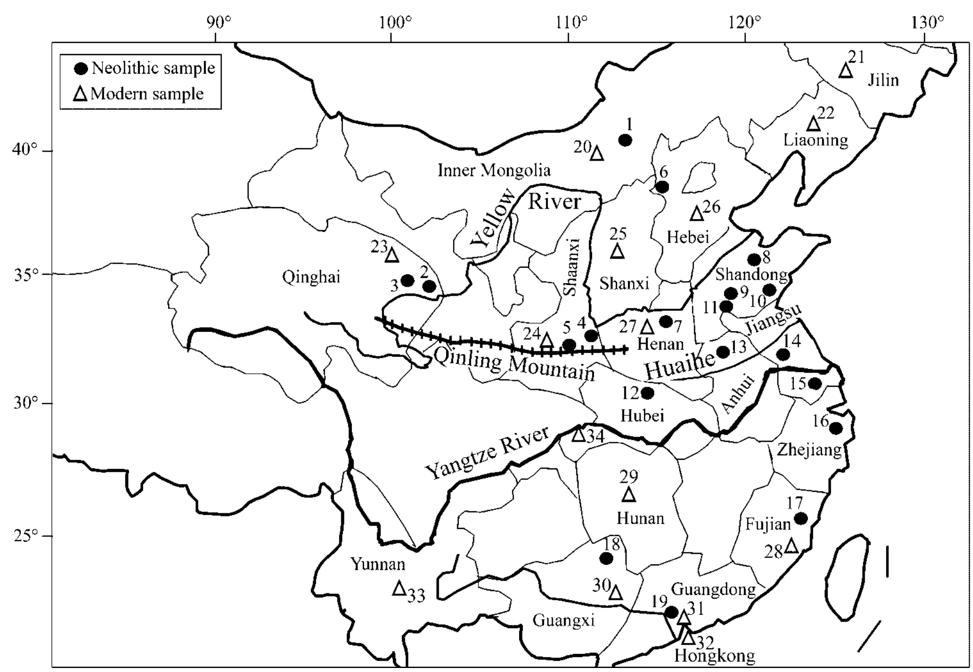

Figure 1. Map showing the approximate locations for the Chinese cranial series used in the present analysis. Number symbols indicate: (1) Miaozigou; (2) Yangshan; (3) Liuwan; (4) Banpo; (5) Huaxian; (6) Jiangjialiang; (7) Xishan; (8) Dawenkou; (9) Xixiahou; (10) Chengzi; (11) Wangyin; (12) Diaolongbei; (13) Yuchisi; (14) Longqiuzhuang; (15) Weidun; (16) Hemudu; (17) Tanshishan; (18) Zhenpiyan; (19) Hedang; (20) Zhenzishan; (21) Changchun; (22) Lamadong; (23) Shangsunjia; (24) Xi'an; (25) Taiyuan; (26) Hebei; (27) Luoyang; Dongshandao; (29) Hunan; (30) Guangxi; (31) Shunde; (32) Hongkong; (33) Yunnan and (34) Chongqing.

Table 1. Samples used in this study (male = 309)

Group	Sample size	Brief information
Neolithic-North (north of Qinling mountain range)		
(1) Miaozigou	6	Ca. 5500–5000 B.P. from Chayouqian Banner, Inner Mongolia (Zhu, 1994; Wei, 2003)
(2) Yangshan	7	Ca. 5000 B.P. from Minhe, Qinghai (Han, 1990a)
(3) Liuwan	9	Ca. 4500–4000 B.P. from Yuedu, Qinghai (Pan & Han, 1984)
(4) Banpo	16	Ca. 6100–6700 B.P. from Xi'an, Shaanxi (Yen *et al.*, 1960)
(5) Huaxian	8	Ca. 5700–7100 B.P. from Yuanjunmiao, Liuzizhen, Huaxian, Shaanxi (Yen, 1962)
(6) Jiangjialiang	14	Ca. 6850 B.P. from Yangyuan, Hebei (Li *et al.*, 2001)
(7) Xishan	6	Ca. 5300–4800 B.P. from Zhenzhou, Henan (Yang, 1997)
(8) Dawenkou	7	Ca. 4300–6500 B.P. from Wenkouzhen, Shandong (Yen, 1972)
(9) Xixiahou	9	Ca. 4300–6500 B.P. from Qufu, Shandong (Yen, 1973)
(10) Chengzi	3	Ca. 5000 B.P. from Zhucheng, Shandong (Han, 1990b)
(11) Wangyin	5	Ca. 6000 B.P. from Yanzhou, Shandong (Han, 2000)
Neolithic-Middle (between Qinling mountain range and Yangtze river)		
(12) Diaolongbei	1	Ca. 5200–4500 B.P. from Zaoyang, Hubei (Zhang, 1988b)
(13) Yuchisi	5	Ca. 4800–4500 B.P. from Mengcheng, Anhui (Zhang & Han, 1998)
(14) Longqiuzhuang	11	Ca. 6300–5500 B.P. from Gaoyou, Jiangsu (Han, 1999)
Neolithic-South (south of Yangtze river)		
(15) Weidun	9	Ca. 5000 B.P. from Changzhou, Jiangsu (Yamaguchi & Huang, 1995)
(16) Hemudu	1	Ca. 7000 B.P. from Yutao, Zhejiang (Han & Pan, 1983)
(17) Tanshishan	3	Ca. 4500–4000 B.P. from Minhou, Fujian (Han *et al.*, 1976)
(18) Zhenpiyan	6	Ca. 6600 B.P. from Guilin, Guangxi (Zhang *et al.*, 1977)
(19) Hedang	2	Ca. 5500 B.P. from Foshan, Guangdong (Han & Pan, 1982)
Modern-North		
(20) Zhenzishan	10	Ca. 700 B.P. from Duolun, Inner Mongolia (Wei, 1999)
(21) Changchun	10	Recent people from Jilin
(22) Lamadong	12	Ca. 1600 B.P. from Beipiao, Liaoning
(23) Shangsunjia	14	Ca. 2000 B.P. from Datong, Qinghai (Han *et al.*, 2005)
(24) Xi'an	10	Recent crania from Shannxi (Dang *et al.*, 1985; Yang *et al.*, 1987)
(25) Taiyuan	12	Recent crania from Shanxi (Wang & Sun, 1988)
(26) Hebei	30	Recent crania from Hebei
(27) Luoyang	10	Recent crania from Henan (Bao, 1986)
Modern-South		
(28) Dongshandao	6	Recent crania from Fujian (Zhang, 1996)
(29) Hunan	9	Recent crania from Hunan (Zhang, 1965)
(30) Guangxi	8	Recent crania from Mashan, Guangxi (Zhu *et al.*, 1989)
(31) Shunde	9	Recent crania from Guangdong (Huang & Zeng, 1984)
(32) Hongkong	11	Recent crania from Hongkong (Wang, 1989)
(33) Yunnan	25	Recent crania from Yunnan
(34) Chongqing	5	Recent crania from Chongqing

Xi'an, Taiyuan, Hebei and Luoyang (Number symbols 20–27); the South groups are Dongshandao, Hunan, Guangxi, Shunde, Hongkong, Yunnan and Chongqing (Number symbols 28–34). The cranial samples are divided into five groups using the Qinling Mountain Range and the Yangtze River as the geographic boundary: Neolithic-North, Neolithic-Middle, Neolithic-South, Modern-North and Modern-South.

The Miaozigou site (5500–5000 B.P.) was discovered in 1985. It is considered the best preserved and largest neolithic site in south–central Inner Mongolia, where excavations of 43 tombs led to the discovery of more than 70 human skeletons, pottery, storage pits and many animal bones and artefacts. The Miaozigou culture is similar to the late Yangshao Neolithic, where the people depended primarily on agriculture, supplemented by hunting and livestock (Zhu, 1994; Wei, 2003). The Yangshan (5000 B.P.), Liuwan (4500–4000 B.P.), Banpo (6100–6700 B.P.), Huaxian (5700–7100 B.P.) and Xishan (5300–4800 B.P.) sites are located along the middle portion of the Yellow River and their culture belongs to the Yangshao. The Jiangjialiang site (6850 B.P.) is located in the Nihewan Basin, Yangyuan in Hebei province. Since 1995, 78 tombs, nine house-foundations, pottery, and seeds were discovered. The Jiangjialiang culture is contemporary with the Yangshao Neolithic (Li *et al.*, 2001). The Dawenkou (4300–6500 B.P.), Xixiahou (4300–6500 B.P.), Chengzi (5000 B.P.) and Wangyin (6000 B.P.) sites are located in Shandong province on the lower reaches of the Yellow River and assigned to the Dawenkou Culture. The Diaolongbei

(5200–4500 B.P.), Yuchisi (4800–4500 B.P.), Longqiuzhuang (6300–5500 B.P.), Weidun (5000 B.P.), Hemudu (7000 B.P.), Tanshishan (4500–4000 B.P.), Zhenpiyan (6600 B.P.) and Hedang (5500 B.P.) sites are located on the south of the Qinling Mountain Range, and the people mainly lived on fishing and gathering. Zhenzishan (700 B.P.) is an upper capital site of the Yuan dynasty in Inner Mongolia discovered in 1990. The analysis of the cemetery and skeletal collections indicate the Zhenzishan people belong to the northern Han (Wei, 1999). The Lamadong cemetery (1600 B.P.) found in Beipiao, Liaoning province, is the largest cemetery of the three-Yan culture known so far in North China. Since 1993, more than 400 tombs, cooking vessels, weapons, chariots and harnesses were found in the site (Liaoning Provincial Institute of Cultural Relics and Archaeology, 2004). These skeletal collections are housed in the Institute of Vertebrate Paleontology and Paleoanthropology, Chinese Academy of Sciences, the Research Center for Chinese Frontier Archaeology of Jilin University and Institute of Archaeology, Chinese Academy of Social Sciences. Due to insufficient sample size from South China, Bronze Age and Iron Age crania were not included in this comparative study. Due to the unbalanced ratio of male and female, only complete or substantially complete, undistorted male specimens were used.

Methods

Since they are very fragmentary and/or had missing values (e.g. Zengpiyan), we were unable to take a complete set of measurements on many of the crania from South China. In order to include as many of the southern groups and variables in the statistical analyses, we chose nine standard linear measures following previous studies (Martin & Saller, 1959; Wang, 1986; Liu *et al.*, 1991; Jantz & Jantz, 2000). They are: cranial length (GOL, Glabello-occipital length), cranial breadth (XCB, eu-eu), basi-bregma height (BBH), upper facial height (NPH, nasion-prosthion height), bizygomatic breadth (ZYB), nasal breadth (NLB), nasal height (NLH, n-ns), orbit breadth (OBB, mf-ek) and orbit height (OBH). All data were collected by the first author. Each cranium was measured three times and the average was used as the final measurement.

We constructed principal component analyses (PCA) and bivariate plots to provide a perspective on metric variation in our sample. The data were divided into north and south groups with the Qinling Mountain Range and the Yangtze River as the arbitrary boundary, in order to test the hypothesis whether the Qinling Mountain Range could have served as a barrier during the Neolithic and Modern periods. In the bivariate plot comparisons, length versus basi-bregma height, facial breadth versus upper facial height, nasal breadth versus nasal height and orbit breadth versus orbit height were used to evaluate the main index changes among the groups. Statistical analyses were run in SPSS 11.0. Mann–Whitney U-Tests were used to determine whether the north were different from the south groups between the Neolithic age and Modern day.

Results

In the PCA analysis of Neolithic sample (Table 2 and Figure 2A), the first three components account for 60.3% of the total variance. The first component explains 28.0% of the total variation in the data. The second PC explains 17.3% while the third PC explains 15.0%. The highest loadings for PC1 are for three variables that are measures of XCB, ZYB and NLH. PC2 has the highest loading for NPH, NLB and OBH.

Table 2. PCA loadings of nine-variable analysis of Neolithic and Modern Chinese

	Neolithic age			Modern day		
	PC 1	PC 2	PC 3	PC 1	PC 2	PC 3
GOL	0.125	−0.334	−0.454	0.395	0.319	0.602
XCB	0.648	−0.190	0.415	0.590	0.292	−0.501
BBH	0.622	−0.263	0.082	0.647	0.235	0.225
NPH	0.616	0.481	−0.385	0.740	−0.360	0.228
ZYB	0.740	−0.068	0.359	0.768	0.101	−0.153
NLB	0.557	−0.460	−0.122	0.367	0.478	0.224
NLH	0.655	0.377	−0.517	0.775	−0.405	0.100
OBB	0.175	0.317	0.628	0.573	0.244	−0.461
OBH	0.047	0.804	0.122	0.444	−0.590	−0.076
Per cent of variance	28.0%	17.3%	15.0%	36.9%	13.1%	11.3%

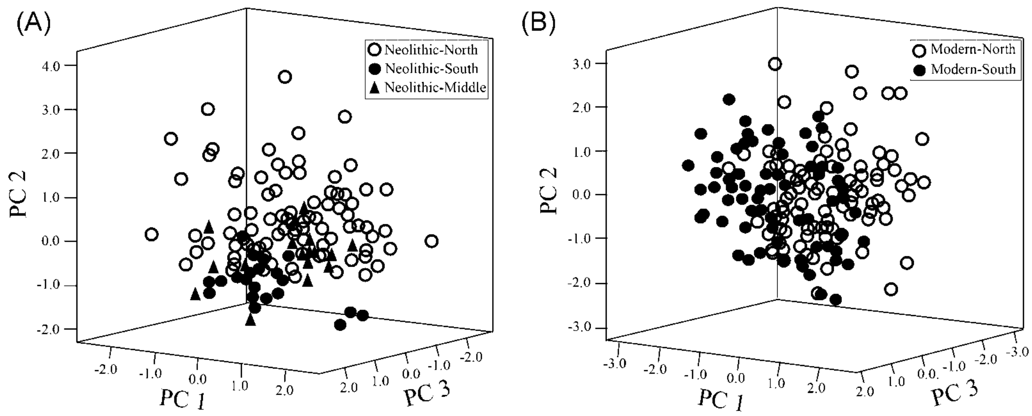

Figure 2. Principal component analyses on metric variation in our sample: (A) Neolithic age; (B) Modern day.

PC3 has the highest loading for OBB. Figure 2 (A) is a visual representation in three-dimensional space of the distribution for the crania using the first three PCs. The Neolithic-North separate from the Neolithic-South on PC2, registering the combination of tall face, narrow nose and high eyes. For the Neolithic-Middle, more crania are close to the Neolithic-South.

In the PCA analysis of modern sample (Table 2 and Figure 2B), the first three components account for 61.3% of the total variance. The first component explains 36.9% of the total variation in the data. The second PC explains 13.1% while the third PC explains 11.3%. The highest loadings for PC1 are for three variables that are measures of NPH, ZYB and NLH. PC2 has the highest loading for NLB, NLH and OBH. PC3 has the highest loading for GOL. Based on the plot of the first three principal components (Figure 2B), the Modern-North separate from the Modern-South on PC1, registering the combination of a tall and broad face and high nose.

Figure 3 is a set of bivariate plots of selected measures of Neolithic groups. The Neolithic-North is different from the Neolithic-South on GOL (Figure 3A), NPH (Figure 3B), NLB (Figure 3C) and OBH (Figure 3D). The Neolithic-Middle are mixed with the Neolithic-North on GOL, BBH (Figure 3A), NLB and NLH (Figure 3C). The Neolithic-Middle are close to the Neolithic-South sample on NPH (Figure 3B), and close to the Neolithic-North sample on NLH and OBH (Figure 3D). The Neolithic-Middle are mixed with the South and North on GOL, BBH, ZYB, NLB and OBB.

Figure 4 is a set of bivariate plots of selected measures of Modern groups. The Modern-North groups are different from the Modern-South groups on the GOL, BBH (Figure 4A), ZYB, NPH (Figure 4B), NLH (Figure 4C) and OBB (Figure 4D).

Mann–Whitney U-Tests indicate that the differences are statistically significant for the BBH, NPH, ZYB, NLB, OBB and OBH between the Neolithic age and Modern day groups (Table 3). The Neolithic sample is different from the Moderns with their relatively tall head, big face, wide nose, low and wide eyes.

Table 4 shows the Mann–Whitney U-Tests between the northern and southern Chinese. Comparing the Neolithic-North with Neolithic-South (except Neolithic-Middle), the differences were statistically significant for the GOL, NPH, NLB, NLH and OBH. The southern Chinese, in contrast to the northern Chinese are charactered by a long head, a short face, a low and wide nose, and low eyes. Comparing the Modern-North with the Modern-South, the differences are statistically significant for the GOL, XCB, BBH, NPH, ZYB, NLH and OBH. The morphological pattern of northern Modern Chinese contrasts with southern Modern Chinese, with their relatively long and wide cranium, short and narrow face, low nose and low eyes.

Discussion

Spatial variation between the northern and southern Chinese

Currently more than 50 different ethnic groups reside within China's borders. Based on previous physical anthropological, genetic, linguistics and archaeological investigations, both the Neolithic and Modern samples can be divided into northern and southern types with the Yangtze River as the boundary (Wang, 1986; Zhang, 1988a; Zhang, 1999; Liu *et al.*, 1991; Ruhlen, 1994; Chu *et al.*, 1998; Su *et al.*, 1999; Yuan *et al.*, 2000; Ke *et al.*, 2001; Du, 2004). For instance, the

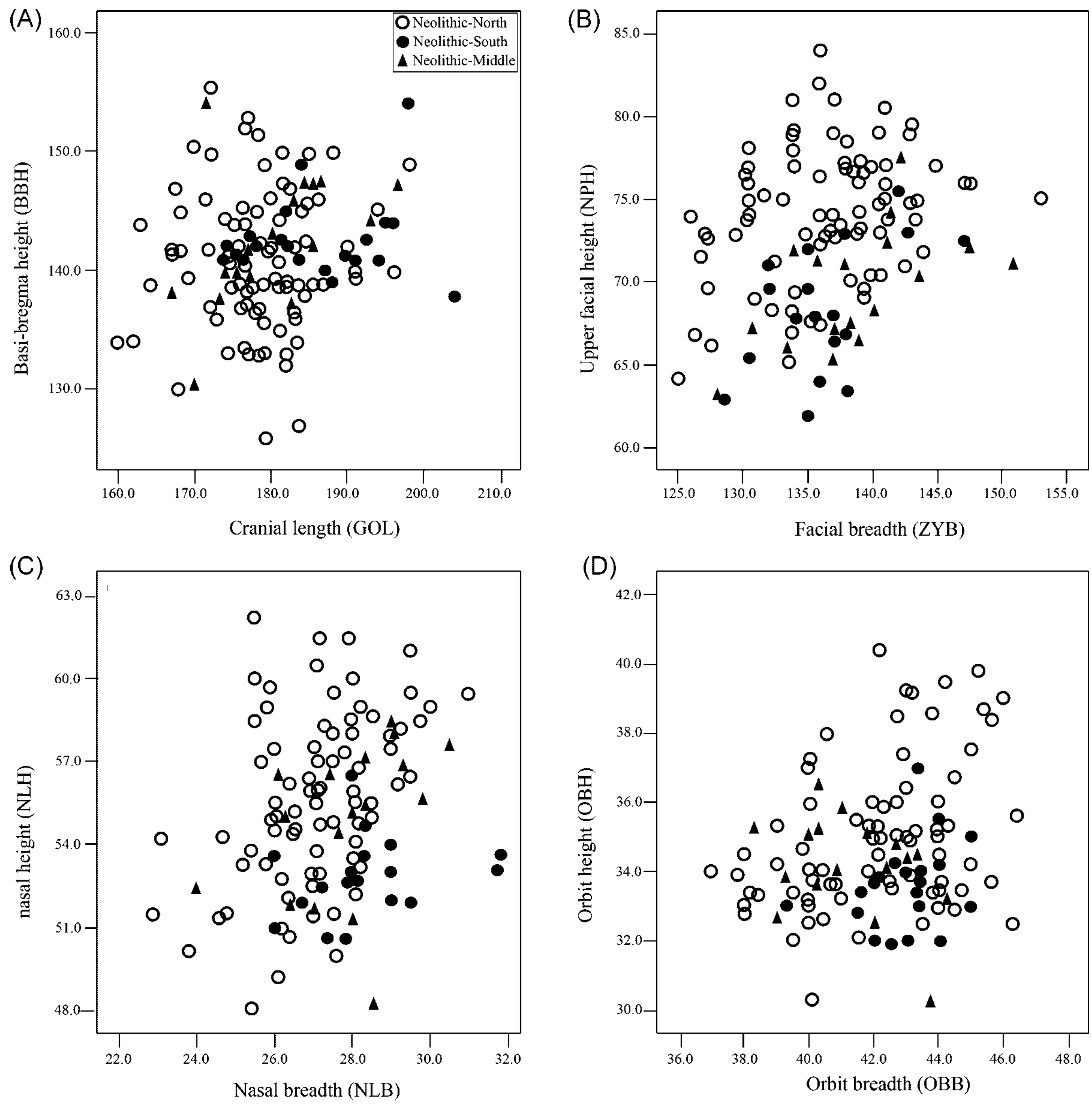

Figure 3. Bivariate plots of cranial measures of Neolithic Chinese: (A) length versus basi-bregma height, (B) facial breadth versus upper facial height, (C) nasal breadth versus nasal height, (D) orbit breadth versus orbit height.

northern Neolithic cultures are represented by the Majiayao, Dawenkou, Yangshao, Longshan and Qijia, while the southern Neolithic cultures are represented by the Hemudu, Majiabing, Liangzhu and Qujialing (Wang, 2005). Only one major language (Mandarin) is widely used in northern China today, while in southern China, at least six dialects, Wu (Shanghainese), Yue (Cantonese), Min, Xiang, Gan and Hakka are commonly used. Each southern dialect represents a separate wave of Chinese fleeing south to avoid persecution during episodes of dynastic change (Ramsey, 1987). The northern and southern Chinese populations differ in both physical and genetic studies (Zhang, 1999; Chu *et al.*, 1998). Southern populations are genetically more polymorphic than northern populations (Ke *et al.*, 2001; Chu *et al.*, 1998; Su *et al.*, 1999). Compared with northern Chinese, the morphological features of the southern Neolithic samples are closer to the Late Pleistocene human fossils (Woo, 1959; Wu, 1961; Chen, 1989).

Many natural barriers exist in central China that served to divide Chinese Holocene populations. For instance, the Qinling Mountain Range constitutes a natural barrier for many flora and fauna (Xie *et al.*,

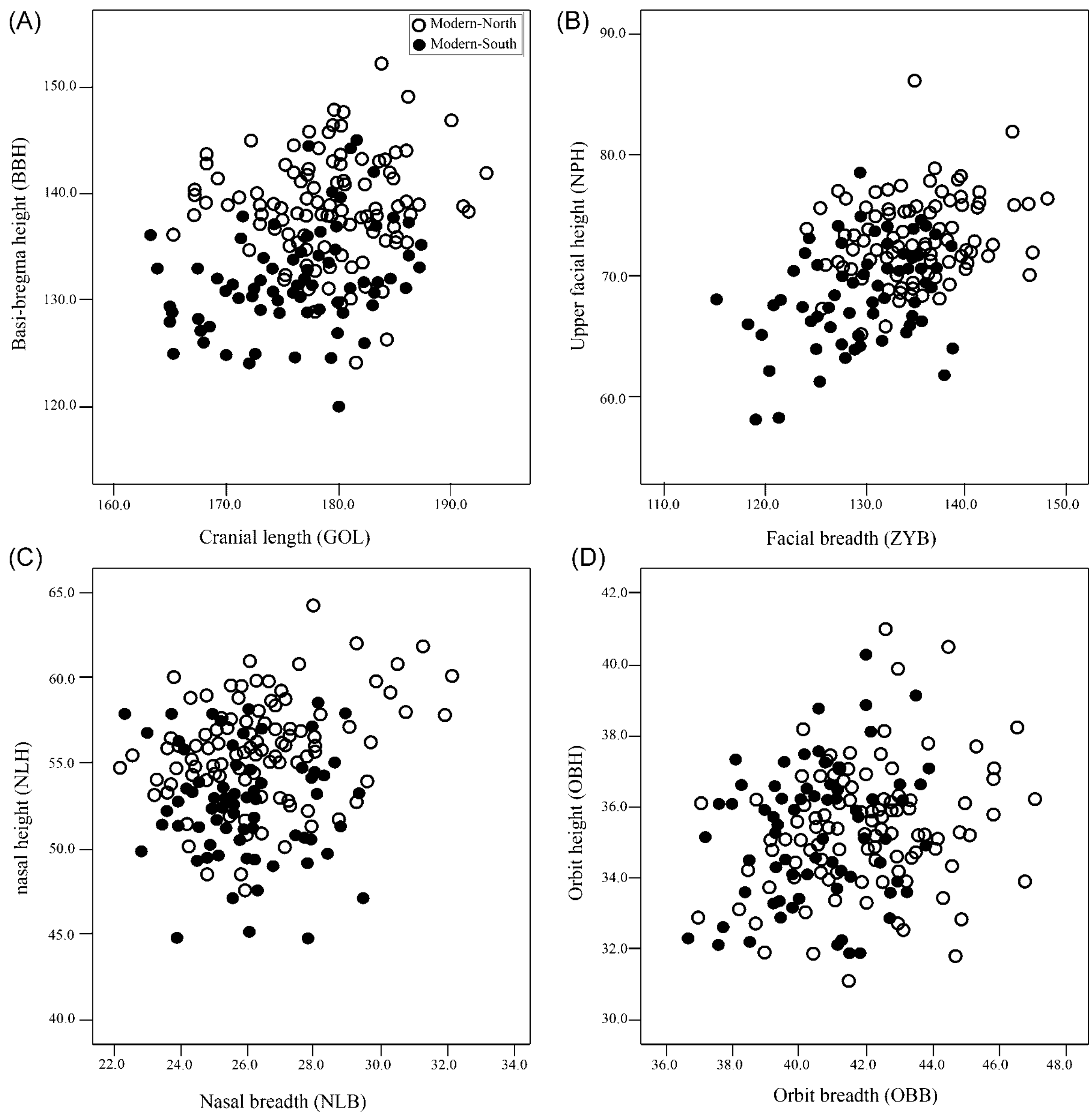

Figure 4. Bivariate plots of cranial measures of Modern Chinese: (A) length versus basi-bregma height, (B) facial breadth versus upper facial height, (C) nasal breadth versus nasal height and (D) orbit breadth versus orbit height.

2004). However, since the Qinling Mountain range is located in the middle of China, it would have served as less of a physical barrier east, where much of the Modern day Chinese populations are aggregated. The Yellow River and Yangtze River are the major river systems in North and South China. Some scientists (e.g. Zhang, 1988a; Liu *et al.*, 1991) propose that the geographic boundary separating northern and southern Chinese populations is the Yangtze River, though others (e.g. Han & Pan, 1984; Pan, 2000) argue that the Yellow River served as the physical boundary of the Chinese civilisation. Our studies presented here indicate that the Neolithic and Modern samples separated by the Qinling Mountain range and the Yangtze River are distinct. Significant differences exist between the north and south groups. The Neolithic-South crania are characterised by low face, wide nose and low eyes. The Modern-South crania are characterised by low and narrow face, and low nose. Overall, the southern Chinese crania are characterised by small face and small nose. However, some degree of morphological similarity appears in both groups. The crania between the Qinling Mountain range and the Yangtze River varied, some close to the north

Table 3. Mann–Whitney U-Test between the Neolithic and Modern Chinese

Variable	Neolithic age (mean ± SD)	Modern day (mean ± SD)	Sig.
GOL	179.9 ± 8.04	177.8 ± 6.02	0.043
XCB	140.3 ± 6.65	139.6 ± 5.64	0.407
BBH	141.3 ± 5.46	135.8 ± 5.94	0.000***
NPH	72.5 ± 4.49	71.3 ± 4.18	0.010**
ZYB	136.4 ± 5.39	132.9 ± 5.67	0.000***
NLB	27.4 ± 1.53	26.1 ± 1.86	0.000***
NLH	55.0 ± 2.95	54.6 ± 3.49	0.387
OBB	42.1 ± 2.06	41.4 ± 2.04	0.001**
OBH	34.6 ± 1.90	35.4 ± 1.77	0.000***

***Significant at the 0.001 level, **Significant at the 0.01 level.

Table 4. Mann–Whitney U-Test between the northern and southern Chinese

Variable	Neolithic age (mean ± SD)			Modern day (mean ± SD)		
	North	South	Sig.	North	South	Sig.
GOL	178.2 ± 7.18	186.6 ± 8.40	0.000**	178.9 ± 5.52	176.1 ± 6.35	0.006**
XCB	140.2 ± 7.20	141.0 ± 6.17	0.601	141.1 ± 5.37	137.3 ± 5.31	0.000***
BBH	140.7 ± 5.79	142.6 ± 3.48	0.073	138.3 ± 5.15	132.0 ± 4.95	0.000***
NPH	74.1 ± 3.92	68.4 ± 3.65	0.000***	72.9 ± 3.45	68.8 ± 3.96	0.000***
ZYB	136.0 ± 5.53	136.3 ± 4.16	0.910	134.9 ± 4.90	129.9 ± 5.43	0.000***
NLB	27.1 ± 1.43	28.3 ± 1.46	0.001**	26.3 ± 1.99	25.9 ± 1.62	0.225
NLH	55.6 ± 3.03	52.9 ± 1.35	0.000***	55.7 ± 3.12	52.9 ± 3.31	0.000***
OBB	42.1 ± 2.21	42.9 ± 1.28	0.127	41.9 ± 2.04	40.5 ± 1.73	0.000***
OBH	34.9 ± 2.02	33.6 ± 1.24	0.007**	35.4 ± 1.70	35.3 ± 1.87	0.756

***Significant at the 0.001 level, **Significant at the 0.01 level.

group, and some close to the south group. Our study concurs with previous suggestions (e.g. Hanihara, 1996) that craniofacial variation of major geographical groups is not necessarily consistent with their geographical distribution pattern.

Temporal change between the Neolithic and Modern Chinese

In the past, it has been proposed that the cranial morphology of Neolithic Chinese is indistinguishable from Modern Chinese (e.g. Black, 1928; Howells, 1983). However, some recent studies of Holocene populations indicate that Chinese Neolithic peoples had larger crania than Modern peoples (Wang, 1986; Zhang, 1999; Wu *et al.*, 2007). From the current study, comparison of the Neolithic and Modern datasets indicate significant temporal variation is present. The Neolithic Chinese crania are characterised by greater BBH, NPH, ZYB, NLB and OBB, while the Modern crania are represented by more pronounced OBH. The physical characters of Chinese populations have evolved significantly throughout the Holocene. Secular change existed in Chinese Neolithic and Modern cranial series (e.g. Miaozigou and Zhenzishan). In general, from the Neolithic to the present day, cranial height decreases, the face and the nose gets narrower, the orbits become narrower and higher.

Proposed reasons for variation

We propose three reasons can explain the variation in physical characters among Holocene Chinese samples. These are genetics, environmental and cultural influences. These explanations are tentative and we are currently developing them in more detail.

Some researchers suggest that populations living in North and South China developed from two different phylogenetic lineages: one population originated in the Yellow River valley, and the other originated in the Yangtze River valley during the early part of the Neolithic (Han & Pan, 1984; Zhao *et al.*, 1987; Zhang, 1999). The southern populations and northern populations can be distinguished at the genetic level. For example, using Y-chromosome data the southern populations are much more polymorphic than northern populations (Ke *et al.*, 2001; Shi *et al.*, 2005). Using genetic data, it has been suggested that the ancestors of Modern Chinese populations entered from Southeast Asia, with a northward migration leading to the peopling of northern China (Chu *et al.*, 1998; Shi *et al.*, 2005). Our studies show that morphological differences are discernible between the various samples. Significant differences exist between the northern and southern human groups. However, the differences are not the same in each pair of samples. For example, some degree of morphological similarity exists across spatial regions. It is difficult to explain the craniofacial variations of Holocene Chinese only with the proposed genetic reasons.

Climatic variation influences human physical and behavioural attributes. During the Holocene, global climates gradually became warmer and more geographic regions were available for human habitation (Shi, 1992). The environment between North and South China was different, warm and humid in the south, cold and dry in the north (Zhu *et al.*, 2001). Northern China experienced its warmest and wettest period from 8000–3000 BP. From 5000–3000 BP northern China became colder and drier, with the temperate/subtropical boundary shifting into southern China at the Yangtze River Basin (Zhu, 1973; Zhu *et al.*, 2001). According to some historic records (e.g. Zhu, 1973; Zhang, 1997) during the period of 4400–4000 BP, there was a 3°C decrease in temperature in the mid-latitude regions, causing drought in some areas (e.g. Yellow River region). There were different cultures in different regions during the Neolithic age. The cultural development was influenced by the geographic environments. Due to the influence of Chinese geographic environment, the culture in the Neolithic age in China is different from those in other countries, and there is a different culture in different regions in the Neolithic age in China (Mao, 2002). Holocene cultural development was strongly impacted by environmental factors and is clearly at least one primary reason for why domestication of millet initially occurred in the north and rice in the south (Huang *et al.*, 2006; Norton, 2007).

These types of climate changes would have impacted the overall physical characters of humans and other members of the biotic community. For example, the northern crania of Miaozigou and Zhenzishan are more globular compared to the southern crania of Hemudu and Yunnan. In addition, the subsistence change from hunting and gathering to plant and animal domestication influenced human morphological features. The transition to softer foods would have led to a degeneration of the muscles related to mastication, which would have resulted in less prognathic facial bones (Yuan, 1999; Wu *et al.*, 2007). Currently, these explanations are tentative and further studies are necessary.

Conclusion

The results of this study indicate that significant craniofacial variation exists between southern and northern Neolithic and Modern Chinese. For example, northern Chinese have more robust crania than southern ones. Principal component analyses show that the Neolithic-North is distinguished from the Neolithic-South in having a tall face, narrow nose and high eyes, while the Modern-North separate from the Modern-South in having a tall, broad face and high nose. Bivariate plots of selected measures indicate the northern Chinese are different from the southern Chinese on cranial length, upper facial height and nasal height. The Neolithic Chinese between the Qinling Mountain range and the Yangtze River are mixed with the North and South. Statistically significant craniometrical differences exist between the Neolithic age and Modern day groups, and between the northern and southern Chinese. Temporal variation is also present. For instance, size decreased through time. However, some degree of morphological similarity exists between North and South China, and also between successive time periods. In the Neolithic sample the separation is clearer between the northern and southern samples than with the Modern arrays. During the Neolithic, the Qinling Mountain Range and the Yangtze River served as a geographic boundary between North and South China.

Environmental and cultural factors clearly played important roles in the development of Modern Chinese cranial morphologies.

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