Subsistence and health in Middle Neolithic (9000–7000) southern China: new evidence from the Dingshishan site

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Supplementary methods

Collagen extraction

The protocol for collagen extraction from human bones followed a modified version of Richards and Hedges (1999) and is introduced in brief as follows. About 2.0g of each bone sample was demineralized in 0.5M HCl at 4°C for a few days and the acid refreshed several times until the remains became soft and no bubbles could be observed. Afterwards, the residues were washed to neutrality with distilled water and soaked in 0.125M NaOH for 20 hours. Then washed to neutrality again, the remains were gelatinized at 70°C for 48h in a 0.001M HCl (pH = 3), filtered and lyophilised for 48h to obtain a dried collagen.

Elemental and isotopic measurements

The purified collagen (about 1mg) was measured at the Department of Archaeology and Anthropology at the University of the Chinese Academy of Sciences, using an IsoPrime 100

IRMS (Elementar, UK) coupled with an Elementar Pyro Cube elemental analyser, with Sulfanilamide, IAEA-600, IAEA-N-2, IAEA-CH-6, USGS 40 and USGS 41 as reference materials. The stable isotope ratios were expressed as δ per thousand (permil or ‰) relative to international standards for carbon (VPDB) and nitrogen (AIR). The measurement errors were less than ±0.2‰ for both $\delta^{13}C$ and $\delta^{15}N$ values. All the sample information and isotopic results are listed in Table S2.

Osteological observation and analysis

The sex and age estimation for all the human skeletons as well as demographic analysis were conducted following the standards put forward by Wu (1984) and Shao (1985). An abridged life table was made according to the method described by Liu (1981). Furthermore, mortality probability and average life expectancy of humans was calculated (Liu 1981).

Table S1. **Results of ^{14}C dating and typological analyses for Dingsishan and other Dingsishan cultural sites.**

Site	Materials	Radiocarbon dates	Typological analyses	Reference
Dingsishan (phase 1)	_	_	10 000 BP	Guangxi team *et al.* (1998)
Dingsishan (phases 2 & 3)	Shell	11 041–11 965 BP	8000–7000 BP	
Dingsishan (phase 4)	_	_	6000 BP	
Huiyaotian	Canarium seed	8590–8430 BP	Similar to Dingsishan phase 2	Li *et al.* (2007, 2017a)
	Canarium seed	8385–8315 BP		
	Human tooth	9030–8975 BP		
Baozitou	Shell	10 730±200BP	8000–7000 BP	Guangxi team *et al.* (2003);
	Shell	10 565±200BP		

	Shell	9625±120BP		Chen (2016)
	Shell	10 155±200BP		
	Shell	9985±200BP		
	Shell	10 720±260BP		
	Bone	5155±300BP		
Liyupo	Canarium	7430–7315 BP	7000 BP	Chen (2016); Li *et al.* (2017b)
	Charcoal	8025–7960 BP		
	Human bone	7430–7320 BP		
	Human bone	6944–6741BP		
	Human tooth	7667–7580 BP		
Jiangxian	Shell	9385±140BP	9000–7000 BP	Chen (2016)
	Shell	9245±140BP		
	Shell	8950±130BP		
Ganzao	_	_	7000 BP	Chen *et al.* (2015)

Table S2. Stable isotope values of collagen extracted from human bones with good preservation.

Period	Tomb number	Sex	Age （years）	Bone part	%C	%N	C/N	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Yield (%)
2	M23	F	35±	Long bone	16.0	6.1	3.1	−21.2	12.7	1.0
2	M24	M	25–30	Long bone	27.7	9.8	3.3	−21.8	11.4	0.7
2	M19	F	50±	Long bone	36.2	12.9	3.3	−21.0	12.3	0.6
2	M20	F	17–19	Long bone	31.9	11.8	3.2	−19.0	11.6	0.9

2	M309	F	45±	Long bone	16.5	6.0	3.2	−21.3	12.4	1.5
2	M21	?	0–5 months	Rib	29.7	11.1	3.1	−21.2	13.4	2.3
2	M17	F	Adult	Rib	20.2	7.5	3.2	−21.1	12.4	1.4
2	M24	M	25–30	Rib	34.3	12.6	3.2	−21.2	11.4	0.7
2	M20	F	17–19	Rib	35.0	12.8	3.2	−19.2	12.1	1.1
2	M309	F	45±	Rib	24.5	8.8	3.3	−21.7	12.2	1.0
2	M36	M	45–50	Rib	44.1	15.8	3.3	−21.7	12.1	0.6
3	M18-1	F	Adult	Rib	28.7	10.1	3.3	−20.6	12.0	1.1
3	M38	M	35–40	Long bone	23.4	8.4	3.2	−21.7	11.8	2.2
3	M48	F	30–39	Long bone	29.0	9.9	3.4	−21.1	12.4	0.9
3	M3	M	Adult	Long bone	29.2	10.1	3.4	−19.6	11.0	0.5
3	M1	F	35±	Long bone	28.6	9.7	3.4	−21.6	12.5	0.7
3	M310	M	>35	Long bone	17.5	6.5	3.1	−21.0	12.9	1.7
3	M301	F	20–25	Long bone	36.9	13.2	3.3	−21.6	11.2	0.6
3	M2	F	>40	Long bone	40.4	14.3	3.3	−21.5	11.9	1.3
3	M230	M	35–45	Long bone	35.5	12.7	3.3	−20.8	12.3	0.6
3	M291	M?	>45	Long bone	34.6	12.2	3.3	−20.2	10.8	0.5

3	M327	M	19–20	Long bone	38.1	13.5	3.3	−21.5	11.9	1.4
3	M278	M	25–30	Long bone	26.4	9.4	3.3	−21.3	11.6	0.6
3	M4-2	?	<16	Long bone	32.1	11.4	3.3	−21.1	13.6	2.2
3	M196	?	40–50	Long bone	34.5	12.5	3.2	−21.0	12.6	0.6
3	M38	M	35–40	Rib	25.6	9.6	3.1	−21.9	12.2	0.6
3	M27	F	40–45	Rib	33.7	12.2	3.2	−20.8	12.3	0.5
3	M2	F	>40	Rib	40.1	14.3	3.3	−21.3	12.5	0.7
3	M327	M	19–20	Rib	25.0	8.8	3.3	−21.3	11.1	1.1
3	M56	?	0–5months	Rib	29.3	10.4	3.3	−20.6	15.0	0.6
3	M6-1	F	30–40	Rib	21.5	7.7	3.3	−21.4	12.4	1.1
3	M42	?	4–5	Rib	35.7	12.8	3.3	−20.6	12.3	1.2
3	M4-2	?	<16	Rib	39.1	14.3	3.2	−21.0	13.1	1.7
4？	M26-1	F	35–40	Long bone	35.1	12.7	3.2	−21.6	12.1	1.1
4？	M72	M	40–45	Long bone	38.5	14.0	3.2	−21.2	13.3	1.3
4？	M315	F	35–45	Long bone	36.7	13.0	3.3	−21.2	13.0	0.5
4？	M26-1	F	35–40	Rib	34.2	12.5	3.2	−20.9	12.8	0.9
4？	M72	M	40–45	Rib	32.8	11.8	3.3	−21.6	12.9	0.6

Table S3. The stable isotope (C & N) values, death rate and average life span in Neolithic sites in China.

Location	Site	Date (BP)	Average±SD		Total population (n)	Sex	Infancy (0–2 years) (%)	Early childhood (3–6 years) (%)	Juvenile (7–14 years) (%)	Adoles cence (15–23 years) (%)	Post-adolesce nce (24–35 years) (%)	Middle age (36–55 years) (%)	Old age (>56 years) (%)	Average life span (years)	Reference
			δ¹³C (‰)	δ¹⁵N (‰)											
Northern China (Yellow River Basin)	Jiangzhai (1st period)	6900–6000	−9.6±0.9 (n=10)	8.7±0.5 (n=10)	15	M	--	--	--	0	26.67	26.67	0	35.66	Xi'an Banpo Museum et $al.$ (1988); Pechenkina et $al.$ (2005); Wang (2009); Guo et $al.$ (2011).
						F	--	--	--	40.0	6.67	0	0	30.6	
						All	--	--	--	40.0	33.30	26.70	0	30.12	
	Jiangzhai (2nd period)		−10.6±1.8 (n=12)	8.6±0.6 (n=12)	23	M	--	--	--	0	17.39	26.09	4.35	--	
						F	--	--	--	8.70	21.74	27.74	0	--	
						All	--	--	--	8.70	39.13	47.83	4.35	--	
Yangtze River Basin	Tianluoshan	7000–5500	−20.0±0.5 (n=10)	8.7±0.9 (n=10)	--	--	--	--	--	--	--	--	--	--	Nan et $al.$ (2011)
	Sanxingcun	6500–5500	−20.1±0.2 (n=19)	9.7±0.3 (n=19)	1190	M	--	--	--	10.00	13.45	12.35	0.92	31.04	Zhang & Wang (2004); Hu et $al.$ (2007)
						F	--	--	--	7.31	7.98	5.71	1.09	29.28	
						Unk.	--	--	--	0.92	0.84	0.17	0.12	--	
						All	4.45	2.69	9.50	18.23	22.27	18.24	2.18	26.26	
Southern China	Dingsishan (2nd period)	8000–6000	−20.9±0.8 (n=11)	12.1±0.6 (n=11)	21	M	0	0	0	4.76	19.05	4.76	0	--	This study; Li (unpublished);
						F	0	0	0	4.76	14.29	4.76	0	--	

					Unk.	14.29	4.76	4.76	4.76	0	4.76	0	--	Zhang *et al.* (2018)
					All	14.29	4.76	4.76	14.29	33.33	14.29	0	21.75	
Dingsishan (3rd period)		- 21.1±0.5 (n=22)	12.2±0.9 (n=22)	361	M	0	0	0.28	6.65	14.40	13.57	0.55	34.26	
					F	0	0	0.28	4.16	9.42	5.83	0.83	33.45	
					Unk.	3.32	1.94	3.05	1.39	0.83	2.49	0	--	
					All	3.32	1.94	3.60	12.47	26.04	24.10	1.66	31.15	

* Demographic data of Dingsishan site provided by F. Li

References

CHEN, W. 2016. Research on Neolithic chronologies and subsistence strategies of Lingnan Area. Unpublished PhD dissertation, Jilin University (in Chinese).

CHEN, X. 2015. Ganzao site in Fusui, Guangxi Province. *China Cultural Relics News* 2015-07-17(008) (in Chinese).

Guangxi team, *et al*. 1998. Excavation of Dingsishan site, Yongning, Guangxi Province. *Archaeology* 11): 11–33 (in Chinese).

Guangxi team, *et al*. 2003. Excavation of Baozitou site, Nanning, Guangxi Province. *Archaeology* 10: 2, 24–36, 99 (in Chinese).

GUO, Y., Y. HU, Q. GAO, C. WANG & M.P. RICHARDS. 2011. Stable carbon and nitrogen isotope evidence in human diets based on evidence from the Jiangzhai site, China. *Acta Anthropologica Sinica* 30: 149–57 (in Chinese).

HU, Y., F. WANG, Y. CUI, Y. DONG, L. GUAN & C. WANG. 2007. Study on the diet of ancient people in Sanxingcun, Jintan, Jiangsu. *Chinese Science Bulletin* 52: 85–88 (in Chinese).

LI, Z. & Y. HUANG. 2008. The Neolithic Huiyaotian site in Nanning, in Q. Liu (ed.) *Yearbook of Chinese archaeology 2007*: 381–83. Beijing: Cultural Relics (in Chinese).

LI, Z., H.C. HUNG, Y. HUANG, H. MATSUMURA & K. SHINODA. 2017a. Huiyaotian site in Nanning, Guangxi, China, in H. Matsumura, H.C. Hung, Z. Li & K. Shinoda (ed.) *Bio-anthropological studies of Early Holocene hunter-gatherer sites at Huiyaotian and Liyupo in Guangxi, China*: 7–16. Tokyo: National Museum of Nature and Science.

LI, Z., H.C. HUNG, Q. HUANG & H. MATSUMURA. 2017b. Liyupo site in Longan, Guangxi, China, in H. Matsumura, H.C. Hung, Z. Li & K. Shinoda (ed.) *Bio-anthropological studies of Early Holocene hunter-gatherer sites at Huiyaotian and Liyupo in Guangxi, China*: 95–104. Tokyo: National Museum of Nature and Science.

LIU, Z. 1981. *Demography*. Beijing: China Renmin University Press (in Chinese).

LU, P. 2011. Study on fauna from shell midden sites along Yong river, Guangxi. *Quaternary Sciences* 4: 715–22 (in Chinese).

NAN, C., J. SONG, C. ZHONG & G. SUN. 2011. Carbon and nitrogen stable isotope research on collagen form human and faunal bones from Tianluoshan site, in Peking University & Zhejiang Institute of Archaeology (ed.) *Research on remains from the Tianluoshan site*: 172–205. Beijing: Cultural Relics (in Chinese).

PECHENKINA, E.A., S.H. AMBROSE, M. XIAOLIN & R.A. BENFER, JR. 2005. Reconstructing northern Chinese Neolithic subsistence practices by isotopic analysis. *Journal of Archaeological Science* 32: 1176–89. https://doi.org/10.1016/j.jas.2005.02.015

RICHARDS, M.P. & R.E.M. HEDGES. 1999. Stable isotope evidence for similarities in the types of marine foods used by Late Mesolithic humans at sites along the Atlantic coast of Europe. *Journal of Archaeological Science* 26: 717–22. https://doi.org/10.1006/jasc.1998.0387

SHAO, X. 1985. *Anthropometric manual*. Shanghai: Shanghai Lexicographical Publishing House (in Chinese).

WANG, J. 2009. A preliminary study on the health of prehistoric population in the Yellow River basin. *Archaeology* 5: 61–69 (in Chinese).

WU, R. 1984. *Anthropometry methods*. Beijing: People's Medical Publishing House (in Chinese).

Xi'an Banpo Museum, *et al.* 1988. *Jiangzhai*. Beijing: Cultural Relics (in Chinese).

ZHANG, J. & G. WANG. 2004. Demographic research on Neolithic tombs in Sanxingcun, Jintan, Jiangsu. *Cultural Relics* 2: 54–60 (in Chinese)