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Palaeohealth at Man Bac

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The purpose of this chapter is to review the evidence of adult and subadult health for individuals recovered from the Man Bac site during the 2005 and 2007 excavation seasons. A fuller appreciation of the inhabitants of Man Bac can only be realised through an examination of the nature and patterning of health markers in the context of other bio-variables such as preservation, demographic profile, stature, diet and genetic relationships with contemporaneous, previous and later populations in the region. To this end, the health profile of the Man Bac inhabitants has been developed towards the end of this monograph.

The palaeohealth of the ancient inhabitants of what is now Vietnam has been extensively examined and discussed in a number of studies (Oxenham et al., 2005; Oxenham, 2006; Oxenham et al., 2006). With respect to Man Bac specifically, limited examinations of childhood health, using remains from the 2005 season only, have been carried out in the context of broader mortuary archaeological questions (Oxenham, 2006). In this chapter, health variables are limited to two non-specific signatures of physiological impairment, cribra orbitalia and linear enamel hypoplasia, as well as a range of oral health indicators, including dental caries, alveolar defects (often termed abscesses) and antemortem tooth loss. Subsequent publications will review the evidence for other health variables including trauma and infectious disease.

MATERIALS AND METHODS

Only individuals excavated by the authors in the 2005 and 2007 seasons were included in this study and operational sample size varied according to the variable of interest. For the oral health assessment 29 adults and 11 subadults had assessable teeth, while 28 adults and 18 subadults possessed assessable alveoli. The sample for assessment of cribra orbitalia included 26 adults and 32 subadults. For the purposes of this study a subadult was any individual aged 15 years or younger, while an adult was any individual aged 16 years or older. Adults were further divided into two age groups (younger 16-29 years; older 30+ years) for assessing any possible age-dependent or correlated affects on the manifestation of health variables.

Oral health variables included caries, antemortem tooth loss (AMTL) and alveolar defects (AD). Carious lesion recording was based on Hillson (2001) and effectively included 10 categories of lesion (limited by the types of lesions occurring in the Man

Bac assemblage): (A) lesion initiated on aproximal (interproximal) attrition facet; (AG) gross lesion with unclear initiation site (includes aproximal facet); (BL) buccal or lingual lesions of crown (not CEJ, occlusal, aproximal etc); (BLG) BL lesion that includes other sites (initiation site unclear); (GG) massive crown/root destruction (initiation point unclear); (OG) occlusal gross (fissure system/occlusal facet initiation unclear); (OWFD) occlusal wear facet initiation (dentine exposed); (P) buccal molar or upper lingual incisor pit initiation; (R) lesion [groove] following cement-enamel junction or just on root; (RG) gross root lesion but also includes other sites (initiation site unclear). In addition to reporting by age and sex, carious lesions were recorded by maxillary and mandibular location as well as position (anterior compared to posterior dentition).

Antemortem tooth loss can be identified in a relatively straightforward manner, and Lukacs' (1989:271) definition was followed: "progressive resorptive destruction of the alveolus". Alveolar defects of pathological origin (AD), often erroneously referred to as abscesses in the literature, have been recorded following the same method, and reasoning, as Oxenham et al. (2005), where they were referred to as alveolar defects of pulpal origin. The further revision of this term avoids assumptions regarding the ultimate origin of the infection. In practical terms, AD were not recorded with reference to their precise location. Moreover, AD includes alveolar defects that are both isolated or circumscribed lesions in the alveolar bone and defects that are continuous with the margins of the alveoli.

Cribra orbitalia (CO) and linear enamel hypoplasia (LEH) were the two signatures of physiological disruption selected for analysis. Linear enamel hypoplastic (LEH) events expressed labially on assessable canines and incisors that met DDE index type 4 (Federation Dentaire International 1982) criteria were recorded. LEH is reported by position (maxillary, mandibular and combined) and tooth class (canine, incisor and combined) using the tooth count and individual count reporting protocols. Moreover, tooth count and individual count frequencies are also reported by age class and sex. An assessable tooth is defined as one where less than 50% of approximated crown height has been removed through wear. Only LEH severity categories 1 and 2, following Duray (1996), are presented in this analysis.

When recording cribra orbitalia (CO), the minimal requirement for inclusion in the analysis was the preservation of the anterolateral and anteromedial aspects of at least one orbital roof. CO was scored using the following categories: (1) absent; (2) presence of faint remodelling scars; (3) presence of clear remodelling scars; (4) presence of light to active lesions and remodelling scars; (5) presence of pronounced active lesions and remodelling scars; (6) presence of light to mild active lesions but an absence of remodelling scars; (7) presence of pronounced active lesions but an absence of remodelling scars. Faint remodelling scars are analogous to Webb's (1995: plate 5-1a) porotic form but without evidence of un-remodelled perforating lesions. Clear remodelling scars are analogous to Webb's (1995: Plate 5-2) recovery scars from remodelling. The use of the term 'remodelling scars', on its own, refers to any manifestation of faint to clear evidence of remodelling. Light to mild active (open) lesions are analogous to Webb's (1995: Plate 5-1a,b) porotic and cribrotic forms of CO, but exclude any reference to remodelling. Pronounced active lesions are analogous to Webb's (1995: Plate 5-1c) trabecular form of CO. For the purposes of reporting, frequencies are provided for these various categories but are collapsed into two broader categories for subsequent analysis and comparison: remodelled CO (includes only cases with remodelled CO and excludes any case that also displays active lesions); and active CO (includes all cases with active CO whether or not they also manifest remodelling).

RESULTS

Oral Health

Caries

Table 7.1 summarises oral structure sample preservation for adults and subadults. A total of 28 individuals (727 alveoli) with entirely adult dentitions and 44 individuals (537 alveoli) with mixed dentitions possessed assessable alveoli, or 29 individuals (581 teeth) with completely adult dentitions and 38 individuals (433 teeth) with mixed dentitions having assessable teeth. Note that Table 7.1 separates individuals with mixed dentitions into a group where only the permanent teeth are assessed and one where only the deciduous dentition is examined. Given good preservation in general there is a relatively high proportion of teeth relative to alveoli, both adult and subadult, in the sample. Comparing anterior relative to posterior teeth present by alveoli demonstrates the lower proportion of preserved anterior teeth. Contributing factors to tooth loss include antemortem loss (including tooth ablation) and postmortem loss. The anterior teeth are more susceptible to postmortem loss and were targeted for tooth ablation. There is slightly better retention of maxillary compared to mandibular teeth in the sample but not to a marked degree. Table 7.2 summarises the frequency and patterning of carious lesions, by tooth count reporting method, for all permanent (males, females and indeterminate sex aged 16+ years; subadults aged 6-15 years) and deciduous (subadults aged 9 months+) teeth. The overall frequency of carious lesions for the adult sample is 11.0%, which declines to 8.6% when the permanent dentition of subadults are included. A statistically significantly (see Table 7.7 for a summary of oral health statistical comparisons) higher frequency of lesions occur in the female dentition (15.5%) as compared to male teeth (7.6%). However, in terms of individuals, 58.3% of female individuals display carious lesions compared to 60.0% of males. Looking at carious lesions by age category shows the expected outcome of a statistically significantly (Table 7.7) higher level of lesions among older females (23.4% of all older female teeth compared to 3.6% of younger female teeth) and older males (10.8% of older male teeth compared to 3.8% of younger male teeth). Further, no subadult permanent teeth displayed carious lesions. In terms of tooth position, statistically significantly more posterior (14.7% of all lesions) permanent adult teeth were affected by lesions than anterior adult teeth (4.0% of all lesions). Finally, the distribution of lesions by upper and lower jaw was very similar with 11.1% of maxillary and 10.9% of mandibular teeth being carious.

When examining the various manifestations (including location) of carious lesions on permanent teeth, the most common type was R (48.4% of all lesions), or lesions following the cement-enamel junction or just on the root. Following R lesions come AG (gross lesion with unclear initiation site) at 18.8% of all lesions and then GG (massive crown/root destruction with unclear initiation point) at 17.2% of all

Table 7.1 Dental sample summary: Man Bac 2004/5-7 seasons.

	females[3]	males[3]	unsexed[3]	adult subtotal	unsexed SA[4]	adult & SA[4] Total	subadult[5]	TOTAL
N[1]	11	15	2	28	18	46	26	72
alveoli	270	429	28	727	208	935	329	1264
alveoli/N	24.5	28.6	14.0	26.0	11.6	20.3	12.7	17.6
N[2]	12	15	2	29	11	40	27	67
teeth	207	354	20	581	163	744	270	1014
teeth/N	17.3	23.6	10.0	20.0	14.8	18.6	10.0	15.1
teeth/alveoli %	76.7	82.5	71.4	79.9	78.4	79.6	82.1	80.2
preserved ant. alveoli	109	160	12	281	84	365	188	553
preserved ant. teeth	77	117	6	200	79	279	151	430
ant. teeth/alveoli %	70.6	73.1	50.0	71.2	94.0	76.4	80.3	77.8
preserved post. alveoli	161	269	16	446	124	570	141	711
preserved post. teeth	130	237	14	381	84	465	119	584
post. teeth/alveoli %	80.7	88.1	87.5	85.4	67.7	81.6	84.4	82.1
preserved max. alveoli	132	209	0	341	99	440	158	598
preserved max. teeth	99	180	0	279	77	356	139	495
max. teeth/alveoli %	75.0	86.1	0.0	81.8	77.8	80.9	88.0	82.8
preserved man. alveoli	138	220	28	386	109	495	171	666
preserved man. teeth	108	174	20	302	86	388	131	519
man. teeth/alveoli %	78.3	79.1	71.4	78.2	78.9	78.4	76.6	77.9

[1]any individual with an assessable alveolus
[2]any individual with an assessable tooth
[3]adult dentition
[4]subadults with partial adult dentition (only permanent teeth assessed)
[5]includes any individual with partial or complete deciduous dentition (only deciduous teeth assessed)
Note: positions/N is low for unsexed due to number of SAs with only partial permanent dentition

lesions. At 7.8% of all lesions, A type (lesion initiated on an interproximal attrition facet) is the fourth most common, followed by relatively rare forms at Man Bac including BL (buccal or lingual lesions of crown) at 3.1%, and several other forms at 1.6%: OG (occlusal gross), OWFD (occlusal wear facet initiation) and RG (gross root lesion but with unclear ignition point). This pattern is broadly maintained when looked at by sex, although GG is the second most common lesion among females (28.1% of all female lesions) but relatively uncommon among males (7.4% of all male lesions).

Table 7.2 also presents a summary of carious lesions affecting the deciduous dentition. Of the 270 deciduous teeth available for inspection, 3.7% (27.8% of subadult individuals with deciduous teeth) displayed carious lesions. Unlike the pattern seen in the permanent dentition, 5.3% of anterior teeth were carious, compared to 1.7% of posterior teeth. Further, again unlike the relatively even distribution of maxillary and mandibular lesions seen in the adult dentition, 5.0% of maxillary as compared to 2.3% of mandibular deciduous teeth were carious. In a pattern different to that seen in the permanent dentition, 60.0% of all lesions were evenly distributed among type A and BL forms with the remaining scattered among BLG, OG, P and R. Neither BLG (BL lesion that includes other sites) nor P (buccal molar or upper lingual incisor pit initiation) are forms seen in the permanent dentition.

Table 7.2 Caries profile (tooth count): Man Bac 2005-7 seasons.

	Permanent Teeth	N[1]	n[2] ant/post	obs caries ant/post	proportion of caries ant/post	n[3] max/man	obs caries max/man	proportion of caries max/man	A	AG	BL	BLG	GG	OG	OWFD	P	R	RG	Total caries	%[4] caries	**caries individ.[5]**
female	16-29yrs	83	31/52	0/3	0.0/5.8	41/42	2/1	4.9/2.4		1							2		3	3.6	1/4 (25.0)
	30+yrs	124	46/78	4/25	8.7/32.1	58/66	11/18	19.0/27.3	1	7			9				12		29	23.4	6/8 (75.0)
	subtotal	207	77/130	4/28	5.2/21.5	99/108	13/19	13.1/17.6	1	8			9				14		32	**15.5**	**7/12 (58.3)**
	%								3.1	25.0			28				44		100.0		
male	16-29yrs	159	50/109	2/4	4.0/3.7	80/79	5/1	6.3/1.3	1		2						3		6	3.8	2/7 (28.6)
	30+yrs	195	67/128	2/19	3.0/14.8	100/95	13/8	13.0/8.4	1	4			2	1	1		11	1	21	10.8	7/8 (87.5)
	subtotal	354	117/237	4/23	3.4/9.7	180/174	18/9	10.0/5.2	2	4	2		2	1	1		14	1	27	**7.6**	**9/15 (60.0)**
	%								7.4	15	7.4		7.4	3.7	3.7		52	3.7	100.0		
indet.	16-29yrs	0	0/0	0/0	0.0/0.0	0/0	0/0	0.0/0.0											0	0.0	0/0 (0.0)
	30+yrs	20	6/14	0/5	0.0/35.7	0/20	0/5	0.0/25.0	2								3		5	25.0	2/2 (100)
	subtotal	20	6/14	0/5	0.0/35.7	0/20	0/5	0.0/25.0	2								3		5	**25.0**	**2/2 (100)**
	%								40.0								60.0		100.0		
subtot.		**581**	**200/381**	**8/56**	**4.0/14.7**	**279/302**	**31/33**	**11.1/10.9**	5	12	2		11	1	1		31	1	64	**11.0**	**18/29 (62.1)**
	%								7.8	18.8	3.1		17.2	1.6	1.6		48.4	1.6	100.0		
SA	6-15yrs	163	79/84	0/0	0.0/0.0	77/86	0/0	0.0/0.0												**0.0**	**0/11 (0.0)**
Total		**744**	**279/465**	**8/56**	**2.9/12.0**	**356/388**	**31/33**	**8.7/8.5**	5	12	2		11	1	1		31	1	64	**8.6**	**18/40 (45.0)**
									7.8	18.8	3.1		17.2	1.6	1.6		48.4	1.6	100.0		
	Deciduous Teeth																				
SA	9mths+	**270**	**151/119**	**8/2**	**5.3/1.7**	**139/131**	**7/3**	**5.0/2.3**	3		3	1		1		1	1		10	**3.7**	**5/18 (27.8)**
									30.0		30.0	10.0		10.0		10.0	10.0		100.0		
TOTAL		**1014**	**430/584**	**16/58**	**3.7/9.9**	**495/519**	**38/36**	**7.7/6.9**	8	12	5	1	11	2	1	1	32	1	74	**7.3**	**23/58 (39.7)**
%									11	16.2	6.8	1.4	14.9	2.7	1.4	1.4	43.2	1.4	100.0		

A lesion initiated on aproximal (interproximal) attrition facet
AG gross lesion with unclear initiation site (includes aproximal facet)
BL buccal or lingual lesions of crown (not CEJ, occlusal, aproximal etc)
BLG BL lesion that includes other sites (initiation site unclear)
GG massive crown/root destruction (initiation point unclear)
OG occlusal gross (fissure sys/occlusal facet initiation unclear)
OWFD occlusal wear facet initiation (dentine exposed)
P buccal molar or upper lingual incisor pit initiation
R lesion (groove) following cement-enamel junction or just on root
RG gross root lesion but also includes other sites (initiation site unclear)

[1] total preserved teeth
[2] preserved anterior teeth (incisors/canines)/ preserved posterior teeth (premolars/molars)
[3] preserved maxillary teeth/preserved mandibular teeth
[4] carious teeth/total assessable teeth for this category x 100
[5] obs/individual (%)

Antemortem tooth loss (AMTL)

Table 7.3 summarises the frequency and patterning of AMTL in all individuals with permanent alveoli. The data presented here exclude all cases of deliberate tooth ablation, a behaviour common amongst the adult Man Bac sample and including several combinations of maxillary and/or mandibular incisor extraction. The patterning and significance of tooth ablation is dealt with in a forthcoming publication. The overall frequency of AMTL for the adult sample is 2.6%, which declines to 2.0% when the permanent alveoli of subadults are included. A statistically significantly (Table 7.7) higher frequency of AMTL occurs in the alveoli of females (4.8%) compared to males (1.4%).

By age group no younger female alveoli show AMTL, compared to 7.5% of older female alveoli, and only 0.5% of younger male alveoli compared to 2.1% of older male alveoli display AMTL. Further, no subadult permanent or deciduous alveoli displayed AMTL. In terms of position, statistically significantly more posterior (3.8%) permanent adult alveoli were affected by AMTL than anterior adult alveoli (0.7%). The distribution of lesions by upper and lower jaw was somewhat similar although more AMTL affected mandibular adult alveoli (2.8%) than maxillary alveoli (2.3%).

Alveolar defects of pathological origin (AD)

The frequency and distribution of AD is summarised in Table 7.3. A slightly higher frequency of AD, by alveoli count, occurs in males (1.9% of all alveoli) than females (1.5%), albeit not to a statistically significant degree. By age, older females and older males both display more AD than their younger age counterparts, however, this is only a statistically significant difference among males. No cases of subadults with either permanent or deciduous dentitions displayed AD. The majority of cases of AD occurred in the posterior alveolar bone (2.7% of all adult alveoli) to a statistically significant degree. The distribution of AD was the same, at 1.8%, for both adult mandibular and maxillary alveoli.

Physiological Health

Cribra orbitalia

Table 7.4 provides information on the frequency and type of CO by age and sex for Man Bac adults and subadults. While the raw frequencies of each of the various forms of CO are presented, small sample sizes mean that meaningful comparisons can only be made in terms of remodelled CO (individuals with remodelling scars but without active lesions) and active CO (individuals with active lesions, regardless of whether or not they also have evidence for remodelling). Males display a higher frequency of CO (92.3%, χ^2 3.128, p 0.077, Yates corrected), active and remodelled combined, than females (53.8%). CO does not appear to vary with age as a similarfrequency of CO occurs among younger (50.0%) and older females (55.6%) and younger males (100%) and older males (87.5%). However, age does appear to be an important factor in the type of CO seen in adults, with active CO absent in females and accounting for only 15.4% of CO among males. While the overall frequency of adult CO is 73.1%, 89.5% of all adult individuals with CO (17/19

Table 7.3 Antemortem Tooth Loss (AMTL) and Alveolar Defect (AD) Profile: Man Bac 2004/5-7 Seasons.

		N[1]	n[2] ant/post	n[3] max/man	obs AMTL[4] ant/post	% AMT ant/post	obs AMTL[4] max/man	% AMTL max/man	**Total % AMTL**	obs AD ant/post	% AD ant/post	obs AD max/man	% AD max/man	**Total % AD**
Permanent Alveoli														
female	16-29yrs	97	37/60	51/46	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/0	0.0/0.0	0/0	0.0/0.0	0.0
	30+yrs	173	72/101	81/92	0/13	0.0/12.9	4/9	4.9/9.8	7.5	0/4	0.0/4.0	2/2	2.5/2.2	2.3
	subtotal	270	109/161	132/138	0/13	0.0/8.1	4/9	3.0/6.5	4.8	0/4	0.0/2.5	2/2	1.5/1.4	1.5
male	16-29yrs	193	72/121	95/98	1/0	4.4/0.0	0/1	0.0/1.0	0.5	0/0	0.0/0.0	0/0	0.0/0.0	0.0
	30+yrs	236	88/148	114/122	1/4	1.1/2.7	4/1	3.5/0.8	2.1	1/7	1.1/4.7	4/4	3.5/3.3	3.4
	sub total	429	160/269	209/220	2/4	1.3/1.5	4/2	1.9/0.9	1.4	1/7	0.6/2.6	4/4	1.9/1.8	1.9
indet.	16-29yrs	0	0/0	0/0	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/0	0.0/0.0	0/0	0.0/0.0	0.0
	30+yrs	28	12/16	0/28	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/1	0.0/6.3	0/1	0.0/3.6	3.6
	subtotal	28	12/16	0/28	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/1	0.0/6.3	0/1	0.0/3.6	3.6
subtot.		**727**	**281/446**	**341/386**	**2/17**	**0.7/3.8**	**8/11**	**2.3/2.8**	**2.6**	**1/12**	**0.4/2.7**	**6/7**	**1.8/1.8**	**1.8**
SA	6-15yrs	208	84/124	99/109	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/0	0.0/0.0	0/0	0.0/0.0	0.0
Total		**935**	**365/570**	**440/495**	**2/17**	**0.5/3.0**	**8/11**	**1.8/2.3**	**2.0**	**1/12**	**0.3/2.1**	**6/7**	**1.4/1.4**	**1.4**
Deciduous Alveoli														
SA[5]	9mths+	329	188/141	158/171	0/0	0.0/0.0	0/0	0.0/0.0	0.0	0/0	0.0/0.0	0/0	0.0/0.0	0.0
TOTAL %		**1264**	**553/711**	**598/666**	**2/17**	**0.4/2.4**	**8/11**	**1.3/1.7**	**1.5**	**1/12**	**0.3/1.7**	**6/7**	**1.0/1.1**	**1.0**

[1]total preserved alveoli

[2]preserved anterior alveoli (incisors/canines)/ preserved posterior alveoli (premolars/molars)

[3]preserved maxillary alveoli/ preserved mandibular alveoli

[4]AMTL antemortem tooth loss, note excludes cases of deliberate tooth ablation

[5]excludes cases of natural deciduous tooth exfoliation

Table 7.4 Cribra Orbitalia Profile: Man Bac 2004/5-7 Seasons.

	Adult orbits					LAL &	PAL &			total[2]	total[3]	TOTAL[4]
			CO	faint	clear	RS	RS			CO remod.	CO active	CO
		N[1]	absent	RS	RS	WT	WT	LAL	PAL	obs (%)	obs (%)	obs (%)
female	16-29yrs	4	2	1	1					2 (50.0)	0 (0.0)	2 (50.0)
	30+yrs	9	4	3	2					5 (55.6)	0 (0.0)	5 (55.6)
	subtotal	13	6	4	3					7 (53.8)	0 (0.0)	7 (53.8)
male	16-29yrs	5	0	2	2	1				4 (80.0)	1 (20.0)	5 (100)
	30+yrs	8	1	3	3	1				6 (75.0)	1 (12.5)	7 (87.5)
	sub total	13	1	5	5	2				10 (76.9)	2 (15.4)	12 (92.3)
subtot.		**26**	**7**	**9**	**8**	**2**				**17 (65.4)**	**2 (7.7)**	**19 (73.1)**
subadults	6-15yrs	6	1	1		2		2		1 (16.7)	4 (66.7)	5 (83.3)
	2.5-5yrs	5	0					5		0 (0.0)	5 (100)	5 (100)
	12-29mths	10	1	2	1	1		4	1	3 (30.0)	6 (60.0)	9 (90.0)
	6-11mths	6	1					5		0 (0.0)	5 (83.3)	5 (83.3)
	0-5mths	5	0	1				3	1	1 (20.0)	4 (80.0)	5 (100)
subtot.		**32**	**3**	**4**	**1**	**3**		**19**	**2**	**5 (15.6)**	**24 (75.0)**	**29 (90.6)**
Total		**58**	**10**	**13**	**9**	**5**		**19**	**2**	**22 (37.9)**	**26 (44.8)**	**48 (82.8)**

L & R orbits assessed whenever possible; most severe lesion form in any give orbit used to score the individual
CO absent: clear of lesions
faint RS: faint remodelling scars
clear RS: clear remodelling scars
LAL & RS: light to mild active lesions and remodelling scars
PAL & RS: pronounced active lesions and remodelling scars
LAL: light to mild active lesions only
PAL: pronounced active lesions only

[1]sample of individuals with at least one assessable orbit
[2]only individuals with 'remodelled only' CO (active cases excluded)
[3]individuals with active CO including those with or without remodelling
[4]all individuals displaying signs of CO (remodelled, active, remodelled & active lesions)

cases) have a remodelled only form, with only 10.5% (2/19 cases) showing evidence of active or un-remodelled lesions.

A higher frequency of subadult CO (90.6%) is seen compared to adults, but not to a statistically significant degree (χ^2 1.988, p 0.159, Yates corrected). The chief difference between subadult and adult CO is that the vast majority of subadults display active or un-remodelled lesions (75.0% of all subadult CO is active). The majority of subadult lesions are characterised as light to mild active lesions (19/29 of all forms of subadult CO, or 65.5%). There does not appear to be any correlation between increasing subadult age and the proportion of active lesions, but this may be due to the limited sample sizes within each subadult age category.

Linear enamel hypoplasia (LEH)

Tooth count

Only permanent incisor and canine LEH is examined in this study. Deciduous tooth hypoplasia, particularly localised hypoplasia of primary canines (LHPC), is examined in detail in a forthcoming publication. Of the total assessable sample of permanent incisors and canines, 181/279 (64.9%) display evidence for LEH (Table 7.5). A higher frequency of female combined canines and incisors displayed LEH (80.5%) than males (67.5%) to a statistically significant degree (χ^2 3.951, p 0.047). The frequency of combined incisor and canine LEH is higher in younger females (87.1%) than their older counterparts (76.1%; χ^2 0.815, p 0.367, Yates corrected) and this is also seen among males (younger 80.0%, older 58.2%; χ^2 6.200, p 0.013), although differences by age class are only statistically significant among males. While a higher degree of LEH is seen among younger adult females and males, the frequency of LEH in the permanent combined canines and incisors of subadults is comparatively low at 45.6%. Further, the frequency of subadult combined canine and incisor LEH (36/79, 45.6%) is statistically significantly lower than the frequency of combined male and female younger adult LEH (67/81, 82.7%: χ^2 24.063, p 0.000) and combined male and female older adult LEH (74/113, 65.5%: χ^2 7.538, p 0.006).

The frequency of female incisor LEH is a little higher (82.5%) than canine LEH (78.4%). This pattern is reversed for males, where the frequency of canine LEH (79.2%) is statistically significantly greater than incisor LEH (57.8%, χ^2 6.073, p 0.014). For subadults with permanent teeth, the frequency of canine LEH (75.0%) is also statistically significantly greater than incisor LEH (35.6%, χ^2 9.351, p 0.002).

The frequency of female incisor LEH is somewhat higher among the maxillary teeth (90.9%) than mandibular teeth (72.2%) (χ^2 1.275, p 0.259, Yates corrected), with the distribution of canine LEH being similar in maxillary (77.8%) and mandibular (78.9%) canines (χ^2 0.00, p 1.0, Yates corrected). For males a similar pattern is seen with a higher frequency of maxillary incisor LEH (68.8%) than mandibular incisor LEH (46.9%, χ^2 3.139, p 0.076). Further, the frequency of male maxillary canine LEH (77.8%) is quite similar to the frequency of mandibular canine

LEH (80.8%) (χ^2 0.072, p 1.0). Regarding subadults with permanent teeth, a statistically significantly higher frequency of maxillary incisor LEH (57.1%) compared to mandibular incisor LEH (16.1%, χ^2 10.795, p 0.001) occurs. In terms of subadult permanent canines, a similar frequency of maxillary (77.8%) and mandibular (72.7%) LEH is seen (χ^2 0.00, p 1.0, Yates corrected).

Table 7.5 Incisor & canine linear enamel hypoplasia profile: Man Bac 2004/5-7 seasons.

	Permanent Teeth	N[1]	I n[2] max/man	C n[3] max/man	obs I LEH[4] max/man	% I LEH[5] max/man	% I LEH total	obs C LEH max/man	% C LEH max/man	% C LEH total	**% Total LEH combin.[6]**
female	16-29yrs	31	9/10	6/6	9/8	100/80.0	89.5	6/4	100/66.7	83.3	**87.1**
	30+yrs	46	13/8	12/13	11/5	84.6/62.5	76.2	8/11	66.7/84.6	76.0	**76.1**
	subtotal	77	22/18	18/19	20/13	90.9/72.2	82.5	14/15	77.8/78.9	78.4	**80.5**
male	16-29yrs	50	14/13	12/11	12/8	85.7/61.5	74.1	10/10	83.3/90.9	87.0	**80.0**
	30+yrs	67	18/19	15/15	10/7	55.6/36.8	45.9	11/11	73.3/73.3	73.3	**58.2**
	sub total	117	32/32	27/26	22/15	68.8/46.9	57.8	21/21	77.8/80.8	79.2	**67.5**
indet.	16-29yrs	0	0/0	0/0	0/0	0.0/0.0	0.0	0/0	0.0/0.0	0.0	**0.0**
	30+yrs	6	0/4	0/2	0/2	0.0/50.0	50.0	0/2	0.0/100	100.0	**66.7**
	subtotal	6	0/4	0/2	0/2	0.0/50.0	50.0	0/2	0.0/100	100.0	
											66.7
subtot.		**200**	**54/54**	**45/47**	**42/30**	**77.8/55.6**	**66.7**	**35/38**	77.8/80.9	**79.3**	**72.5**
SA	6-15yrs	79	28/31	9/11	16/5	57.1/16.1	35.6	7/8	77.8/72.7	75.0	**45.6**
Total		**279**	**82/85**	**54/58**	**58/35**	**70.7/41.2**	**55.7**	**42/46**	**77.8/79.3**	**78.6**	**64.9**

[1]total preserved maxillary and mandibular incisors and canines
[2]preserved maxillary/ mandibular incisors
[3]preserved maxillary/ mandibular canines
[4]observed LEH count for tooth class
[5]% LEH for tooth class
[6]% LEH for combined incisors and canines

Individual count

Table 7.6 presents the frequency of individuals, by age class and sex, with LEH in either their canines or incisors. In lieu of matching LEH events across the teeth in any given individual, Table 7.6 presents a way of determining the minimum number of LEH formation events affecting any individual by reporting the maximum number of observable LEH events as determined by the tooth with the most hypoplastic signatures.

While the vast majority of adults displayed LEH, the majority of adults had either a minimum of two LEH events (9/28, 32.1%) or 3+ LEH events (17/28, 60.7%). Low sample sizes mean it is difficult to assess any potential differences in the number of LEH events by age category. What can be said is that a higher proportion of young females have 3+ LEH events (75%) than older females (62.5%). The same general pattern is seen for males with a much higher proportion of younger males have 3+ LEH events (85.7%) and older males (37.5%). For subadult individuals with permanent teeth, 72.7% (8/11) of individuals displayed LEH, with 18.2% of those with LEH having at least one or a minimum of two events and 36.4% having 3+ LEH events.

Table 7.6 Incisor & canine linear enamel hypoplasia by individual: Man Bac 2004/5-7 seasons.

		N[1]	I/C n[2]	I/C[3] LEH obs	I/C[4] LEH%	I C combin.[5] LEH obs (%)	I C combin.[6] 1 LEH obs (%)	I C combin.[6] 2 LEH obs (%)	I C combin.[6] 3+ LEH obs (%)
Permanent Teeth									
female	16-29yrs	4	4/4	4/4	100/100	4 (100)	0 (0.0)	1 (25.0)	3 (75.0)
	30+yrs	8	6/8	5/7	83.3/87.5	8 (100)	1 (12.5)	2 (25.0)	5 (62.5)
	subtotal	12	10/12	9/11	90.0/91.7	12 (100)	1 (8.3)	3 (25.0)	8 (66.7)
male	16-29yrs	7	7/6	7/6	100/100	7 (100)	0 (0.0)	1 (14.3)	6 (85.7)
	30+yrs	8	8/8	6/8	75.0/100	8 (100)	1 (12.5)	4 (50.0)	3 (37.5)
	sub total	15	15/14	13/14	86.7/100	15 (100)	1 (6.7)	5 (33.3)	9 (60.0)
indet.	16-29yrs	0							
	30+yrs	1	1/1	1/1	100/100	1 (100)	0 (0.0)	1 (100)	0 (0.0)
	subtotal	1	1/1	1/1	100/100	1 (100)	0 (0.0)	1 (100)	0 (0.0)
subtot.		**28**	**26/27**	**23/26**	**88.5/96.3**	**28 (100)**	**2 (7.1)**	**9 (32.1)**	**17 (60.7)**
SA	6-15yrs	11	10/7	6/7	60.0/100	8 (72.7)	2 (18.2)	2 (18.2)	4 (36.4)
Total		**39**	**36/34**	**29/33**	**80.6/97.1**	**36 (92.3)**	**4 (10.3)**	**11 (28.2)**	**21 (58.3)**
Deciduous Teeth									
SA	9mths+	24	21/20	0/4	0.0/20.0	4 (16.7)	4 (16.7)	0 (0.0)	0 (0.0)
TOTAL %		**63**	**57/54**	**29/37**	**50.9/68.5**	**40 (63.5)**	**8 (12.7)**	**11 (17.5)**	**21 (33.3)**

[1]total individuals with canines and/or incisors
[2]total individuals with incisors/canines
[3]number of individuals with at least one LEH event affecting incisors/canines
[4]% of individuals with at least one LEH event affecting incisors/canines
[5]% of individuals with at least one LEH event affecting incisors and/or canines combined
[6]number and proportion of individuals with 1 only, 2, and 3 or more LEH events affecting any given incisor and/or canine

DISCUSSION

For the purposes of this discussion, oral and physiological signature comparisons will be limited to other northern Vietnamese assemblages: Mid Holocene Da But and early Metal Period materials. Comparative Vietnamese data referred to is from Oxenham (2006) unless otherwise stated.

Oral Health

Caries

The overall frequency of caries by the tooth count reporting method is 11.0%, or 8.6% if subadult permanent teeth are included. This rate is considerably higher than that seen for either the temporally earlier Da But period (1.5%) or later Metal Period (2.3%). Incidentally, this is the highest (Khok Phanom Di just lower at 10.9%) rate of caries reported for an ancient Southeast Asian site to date (Tayles, 1999; Oxenham et al., 2006). Caries by individual in the Man Bac sample is 62.0% of adults, in comparison to 13.8% of Da But (Con Co Ngua) and 20.8% of metal period adults. The trend toward higher caries rates in females (Da But females 2.1% of teeth, 21.4% of individuals; males 1.6% of teeth, 13.9% of individuals: metal period females 3.7% of teeth, 37.0% of individuals; males 1.4% of teeth, 19.2% of individuals) is also evident in the Man Bac assemblage, with 15.5% of female teeth carious compared to 7.6% of male teeth, although 60% of male individuals compared to 58.3% of female individuals suffered from caries at Man Bac.

In terms of the frequency of caries by age-at-death, the expected pattern of more carious teeth and a higher proportion of older people displaying caries occurred at Man Bac. This pattern is also seen in the Da But assemblage where 28.4% (2.8% of teeth) of 40+ years, 4.8% (0.4% of teeth) of 30-39 years and only 4.0% (0.7% of teeth) of <30 years individuals displayed lesions. The older Man Bac and even earlier Da But series differ from the Metal Period where the reverse pattern was seen; 12.5% (1.6% of teeth) of 40+ years, 18.8% (1.9% of teeth) of 30-39 years and only 27.5% (2.8% of teeth) of <30 years individuals displaying lesions.

Table 7.7 Summary of oral health statistical comparisons.

AMTL	X^2	p	GV[2]
female young/old	**6.11***	**0.013**	**old**
male young/old	0.98*	0.322	old
female/male	**7.31**	**0.014**	**fem**
anterior/posterior[1]	**5.35***	**0.021**	**post**
maxillary/mandibular[1]	0.18	0.848	man
AD			
female young/old	0.97*	0.325	old
male young/old	**5.78***	**0.016**	**old**
female/male	0.09*	0.764	male
anterior/posterior[1]	2.60*	0.107	post
maxillary/mandibular[1]	0.06*	0.815	max
Caries			
female young/old	**13.40***	**0.000**	**old**
male young/old	**6.08**	**0.014**	**old**
female/male	**8.51**	**0.004**	**fem**
anterior/posterior[1]	**15.31**	**0.000**	**post**
maxillary/mandibular[1]	0.01	0.944	max

Bold = statistically significantly different
* Yates Corrected
[1]Adults only
[2]GV = Greatest Value

Regarding lesion location, the higher proportion of posterior relative to anterior lesions is to be expected with the frequency of lesions seen at Man Bac (see discussion of differential susceptibility of teeth to caries in Hillson, 2001). Regarding the type of lesions seen here, 48.4% of Man Bac carious lesions occurred on the root or followed the cement-enamel junction. This is in contrast to 35.7% of Da But and 26.9% of Metal Period lesions manifesting in this manner (Oxenham, 2000). While it has been suggested that an increase in the grain component of a diet can increase the risk of such lesions (e.g. Molnar and Molnar, 1985; Moore, 1993), increases in agricultural intensification in southeast Asian assemblages is not associated with an increase in root/CEJ caries (Oxenham et al., 2006).

In the context of ancient Southeast Asia, the very high rate of caries at Man Bac is intriguing. Given the complete lack of physical evidence for rice agriculture or rice consumption it is unlikely that this particular food stuff contributed to poor oral health. Moreover, rice consumption in the region is not believed to be associated with caries anyway (Oxenham et al., 2006; Tayles et al., 2009). Preliminary stable isotopic work on a small Man Bac sample suggests more than 50% of the protein component of the diet derived from marine and/or freshwater sources and later Metal Period populations consumed more C3 plants (including rice) than was the case at Man Bac (Yoneda, 2008; Bower et al., 2006). The only other Southeast Asian assemblage with a comparably high rate of caries is Khok Phanom Di, where it has been suggested that the consumption of cariogenic foodstuffs such as taro, yam and banana may have had a contributory role (Tayles, 1999). The presence of such crops has not been identified at Man Bac.

While a similar proportion of adult male and female individuals displayed carious lesions, females with caries had a much greater number of affected teeth. Interestingly the lesion rate per tooth (males 7.6%, females 15.5%) is very similar to that seen at Khok Phanom Di (males 6.9%, females 14.6%). In both cases females have a rate more than twice that of males, and it is the female rate that contributes significantly to the overall high frequency of carious lesions in these two early, and essentially contemporaneous, assemblages. While the nature of the Man Bac diet is still unclear (apart from the significant aquatic food component and relatively low C3 component), Yoneda's (2008) preliminary isotopic results suggest females and males had slightly different diets (females show more negative d13C values and lower d15N values), which may have been a contributing factor to higher female rates of caries. Without knowing the Man Bac diet specifically, a range of possible reasons may be contributing to an elevated risk of caries in females including: rate and composition of female saliva; differential diet, genetic factors as well as the deleterious affects of pregnancy (see Ferraro and Vieira, 2010; Lukacs and Largaespada, 2006 for recent reviews). Regarding pregnancy, Lukacs (2008) has argued for a direct link between high fertility and greater rates of caries in females. The poor level of oral health in Man Bac females, particularly, is consistent with the elevated level of fertility suggested for the site (see Chapter 2). Clearly, oral disease is aetiologically multifactorial, however, whatever the range of proximate causes for poor oral health at Man Bac, the effects of pregnancy in the female sample is likely to have been a significant contributor.

Before moving on to consider other oral health variables some mention of subadult caries is required. Using a much smaller sample of Man Bac subadults, 50% of individuals (n=6) and 8.5% of deciduous teeth were previously reported as carious by Oxenham et al. (2008). With a much larger sample assessed (18 individuals and 290 teeth) the risk of subadult caries is somewhat lower (27.8% of individuals, 3.7% of teeth) making the rate of subadult caries similar to that seen at contemporaneous Khok Phanom Di (33.3% of individuals, 4.8% of teeth). It is somewhat intriguing that the Khok Phanom Di series displays very similar rates and patterns of carious lesions in the adult and subadult portions of their respective assemblages. Risk factors for subadult caries in ancient Southeast Asian assemblages are discussed in Oxenham et al. (2008) and include issues surrounding fluoride levels, oral hygiene, predisposing risks from hypocalcifications and LEH, and breast feeding practices.

Antemortem tooth loss (AMTL)

The overall adult level of AMTL in the Man Bac sample (2.6% of alveoli) is lower than that seen in both the Da But (4.8% of alveoli) and Metal Period samples (3.0% of alveoli). However, it is interesting to note that the frequency of Man Bac female AMTL by alveoli is nearly 3.5 times greater than that seen for males. Not only is the elevated rate of female AMTL consistent with the high rate of caries seen in Man Bac females, but given the correlation between AMTL and caries, is further evidence for the link between elevated fertility and poor oral health in females. It is worth noting that at least two papers have argued in support of the oral health and fertility hypothesis based on the use of AMTL alone (Watson et al., 2010; Fields et al., 2009). The distribution of AMTL by both age-at-death and location (posterior vs anterior) is consistent with expectations.

Alveolar defects of pathological origin (AD)

The overall adult level of AD in the Man Bac sample (1.8% of alveoli) is slightly higher than seen in the Da But sample (1.5% of alveoli) and somewhat lower than the Metal Period sample (2.6% alveoli). Given the much higher rates of female caries and AMTL at Man Bac it is a little surprising that there is a lower, albeit very slight, level of female AD compared to males. Part of the reason is likely the very low level of AD in general seen at Man Bac and the possibility that AD operates under different aetiological constraints than either caries or AMTL. The elevated level of AD seen in the Metal Period sample was attributed to the effects of often using the anterior teeth as tools (Oxenham et al., 2006).

Physiological Health

Cribra orbitalia (CO)

A remarkably high frequency of cribra orbitalia (CO) is seen in the Man Bac sample (73.1% of adults) relative to the Da But (28%) and Metal Periods (30%) of northern Vietnam. The even higher proportion of subadults exhibiting cribra orbitalia (the majority of which manifests as un-remodelled lesions in subadults) is indicative of a ubiquity of responsible stressors. The sedentary nature of the population, in addition to the elevated parasite loads of a tropical environment and riverine/marine focus in resource gathering, are likely the chief contributors to such physiological stressors (see discussion in Oxenham, 2006:228-9; Oxenham and Cavill, 2010). There is a clear, and expected, separation between adults and subadults in terms of the type of CO, with subadults having unremodelled lesions and adults displaying remodelled CO. There can be no doubt that whatever the stressors were, children were more vulnerable.

Linear enamel hypoplasia (LEH)

Compared to the Da But (72% of individuals; 63% male, 81% female) and Metal Period samples (67% of individuals; 65% males, 67% females), 100% (see Table 7.6) of Man Bac adult individuals displayed at least one canine and/or incisor LEH event. Clearly, whatever the aetiology of LEH at Man Bac, in terms of LEH this population appears to have been physiologically compromised relative to earlier and later populations in the region.

With every adult individual displaying at least one LEH event we need to turn to the distribution of LEH by sex, age and frequency of stressors in order to explore the implication of LEH at Man Bac. In terms of sex differences, females display a higher frequency of LEH by tooth count even though all adults have LEH. It would appear that greater male vulnerability was possibly offset at Man Bac by cultural and/or behavioural factors that elevated the risk of the development of LEH in female children.

In terms of LEH and age-at-death, the lower frequency of LEH affected teeth in the older male and female age cohorts might suggest a link between an increased level of LEH and lower age-at-death. Such a relationship has been suggested for both the Da But and Metal Period samples from Vietnam, as well as other studies globally (e.g. Duray, 1996; Goodman and Armelagos, 1988; Saunders and Keenleyside, 1999). Further support for this correlation can be observed when LEH is looked at by the minimum number of LEH events per individual. For instance, a greater proportion of individuals with 3 or more LEH events were found in the younger age cohort, particularly with regard to males.

Compromised Health Experience

This chapter set out to examine the evidence for adult and subadult health at Man Bac through the lens of oral (caries, antemortem tooth loss, and alveolar defects) and physiological health (cribra orbitalia and LEH). No matter what health indicator is looked at, the inhabitants of Man Bac appear to have been more compromised in their health than either the earlier Da But period or subsequent Metal Period assemblages. A number of factors, to a greater or lesser degree, may have contributed to the sub-optimal level of health seen at Man Bac: (1) colonising population; (2) migration; (3) sedentism; (4) adoption of new subsistence strategies; and (5) elevated fertility. Moreover, it is probable that whichever factors were responsible, they were probably not acting in isolation.

Evidence presented in Chapter 3 indicates that Man Bac is phenotypically and genetically heterogeneous, suggesting a population in biological transition. If indeed Man Bac is one of those archaeologically rare occurrences of a population undergoing rapid genetic change due to the effects of an influx of new migrants from the north, new genotypic expressions in an equally new environment may have resulted in a net health cost. Such a scenario is also consistent with some level of colonisation of the region as well as adoption of new subsistence strategies, all contributing to a greater impact on the health of the Man Bac community.

Intensification of agricultural practices in the later Metal Period have been argued to have been associated with a marked increase in the frequency of infectious disease in northern Vietnam (Oxenham et al., 2005). While infectious disease levels have not been examined for Man Bac yet, the base line health data discussed in this chapter are certainly consistent with the significant changes to the relationship between humans and the land. Sedentism in and of itself has been argued to be associated with compromised physiological health in earlier and later Vietnamese populations (Oxenham et al., 2006). Moreover, sedentism, the adoption of new subsistence strategies and increasing fertility are also familiar bedfellows and entirely consistent with the scenario being sketched for Man Bac some 3,500 years ago.

To conclude, while still early days in terms of analytical intensity, at face value it appears that the relatively poor base line health data for this population are consistent with a raft of biological and archaeological findings suggesting that Man Bac was a population in major transition.

LITERATURE CITED

Bower NW, Yasutomo Y, Oxenham MF, Nguyen LC, Nguyen KT. 2006. Preliminary reconstruction of diet at a neolithic site in Vietnam using stable isotope and Ba/Sr analyses. Bulletin of the Indo-Pacific Prehistory Association 26: 79-85.

Duray SM. 1996. Dental indicators of stress and reduced age at death in prehistoric native Americans. Am J Phys Anthropol 99:275-286.

Federation Dentaire International 1982. An epidemiological index of developmental defects of dental enamel (DDE Index). International Dental Journal 32:159-167.

Fields M, Herschaft EE, Martin DL, Watson JT. 2009. Sex and the agricultural transition: dental health of early farming females. Journal of Dentistry and Oral Hygiene 1:42-51.

Ferraro M, Vieira AR. 2010. Explaining gender differences in caries: a multifactorial approach to a multifactorial disease. International Journal of Dentistry, doi:10.1155/2010/649643.

Goodman, AH, Armelagos GJ. 1988. Childhood stress and decreased longevity in a prehistoric population. American Anthropologist 90:936-944.

Hillson S. 2001. Recording dental caries in archaeological remains. International Journal of Osteoarchaeology 11:249-289.

Lukacs JR. 1989. Dental paleopathology: methods for reconstructing dietary patterns. In: Iscan MY, Kennedy KAR, editors. Reconstruction of Life from the Skeleton. New York: Wiley-Liss. p 261-286.

Lukacs JR. 2008. Fertility and agriculture accentuate sex differences in dental caries rates. Current Anthropology 49: 901-914.

Lukacs JR, Largaespada LL. 2006. Explaining sex differences in dental caries prevalence: saliva, hormones, and "life-history" etiologies. Am J Hum Biol 18:540–555

Molnar S, Molnar I. 1985. Observations of dental diseases among prehistoric populations of Hungary. Am J Phys Anthropol 67:51-63.

Moore WF. 1993. Dental caries in Britain from Roman times to the nineteenth century. In: Geissler CG, Oddy DF, editors. Food, Diet and Economic Change Past and Present. Leicester: Leicester University Press. p 50-61.

Oxenham MF. 2000. Health and Behaviour During the Mid-Holocene and Metal Period of Northern Viet Nam. Unpublished PhD Thesis, Northern territory University, Darwin, NT, Australia.

Oxenham MF. 2006. Biological responses to change in prehistoric Vietnam. Asian Perspectives 45:212-239.

Oxenham MF, Cavill I. 2010. Porotic hyperostosis and cribra orbitalia: the erythropoietic response to Iron-deficiency anaemia. Anthropological Science DOI: 10.1537/ase.100302.

Oxenham MF, Nguyen KT, Nguyen LC. 2005. Skeletal evidence for the emergence of infectious disease in bronze and iron age northern Vietnam. Am J Phys Anthropol 126:359-376.

Oxenham MF, Nguyen LC, Nguyen KT. 2006. The oral health consequences of the adoption and intensification of agriculture in Southeast Asia. In: Oxenham M, Tayles N, editors. Bioarchaeology of Southeast Asia. Cambridge: Cambridge University Press. p 263-289.

Oxenham MF, Matsumura H, Domett K, Nguyen KT, Nguyen KD, Nguyen LC, Huffer D, Muller S. 2008. Health and the experience of childhood in late Neolithic Vietnam. Asian Perspectives 47:190-209.

Saunders SR, Keenleyside A. 1999. Enamel hypoplasia in a Canadian historic sample. Am J Hum Biol 11:513-524.

Tayles N. 1999. The People. Vol. 5 of The Excavation of Khok Phanom Di: A Prehistoric Site in Central Thailand. London; Society of Antiquities of London.

Tayles N, Domett K, Halcrow S. 2009. Can dental caries be interpreted as evidence of farming? The Asian experience. In: Kope T, Meyer G, Alt KW, editors. Comparative Dental Morphology. Basel: Karger. p 162-166.

Watson JT, Fields M, Martin D. 2010. Introduction of agriculture and its effects on women's oral health. Am J Hum Biol 22: 92-102.

Webb S. 1995. Palaeopathology of Aboriginal Australians: Health and Disease Across a Hunter-Gatherer Continent. Cambridge: Cambridge University Press.

Yoneda M. 2008. Dietary reconstruction of ancient Vietnamese based on carbon and nitrogen isotopes. Paper presented at the Man Bac Symposium, Institute of Archaeology, Hanoi, Vietnam, 19 July 2008