THE BIOARCHAEOLOGY OF THE VAT KOMNOU CEMETERY, ANGKOR BOREI, CAMBODIA

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ABSTRACT

Approximately 60 inhumation burials, of varying states of completeness and preservation, dated between 200 BC and AD 400 (or the early historic period in the Mekong delta) were excavated at the Vat Komnou cemetery located in Angkor Borei, Cambodia, by the University of Hawaii and the Royal University of Fine Arts in 1999 and 2000. The cemetery contained the remains of all age groups from infants to old adults. Over 40% of the burials are subadults. Adult males outnumber females 2 to 1 and most of the adults died as young adults. Osteological analyses are beginning to provide us with our first glimpses of these protohistoric people, associated with early Khmer culture, including evidence of health, disease, physiological stress, injury, physical activity, subsistence, length of life, and cultural modification of bone and teeth. Among the findings are tooth caries, moderate to extreme tooth attrition, and evidence of periodontal disease. Many of the teeth show evidence of betel staining. Healed fractures of the cranium and the infracranial skeleton, although rare, were also observed. Comparisons with other skeletal series from Southeast Asia provide regional context for these preliminary observations.

INTRODUCTION

Two seasons of field excavation, in 1999 and 2000, of a portion (4 x 5 m trench) of an early historic cemetery located at Vat Komnou, Angkor Borei, Cambodia, resulted in the recovery of at least 60 inhumation burials (Figure 1). This work was part of the Lower Mekong Archaeological Project (LOMAP), under the direction of Dr. Miriam Stark of the University of Hawaii and the Royal University of Fine Arts in Phnom Penh. Calibrated dates for the site indicate that the cemetery may have been in use from approximately 200 B.C. to A.D. 400, dates that coincide with the early historic, or Pre-Angkorian, period in the Mekong delta (Stark 2001, Stark and Sovath 2001).

The Vat Komnou cemetery sample constitutes the largest archaeological skeletal series excavated from Cambodia. The osteological analysis of these remains will provide the first comprehensive skeletal analysis of an early historic period human skeletal assemblage from Cambodia.

The study of human skeletal remains from archaeological sites provides researchers with an unprecedented opportunity to document firsthand lifetime events of once living human populations (Larsen 1997, 2002). These events include the health and disease, physiological stress, injury and trauma, physical activity, diet, cultural use of bones and teeth, and the demographic history of earlier human societies.

The major objective of this paper is to report on a preliminary study of several skeletal and dental indicators of physiological stress in the Vat Komnou cemetery skeletal series from Angkor Borei in Cambodia. Limited comparisons with other skeletal series from this and surrounding regions are also made. Although the sample is at times small, this examination provides one of the first glimpses of the health and disease, diet, physical activity, and lifestyles of this early historic Khmer skeletal series.

VAT KOMNOU SKELETAL SERIES

Thus far, a total of 61 individuals have been identified in the remains from the Vat Komnou cemetery (Table 1). Of these, 25 are subadults whose ages range from a few months to 19 years of age. Two of the subadults are aged between newborn and 11 months, eleven are aged between 1-9.9 years, and ten are aged between 10-19 years. Two other subadults were determined to be children. Thirty-six of the 61 skeletons were determined to be adults. At the time of their deaths, 22 were young adults, 5 middle-aged, and one was an old adult. Eight other skeletons were determined to be adults. Of the adults, 24 are male and ten are females, two are of indeterminate sex. Adult males outnumber females more than 2 to 1.

The completeness of these human remains ranges from nearly complete skeletons to only a few bones. Many of the burials are commingled (in one case the remains of at least five individuals are represented) and lack clear grave cuts. The incomplete and commingled nature of the remains is due, in large measure, to past disturbances of this stratified and densely packed cemetery, often resulting in subsequent interments in the same location. As well, excavation technique (e.g., portions of the skeleton that extended outside the

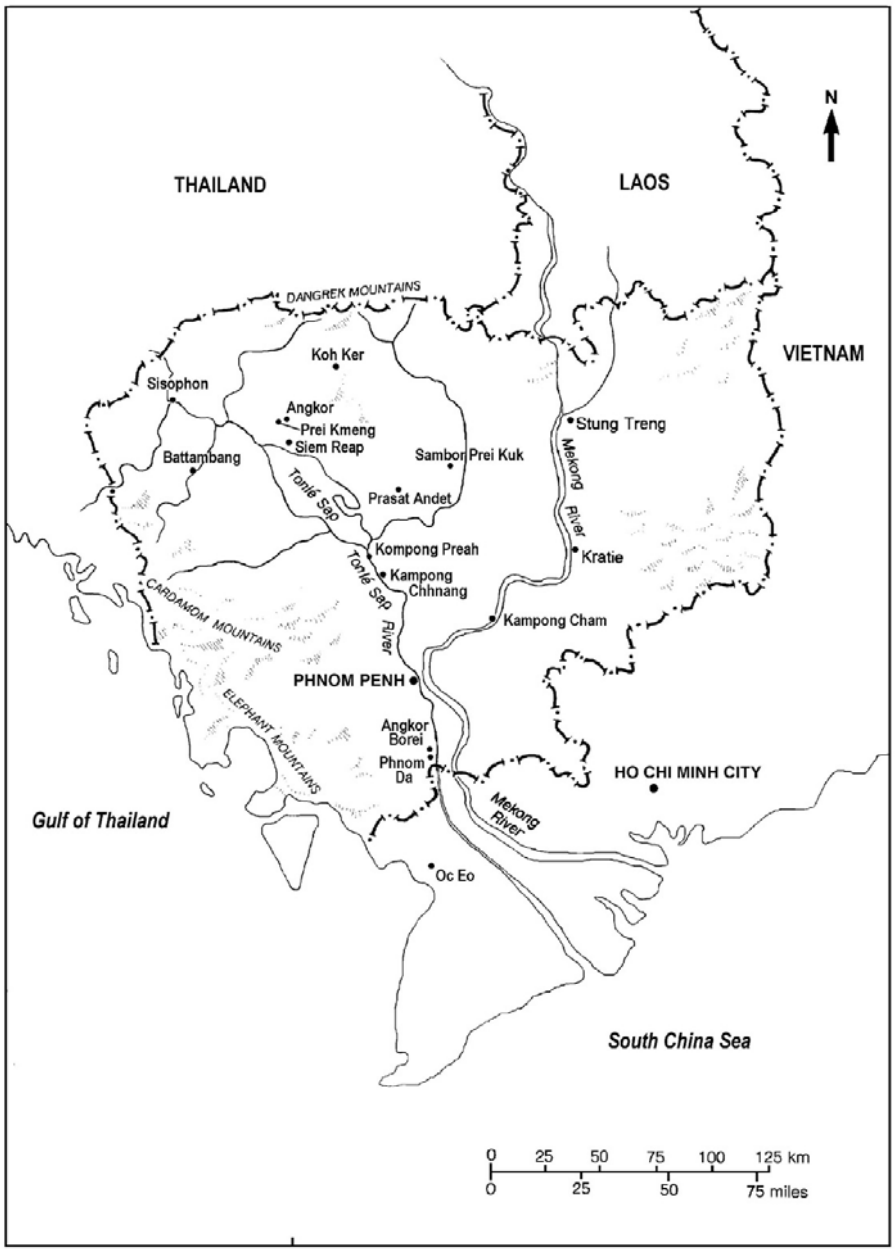

Figure 1. Map showing the location of Angkor Borei in southern Cambodia. Reprinted with permission from the University of Hawaii Press from Figure 1, p. 52 in "A New Date for the Phnom Da Images and Its Implications for Early Cambodia." by N.H. Dowling, Asian Perspectives 38(1):51-61.

excavation unit were not recovered) has impacted skeletal completeness. Overall, the preservation of the Vat Komnou skeletal remains is poor to fair; only a few burials can be characterized as being well preserved.

METHODS

The methods used to determine age, sex, stature, and to record paleopathology, including skeletal and dental indicators summarized in this paper, are given in Pietrusewsky and Douglas (2002a, b). The chi-square statistic was used to test for significant differences.

The skeletal indicators investigated in this paper include general as well as specific indicators of physiological stress (Goodman et al. 1984). General or episodic stress indicators, where the exact cause is unknown, include mortality data, stature, and the prevalence of defects of the enamel such as dental enamel hypoplasias. Examples of more specific physiological stressors, where the cause can usually be determined, include cribra orbitalia, evidence of infectious disease, trauma, osteoarthritis, and dental pathology.

INDICATORS OF HEALTH

Stature Estimation

Estimations of living stature from long limb bone measurements were made for six males and six females using several different stature regression formulae. The results are presented in Tables 2 and 3.

Using Sjøvold's non-ethnic stature formulae male stature ranges from approximately 160.5 cm (5' 3") to 174.2 cm (5' 9"), the mean is 167 cm (5' 6") (Sjøvold 1990). Using the same methods, female statures range from 151.1 cm (4' 11") to 159.8 cm (5' 3"). The average female stature is nearly 156.6 cm (5' 2").

A comparison of male mean statures (Table 4) indicates that the average stature for Vat Komnou adult males is close to several prehistoric skeletal series from Thailand including Ban Chiang, Ban Na Di and Nong Nor. Basic information for these and the other skeletal series used in these comparisons are given in Table 6.

Dental Enamel Hypoplasia

Dental enamel hypoplasia results from a disruption of normal enamel development during the early years of growth (Hillson 2000). Dental enamel hypoplasias are a non-specific indicator of stress, as a single cause can rarely be attributed to a specific defect (Goodman et al.1980; Goodman and Rose 1990, 1991). The suggested causes for this defect include a variety of nutritional, emotional, and infectious diseases affecting the mother and/or growing child. While all teeth are scored for the presence of these disruptions, they are more frequent in the incisor and canine teeth.

The total frequency of linear enamel hypoplasia in the Vat Komnou incisor and canine teeth is 8.3%, a relatively low frequency (Table 5). The frequency of this condition is higher (12.9%) in males than females (4.9%), a difference that is not statistically significant.

Compared to other skeletal series (Table 7), the overall frequency of dental enamel hypoplasia in the Vat Komnou series is among the lowest. Other skeletal series that have relatively low frequencies of hypoplastic defects include Ban Lum Khao and Nong Nor, sites located in Thailand, and prehistoric Hawaiian teeth.

Cribra Orbitalia

Cribra orbitalia, typically described as the presence of coarse, sieve-like openings in the orbital roof, is commonly attributed to a specific disease stress such as iron deficiency anemia, presumably caused by dietary deficiency. Stuart-Macadam has suggested that both cribra and the related condition of porotic hyperostosis are the result of parasitic infection, such as intestinal worms, rather than an indication of illness or failure of adaptation (Stuart-Macadam 1987, 1989, 1991, 1992).

Cribra orbitalia was scored in the right and left adult eye sockets from the Vat Komnou site. Although very few observations of this condition were permitted, cribra orbitalia was observed in four of the six male eye sockets and in neither of two female eye sockets available for observation. By individual, three of the four males and neither of the two females exhibited this condition for a combined frequency of 50.0% (3/6 adults) (Table 5).

Compared to other skeletal series, the prevalence of cribra orbitalia in the Vat Komnou series is relatively high (50.0%). Only one other skeletal series, Khok Phanom Di from southeastern coastal Thailand has a higher reported frequency (Table 8).

Spondylolysis

Fractures of the adult long limb bones can provide an indication of the frequency and type of traumatic, accidental and/or deliberate injury in a population. An example of healed bone fractures and/or bone trauma in the Vat Komnou remains is spondylolysis, a stress fracture in the lower lumbar vertebrae (Merbs 1989), observed in two adult females. The overall frequency of spondylolysis in the lumbar vertebrae from Vat Komnou is 7.7% (Table 9). Although this frequency is relatively high, it is not significantly different from most of the frequencies observed in the other skeletal series.

Osteoarthritis

Degenerative osteoarthritis is characterized by the progressive breakdown of articular cartilage and the formation of new bone, usually manifested by the formation of osteophytes or lipping at the joint surfaces. These changes are associated with the normal wear and tear of living and are distinguished from traumatic arthritis that is related to the disruption of the biomechanical functioning of a joint. Each of the articulating surfaces of the appendicular and vertebral skeleton was systematically scored for degenerative osteoarthritis on a none, slight, moderate, and marked scale. Given that the majority of the skeletons examined from the Vat Komnou site were young adults at the time of their deaths, it is not surprising that there is little or no osteoarthritis in the appendicular skeletons.

Degenerative Changes Results

The overall frequency of slight osteoarthritis in the Vat Komnou appendicular skeletons is 19.2% (Tables 5 & 10). A significant difference was found between the male (24.5%) and female (10.9%) frequencies of slight osteoarthritic involvement. The frequency of advanced (moderate and marked) osteoarthritis in males is 5.1% and 2.3% in females, a difference not found to be significant. Although observations are extremely limited, the most severely affected joints in the Vat Komnou appendicular skeletons are in the shoulder region followed by the elbow and knee regions. The combined frequency of advanced appendicular osteoarthritis in the Vat Komnou remains (4.0%) is most similar to frequencies reported for Ban Chiang (4.6%) and prehistoric skeletons from Hawaii (3.7%).

Vertebral Osteoarthritis and Osteophytosis

The frequencies of slight and moderate vertebral osteoarthritis and osteophytosis in the Vat Komnou

remains are 19.0% and 7.8%, respectively (Table 5). No significant differences in the frequencies of occurrence were found between the sexes. Much lower frequencies of moderate to marked osteoarthritis (0.7%) and osteophytosis (1.8%) were observed in the Vat Komnou remains.

Comparisons of moderate and marked expressions of degenerative changes in the vertebrae from Vat Komnou and other groups indicate minimal or nonexistent levels of involvement in the Vat Komnou series (Tables 11 & 12). The frequency of advanced vertebral osteophytosis in the Vat Komnou remains is most similar to the prehistoric aboriginal series from Taiwan, Shi San Hang.

Dental Pathology

Lastly, we examine evidence of dental pathology. Premortem tooth loss, dental caries, and dental abscessing in the skeletal remains from the Vat Komnou site were recorded on a per tooth, or tooth socket, basis. The loss of teeth before death can be attributed to several causes including periodontal disease, carious lesions, and dental abscessing (Dias and Tayles 1997; Hillson 2000; Tayles et al. 2000).

The overall frequency of premortem tooth loss in the remains from the Vat Komnou site is low, 4.1% (Table 5). No significant difference is found between the male (5.5%) and female (1.4%) frequencies of premortem tooth loss for this site. Although tooth ablation, or the deliberate removal of teeth, has been suggested for a number of prehistoric skeletal series from Southeast Asia (e.g., Oxenham et al. 2002; Tayles 1997), none is observed in the Vat Komnou series.

The overall frequency of carious lesions in the Vat Komnou series is low, 3.0%. A significant difference is found between male (1.2%) and female (5.3%) frequencies of dental caries.

The frequency of dental abscessing in the Vat Komnou series is 2.4%. Again, there is no significant difference in the frequencies for adult males (3.3%) and females (0.9%) from this site.

The frequencies of premortem tooth loss, dental caries, and dental abscessing in the Vat Komnou series are closest to frequencies for the same indicators of dental infections found in several of the prehistoric series from Thailand such as Nong Nor, Ban Lum Khao, and Ban Na Di (Table 13).

Two indicators of periodontal disease, calculus build-up and alveolar resorption, are tabulated for the Vat Komnou skeletal series (Table 5).The frequencies of advanced (moderate) calculus build-up and advanced (moderate and marked expressions) levels of alveolar resorption, two indicators of periodontal disease, in the Vat Komnou skeletal series are 22.5 % and 32.1%, respectively. Males have significantly more (26.6%) dental calculus than females (17.1%). There is no significant difference between the sexes in the frequencies of alveolar resorption.

The frequency of dental calculus in the Vat Komnou series is most similar to that reported for the Ban Chiang (28.3%) and an aboriginal skeletal series from Taiwan (28.9%). Significantly lower frequencies of dental calculus were observed in the two prehistoric Pacific Island samples (Table 14). With the exception of prehistoric skeletal series from Hawaii and the Mariana Islands, the frequency of alveolar resorption in the Vat Komnou remains is relatively high in comparison to other skeletal series.

One final dental paleopathology recorded in the Vat Komnou teeth is dental attrition, or tooth wear. The overall incidence of advanced dental attrition, that exposes the dentin and pulp cavity, is relatively high in males (70.5%) and females (62.8%), a difference that is not statistically significant (Table 5). The frequency of advanced dental attrition in the Vat Komnou sample (67.8%) is one of the highest reported in these comparisons and closest to the frequency reported for Ban Chiang (61.2%) (Table 14).

A cultural modification of teeth that may be useful in explaining the dental pathological conditions observed in these remains is tooth staining due to betel chewing, a practice common in many Asian and Pacific cultures today. The majority (229/305, 75.1%) of the adult Vat Komnou teeth exhibit evidence of betel staining. The frequency of betel stained teeth in this series is almost identical in male (131/174, 75.3%) and female (98/131, 74.8%) teeth. By tooth category the frequencies of betel stained teeth are: molars (58/121, 47.9%), premolars (74/83, 89.2%), canines (36/38, 94.7%), incisors (61/63, 96.8%).The staining generally ranges from light brown to darker shades of reddish brown and is found equally on the labial/buccal and lingual tooth crown surfaces, a pattern that suggests incidental rather than deliberate staining.

DISCUSSION/CONCLUSION

The evidence presented in this study suggests that the early historic inhabitants of Angkor Borei buried at Vat Komnou, with a few exceptions, were relatively healthy. Adult Vat Komnou males, on average, were approximately 5.5 cm taller than recent Cambodian and other Southeast Asian males and they are most similar to statures reported for prehistoric skeletal series from Thailand. The inhabitants of early historic Angkor Borei were well adapted and not experiencing significant disruption to growth. There is only limited evidence in these remains for skeletal changes suggestive of infectious diseases.

The relatively low frequencies of dental enamel hypoplasia in the Vat Komnou remains suggest that these early inhabitants did not experienced much in the way of physiological stress including possible nutritional deficiencies and childhood infectious diseases. The frequency of cribra orbitalia observed in these remains, although based on few observations, however, suggests that some of the people buried at Vat Komnou may have been subjected to parasitic diseases, iron-deficient diets, and/or other chronic stressors in their environment.

With the exception of some indicators of periodontal disease and dental attrition, the dental health of these early inhabitants was generally very good. The low frequencies of dental infections suggest a mixed economy, or at least one that was low in starches and sugars. It is also known that chewing betel nut has probable cariostatic properties (Howden 1984). The significantly higher levels of dental caries observed in females might suggest differences in diet between the two sexes. The very high frequency of advanced dental attrition observed in these remains is comparable to at least one prehistoric skeletal series from Southeast Asia, Ban Chiang. The relatively advanced levels of dental attrition observed in the Vat Komnou remains may be indicative of a coarse diet, chewing betel, and/or task-related activities that involve teeth.

Evidence of periodontal disease in this skeletal series suggests a more alkaline oral environment that may be associated with several factors including the chewing of betel nut, a diet high in carbohydrates, or poor dental hygiene. A significantly higher level of dental calculus observed in the teeth of Vat Komnou males that suggests a gender difference in diet and/or the occupational/cultural use of teeth.

The very few examples of cranial or healed limb bone fractures in this small sample is surprising and suggests that there is little or no deliberate or accidental injury experienced by this early historic community. However, the finding of at least one healed skull trauma and a possible healed humerus fracture indicates that this early group was not immune to injury, deliberate or otherwise. Although the sample size is small, the relatively high frequency of spondylolysis, a stress fracture in the lower lumbar vertebrae, indicates that the early historic females at Angkor Borei are likely to have experienced heavy mechanical demands on their lower backs as a results of occupation and/or physical activities.

The low levels of advanced osteoarthritis and osteophytosis in these remains is consistent with the young age-at-death for the majority of the skeletons examined in this series, levels that are generally similar to those observed in other early skeletal series. Additional data are currently being analyzed in this ongoing osteological study of the Vat Komnou archaeological sample, which will refine our understanding of the protohistoric inhabitants of Cambodia.

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Table 1: Age and sex distribution of the Vat Komnou skeletal series

Age Category	Male	Female	?Sex	Total
Newborn – 0.9			2	2
1 – 4.9		1	2	3
5 – 9.9	4	1	3	8
Child			2	2
10 – 14.9	2	2	1	5
Adolescent			2	2
15 – 19.9	1	2		3
Subadult Total	**7**	**6**	**12**	**25**
Young Adult	14	7	1	22
Middle-aged	4	1		5
Old	1			1
Adult	5	2	1	8
Adult Total	**24**	**10**	**2**	**36**
Total	31	16	14	61

Table 2: Summary of estimated statures for Vat Komnou males

Burial ID.	Age[a] (yrs.)	Stature (N[b] = 15)		Regression Formula[c]	Side/Bone(s)
		Cm.	Ft./In.		
13	25-35	173.1 ± 5.0	5'8"	Non-ethnic	L. ulna
		171.2 ± 4.6	5'7"	Mongoloid	L. radius
17	30-35	161.3 ± 4.9	5'4"	Non-ethnic	L. humerus
		165.7 ± 4.3	5'5"	Mongoloid	L. humerus
36	35-45	174.2 ± 4.9	5'9"	Non-ethnic	R. humerus
		173.2 ± 4.3	5'8"	Mongoloid	R. humerus
43b	45-55+	168.6 ± 4.0	5'6"	Non-ethnic	R. femur
		169.6 ± 3.2	5'7"	Mongoloid	R. fibula
		168.6 ± 4.1	5'6"	Thai-Chinese	R. femur
39b	YA	160.5 ± 5.0	5'3"	Non-ethnic	R. radius
		162.4 ± 4.6	5'4"	Mongoloid	R. radius
43a	35-45	164.5 ± 4.2	5'5"	Non-ethnic	R. tibia
		169.4 ± 4.6	5'7"	Mongoloid	L. radius
		161.1 ± 4.5	5'3"	Thai-Chinese	R. tibia

[a] Age in years; YA = young adult.
[b] N = number of individuals.
[c] Non-ethnic stature formulae (Sjøvold 1990); Mongoloid stature formulae (Trotter 1970); Thai-Chinese stature formulae (Sangvichien et al. 1985, n.d.).

Table 3: Summary of estimated statures for Vat Komnou females

Burial ID.	Age [a] (yrs.)	Stature (N[b] = 7)		Regression Formula[c]	Side/Bone(s)
		Cm.	Ft./In.		
5	19-20	151.1 ± 4.9	4'11"	Non-ethnic	R. humerus
16	25-35	157.6 ± 4.9	5'2"	Non-ethnic	L. humerus
20	18-25	157.5 ± 5.0	5"2"	Non-ethnic	R. radius
39	YA	154.8 ± 4.5	5'1"	Non-ethnic	L. femur
44	30-40	159.0 ± 4.9	5'3"	Non-ethnic	L. humerus
48	30-35	159.8 ± 5.0	5'3"	Non-ethnic	L. ulna

[a] Age in years; YA = young adult.
[b] N = number of individuals.
[c] Non-ethnic stature formulae (Sjøvold 1990).

Table 4: Comparison of mean male statures[a]

Group	Stature (cm)	Source
Vat Komnou	167.0	this study
Ban Chiang	168.3	Pietrusewsky & Douglas (2002a)
Ban Lum Khao	164.7	Domett (1999)
Ban Na Di	168.0	Domett (1999)
Khok Phanom Di	162.2	Tayles (1992)
Nong Nor	167.2	Tayles et al. (1998)
Burmese (modern)	164.0	Olivier (1968)
Malays (modern)	163.0	Olivier (1968)
Thai (modern)	162	Olivier (1968)
Cambodian	161.5	Olivier (1968)
Vietnamese	160.0	Olivier (1968)

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Laotian	159.0	Olivier (1968)
Southern Chinese	161.0	Bowles (1984:89)
Northern Chinese	169.0	Bowles (1984:89)
Shi San Hang, Taiwan	165.2	Pietrusewsky & Tsang (2003)
Modern Japanese	165.0	Average taken from Suzuki (1981)
Mariana Is., prehistoric	173.1	Pietrusewsky et al. (1997)
Hawaiians, prehistoric	172.4	Pietrusewsky and Douglas (1994)
Australian Aboriginal, central	165.0	Howells & Schwidetzky (1981:131)

[a] The statures reported in this table are based on a variety of methods for estimating living height.

Table 5: Frequency of occurrence[a] and level of significance for indicators of stress recorded in the Vat Komnou skeletons

Indicator of Stress	Male		Female		Total		Significance[c]		
	A / O[b]	%	A / O[b]	%	A / O[b]	%	χ^2	n.s.	*p*-value
Dental enamel hypoplasia (canines & incisors)	4/31	12.9	2/41	4.9	6/72	8.3	1.488	n.s.	$p \leq 1.0$
Cribra orbitalia (per individual)	3/4	75.0	0/2	0.0	3/6	50.0	3.000	n.s.	$p \leq 0.10$
Spondylolysis (lumbar vertebrae)	0/13	0.0	2/13	15.4	2/26	7.7	2.167	n.s	$p \leq 0.20$
Osteoarthritis appendicular (slight)	49/200	24.5	14/128	10.9	63/328	19.2	9.251		$p \leq 0.01$*
Osteoarthritis appendicular (moderate & marked)	10/197	5.1	3/128	2.3	13/325	4.0	1.509	n.s	$p \leq 1.0$
Osteoarthritis vertebrae (slight & moderate)	55/258	21.3	47/280	16.8	102/538	19.0	1.800	n.s	$p \leq 0.20$
Osteoarthritis vertebrae (moderate & marked)	1/258	0.4	3/280	1.1	4/538	0.7	0.851	n.s.	$p \leq 1.0$
Osteophytosis vertebrae (slight & moderate)	22/230	9.6	4/105	3.8	26/335	7.8	3.336	n.s.	$p \leq 0.10$
Osteophytosis vertebrae (moderate & marked)	5/230	2.2	1/105	1.0	6/335	1.8	0.612	n.s.	$p \leq 1.0$
Premortem tooth loss	14/253	5.5	2/138	1.4	16/391	4.1	3.795	n.s	$p \leq 0.10$
Dental caries	2/172	1.2	7/132	5.3	9/304	3.0	4.456		$p \leq 0.05$*
Dental abscessing	6/184	3.3	1/113	0.9	7/297	2.4	1.717	n.s	$p \leq 0.20$
Dental calculus (moderate)	46/173	26.6	22/129	17.1	68/302	22.5	3.851		$p \leq 0.05$*
Alveolar resorption (moderate & marked)	53/151	35.1	28/101	27.7	81/252	32.1	1.510	n.s	$p \leq 1.0$
Dental attrition (moderate & marked)	117/163	70.5	83/132	62.9	200/295	67.8	2.646	n.s	$p \leq 0.20$

[a]Frequency of occurrence include right and left sides, where applicable.

[b]A/O = affected / observed.

[c]Chi-square (χ^2) value and probability (*p*) are indicated to test the null hypothesis that there is no statistical significance between the frequency in males and females at the .05 level; n.s. = not significant, degrees of freedom (d.f.) =1, * = significant difference.

Table 6: Comparative skeletal series

Skeletal Series	Location	Dates for burials	References for data
Shi San Hang	Taiwan	Ca 150-1450 AD	Tsang and Liu (2001)
Ban Chiang	Northeast Thailand	2100 BC- AD 200	Pietrusewsky and Douglas (2002a)
Ban Lum Khao	Northeast Thailand	1000 B.C. – 500 B.C.	Domett (1999, 2001)
Ban Na Di	Northeast Thailand	600-400 BC	Domett (1999, 2001)
Khok Phanom Di	Coastal southeastern Thailand	2000 - 1500 BC	Tayles (1992, 1996)
Nong Nor	Coastal southeastern Thailand	1100-700 BC	Tayles et al. 1998
Hawaii, prehistoric	Hawaiian Islands	pre-1778	Pietrusewsky and Douglas (1994)
Mariana Is., prehistoric	Mariana Islands	pre-1521	Pietrusewsky et al. (1997)

Table 7: Frequency of occurrence of dental enamel hypoplasia in canine and incisor teeth at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α= .05)[b]	
Vat Komnou	6/72	8.3		
Ban Chiang, Northeast Thailand	76/366	20.8	$\chi^2 = 6.111$	$p \leq 0.025$*
Ban Lum Khao	94/799	11.8	$\chi^2 = 0.765$	$p \leq 1.0$
Ban Na Di	70/473	14.8	$\chi^2 = 2.177$	$p \leq 0.20$
Khok Phanom Di	130/297	43.8	$\chi^2 = 31.272$	$p \leq 0.001$*
Nong Nor	101/843	12.0	$\chi^2 = 0.855$	$p \leq 1.0$
Shi San Hang, Taiwan	69/186	37.1	$\chi^2 = 20.827$	$p \leq 0.001$*
Hawaiian, prehistoric	159/2053	7.7	$\chi^2 = 0.034$	$p \leq 1.0$
Mariana Is., prehistoric	183/563	32.5	$\chi^2 = 17.841$	$p \leq 0.001$*

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 8: Frequency of occurrence of cribra orbitalia in individuals at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α= .05)[b]	
Vat Komnou	3/6	50.0		
Shi San Hang, Taiwan	8/18	44.4	$\chi^2 = 0.056$	$p \leq 1.0$
Ban Chiang, Northeast Thailand	6/33	18.2	$\chi^2 = 2.900$	$p \leq 0.10$
Khok Phanom Di, Central Thailand	31/57	54.4	$\chi^2 = 0.042$	$p \leq 1.0$
Hawaiian, prehistoric	139/1031	13.5	$\chi^2 = 6.731$	$p \leq 0.01$*
Mariana Is., prehistoric	12/104	11.5	$\chi^2 = 7.126$	$p \leq 0.01$*

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 9: Frequency of occurrence of spondylolysis in lumbar vertebrae at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α = .05)[b]	
Vat Komnou	2/26	7.7		
Shi San Hang, Taiwan	3/85	3.5	χ^2 =0.802	$p \leq 1.0$
Ban Chiang, Northeast Thailand	5/191	2.6	χ^2 =1.888	$p \leq 0.20$
Khok Phanom Di, Central Thailand	5/151	3.3	χ^2 = 1.121	$p \leq 1.0$
Hawaiian, prehistoric	21/1396	1.5	χ^2 = 6.142	$p \leq 0.025$*
Mariana Is., prehistoric	10/233	4.3	χ^2 =0.612	$p \leq 1.0$

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 10: Frequency of occurrence of advanced (moderate and marked) appendicular osteoarthritis at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α = .05)[b]	
Vat Komnou	13/325	4.0		
Shi San Hang, Taiwan	1/993	0.1	χ^2 =35.43	$p \leq 0.001$*
Ban Chiang, Northeast Thailand	79/1704	4.6	χ^2 =0.26	$p \leq 1.0$
Hawaiian, prehistoric	254/6793	3.7	χ^2 = 0.06	$p \leq 1.0$
Mariana Is., prehistoric	73/799	9.1	χ^2 = 8.63	$p \leq 0.01$*

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 11: Frequency of occurrence of advanced (moderate and marked) vertebral osteoarthritis at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α = .05)[b]	
Vat Komnou	4/538	0.7		
Shi San Hang, Taiwan	0/1750	0.0	X^2 = 13.034	$p \leq 0.001$*
Ban Chiang, Northeast Thailand	171/2618	6.5	X^2 = 28.548	$p \leq 0.001$*
Hawaiian, prehistoric	1682/27,444	6.1	X^2 = 27.026	$p \leq 0.001$*
Mariana Is., prehistoric	259/3925	6.6	X^2 = 29.250	$p \leq 0.001$*

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 12: Frequency of occurrence of advanced (moderate and marked) osteophytosis in pre-sacral vertebrae at Vat Komnou compared to other skeletal series

Sample	A/O[a]	%	Significance (α = .05)[b]	
Vat Komnou	6/335	1.8		
Shi San Hang, Taiwan	15/778	1.9	χ^2 = 0.024	$p \leq 1.0$
Ban Chiang, Northeast Thailand	32/958	3.3	χ^2 = 2.088	$p \leq 0.20$
Hawaiian, prehistoric	1091/12,000	9.1	χ^2 = 21.438	$p \leq 0.001$*
Mariana Is., prehistoric	139/1113	12.5	χ^2 = 32.702	$p \leq 0.001$*

[a] A/O =affected/observed; % = frequency of occurrence.
[b] Significance is tested at .05 level, χ^2 = chi-square, p = probability, d.f.=1, *=significant difference.

Table 13: Frequency of occurrence of dental infection (sides combined) at Vat Komnou compared to other skeletal series

Sample	Premortem Tooth Loss				Carious Lesions				Abscessing			
	A/O[a]	%	Significance ($\alpha = .05$)[b]		A/O	%	Significance ($\alpha = .05$)		A/O	%	Significance ($\alpha = .05$)	
Vat Komnou	16/391	4.1			9/304	3.0			7/297	2.4		
Shi San Hang, Taiwan	2/633	0.3	$\chi^2 = 19.957$	$p \leq 0.001$*	6/585	1.0	$\chi^2 = 4.515$	$p \leq 0.05$*	4/598	0.7	$\chi^2 = 4.658$	$p \leq 0.05$*
Ban Chiang, Northeast Thailand	87/1279	6.8	$\chi^2 = 3.800$	$p \leq 0.10$	74/1016	7.3	$\chi^2 = 7.421$	$p \leq 0.01$*	67/1055	6.4	$\chi^2 = 7.145$	$p \leq 0.01$*
Ban Lum Khao	59/1154	5.1	$\chi^2 = 0.659$	$p \leq 1.0$	40/885	4.5	$\chi^2 = 1.392$	$p \leq 1.0$	15/1154	1.3	$\chi^2 = 1.768$	$p \leq 0.20$
Ban Na Di	38/707	5.4	$\chi^2 = 0.886$	$p \leq 1.0$	24/515	4.7	$\chi^2 = 1.428$	$p \leq 1.0$	15/707	2.1	$\chi^2 = 0.054$	$p \leq 1.0$
Khok Phanom Di, Central Thailand	183/2047	8.9	$\chi^2 = 10.292$	$p \leq 0.01$*	139/1182	10.8	$\chi^2 = 14.087$	$p \leq 0.001$*	122/2047	6.0	$\chi^2 = 6.475$	$p \leq 0.025$*
Nong Nor	58/1323	4.4	$\chi^2 = 0.062$	$p \leq 1.0$	66/1017	6.5	$\chi^2 = 5.443$	$p \leq 0.025$*	11/1323	0.8	$\chi^2 = 5.137$	$p \leq 0.025$*
Harappa, Pakistan	70/821	8.5	$\chi^2 = 7.900$	$p \leq 0.01$*	51/721	6.8	$\chi^2 = 6.564$	$p \leq 0.025$*	23/751	3.1	$\chi^2 = 0.381$	$p \leq 1.0$
Hawaiian, prehistoric	976/10,137	9.6	$\chi^2 = 13.519$	$p \leq 0.001$*	1160/8292	14.0	$\chi^2 = 30.357$	$p \leq 0.001$*	443/8551	5.2	$\chi^2 = 4.741$	$p \leq 0.05$*
Mariana Is., prehistoric	265/4532	5.8	$\chi^2 = 2.060$	$p \leq 0.20$	157/1591	9.9	$\chi^2 = 15.237$	$p \leq 0.001$*	122/2380	5.1	$\chi^2 = 4.415$	$p \leq 0.05$*

[a] A/O =affected/observed.
[b] Significance is tested at .05 level, $p \leq 0.001$, when compared to Vat Komnou, d.f.=1; χ^2 = chi-square p = probability, *=significant difference.

Table 14: Frequency of occurrence of periodontal disease and attrition (sides combined) at Vat Komnou compared to other skeletal series

Sample	Calculus				Resorption				Attrition			
	A/O[a]	%	Significance (α = .05)[b]		A/O	%	Significance (α = .05)		A/O	%	Significance (α = .05)	
Vat Komnou	68/302	22.5			81/252	32.1			200/295	67.8		
Shi San Hang, Taiwan	162/560	28.9	$\chi^2 = 4.123$	$p \leq 0.05$*	130/508	25.6	$\chi^2 = 3.606$	$p \leq 0.10$	181/584	31.0	$\chi^2 = 108.105$	$p \leq 0.001$*
Ban Chiang, Northeast Thailand	253/893	28.3	$\chi^2 = 3.884$	$p \leq 0.05$*	115/869[c]	13.2	$\chi^2 = 48.415$	$p \leq 0.001$*	621/1015	61.2	$\chi^2 = 4.274$	$p \leq 0.05$*
Ban Lum Khao	-----	-----	-----	-----	-----	-----	-----	-----	113/872	13.0	$\chi^2 = 337.729$	$p \leq 0.001$*
Ban Na Di	-----	-----	-----	-----	-----	-----	-----	-----	61/510	12.0	$\chi^2 = 265.934$	$p \leq 0.001$*
Khok Phanom Di, Central Thailand	-----	-----	-----	-----	-----	-----	-----	-----	112/1272	8.8	$\chi^2 = 522.588$	$p \leq 0.001$*
Nong Nor	-----	-----	-----	-----	-----	-----	-----	-----	175/1014	17.3	$\chi^2 = 285.536$	$p \leq 0.001$*
Harappa, Pakistan	-----	-----	-----	-----	-----	-----	-----	-----	37/821	4.5	$\chi^2 = 519.710$	$p \leq 0.001$*
Hawaiian, prehistoric	529/8138	6.5	$\chi^2 = 113.639$	$p \leq 0.001$*	3873/7900	49.0	$\chi^2 = 27.867$	$p \leq 0.001$*	3715/8386	44.3	$\chi^2 = 63.543$	$p \leq 0.001$*
Mariana Is., prehistoric	400/2617	15.3	$\chi^2 = 10.519$	$p \leq 0.01$*	629/1667	37.7	$\chi^2 = 2.934$	$p \leq 0.10$	871/2876	30.3	$\chi^2 = 168.317$	$p \leq 0.001$*

[a] A/O =affected/observed.
[b] Significance is tested at .05 level, $p \leq 0.001$, when compared to Vat Komnou, d.f.=1; χ^2 = chi-square,. p = probability, *=significant difference.
[c] Alveolar resorption in the Ban Chiang series was not scored as tooth root exposure above the alveolus but rather as porosity in the alveolar rim.