

THE PREHISTORIC PEOPLE OF BAN LUM KHAO, CENTRAL THAILAND

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ABSTRACT

Ban Lum Khao is a Bronze Age cemetery located on the Khorat Plateau in northeast Thailand. One hundred and ten human skeletons were excavated and an investigation of the health of the 59 adult human skeletons is the focus of this paper. Age and sex estimations and a selection of other skeletal and dental health parameters are presented, including stature estimates, evidence of growth disturbances, joint degeneration, trauma and oral health. Results indicate a number of differences between males and females, particularly in joint degeneration, trauma and dental health, differences that may have been influenced by their social environment. A sexual division of labour is postulated as well as the consumption of different diets by males and females. A large variation within the male stature estimates also provides evidence of a subdivision within this sex during childhood, perhaps in relation to diet. These health parameters are also discussed with reference to other prehistoric Thai populations to determine their relative level of health.

A recent multidisciplinary archaeological project in Thailand has uncovered a number of prehistoric cemetery and occupation sites. The aim of "The Origins of Angkor" project is to identify the prehistoric populations that were living prior to the expansion and establishment of a centralised state organisation level in northeast Thailand during the latter half of the first millennium AD. Information was previously lacking for the lead up to this economic, social and political transition in this vicinity. One aspect of this project was to investigate the health of communities during the Bronze and Iron Ages. In order for a population to undergo expansion it must have an adequate level of health.

Ban Lum Khao is a modern village built on a prehistoric mound in the Mun River valley of northeast Thailand. An area of the village was excavated under the direction of

Professor Charles Higham and Dr Rachanie Thosarat as part of the "Origins of Angkor" project. The excavation area covered a 10 x 15 m² and reached a depth of 1.7 m. Within this a Bronze Age cemetery was located between two Bronze Age occupation levels. Dating has indicated the initial occupation at around 1400 BC, with the cemetery phase being approximately 500 - 1000 years later (Higham and Thosarat 1998; O'Reilly 1998). In the graves of Ban Lum Khao there were shell and stone ornaments and an abundant and diverse range of pots, but no bronze. At this stage there has been no subgroup identified with a higher level of 'wealth' or rank than the rest of the population in the analysis of the site (O'Reilly pers. comm.).

One hundred and ten individuals were identified from 112 burials excavated. The human bone was generally very well preserved, but a calcium-based concretion limited the observation of the bone surface in many cases. Eighteen percent of the burials were complete and articulated. Others were of varying incompleteness, disturbed or scattered. Many infants were buried in large pottery jars and well preserved.

AIM

The reconstruction of a population's health status can provide information about the biological, cultural and environmental factors acting upon it. The focus of this paper is the health of the adult (over 15 years of age) population from prehistoric Ban Lum Khao through an analysis of their skeletal biology, combined with relevant archaeological information. The major questions being addressed concern the health status of males and females and whether or not they were differently affected by their physical and cultural environments. Environment is defined here in its broadest sense, including the population's diet, food availability and variety, and also the types of subsistence they would have been involved in, the latter as an indication of the types of activities that were undertaken and the influence of available technology.

In order to address these questions a selection (by no means exhaustive) of generally non-specific skeletal biological parameters are considered. They include (1) the age structure of the adult population; (2) growth, which can be observed through stature and bone mass measurements; (3) disturbances of growth during childhood, which can be observed in the adult through dental and skeletal developmental defects; (4) skeletal pathology, which will include joint degeneration and signs of trauma as evidence of the demands of labour and prehistoric lifestyle (Larsen 1995); and (5) a selection of parameters for assessing dental health.

There are a number of assumptions made in the analysis of any excavated skeletal population. One is that the excavated sample is representative of the living population from which it came and is not a biased subsample based on rank, wealth, age, sex or health. Another factor to be considered is the completeness of each individual skeleton. There is nearly always some element of "missing data" because of incomplete skeletons. In some of what follows this has been accounted for, but in other cases it cannot be and therefore only the minimum prevalence of the condition can be estimated.

In order to obtain a relative view of this population's health status it is compared with other prehistoric Thai populations. Ban Na Di is also in the northeast, but is slightly later. This site's environment was probably quite similar to that of Ban Lum Khao but the technology, for example, in knowledge of rice agriculture, may have been more advanced (Higham and Kijngam 1984). Khok Phanom Di is a prehistoric coastal Thai site predating Ban Lum Khao and differing in environment and technology. Nong Nor is also in central Thailand and was used as a cemetery from about 1100 BC through to 700 BC (Higham and Hogg 1998). The preservation of the skeletal material from this site is very poor and can only be used in a few of the comparisons with Ban Lum Khao. Even though there are differences among these sites, a general comparison with Ban Lum Khao is possible.

METHODS AND RESULTS

A. DEMOGRAPHY

Age Estimation

A multifactorial approach was used in the estimation of adult age. This involved assessing a selection of the most reliable ageing criteria from the material available, such as pubic symphysis ageing, molar wear and stage of epiphysis fusion. The results were then averaged and based on seriation. Adults were assigned to 10-year age groups. The ages estimated may not be absolutely accurate but it is important that individuals within the site are aged relative to one another, hence the advantage of seriation.

Sex Estimation

Pelvic and/or cranial morphology was able to be used in the estimation of the sex of 50 of the 59 adults (taken as those aged over 15.0 years). Other morphological aspects that were considered where necessary were mandibular morphology and overall impression of body size - relative gracility and robustness.

Results

The age and sex structures of both the male and female groups from Ban Lum Khao are presented in Figure 1. One individual could only be tentatively assigned as male and another burial, Burial 22, could not be assigned to either sex category as this burial consisted of foot bones only. Sex estimates placed the 59 adults into almost equal groups of males (44.1%) and females (54.2%). Age estimates were more unevenly divided between the sexes. The mortality of young (20-29 years) females is substantially higher than that of males of a similar age. This may well be explained by the risks of childbearing, risks which may have had implications for this population's ability to maintain itself. In the older age group (40-49+ years) there are more males than females surviving.

This distribution is not entirely "typical" of prehistoric populations and there are a number of possible explanations. The first is that the cemetery sample may not be representative of the living population from which it came. It is possible that at some stage the use of this cemetery was only for young women. On the other hand, the ratio of males to females (1:1.2) is quite close, indicating no obvious bias in sex. It would seem reasonable to assume that childbearing carried high risk. At Khok Phanom Di, by comparison, the sex ratio is very similar (1:1.1) but there is a more even distribution of the sexes amongst the age groups, except for the 40+ years group where more females than males survived

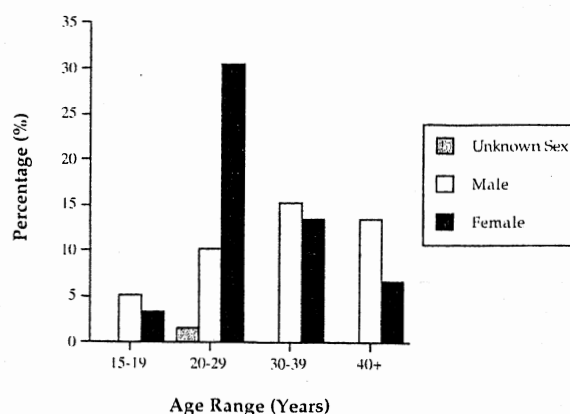


Figure 1: The age and sex structure of the cemetery sample from Ban Lum Khao.

(Tayles 1999). At Ban Na Di the sex ratio was 1:0.8, that is, fewer females than males. There were more males than females surviving into their 40s, but slightly more females surviving into old age. However, the sample size from Ban Na Di was quite small and a number of individuals could not be given age estimates. Both of these distributions are quite different from that of Khok Phanom Di.

B. GROWTH AND DISTURBANCES OF GROWTH

Stature

Stature was estimated from the lengths of long bones using regression equations derived from a study of modern Thai cadavers by Sangvichien *et al.* (n.d., 1985). 74% of adults from Ban Lum Khao were able to have their stature estimated. Results are given in Figure 2, which shows that male mean stature is significantly taller than the female mean (t-value = 6.23, p-value <0.0001). This sexual dimorphism (6.1%) is a normal phenomenon for all human populations. The range of stature in the male group (22.5 cm) is much wider than the female range (14.3 cm), and this indicates that males were more varied in their growth and, assuming genetic homeogeneity, did not all reach their genetic potential.

The growth of an individual is linked strongly with the quality of their diet, particularly during childhood and adolescence. It is proposed that at Ban Lum Khao there may have been a division within the male group that resulted in differential access to food and a resultant large differential in growth. In contrast, females were all reaching a similar height, implying a similar diet. Growth can also be influenced by childhood illnesses, as such illnesses can retard or completely stop growth to focus energy on surviving the insult.

A division within a group can be based on social factors such as the establishment of a hierarchy of wealth or rank, with the more wealthy individuals receiving a better diet for example. The relationship between stature and grave wealth has been investigated at Ban Lum Khao but no pattern was obvious (O'Reilly pers. comm.).

Ban Lum Khao male and female mean statures were compared with the three other prehistoric Thai populations from Khok Phanom Di, Nong Nor and Ban Na Di using ANOVA tests (Figure 3). There were no statistically significant differences among the females from each site (F ratio =0.8531, F probability =0.4689) and no differences when Ban Lum Khao males were compared to each site, although differences between the other sites are apparent among the males (F ratio =4.2476, F probability =0.0007).

Bone Mass

Bone mass is a valuable indicator of how well bone has been maintained throughout life, of nutritional status and as an index of the strength of bone (Martin *et al.* 1985; Aloia

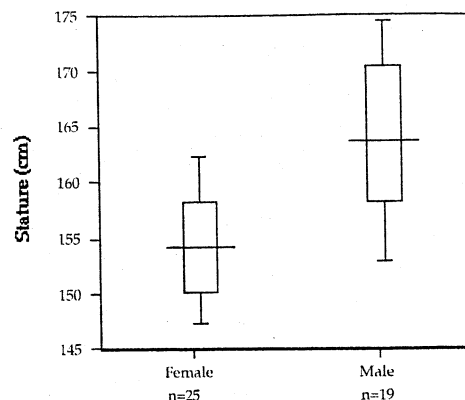


Figure 2: Ban Lum Khao stature estimates showing the mean, standard deviation and range.

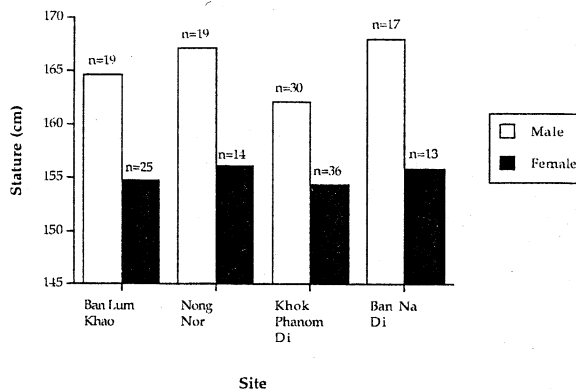


Figure 3: Stature in prehistoric Thailand, estimated using modern Thai regression formulae from Sangvichien *et al.* (n.d. 1985). Khok Phanom Di data from Tayles (1999).

1994; Resnick and Niwayama 1995). Low levels, for example, can be indicative of osteoporosis and leave an individual with an increased risk of fracture (Mazess 1982). Cortical bone mass was measured in the Ban Lum Khao population from radiographs of the second metacarpal following the method of Barnett and Nordin (1960) and Garn (1970). Bone mass is calculated as an index to eliminate the effect of different sized bones between individuals.

Overall, females had a lower average bone mass compared with males but the difference was not significant (t-value = 1.82, p-value =0.0981) (Figure 4). What is apparent again is the much wider range of values for the male group. This gives more support to the proposal of a status division within the male group as seen in the stature results. Modern clinical studies show a decline in bone mass with age but the data set from Ban Lum Khao was too small to be divided into age

groups for statistical tests. The general impression is that there is no decline with age in either males or females at Ban Lum Khao.

Both nutrition and physical exercise are important in skeletal maintenance and therefore both should be considered when analysing bone thickness and bone distribution (Larsen 1995). It is also assumed that prehistoric populations were exposed to physical activity from an early age as they relied on their own physical labour for their subsistence, which could lead to enhanced development of bone (Pfeiffer and Lazenby 1994). Perhaps this prehistoric population was not living long enough to show age-related bone loss, or perhaps their diet and lifestyle facilitated effective bone maintenance.

The mean bone mass from each sex at Khok Phanom Di and Ban Na Di was tested against Ban Lum Khao using an ANOVA table. The results (Figure 5) indicate no statistically significant differences in either sex (male p-value =0.5687, female p-value =0.8503).

DISTURBANCES OF GROWTH

Skeletal Disturbances: Harris Lines (tibia)

Harris Lines, or lines of arrested growth, are seen as transverse lines of greater radio-opacity in long bones. In paleopathology, Harris Lines are considered to be indicators of nonspecific stress in childhood (Martin *et al.* 1985; Grolleau-Raoux *et al.* 1997), induced by periods of malnutrition, infections and other illnesses. There are some limitations in the use of these observations, including the possibility that lines in some individuals have remodelled and are no longer visible. This can be confounded by the fact that males and females often have different bone remodelling rates (Lewis and Roberts 1997). No comparisons have been attempted with other populations due to these factors.

At Ban Lum Khao, ten individuals (4 females, 6 males) could have their tibiae radiographed. Of these, 25% of females and 17% of males showed evidence of one or more Harris lines (Figure 6). There do not appear to be any large differences between the sexes in their susceptibility to periods of childhood illness and/or malnutrition, but the sample sizes were too small to be tested statistically. This small sample of tibiae suitable for radiography therefore provides only the minimum prevalence.

Dental Disturbances: Enamel Hypoplasia

Enamel Hypoplasia is seen macroscopically as a transverse line or pit across the external surface of the tooth crown. It is a nonspecific indicator of a disturbance in growth during the formation of the crown. For permanent teeth this relates to the first seven years of life (Lewis and Roberts 1997). As

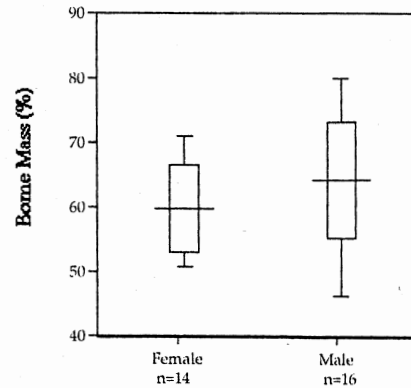


Figure 4: Ban Lum Khao bone mass showing the mean, standard deviation and range.

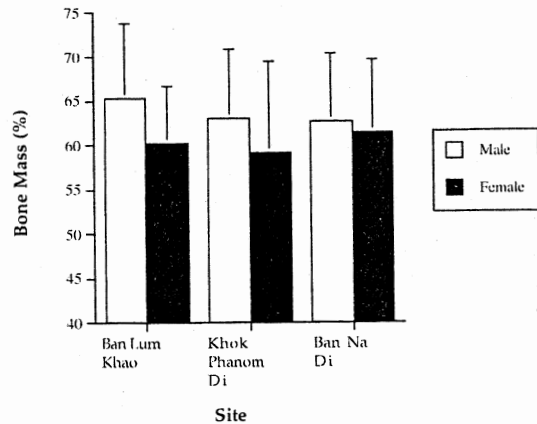


Figure 5: Average bone mass in prehistoric Thailand, represented by the top limit of the bars, with the line above the bars showing a standard deviation. Khok Phanom Di data from Tayles (1999).

for Harris lines, the disturbance in growth can be caused by a variety of health problems during childhood, including malnutrition or infectious illness.

The results from Ban Lum Khao show females with a higher prevalence (46%) (per individual) than males (32%) (Figure 6), although the difference was not statistically different (Fisher's Exact Test value =0.3694).

In comparison with the other Thai sites mentioned, Ban Lum Khao had a moderate level of enamel hypoplasia. Ban Na Di exhibited lower prevalences, with males having a higher percentage (42%) than females (21%). Khok Phanom Di had very high prevalences (females having 92% and males 85%), which may reflect a relatively high level of childhood illness in this population (Tayles 1999).

C. SKELETAL PATHOLOGY

Osteoarthritis

Osteoarthritis is the most common form of joint degeneration and is seen as a non-inflammatory disorder of moveable joints. It is characterised by deterioration of articular cartilage finally resulting in bone rubbing on bone, as well as the formation of new bone around the joint margins. This condition has been associated with numerous aetiological factors including advancing age, joint use (physical activity), trauma, obesity, and possibly even a genetic component (Resnick and Niwayama 1981; Rogers *et al.* 1987). This analysis was restricted to the major appendicular joints with each articular surface being graded initially before a combined grade was given for the joint overall. The grading system used is outlined in Table 1. A joint was considered pathological if it had a grade 2 or more. Grade 1 changes represented non-pathological joint remodelling, only possibly representing the initial stages of osteoarthritis.

The results given in Figure 7 represent the number of individuals with a grade 2 or more observation. With allowance made for missing data the results can be converted to a rate per 100 individuals, following the method of Waldron (1994). It is evident that, in all joints analysed, males exhibited more cases of osteoarthritis than females (Figure 7). The majority of the differences, though, were not statistically significant. Only the osteoarthritis in the right feet of the males was significantly different (Fisher's Exact Test value =0.0318). The foot joints, particularly the first metatarsal-phalangeal joints of both feet, showed the severest cases of osteoarthritis while the elbow was the most frequently affected joint.

It is known from clinical studies that osteoarthritis can increase with age. Therefore, it is important to establish there are no age structure differences between the males and females that might be affecting the results. The sample from Ban Lum Khao has no statistically significant age structure differences between the sexes (Fisher's Exact Test value =0.0810).

The consistently higher rate of osteoarthritis seen in males over females could indicate that the two groups were involved in different activities. Males with the higher rates may have been participating in tasks that involved more strain on the joints than females. This idea of a sexual division of labour is also supported by observations in the joints of the spine, in particular from the data on vertebral osteophytosis, analysed below.

Osteoarthritis has been shown to develop earlier in males than females, but the rate of progress is faster in females (Moskowitz 1984). This factor may be an alternative explanation for the results from Ban Lum Khao. Because there are no age differences between the sexes, the higher

level seen in males may be explained by the relatively low life expectancy of prehistoric compared to modern populations.

The comparison of Ban Lum Khao levels of osteoarthritis with those of other Thai populations (results from both sexes

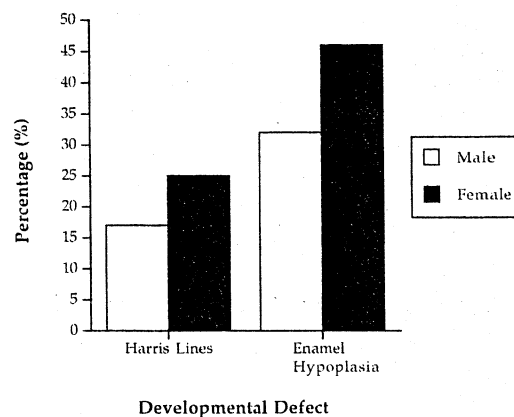


Figure 6: Percentage of individuals at Ban Lum Khao with growth disturbances.

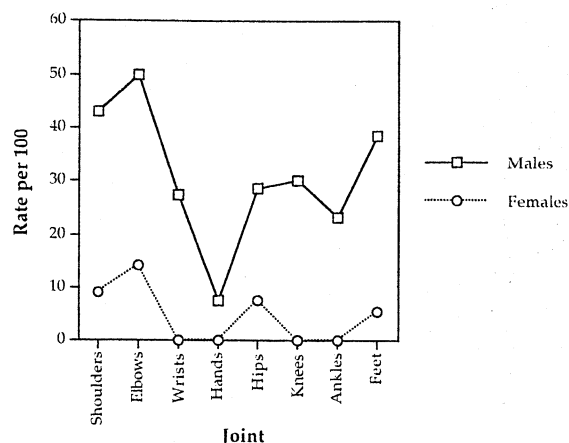


Figure 7: Rates (per 100 individuals) of osteoarthritis at Ban Lum Khao for each major joint.

Table 1: Osteoarthritis grading system

Grade	Observation
0	no changes
1	Minimal lipping (osteophyte formation)
2	Moderate lipping and/or porosity
3	severe lipping, eburnation and/or porosity
4	fusion of osteophytes/ joint fusion and immobilisation

combined) resulted in statistical differences only with Khok Phanom Di. The hands at Khok Phanom Di had significantly higher levels of osteoarthritis. This difference was probably due to the higher level of pottery manufacturing carried out at Khok Phanom Di, as investigated in an earlier study (Domett 1994, 1998). The knee joints of the Khok Phanom Di people also exhibited significantly higher levels of osteoarthritis than at Ban Lum Khao. The absence of significant differences between Ban Lum Khao and Ban Na Di may be a result of similarities in environment and therefore potentially similar types of subsistence activity.

Vertebral Osteophytosis (Spondylosis)

Vertebral osteophytosis is the degeneration of the fibrocartilaginous joints of the vertebral discs with a characteristic formation of new bone around the joint margin (Rogers *et al.* 1987). The grading is based on a similar system as for osteoarthritis, but with an emphasis on the lipping (osteophytes) around the joint margins of the vertebral bodies.

The results are presented (Figure 8) as a rate per 100 individuals, following the same equation used for the analysis of osteoarthritis. There are no confounding age structure differences between the sexes (Fisher's Exact Test value = 0.1055). Overall, males exhibited about twice the rate of degeneration in the spine compared with females. That is a rate of 43.8 per 100 males, compared with only 24.0 per 100 females (Fisher's Exact Test value = 0.3024), but the difference was only statistically significant at the thoracic level (Fisher's Exact Test value = 0.0030). This can be seen in Figure 8 where the largest difference is seen in the thoracic vertebrae between the males and females.

Vertebral osteophytosis is known to increase with age, but can also be increased by hard physical labour (Kennedy 1989). The presence of osteophytes can therefore be used as an indicator of physical activity involving strain on the back. Most osteophytes are seen in the lumbar vertebrae, which is the case in this population. The lumbar spine is known to be a particularly vulnerable area during flexion of the spine, which would include activities such as lifting heavy objects or digging.

In other prehistoric populations compared with Ban Lum Khao, all showed the same increase from cervical through to lumbar degeneration with both sexes combined. Overall, only the difference between Ban Lum Khao (31.7 per 100) and Khok Phanom Di (56.3 per 100) was large enough to be statistically significant (Fisher's Exact Test value = 0.0168). The Ban Na Di levels of spinal degeneration were closer to those of Ban Lum Khao, at a rate of 38.5 per 100.

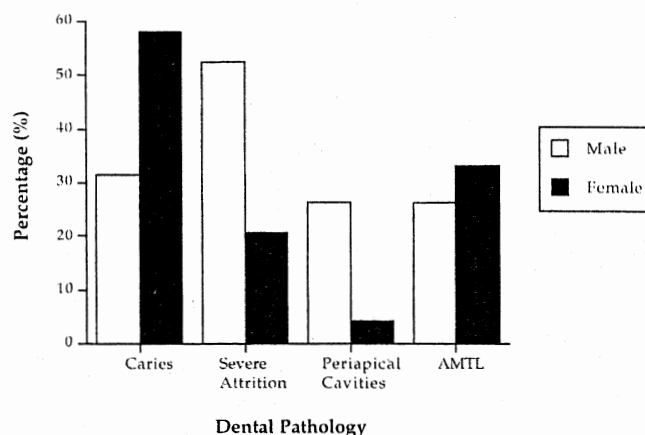


Figure 8: Vertebral osteophytosis rates (per 100 individuals) for Ban Lum Khao.

Trauma

Trauma indicates an extrinsic influence on the skeleton (Lovell 1997) from environmental and physical factors. Also, the nutritional status and genetic phenotype of an individual can predispose it to fracture, as mentioned in connection with loss of bone mass in osteoporosis (Mazess 1982). Acute trauma in the appendicular skeleton, indicative of a single traumatic event, and vertebral fatigue fractures provide evidence of repetitive stress over time.

Appendicular Fractures

There were seven fractures in six individuals at Ban Lum Khao, 2/3 male, 1/3 female, indicating a possible higher risk of injury to males than females. There appeared to be no association of risk of fracture with age. Five individuals out of the six with fractures had a break in the ulna and/or the radius. There are a number of possibilities in the aetiology of fractured forearms. They can be the result of an accident where the arms take the weight as the individual falls or, alternatively, forearm fractures are common when one is defending oneself from a blow to the face or head.

A fracture of the distal forearm or wrist was seen in Burial 65, a 40+ year-old male with a Colle's fracture of the right distal radius. Some misalignment is evident, but otherwise the fracture is well healed, with probably no reduction in ability to use the arm. This is a typical example of the result of a fall, especially in an older individual. The fracture has healed well, as have about half (4 of the 7) fractures at Ban Lum Khao, indicating some degree of care within the community and/or good levels of general health and nutrition. Neither sex showed a higher level of healing than the other.

Complications in some other cases would have been more severe and debilitating, as seen in the right ulna of Burial 98, a 35-39 year-old female. This is termed a Monteggia type I fracture with characteristic complications. These include associated dislocation of the radial head, new radio-humeral joint formation, and osteoarthritis as a result of the misalignment. A large amount of force would have been required for this to have occurred compared to the previous fracture example. This could be explained by a fall from a height (with forearm in full pronation), or a direct blow over the posterior ulna (Anderson and Meyer 1991).

Fracture patterns at other prehistoric Thai sites are much more random and infrequent in presence than at Ban Lum Khao. Each of the other three sites had examples of broken foot bones, and both Khok Phanom Di and Nong Nor had individuals with clavicular fractures. But other than these and a few other bones affected, no obvious patterns were evident.

Vertebral Fractures - Spondylosis

Spondylosis is a defect in the pars interarticularis of the vertebra. This type of fracture is often considered to be induced through chronic stress, but many individuals can also have some genetic weakness in this area making them more vulnerable to this type of problem. Continued heavy labour has been known to induce this fatigue fracture and is rarely the result of acute trauma (Merbs 1989).

The cases at Ban Lum Khao typify the epidemiology seen in modern cases. The fifth lumbar vertebra is most often affected, with males having the higher frequency than females (5 males, 3 females). Compared with the other prehistoric Thai sites, again Ban Lum Khao has the highest number of individuals with this condition, but rates incorporating the presence and absence of each vertebra are required for formal comparison and this information is not available at present.

D. DENTITION

Assessment of the dentition can provide information on diet, techniques of food preparation and food consumption, as teeth are continuously subjected to mechanical, chemical and pathogenic stressors that are all strongly influenced by dietary factors (Powell 1985). Poor dental health can have serious consequences for general physical health. All data represent the percentage of individuals with one or more teeth affected in each category.

Several indicators of poor dental health are considered. Caries is a pathological condition caused by bacteria in plaque that produce acid while digesting carbohydrates (sugars and starches). Caries destroys the tooth, usually

creating a cavity (Hillson 1996; Powell 1985). The results presented here for caries are based purely on presence or absence in each individual. Severe attrition of the occlusal tooth surface is not a pathological condition but the natural results of masticatory stress. Attrition can become pathological when wear has advanced so far that the pulp cavity is exposed and infection may result with the possibility of tooth loss (Powell 1985). Attrition is graded on a 1 through 8 scale based on the study by Molnar (1971). Severe attrition in this study is analogous to a grade of 6 to 8 on the Molnar scale, indicating pulp exposure.

Periapical cavities in the alveolar bone around a tooth indicate that an infection has passed from the dental pulp of a tooth into the periapical tissues, causing inflammation (Dias and Tayles 1997). At Ban Lum Khao the presence or absence of such cavities was recorded. Finally, antemortem tooth loss (AMTL) can be caused by a number of pathological problems, such as caries, calculus accumulation, advanced attrition or periodontal disease. The cause is not always going to be obvious as the evidence is lost when the tooth is lost. The possibility of ablation in some individuals was also investigated but could not be confirmed. Therefore, the AMTL prevalences presented here are assumed to be pathological.

Results for dental pathology

The results for each parameter (Figure 9) show the percentages of individuals with one or more teeth affected. It is evident that the prevalence of caries is higher in females than males, while higher percentages of excessive wear and periapical cavities occur in males. Neither of these differences

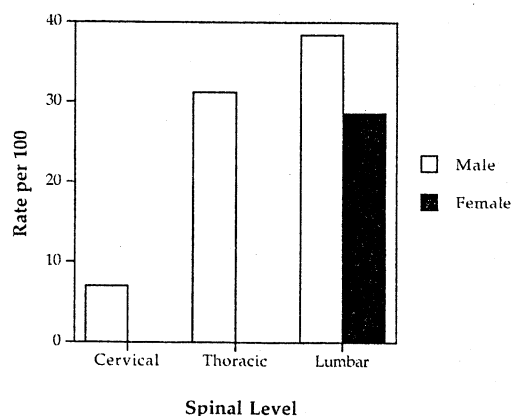


Figure 9: The percentages of individuals at Ban Lum Khao with one or more teeth exhibiting dental pathology. (AMTL = Antemortem tooth loss).

is at a statistically significant level. There is no clear difference in the levels of antemortem loss between the sexes.

The progression of many dental pathologies has a direct relationship with age, but in this sample there are no statistically significant age structure differences between the male and female group that may be affecting the results (Fisher's Exact Test value = 0.0666). This may reflect a relationship between degree of attrition and caries incidence, this being that the more a tooth is worn the fewer sites there are available for caries to become established. Caries are more likely to be established in the pits and fissures of a tooth crown, but these are the first to disappear when a tooth is worn. At Ban Lum Khao the females have the higher level of caries, possibly because they have a lower rate of tooth wear compared to the males. Males, on the other hand, have a lower level of caries incidence because they have a high level of attrition. Diet is one factor that may influence the rate of attrition and it is possible that the diets of the male and female groups were different at Ban Lum Khao.

The frequency of periapical cavities can be associated with caries or advanced attrition, as stated earlier. At Ban Lum Khao it appears that advanced attrition is the more prevalent cause of such cavities since males, with the higher levels of attrition, also have the most frequent cavities. The level of actual tooth loss is almost the same in both sexes and it is therefore possible that females lost their teeth due to caries while males lost them to the resultant infection from a high rate of attrition.

Thus, the main outcome of these results is the evidence they provide for different male and female food consumption patterns at Ban Lum Khao. A new paper (Tayles *et al.* 2000) details the differences between the four sites. Ban Lum Khao and Ban Na Di are similar in all dental parameters observed, perhaps reflecting their similar environments. The population of Nong Nor is also quite similar to Ban Lum Khao, except for its high level of severe attrition (56.5%). This may be a consequence of differing environments. Khok Phanom Di has particularly high occurrences of periapical cavities and AMTL (55.2% and 50.7% respectively), perhaps reflecting a different diet.

SUMMARY

The physical environment is the source of both the resources necessary for survival and the insults that can adversely affect a population's health and ability to survive. The cultural environment can also have adverse effects by allowing unequal access to resources, and differing opportunities to certain subgroups based on wealth, rank or sex. These factors had an impact on the health of the adult population of Ban Lum Khao and differentially affected the male and female groups.

For instance, there is evidence in the skeletal and dental biology of these people that males and females were consuming a different diet, different probably in composition rather than quantity. A coarse diet is known to increase tooth attrition so it is proposed that the males had a coarser diet and females a softer one. Another factor to be considered is that a high carbohydrate diet can increase the prevalence of caries. Carbohydrate diets are often of a softer composition, which would possibly account for some aspects of female dental health.

Growth is another parameter influenced by diet, but the variations in growth patterns at Ban Lum Khao could be explained by differing access to food resources for male children. However, no archaeological analyses of grave wealth have yet indicated that this was the case, whether in childhood or adulthood. An alternative explanation could be that males were joining this population from elsewhere and creating more heterogeneity. Overall mean stature is on par with other prehistoric Thai populations.

Another parameter influenced by the physical environment is joint degeneration. The level of technology available for subsistence activities may have played a role here. There is evidence of a sexual division of labour at Ban Lum Khao as the males consistently show more joint degeneration in both major appendicular joints and the spine, compared with females. Finally, evidence for differentials in health status between the sexes is found in the age at death results. The number of young females dying relative to males is substantially larger, probably due to the risks of giving birth.

An important indication of this study is that the population of Khok Phanom Di had a different level of health from the inhabitants of the other sites, including Ban Lum Khao, in many of the parameters analysed. Explanations for this are currently being considered, some of which are presented in Domett 2001.

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