

Social Status and Its Relationship to Non-specific Stress at Late Iron Age Non Ban Jak, Northeast Thailand

Stacey M. Ward,^{a*} Siân E. Halcrow,^a Hallie R. Buckley,^a Andrew R. Gray,^b Charles F. W. Higham,^c Kate Domett,^d Dougal J. W. O'Reilly,^e and Louise G. Shewan^f

^aDepartment of Anatomy, School of Biomedical Sciences, University of Otago, Dunedin, New Zealand

^bCentre for Biostatistics, Division of Health Sciences, University of Otago, Dunedin, New Zealand

^cDepartment of Anthropology and Archaeology, University of Otago, Dunedin, New Zealand

^dCollege of Medicine and Dentistry, James Cook University, Townsville, Australia

^eSchool of Archaeology and Anthropology, Australian National University, Canberra, Australia

^fSchool of Earth Sciences, The University of Melbourne, Melbourne, Australia

*Correspondence to: Stacey M. Ward, Department of Anatomy, University of Otago, P.O. Box 56, Dunedin 9054, New Zealand
e-mail: stacey.ward@otago.ac.nz

ABSTRACT The rise of social inequality is a key development in human history and is linked to deteriorating health. These associated health impacts are poorly understood for Iron Age (420 B.C.–A.D. 500) northeast Thailand. To clarify this issue we investigate whether social status differences influence non-specific stress at the site of Non Ban Jak (A.D. 300–800), which comprises two separate burial mounds. These mounds are thought to represent the neighborhoods of two distinct social groups at the site. Quantitative analyses were used to explore differences in grave goods among the adults of Non Ban Jak ($N=47$). Long bone lengths, ages at death, and linear enamel hypoplasia (LEH) were examined to explore differences in non-specific stress on the basis of age, sex, burial mound, and mortuary phase. Results demonstrated that older adults of both sexes, males of all ages, and west mound individuals received greater grave good quantities and may therefore have been of higher social status. West mound individuals were taller and had a lower prevalence of LEH compared to those from the east mound. Although female LEH prevalence and mortality were reduced relative to males, decreasing stature over time and high neonatal mortality indicated greater female stress. Lower-status individuals may therefore have suffered increased stress relative to those of higher status. Artifactual and epigraphic evidence supports the suggestion of sex- and class-based status differences at Non Ban Jak, legitimized and perpetuated through the adoption of residential burial and new religious ideologies.

Keywords: grave goods; inequality; health

การปรากฏขึ้นของความไม่เท่าเทียมทางสังคมเป็นพัฒนาการสำคัญอย่างหนึ่งในประวัติศาสตร์มนุษยชาติและเชื่อมโยงกับสุขภาพที่เสื่อมลง ความรู้ความเข้าใจเกี่ยวกับสุขภาพที่เกี่ยวเนื่องกับความไม่เท่าเทียมทางสังคมในสมัยเหล็ก (ประมาณ ๒,๕๐๐ – ๑,๕๐๐ ปีมาแล้ว) ในภาคตะวันออกเฉียงเหนือยังมีน้อย ดังนั้น เพื่อสร้างความเข้าใจให้ชัดเจนในเรื่องนี้ เราจึงได้ศึกษาตรวจสอบว่าความแตกต่างด้านสถานะทางสังคมมีอิทธิพลต่อความตึงเครียดหรือไม่ ทั้งนี้ เราใช้หลักฐานทางโบราณคดีจากแหล่งโบราณคดีโนนบ้านจาก (กำหนดอายุระหว่าง ๒,๓๐๐ – ๑,๒๐๐ ปีมาแล้ว) ซึ่งมีเนินหลุมฝังศพ ๒ เนิน เราเชื่อว่าเนินดินหลุมฝังศพทั้งสองเนินนี้เป็นแหล่งฝังศพของกลุ่มคน ๒ กลุ่มที่เป็นเพื่อนบ้านกัน หรือมีความใกล้ชิดทางสังคม เราใช้วิธีการวิเคราะห์เชิงปริมาณในการศึกษาตรวจสอบความแตกต่างของวัตถุที่ศพพร้อมกับหลุมฝังศพของคนในวัยที่เป็นผู้ใหญ่ นอกจากนี้ เรายังวิเคราะห์ความยาวของกระดูกแขน-ขา อายุเมื่อตาย และ

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การเสื่อมของเคลือบฟัน เพื่อตรวจสอบระดับความแตกต่างของความตึงเครียดตามเพศ อายุ/วัย กลุ่มสังคม และช่วงเวลา ผลการศึกษาพบว่าผู้ใหญ่วัยสูงอายุทั้งเพศหญิงและชาย ผู้ชายทกรวย และกลุ่มคนจากเนินฝังศพด้านตะวันตกมีจำนวนวัตถุที่มากกว่ากลุ่มคนจากเนินฝังศพทางตะวันออก และดังนั้นคนที่ถูกฝังในเนินดินฝังศพทางตะวันตกอาจจะมีสุขภาพสูงกว่าคนที่ถูกฝังในเนินดินหลุมฝังศพทางตะวันออก คนที่ถูกฝังในเนินดินหลุมฝังศพทางตะวันตกมีร่างกายที่สูงกว่าและมีการเสื่อมของเคลือบฟันน้อยกว่าคนที่ฝังที่เนินดินทางตะวันออก และแม้ว่าการเสื่อมของเคลือบฟันและอัตราการเสียชีวิตของผู้หญิงลดลงเมื่อเปรียบเทียบกับผู้ชาย แต่ผู้หญิงก็มีส่วนสูงเฉลี่ยลดลง และมีอัตราการเสียชีวิตของทารกในครรภ์สูงขึ้นตามช่วงเวลาซึ่งอาจจะแสดงว่าผู้หญิงมีชีวิตความตึงเครียด และคนที่มียุทธศาสตร์ทางสังคมต่ำก็มีความตึงเครียดมากกว่าคนที่มียุทธศาสตร์ทางสังคมที่สูงด้วย หลักฐานประเภทโบราณวัตถุและจารึกโบราณสนับสนุนว่าความแตกต่างทางสุขภาพทางสังคมและเพศที่แหล่งโบราณคดีในเนป่านจากเกิดขึ้นและดำรงอยู่ตั้งแต่สะท้อนให้เห็นจากการฝังศพในที่อยู่อาศัยและการเข้ามาของระบบความเชื่อทางศาสนาอันใหม่

The development of social inequality, defined as resource and power imbalances between groups and individuals of varying social status, is one of the most significant transitions in human history, and it is well established in both modern and ancient societies that it has resounding implications for human health¹ (Ames 2008; Earle 1987; Feinman 1995; Renfrew and Bahn 2004). Although these health impacts affect all members of unequal societies, they are magnified among individuals of lower status due to inadequate nutrition and greater exposure to unsanitary living conditions and disease vectors (Marmot 2006). This results in an increased proportion of pre-term births, increased infant, maternal, and adult mortality, and a higher prevalence of infectious disease among this portion of society (Adler et al. 1994; Di Cesare et al. 2013; Kawachi and Kennedy 1999; Marmot 2005; Morello-Frosch and Shenassa 2006; Siegrist and Marmot 2006). The indirect costs of illness, such as reduced incomes and depleted financial reserves, further exacerbate inequality through creating a cycle of poverty, institutionalizing the social position of low-status individuals over time (Leatherman and Jernigan 2014).

Consideration of the impacts of inequality is therefore of critical importance when striving to obtain a nuanced view of health in populations where social inequality is present. As a crucial component of stratified state societies, inequality is often considered in archaeological studies focusing on the pathways to state development (Trigger 2003). Inequality is recognized through evidence for the presence of institutionalized status differences between groups of differing identity. As such, investigation of social status provides a first step for understanding inequality.

Bioarchaeological studies, typically employing a biocultural perspective to study past populations, focus on how status shapes an individual's experience of the environment and how this influences health (Mays

et al. 2009; Pechenkina et al. 2017; Peck 2013; Redfern and DeWitte 2011; Reitsema and Vercellotti 2012; Robb et al. 2001; M. C. Stewart and Vercellotti 2017). Analyses of non-specific stress are commonly used in these studies as proxies for relative health (Reitsema and McIlvaine 2014; Temple and Goodman 2014), while identification of status in past populations poses a more difficult question.

Social differentiation, defined here as the differentiation of individuals based on certain identity traits (e.g., age, sex), and variation in status, defined as differences in power and prestige among differentiated individuals, are present in all societies (Price and Feinman 1995; Wason 1994). However, status is temporally, geographically, and culturally variable, and interactions between status and other facets of the identity makes its identification from the archaeological record challenging (Price and Feinman 2010; Wason 1994).

Where available, written documents may allow identification of social status differences within a community. In prehistoric societies, mortuary treatment, and particularly grave offerings, have been used to represent differences in social status (Binford 1971; Wason 1994). However, it is now well established that these items may reflect myriad other factors, such as social beliefs about life and personhood (Ross 2007), acknowledgment of status achieved throughout the lifetime (Ames 2008), and the agenda of the survivors (Fowler 2013; Parker Pearson 1982; Shanks and Tilley 1982). Despite these theoretical difficulties, there has been a recent increase in bioarchaeological research investigating status differences and health in archaeological populations from Europe, the United Kingdom, the Americas, and China (e.g., Pechenkina and Delgado 2006; Pechenkina et al. 2017; Robb et al. 2001; M. C. Stewart and Vercellotti 2017). However, these issues remain relatively unexplored in Southeast Asia.

Recent archaeological research has characterized the Iron Age (420 B.C.–A.D. 500) of northeast Thailand as a period of environmental and economic changes relating to the development of unequal

1. Here we define health as non-specific stress at the population level, acknowledging that many aspects of health (e.g., mental well-being) are not observable in skeletal remains and that health is a continuum.

societies (Castillo et al. 2018; Higham 2011, 2012, 2014, 2016; Higham and Kijngam 2012; Higham and Rispoli 2014; O’Reilly and Shewan 2015, 2016; O’Reilly et al. in press). Weakening monsoon cycles (Chawchai et al. 2015a, 2015b; Wohlfarth et al. 2016) triggered a shift to intensified wet rice cultivation during this period, evidenced by reservoir construction, new agricultural tools, and wet-field weed species at Iron Age Ban Non Wat, Noen U-Loke, and Non Ban Jak (Fig. 1) (Castillo et al. 2018; O’Reilly 2014; G. Scott and O’Reilly 2015).

The development of unequal societies following these economic and environmental shifts is suggested by the mortuary differentiation of individuals at the Iron Age site of Noen U-Loke (Higham 2014, 2016). Increasing trade of agricultural goods and private land ownership are posited to have provided the mechanisms through which enterprising individuals created and monopolized wealth, which was then represented through grave offerings in death (Hayden 2001; Higham 2012; O’Reilly 2014).

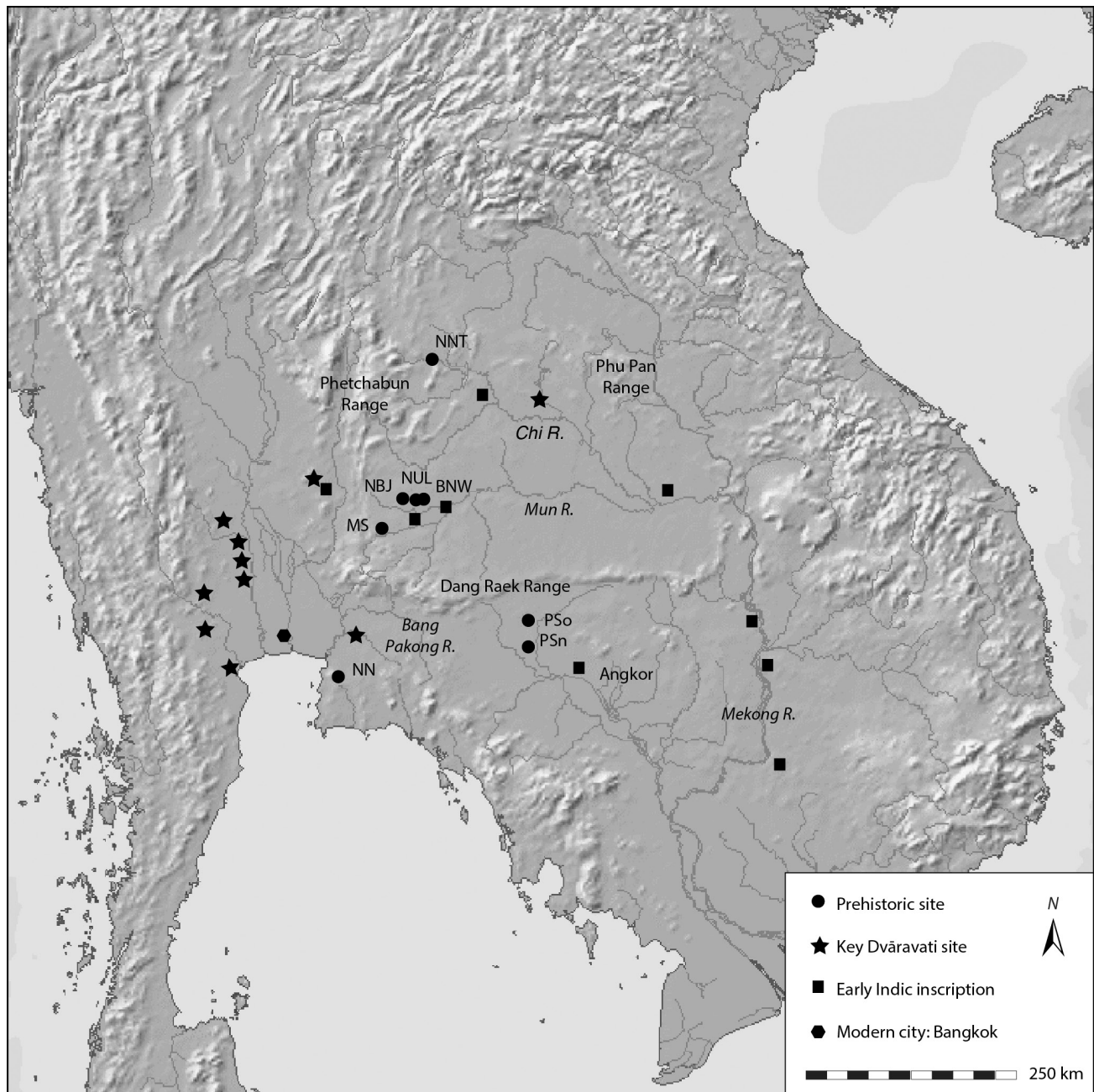


Figure 1. Map of mainland Southeast Asia situating the archaeological sites mentioned in the text. NBJ = Non Ban Jak; NUL = Noen U-Loke; BNW = Ban Non Wat; MS = Muang Sema; NNT = Non Nok Tha; NN = Nong Nor; PSo = Phum Sophy; PSn = Phum Snay. The locations of the early Indic inscriptions are drawn from Vickery (1998) and the Dvāravati sites from Murphy (2016).

In contrast to archaeological research in the area, the poor preservation of Iron Age skeletal samples in northeast Thailand has largely precluded bioarchaeological study, resulting in a limited understanding of health during this period. The limited evidence gleaned from the Iron Age phase of Ban Non Wat and the site of Noen U-Loke indicates fluctuations in oral health (Shkrum 2014), increased infant and maternal mortality and morbidity (Halcrow et al. 2008, 2016), and an increased prevalence of specific infectious diseases, suggesting a deterioration in health during the late Iron Age (Halcrow et al. 2016; Tayles and Buckley 2004; Tayles et al. 2007). An increasing reliance on wet rice agriculture, reduced dietary diversity, and landscape modification have been implicated as the chief drivers of this health deterioration (Halcrow et al. 2016; King et al. 2014, 2017).

While the development of inequality and a deterioration of health have been hypothesized for the Iron Age of northeast Thailand, investigations of the relationship between health and social status have, as

noted, been limited by poor bone preservation in this region. However, the recently excavated late Iron Age site of Non Ban Jak (A.D. 300–800) has, for the first time, provided well-preserved skeletal remains ($n = 161$) from intact mortuary contexts, allowing investigation of the relationship between social status and health. This assemblage constitutes the largest Iron Age skeletal collection in the region to date.

Non Ban Jak is notable for the presence of two distinct but contemporaneous mounds enclosed in a moat system (Higham et al. 2014) (Fig. 2). Observations during excavation revealed that west mound individuals were interred with greater numbers of iron sickles, while the houses of the east mound were thicker-walled (Higham et al. 2014). These differences in energy, labor, and resource investment have led Higham et al. (2014) to hypothesize that each mound's inhabitants represented a distinct social group within Non Ban Jak society, with the east mound representing a purported higher-status group. The separate mounds are believed to represent the "neighborhood" of each group.

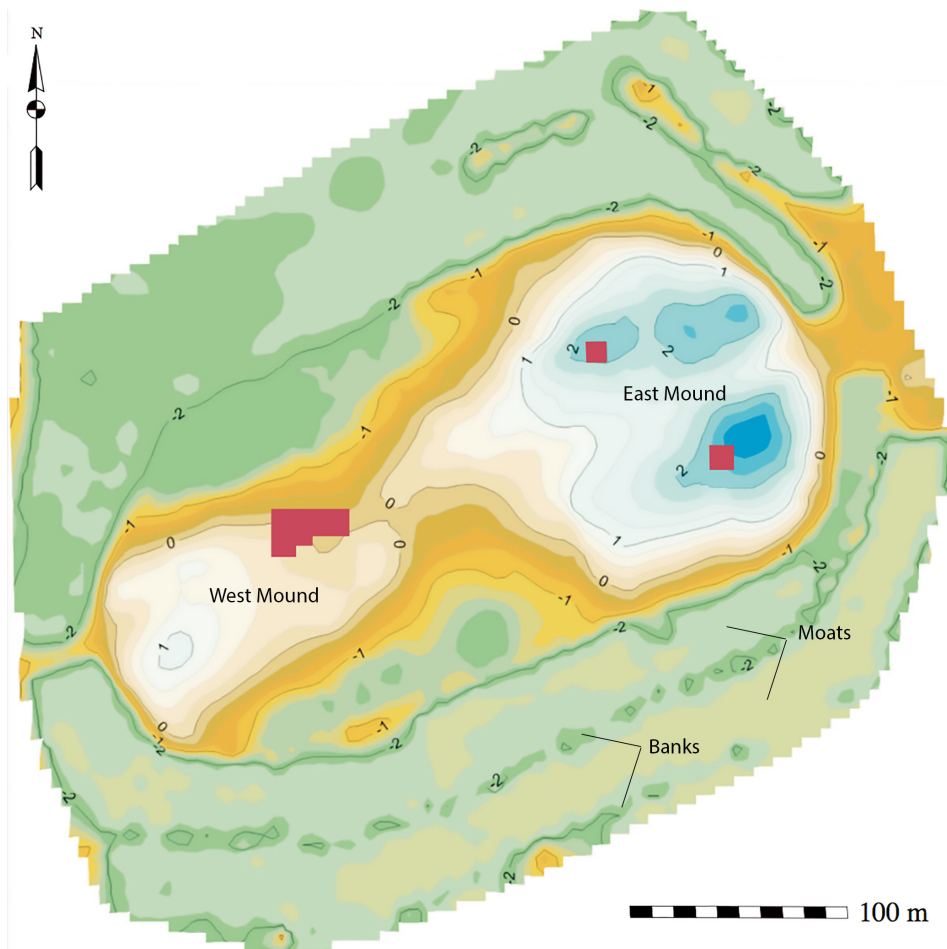


Figure 2. Map of Non Ban Jak showing the east and west mounds and the archaeological excavation areas (squares) opened between 2011 and 2017. The areas between the -1m and 2m contour lines represent the built-up mound areas, while areas between the -1m and -2m contour lines are low-lying. Image provided by permission of C. F. W. Higham and N. Chang.

The discovery of residential burial at Non Ban Jak also has significant implications for the development of social hierarchy (Higham et al. 2019). Houses are corporate landholding entities that receive social rights, duties and obligations and perpetuate themselves through the transmission of their names and wealth through kinship lines (González-Ruibal 2006). Houses can be seen as crucial for the development of inequality, as they represent the materialization of wealth and power and provide a means for its legitimization and display (Gillespie 2000; Waterson 1995). Houses may also be ranked relative to each other and may fission to produce junior and senior lineages (Gillespie 2001). As a symbolic concept, residential burial legitimizes claims to the land and reinforces entitlement to the wealth and privilege of the deceased (Gillespie 2001).

In this article we aim to investigate whether differences in grave goods quantities, representing differences in social status, were present between varying age, sex, and mound groups at the unique site of Non Ban Jak. We also seek to investigate how these possible social differences related to differing experiences of non-specific stress. Based on the archaeological and bioarchaeological information on northeast Thailand to date, we make the following predictions:

Grave good quantities will vary with age, sex and burial mound. Recently it has been argued that quantitative differences in grave goods reflect status differences in Southeast Asia (Ward 2019; also see below). Analysis of how grave good quantities vary by age, sex, and mound may therefore provide insight into the presence of status differences between these groups. This in turn may provide insight into social inequality. To determine which forms of inequality, if any, were operating at Non Ban Jak, we broadly explore grave good differences between all of these demographic categories.

Non-specific stress, represented by LEH and long bone length, will vary with sex and burial mound. Sex differences in labor, diet, and health have been identified through bioarchaeological studies of skeletal remains from various prehistoric sites in northeast Thailand, although these differences vary across sites and over time (Domett 2001; Domett et al. 2011; Douglas 1996; Foster 2011; Ikehara-Quebral et al. 2017). These studies show no clear sex differences in LEH prevalence, while male stature appears to increase in later prehistory. We therefore hypothesize that males will show less evidence of non-specific stress at Non Ban Jak. As lower status is associated with poorer health, we hypothesize that the purported high-status east mound individuals will show less evidence of non-specific stress.

Individuals with fewer grave goods will show more evidence of non-specific stress. As noted above, higher quantities of grave goods are interpreted as evidence of higher social status, while lower quantities reflect lower social status. Lower social status has been linked to poor health in both modern and bioarchaeological communities. Therefore, it is expected that at Non Ban Jak, individuals of lower status will show more evidence of non-specific stress. Evidence of greater non-specific stress will manifest as a higher prevalence of LEH, shorter mean long bone lengths, and reduced variation in long bone lengths.

Grave Goods and Social Status

Mortuary offerings are a common inclusion in burial contexts in a wide range of archaeological settings. Based on ethnographic observations, proponents of the processual perspective argued that increased grave good quality, quantity, and diversity were an accurate indicator of high status (Binford 1971; Brown 1995; O'Shea 1984; Peebles 1971). Differences in social status were seen as representative of social inequality, while the presence or absence of inequality provided insight into social organization (Binford 1971; Saxe 1971; Tainter 1978).

More recently, this approach has been critiqued as not considering human agency, ideology, or symbolism, leading to the placement of greater emphasis on the multifaceted nature of grave goods (Brown 1995; Ekengren 2013; Parker Pearson 1982, 1999; Shanks and Tilley 1982). Although grave goods are viewed as related to social status, it is acknowledged that they may not directly represent social organization due to the fluidity and multiplicity of their meanings (Chapman 2013; Ekengren 2013; Hodder 1982; Ucko 1969). For example, the form, material, frequency, and placement of items may act to obscure the meaning and function of other items (Parker Pearson 1999). Furthermore, identities represented through grave goods may be manipulated by the survivors of the deceased, demonstrating individual agency (Fowler 2013; Parker Pearson 1982; Shanks and Tilley 1982).

To address the complex nature of grave goods, new approaches have been developed that combine bioarchaeological and mortuary information to investigate social difference. "Lived" experiences represented in human skeletal remains may be contrasted with "performed" experiences represented by mortuary offerings to give insight into the overall coherence or dissonance of a society's structuring ideologies (Quinn and Beck 2016). Individual identity, community diversity, and embodied daily experiences also provide alternate routes for the bioarchaeological

analysis of social difference (Cekalovic 2014; Ross 2019; Schrader 2019; Torres-Rouff et al. 2015), while analyses of trauma and enthesal changes can be used to provide insight into power differentials and roles within society (Schrader 2015; Torres-Rouff et al. 2015).

In Southeast Asia, processually influenced material culture analyses have remained a mainstay in archaeological research. Based on a recent synthesis of 35 years of grave goods studies in Southeast Asia, Ward (2019) has argued that two levels of social signaling were used in prehistoric northeast Thailand. Age, sex, and kin group identity were likely signaled using certain symbolic items (e.g., a particular ceramic form), although these symbols varied regionally and were likely only of local significance (Bayard 1984; Cekalovic 2014; Chang 2001; Heath 2017; O'Reilly 1999; Ross 2007, 2019; see Crass 2001; Peebles 1971; Petr  1993; Shennan 1975 for discussions of sex symbolism in Europe and North America). In contrast, variation in overall grave goods quantities crosscuts this recognition of age and sex, suggesting that these quantitative differences may reflect recognition of an additional facet of the identity such as occupation, ethnicity, or kin group. Despite a lack of critical interrogation of the significance of grave good quantities in Southeast Asia, it is often assumed that they are representative of social status (Higham 2011, 2014, 2016; Talbot 2002, 2007). The current work assumes that a greater number of grave inclusions represents higher social status and that status differences may indicate the presence of social inequality. However, it is acknowledged that social phenomena such as identity, differentiation, status, and inequality are complex and interacting and that this simplistic view may not accurately reflect the use and meaning of grave goods in prehistoric Thailand.

Non-specific Stress and Its Links to Social Status

Non-specific stress occurs when external influences alter the equilibrium of the body, triggering an endocrine response (Selye 1950, 1973). This response results in biological trade-offs between survival and normal physiological function (Goodman and Armelagos 1988; Goodman et al. 1980; Sapolsky et al. 1986; Selye 1950).

Physiological trade-offs are important in the bioarchaeological analysis of human remains, as they can result in the development of non-specific stress indicators in the skeleton. These indicators provide insight into stress during periods of environmental and social change, allowing bioarchaeologists to investigate health during major human transitions. Long bone lengths are commonly used as a proxy for stature and

can represent stress-related growth disruptions in childhood (Eveleth and Tanner 1991; Jantz et al. 1994). Comparison of long bone lengths within and between populations may reveal disparities in growth that reflect variation in frailty and stress burdens. LEH represents periods of insufficient enamel secretion resulting from stress-related disruptions during tooth development (Goodman and Rose 1990, 1991; Hillson 2005, 2014).

Human clinical studies have shown that these physiological trade-offs are intensified under conditions of social inequality. While individuals may occupy the same environment, their experience of it is mediated by their social status. For example, lower-status individuals are exposed to constant "background stress" stemming from increased risk of disease and insufficient nutrition (Adler et al. 1994), leading to increased stress reactivity (G. W. Evans and Kim 2013; Lynch et al. 1998; Steptoe et al. 2003; Steptoe and Marmot 2002). Thus it is expected that low-status individuals will show more evidence of non-specific stress, although it is possible that these individuals will die before manifesting stress markers in their skeletons (Wood et al. 1992). In contrast, immune responses are strengthened in high-status individuals, suggesting that biological buffering of physiological stress can occur as a result of higher social status (Brunner 1997). However, the amount of protection provided by social status differs between and within populations, and inherent biological frailty varies between individuals, between the sexes, and across different stages of the life course (Eveleth 1975; Goodman and Armelagos 1989; Stini 1969; Stinson 1985, 2012; Tobias 1975).

Materials and Methods

Non Ban Jak and its skeletal assemblage

Non Ban Jak is located in Amphoe Non Sung of Nakhon Ratchasima province, northeast Thailand (Fig. 1). Human burials date between A.D. 300–800 (Higham 2015), placing Non Ban Jak in the Iron Age and Pre-Angkorian periods (A.D. 500–800) (Higham 2014). Site occupation is divided into an early phase (ca. A.D. 300–500) and late phase (ca. A.D. 500–800) based on radiocarbon dates, grave good assemblages, burial superimposition, and burial orientation, allowing for the investigation of change over time.

As noted above, the site is unusual for its double-peaked occupation mound (Fig. 2). Within the neighborhoods represented by each mound, clay floors and wall foundations suggestive of residential structures have been recorded, and some burials from the site have been recovered from within these domestic contexts (Higham et al. 2014). This custom,

interpreted as residential burial, has not previously been observed elsewhere in northeast Thailand (Higham 2014, 2015; but see White and Eyre 2010 for an alternate view).

The majority of the site's 161 burials contained subadults (70.8%, 114/161) (Table 1), with the site having the highest infant and child mortality rates in prehistoric Southeast Asia to date (Buckley et al. in press). The adults of Non Ban Jak (defined as individuals aged 20 years or older) with secure age and sex estimates ($N = 47$) form the focus of the current investigation. The adult skeletal assemblage of the west mound ($n = 41$) is larger than that of the east mound ($n = 6$), although each mound is divided into roughly equal portions of early and late phase individuals (east, three early and three late; west, 21 early and 20 late). The skeletal assemblage as a whole is also divided into roughly equal portions of early ($N = 24$) and late phase individuals ($N = 23$).

Assessing social status at Non Ban Jak: Grave goods analysis

Three groupings of grave goods were explored, adapting category-focused methods established in previous studies of social status in Southeast Asia to increase the comparability of research in this region (e.g., Cekalovic 2014; Higham et al. 2019; Talbot 2002): the total number of items per individual, probable artifact function ("functional categories"), and construction material ("material categories"). Functional categories included ornamental items such as jewelry, utilitarian items such as knives, and "other" items. Material categories comprised clay, metal, stone, glass, shell, and "other." Ceramic items were included as their own functional category, as ceramic vessels may have both ornamental and utilitarian value. Items defined as "other" included eggshells, rounded pebbles, and rice. Although the use of grave good categories requires classifications to be made regarding possible artifact use and construction material, we seek to avoid biased "value" judgments on the meaning and worth of each object (Talbot 2002). Following this system, we have not attempted to define "other" objects to avoid making biased judgments regarding their function (Cekalovic 2014).

Assessing mortality and non-specific stress at Non Ban Jak: Age and sex estimation, osteometrics, and LEH

Adult age-at-death estimation was performed based on visual observations of morphological changes in the pubic symphysis and auricular surface (Brooks and Suchey 1990; Lovejoy et al. 1985), late fusing epiphyses (Buikstra and Ubelaker 1994), morphological

changes of the sternal ends of the ribs (İşcan et al. 1984, 1985), and dental wear (Smith 1984). All adults were placed into broad age categories in keeping with previous bioarchaeological research in Southeast Asia (Tayles and Halcrow 2016): young adult (20–30 years old), middle adult (30–40 years old), and old adult (40+ years). Adult sex estimation was based on observations of cranial and pelvic morphology following Bruzek (2002), Buikstra and Ubelaker (1994) and Phenice (1969). Adult individuals of indeterminate age and sex as well as individuals lacking complete long bones or teeth were excluded from analysis, leaving a total of 47 adults available for the grave goods study, 36 for the long bone length study, and 38 for the LEH analysis.

To investigate stress-related growth disruptions, maximum length measurements were taken for the tibia, fibula, humerus, radius, and ulna, and bicondylar length was measured for the femur following Buikstra and Ubelaker (1994). All measurements were taken using an osteometric board. To investigate the level of long bone asymmetry, intraclass correlation coefficients (ICCs) were estimated using a one-way random effects model for absolute agreement for long bone measurements paired by side. For all long bones, individual ICCs were above 0.91, indicating "excellent" agreement (Koo and Li 2016) (Supporting Information, Online Table S1). Measurements from the left side were given preference but when absent, measurements from the right side were substituted due to low asymmetry.

Macroscopic recording of LEH defects has been a mainstay in bioarchaeological studies of health, and a number of methods have been developed for their analysis. This has resulted in a lack of standardized methods for LEH research. Recently, researchers have also argued for the adoption of microscopic analysis of LEH due to its increased objectivity (Cares Henriquez and Oxenham 2017, 2019). However, these techniques are not yet widely applied in Southeast Asia, and to increase the comparability of the current study to those previously performed in the region, a conservative macroscopic technique was employed.

Criteria for the inclusion of individuals were the presence of at least two teeth with visible buccal or labial surfaces and at least 50% of the crown remaining. The buccal or lingual surfaces of each tooth were macroscopically investigated under natural outdoor light, and LEH were identified as continuous grooves spanning at least 50% of the tooth's width. A flat-edged wooden probe and 5x magnification hand lens were used to confirm LEH presence, and defects were recorded following the Fédération Dentaire Internationale Developmental Defects of Dental Enamel Index (1982). For calculation of the age at defect formation, the distance from the occlusal edge of each defect to the cemento-enamel junction (CEJ) was

Table 1. Demography of the aged and sexed portion of the Non Ban Jak assemblage (N = 161).

Age	East Mound						West Mound						Site Total	
	Females		Males		Total		Females		Males		Total		All Sexes	
	n	%	n	%	n	%	n	%	n	%	n	%	n	%
<0 months	0	0.00	0	0.00	3	7.50	0	0.00	0	0.00	17	14.05	20	12.42
0-0.9 months	0	0.00	0	0.00	3	7.50	0	0.00	0	0.00	18	14.88	21	13.04
1-11.9 months	0	0.00	0	0.00	19	47.50	0	0.00	0	0.00	26	21.49	45	27.95
1-4.9 years	0	0.00	0	0.00	3	7.50	0	0.00	0	0.00	8	6.61	11	6.83
5-9.9 years	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	2	1.65	3	1.86
10-14.9 years	0	0.00	0	0.00	1	2.50	0	0.00	0	0.00	1	0.83	2	1.24
15-19.9 years	1	2.50	1	2.50	4	10.00	2	1.65	3	2.48	3	2.48	8	7.45
Young	1	2.50	3	7.50	4	10.00	4	3.31	5	4.13	9	7.44	13	8.07
Middle	1	2.50	0	0.00	1	2.50	10	8.26	8	6.61	18	14.88	19	11.80
Old	1	2.50	0	0.00	1	2.50	6	4.96	8	6.61	14	11.57	15	9.32
Sex total	4	10.00	4	10.00	32	80.00	22	18.18	24	19.83	75	61.98	121	100.00
					40	100.00					121	100.00	161	100.00

measured using Mitutoyo digital calipers following Buikstra and Ubelaker (1994). Age at formation was then calculated following Goodman and Rose (1991:289). Age at crown completion and years of formation were obtained from Schour and Massler (1940:1920), and average crown heights for each tooth were calculated from unworn teeth from the Non Ban Jak assemblage. Defects were then matched chronologically between the teeth to ensure that only defects representing systemic stress were included (e.g., Clark et al. 2014; Goodman et al. 1980; Littleton 2005). To be considered representative of systemic stress, a defect had to have formed in the same chronological unit as at least one other defect from at least one other tooth. Other forms of enamel hypoplasia (e.g., plane form defects) were excluded from the study due to the difficulty of assigning these defects an age at formation for chronological matching (Hillson and Bond 1997).

Statistical analysis

All statistical analyses were selected accounting for small sample sizes (Morgan 2017). To investigate variation in grave good quantities where likelihood ratio tests indicated excessive variation within the data distribution, negative binomial regression with incidence rate ratios (IRRs) was used (StataCorp 2019). Where the likelihood test was not significant, Poisson regression was used instead. In both cases, models were developed in a step-forward manner by adding terms, including interactions, depending on sample sizes.

Descriptive statistics were calculated for long bone lengths by sex, mortuary phase, and mound to investigate general trends. Quantile regression was then employed following a backwards selection strategy to investigate the statistical significance of these trends. A Wald test was used to evaluate the simpler model compared to the previous “parent” model. Quantile regression was selected, as it models median values and is therefore less influenced by outlier effects than mean-based regression methods (A. Stewart 2016).

Recent bioarchaeological research has shown that greater stress in a community may result in reduced variation in stature (DeWitte and Hughes-Morey 2012; Hughes-Morey 2016; Vercellotti et al. 2014). To test this hypothesis at Non Ban Jak, Levene’s tests for equality of variance were used to assess the statistical significance of differences in long bone length variation between groups.

Chi-squared tests were used to investigate differences in LEH prevalence and demographics between age, sex, phase, and mound groups. Where 20% or more of the cells of the contingency table had expected cell

counts under five, Fisher’s exact tests were employed (Kim 2017). All statistical analyses were performed using StataCorp Stata/IC 15.1 for Mac, and the threshold for statistical significance was set at $p < 0.05$. The data that support the findings of this study are available from the corresponding author upon reasonable request.

Results

Variations in grave goods quantities at Non Ban Jak

Grave goods analyses are summarized in Online Tables S2–S7.

Investigation of univariable models showed that total grave goods quantities did not increase significantly with age, and so age was excluded from subsequent modeling (IRR = 1.10, $p = 0.286$). Grave goods quantities were significantly increased among males (IRR = 1.75, $p = 0.045$), late phase individuals (IRR = 2.16, $p = 0.003$), and individuals from the west mound (IRR = 3.39, $p = 0.009$). A main effects model was then adopted, which confirmed the increase in grave goods among males (IRR = 1.59, $p = 0.043$), late phase (IRR = 2.22, $p < 0.0001$), and west mound individuals (IRR = 3.7, $p = 0.006$) when adjusting for the other variables. Interactions models including phase by mound, mound by sex, and phase by sex interactions revealed that only the diachronic change in sex differences in grave goods was significant (Wald test, $p = 0.017$). This interaction showed that the disparity in grave goods between males and females equalized over time when mound differences in grave goods were removed.

Univariable analysis showed that late phase individuals were interred with significantly greater numbers of ceramics (IRR = 1.82, $p = 0.024$), numbers of metal items (IRR = 2.65, $p = 0.007$), and quantities of utilitarian items (IRR = 9.56, $p < 0.001$) relative to early phase individuals. West mound individuals received significantly greater numbers of ornaments (IRR = 3.42, $p = 0.039$). Adjusted models and interactions could not be assessed for the functional and material categories due to small sample sizes, and so confounding interactions of phase and mound cannot be excluded.

Age structure of the mounds

The west mound comprised a larger assemblage of adult skeletal human remains ($n = 41$) than the east mound ($n = 6$). The east mound had a higher percentage of young adults relative to the west mound, while adults of middle and old aged comprised the largest percentage of the west mound assemblage (Table 1).

Meanwhile, equal percentages of males and females were present in both mounds. The differences in age group percentages between the mounds were not statistically significant (Fisher's exact test, $p = 0.106$). Small sample sizes in the east mound precluded statistical analysis of sex differences between the east and west areas of the site.

Non-specific stress at Non Ban Jak

Descriptive statistics for adult long bone lengths show that male mean long bone lengths increased over time (Table 2). Among the females, long bone lengths decreased over time with the exception of the tibia and fibula. Long bone lengths were largest in the west mound for both males and females (Table 3), while west mound males had greater variation in long bone lengths, represented by the standard deviation and

coefficient of variation, than west mound females. In the east mound, females had a greater variety of long bone lengths than males ($p > 0.187$, Online Table S8).

However, an interaction model, which explored whether the sex differences in long bone length changed over time while adjusting for mound differences, was non-significant in all long bones (all interaction $p \geq 0.303$, Table 4). A main effects model exploring the adjusted associations between sex, phase, and mound showed that west mound individuals had longer long bone lengths than east mound individuals. However, this difference was not statistically significant in any bone except the radius ($p = 0.034$, all other $p \geq 0.196$, Table 5).

Although a slight increase in the prevalence of LEH with age was observed from young adults to older adults, this increase was not statistically significant (Fisher's exact test, $p = 0.276$). As such, analyses by sex,

Table 2. Descriptive statistics for long bone lengths by sex and phase.

Long Bone	Sex	Early Phase ($n = 22$)					Late Phase ($n = 14$)				
		<i>n</i>	Mean (cm)	SD	CV	Median (cm)	<i>n</i>	Mean (cm)	SD	CV	Median (cm)
Femur	Female	8	42.04	1.19	0.029	41.95	3	41.04	2.59	0.063	40.00
	Male	7	44.44	1.71	0.039	44.50	7	45.04	2.39	0.053	44.80
Tibia	Female	6	34.84	1.34	0.038	35.19	2	36.55	1.06	0.029	36.55
	Male	6	38.25	1.92	0.050	37.85	5	39.59	2.30	0.058	40.10
Fibula	Female	5	34.21	1.66	0.049	34.50	1	36.90	–	–	36.90
	Male	5	36.34	1.89	0.052	35.63	1	39.60	–	–	39.60
Humerus	Female	8	29.65	1.14	0.039	30.02	2	28.06	3.01	0.108	28.07
	Male	7	31.43	1.56	0.050	32.00	6	31.58	1.13	0.036	31.49
Radius	Female	8	23.10	1.11	0.048	23.50	3	23.03	1.58	0.069	23.90
	Male	7	25.60	1.49	0.058	25.60	5	25.70	1.80	0.070	25.17
Ulna	Female	9	24.90	1.22	0.049	25.30	3	24.86	1.70	0.069	25.70
	Male	4	26.63	0.61	0.023	26.60	5	28.00	1.88	0.067	27.07

Key: SD = standard deviation; CV = coefficient of variation.

Table 3. Descriptive statistics for long bone lengths by sex and mound.

Long Bone	Sex	Early Phase ($n = 7$)					Late Phase ($n = 29$)				
		<i>n</i>	Mean (cm)	SD	CV	Median (cm)	<i>n</i>	Mean (cm)	SD	CV	Median (cm)
Femur	Female	2	40.95	2.57	0.063	40.95	9	41.95	1.47	0.035	41.40
	Male	3	43.33	1.82	0.042	43.00	11	45.13	1.98	0.044	44.80
Tibia	Female	0	–	–	–	–	8	35.27	1.43	0.041	35.59
	Male	2	36.41	0.87	0.024	36.42	9	39.40	1.91	0.049	40.10
Fibula	Female	0	–	–	–	–	6	34.66	1.84	0.053	34.85
	Male	3	35.17	0.40	0.011	35.00	3	38.59	1.63	0.042	39.47
Humerus	Female	2	28.45	3.56	0.125	28.45	8	29.55	1.05	0.036	30.02
	Male	3	30.95	2.11	0.068	31.10	10	31.66	1.11	0.035	31.75
Radius	Female	2	21.38	0.26	0.012	21.39	9	23.46	0.91	0.039	23.90
	Male	3	24.53	0.95	0.039	24.20	9	26.01	1.57	0.060	25.30
Ulna	Female	3	24.10	1.25	0.052	24.00	9	25.15	1.23	0.049	25.33
	Male	2	26.66	0.89	0.034	26.67	7	27.60	1.70	0.062	27.00

Key: SD = standard deviation; CV = coefficient of variation.

Table 4. Wald tests assessing the overall significance of the phase by sex interactions model, which investigated change over time between the sexes while removing mound differences.

Long Bone	<i>n</i>	p-value
Femur	25	0.321
Tibia	19	–†
Humerus	23	0.758
Radius	23	0.303
Ulna	21	0.833

†Small sizes (<20) precluded the exploration of interactions for the tibia.

mound, and phase were conducted using a pooled adult age sample to increase sample sizes. These analyses showed that males, late phase, and east mound individuals had a higher prevalence of LEH relative to females, early phase, and west mound individuals, respectively (Table 6). However, none of these changes were statistically significant.

Discussion

Social status differences at Non Ban Jak

The adults of Non Ban Jak received differing quantities and types of grave goods depending on their age, sex, and mound affiliations, although only sex and mound differences were statistically significant. As argued above, grave good *types* are believed to signal age and sex identity, while variation in grave goods *quantities*

crosscuts typological groups and is believed to represent another aspect of identity, such as kin group, ethnicity, or occupation. In Southeast Asian archaeology, grave goods quantities are believed to represent social status differences, following the processual perspective outlined above. To explore this issue, the findings presented above are contextualized against artifactual and epigraphic analyses spanning the prehistoric, protohistoric, and historic periods of Southeast Asia.

At Non Ban Jak, young individuals of both sexes received fewer grave items relative to older individuals, although this difference was not statistically significant. Age-based status differences are suggested by variations in grave goods quantities and types at the prehistoric sites of Ban Non Wat, Noen U-Loke, and Nong Nor (Fig. 1) in northeast and central Thailand (Cekalovic 2014; Chang 2001). More recent material culture research in the region has focused on prehistoric mortuary artifacts as markers of identity and personhood (Cekalovic 2014; Heath 2017; Lim 2018). For example, specific ceramic types have been linked to adult and subadult age categories at Non Ban Jak, suggesting that age was symbolized through grave goods in late prehistory (Heath 2017; Lim 2018).

Turning to the historic period, inscriptions dating to A.D. 1500–1600 from Cambodia suggest that age was recognized in addition to social class (Ebihara 1984:294). A parallel is seen in earlier pre-Angkorian inscriptions (A.D. 600s), which recognize a number of social age groups among children (Vickery 1998). Together, these findings suggest that grave goods may

Table 5. Quantile regression: main effects model assessing how long bone lengths change between the sexes, east and west mounds, and over time while adjusting for the effects of each co-variable.

Long Bone	<i>n</i> Observed	Predictor	Level	Coefficient	95% CI	<i>p</i> -value
Femur	25	Constant	Early East Females†	39.36	36.58, 42.14	<0.001
		Sex	Male	3.63	1.36, 5.90	0.003
		Phase	Late	–0.23	–2.25, 2.11	0.837
		Mound	West	2.03	–0.76, 4.83	0.146
Tibia	19	Constant	Early East Females†	32.73	27.69, 37.76	<0.001
		Sex	Male	4.29	1.35, 7.24	0.007
		Phase	Late	0.79	–2.19, 3.79	0.577
		Mound	West	2.27	–2.53, 7.07	0.330
Humerus	23	Constant	Reference	29.10	26.86, 31.33	<0.001
		Sex	Early East Females†	2.00	0.09, 3.90	0.041
		Phase	Late	–0.53	–2.54, 1.48	0.588
		Mound	West	0.89	–1.33, 3.13	0.410
Radius	23	Constant	Early East Females†	22.05	20.26, 23.83	<0.001
		Sex	Male	2.15	0.67, 3.62	0.006
		Phase	Late	–0.85	–2.40, 0.70	0.268
		Mound	West	1.94	0.16, 3.73	0.034
Ulna	21	Constant	Early East Females†	24.33	22.92, 25.73	<0.001
		Sex	Male	1.70	0.35, 3.04	0.016
		Phase	Late	0.40	–1.00, 1.80	0.556
		Mound	West	0.96	–0.55, 2.49	0.196

Key: CI = confidence interval. Bold values are statistically significant.

†The coefficient for the model constant is the median long bone length for early east mound females.

Table 6. Crude prevalence for linear enamel hypoplasia by age, sex, phase, and mound.

Age	Sex	Early Phase						Late Phase						Age, Phase, and Mound Totals																											
		East			West			East			West			Early Phase Total		Late Phase Total		East Mound Total		West Mound Total		Age Total																			
		A	O	P(%)	A	O	P(%)	A	O	P(%)	A	O	P(%)	A	O	P(%)	A	O	P(%)	A	O	P(%)	A	O	P(%)																
Young	Female	0	0	0	2	2	100	1	1	100	1	1	100	2	2	100	2	2	100	1	1	100	3	3	100	11	11	100													
	Male	2	2	100	0	0	0	0	0	0	5	5	100	2	2	100	5	5	100	2	2	100	5	5	100	11	11	100													
Middle	Female	0	0	0	2	3	67	0	0	0	4	4	100	2	3	67	4	4	100	0	0	0	6	7	86	12	15	80													
	Male	0	0	0	3	5	60	0	0	0	3	3	100	3	5	60	3	3	100	0	0	0	6	8	75	12	15	80													
Old	Female	0	0	0	0	2	0	1	1	100	1	2	50	0	2	0	2	3	67	1	1	100	1	4	25	9	12	75													
	Male	0	0	0	2	2	100	0	0	0	5	5	100	2	2	100	5	5	100	0	0	0	7	7	100	11	11	100													
Grand Totals		11						16						69						21		22		95		4		4		100		28		34		82		38		84	

Key: A = affected; O = observed; P(%) = prevalence.

reflect the attainment of age-related milestones in prehistoric Southeast Asia, although recognition of milestones and the presence of inequality may not be mutually exclusive.

Females of all ages at Non Ban Jak received statistically significantly fewer grave items than males, suggesting a social difference between the sexes. Evidence of sex-based inequality has previously been identified at the Bronze Age site of Non Nok Tha, where males received increased quantities of grave goods and greater energy expenditure on burial rites over time (Bacus 2006). This trend continued into the Iron Age at Noen U-Loke, where females received fewer grave goods relative to males (Cekalovic 2014; Chang 2001).

In contrast, queens have been identified in the later pre-Angkorian period (A.D. 500–800), suggesting that women were active political players at this time (Andaya 1994, 2007; Jacobsen 2003). However, while land ownership was passed through the maternal line (Jacobsen 2003), the use of male titles and an emphasis on male ancestry was still required in order to legitimize female leadership (Jacobsen 2003; Vickery 1998). Royal manipulation of descent rules for personal gain throughout this period is likely to have created fluctuations in the relative statuses of males and females (Jacobsen 2003; Vickery 1998).

The adoption of Brahminism and Buddhism during the late Iron Age and pre-Angkorian period further encouraged the development of an increasingly patriarchal society (Andaya 1994; Jacobsen 2003:361–362). Buddhist ideologies were key to the development of the proto-Dvāravati (A.D. 300–400) and Dvāravati (A.D. 600–1000) cultures in central Thailand (Glover 2010; Murphy 2016) (Fig. 1), while both Brahminism and Buddhism were significant in Funan (A.D. 100–600) in the Mekong Delta and early Khmer polities in central Cambodia (Briggs 1999; Stark 2004; Terwiel 1975) (Fig. 1).

The presence of Buddhist icons in the upper layers of the east mound of Non Ban Jak and Dvāravati deposits at Muang Sema to the west of Non Ban Jak (Fig. 1) suggest contact between northeast and central Thailand in the pre-Angkorian period (Higham and Kijngam in press; Higham et al. 2019; Talbot and Jantred 2001). Contact between early Cambodia and northeast Thailand is also suggested through the presence of northeast Thai Phimai Black ceramics at the sites of Phum Sophy and Phum Snay in northwest Cambodia (Domett and O'Reilly 2009; O'Reilly et al. 2008).

The appearance of brick temples, inscriptions, and changing settlement patterns in northeast Thailand after this period of contact suggests a cultural transition in northeast Thailand, leading C. Evans et al. (2016) to argue that agrarian villages such as Non Ban

Jak may have been absorbed into regional polities to form supply centers. While the links between Non Ban Jak and epigraphic accounts of increasing patriarchy are tenuous, we hypothesize that contact between these polities and Non Ban Jak led to the adoption of new social ideologies for legitimizing sex-based status differences. However, more research is needed to test this theory and determine the nature, timing, and duration of these putative contacts.

This article has demonstrated that east mound individuals of all ages and sexes received significantly fewer grave goods than those from the west mound. This difference may reflect mortuary recognition of social differences between the mounds. Possible social differences are now explored, before presenting the argument for the presence of a class system at Non Ban Jak.

The spatial separation of east and west mound graves may reflect the spatial embodiment of differences in age, sex, ideology, and ethnicity as well as practical divisions of the living and the dead (Binford 1971; Goldstein 1981; Meskell 1998; Parker Pearson 1993, 1999; Ucko 1969). Segregation may also represent social exclusions related to class differences, or interactions of multiple factors outlined above (Delle 1998; Reidpath et al. 2005). However, spatial statistical analysis at Non Ban Jak has revealed no segregation of individuals based on age or sex, or health status (Ward 2019), and isotopic evidence has shown that very little migration of isotopically unique people occurred in northeast Thailand in the Iron Age. This suggests that Non Ban Jak is a genetically homogeneous population, although isotopic analysis does not exclude the possibility of migration of isotopically similar groups (Cox et al. 2011; Schalburg-Clayton et al. 2018). As such, the mounds are not likely to represent different populations.

As evidenced by inscriptions in inland Cambodia, polities containing distinct social classes existed concurrently with Non Ban Jak (Vickery 1998). These social classes are thought to have formed out of ranked lineage groups, with higher social status given to more senior family lines (Vickery 1998). Given the presence of class societies contemporaneous with Non Ban Jak and differences in grave goods quantities between the east and west mounds of this site, we argue that spatial differences between the east and west mounds of Non Ban Jak reflect a putative kinship-based class structure. It is hypothesized that residential burial provided a mechanism for the formation and legitimization of these social classes.

Residential burial and the presence of *physical* houses at Non Ban Jak are suggestive of *social* houses, which provide a lineage-based route for the transmission of wealth accrued through trade (Higham

et al. 2019; O'Reilly 2014). Furthermore, house burials provide a means of claiming land through the interment of ancestors, suggesting the possibility of ownership of residential mound areas at the site. However, it is unclear whether these residential mound areas were owned by "houses" or "classes" and whether ownership extended to the surrounding agricultural land. No evidence for this (e.g., banded rice fields) has been observed in prehistoric northeast Thailand to date, although banded, irregularly oriented rice fields indicate that separate collective, yet private, land ownership existed in Iron Age Cambodia (Hawken 2013). It is clear that more research is needed on this compelling issue, particularly as control of agricultural areas may have provided a valuable pathway for wealth accrual.

Exploring non-specific stress and its links to social status at Non Ban Jak

Although growth disruptions leading to short stature and LEH occur as a result of childhood stress and cannot provide information on adult health, identification of variations in the prevalence of these stress indicators between adult age groups may provide information on short-term (e.g., generational) fluctuations in health within a population. Considered together, they may also provide insight into selective mortality and heterogeneity in frailty, which are among the key tenets of the osteological paradox (DeWitte and Stojanowski 2015). Therefore, differences in stress between adult age groups are briefly discussed.

The stress indicators investigated paint varying pictures of adult health at Non Ban Jak. Variation in stature is considered first. As noted above, the inhabitants of northeast Thailand are thought to represent a homogeneous population (Cox et al. 2011; Schalburg-Clayton et al. 2018). Analysis of stature at Non Ban Jak is therefore likely to reveal social, rather than biological, differences between age, sex, phase, and mound groups.

This study has demonstrated that young adults experienced increased variation in long bone lengths relative to older adults. According to recent bioarchaeological research, greater stress in a community may result in reduced variation in stature, as frail individuals who would typically become short adults are removed from the population through natural selection (DeWitte and Hughes-Morey 2012; Domett 2001; Hughes-Morey 2016; Vercellotti et al. 2014). As such, variation in long bone lengths may provide insight into selective pressures acting on a population. Following this argument, increased variation in stature among young adults at Non Ban Jak may be linked to reduced mortality risk during childhood. Stature variation may also be used as an indicator of

social organization (e.g., Domett 2001). For example, Domett (2001) argues that low variation in stature reflects equal access to resources, which creates equal opportunity for all individuals to reach their genetic potential for stature. Therefore, reduced variation may reflect a more egalitarian social structure. However, to affect childhood health, status must be inherited. Where status is achieved over time, it is likely that all young individuals would receive similar treatment in childhood and that stature variation would result from variation in frailty and selective mortality, rather than differences in status.

However, consideration of LEH evidence alongside stature suggests a contrasting perspective. The higher prevalence of LEH observed among young adults indicates *increased* early life exposure to stress. When stature is reinterpreted in the context of high subadult mortality and prevalent LEH at Non Ban Jak, it is likely that in the increased variation in stature may paradoxically represent conditions of high mortality (Wood et al. 1992). Furthermore, LEH has been linked to lowered life expectancy, particularly in young adults and males (Boldsen 2007; DeWitte and Wood 2008; Palubeckaitė et al. 2002; Steckel 2005). The fact that these individuals died as young adults may therefore be reflective of selective mortality, and as such, childhood stress burdens may have been higher among this age group (DeWitte and Stojanowski 2015; Wood et al. 1992). This suggests the presence of short-term fluctuations in stress levels between generations at Non Ban Jak.

Patterns of age at death, LEH prevalence, and stature provide conflicting information regarding stress levels among the sexes. Results showed that female mortality reduced over time, stature decreased, and LEH prevalence decreased, while males showed the opposite trends. Two interpretations may be drawn from this information and are discussed below.

A number of researchers have argued that males experience higher mortality risk and reduced survivorship compared to females, suggesting that an interpretation of greater male stress may be more applicable to Non Ban Jak (Eveleth 1975; Stini 1969; Stinson 1985; Tobias 1975). The first possible interpretation builds on this argument: High levels of mortality among the males may reflect inherent frailty exacerbated by exposure to physiological stress. Increases in adult male stature are therefore paradoxically attributed to high mortality in childhood, which removed frail short individuals prior to their reaching adulthood and entering the adult sample (e.g., Wood et al. 1992). This interpretation accords with the stressful childhood environment suggested by the high prevalence of LEH among the males. However, this perspective is challenged by the fact that many male individuals still survived to form defects and to reach

adulthood, suggesting moderate robusticity among the males from the site.

The second possible interpretation draws on the osteological paradox, arguing that females may have experienced social disadvantage that increased their frailty. Here we argue that low mortality among females may be a product of selective mortality, as the frailest individuals would have died in childhood, reducing mortality risk in adulthood (Wood et al. 1992). The purported higher mortality among the females suggests that fewer females would have lived long enough during childhood to form LEH (Hillson and Bond 1997), which may explain the reduced LEH prevalence observed among the Non Ban Jak females. More robust female individuals who survived childhood may have been unable to reach their genetic potential for stature due to inadequate conditions for growth during development, reducing female stature (Bogin 1999; Eveleth and Tanner 1991; Stinson 2012).

High neonatal mortality rates at the site also provide support for this argument (Table 1). Deaths in the neonatal period (0–1 month postpartum) are attributed to high maternal stress, which clinical studies have demonstrated results in higher rates of pre-term birth and neonatal and maternal mortality (Austin and Leader 2000; Bourgeois-Pichat 1951; Dole et al. 2003; Lewis and Gowland 2007; S. Scott and Duncan 1999). Therefore, female stress burdens at Non Ban Jak are likely to have been high relative to those of the males. An increased prevalence of pre-term births and infant, maternal, and adult mortality is seen among low-status individuals in modern populations (Adler et al. 1994; Di Cesare et al. 2013; Kawachi and Kennedy 1999; Marmot 2005; Morello-Frosch and Shenassa 2006; Siegrist and Marmot 2006). This supports the suggestion of lower social status among the Non Ban Jak females made above and suggests that low status had a negative effect on health among these members of the Non Ban Jak community.

The small sample sizes involved in this study make differences in non-specific stress between the east and west mounds difficult to discern, and the following interpretations are offered with caution. Results showed that west mound individuals, interred with greater quantities of grave goods, had taller stature, a lower prevalence of LEH, and reduced subadult mortality (66.11%, 41/121) relative to the east mound individuals (85%, 34/40), suggesting that they represent a less stressed portion of the community. In contrast, the east mound may represent the more impoverished, and more stressed, members of the community. While the most robust individuals in the east mound survived into adulthood, they appear to have been unable to recover from childhood stress, represented by reduced stature relative to the west mound adults.

However, an alternative interpretation for the mound differences in non-specific stress is possible. Paradoxically, shorter stature may indicate decreasing stress in a population (Costa 2012; Hughes-Morey 2016; Wood et al. 1992). This suggests that the shorter-statured east mound may have suffered less stress. However, this argument does not account for stress-related increases in frailty among survivors, which have the effect of increasing mortality risk even under normal conditions (DeWitte and Hughes-Morey 2012; DeWitte and Wood 2008; Yaussy and DeWitte 2018; Yaussy et al. 2016). In addition, paradoxical views are negated by the high levels of subadult mortality and greater prevalence of LEH in the east mound (Buckley et al. in press), which suggest high stress in early childhood. Given the conditions of stress, the reduced mortality seen among east mound adults is likely to be an illusion created by selective mortality (Wood et al. 1992). This interpretation of greater stress in the east mound accords with established inequality literature, which demonstrates that lower social status is associated with poorer health (Dahl et al. 2006; Dunn and Hayes 2000; Kawachi and Kennedy 1997, 1999; Leon et al. 1992; Murali and Oyebode 2004; Pickett and Wilkinson 2015; Siegrist and Marmot 2006; Wilkinson and Pickett 2009).

Differences in stress burdens between the mounds may represent the different social roles of the putative classes at Non Ban Jak, varying exposure to disease environments as a result of these roles, and status-based buffering of stress. Analysis of skeletal trauma at Non Ban Jak demonstrates a higher prevalence of injuries related to agricultural activity in the east mound, suggesting that east mound individuals represent an agricultural laborer class (Pedersen et al. 2019). The transition to wet rice agriculture itself is also likely to have had severe repercussions on health, including providing habitats (e.g., rice paddies) for colonization by parasites and their vectors (Halcrow et al. 2016; Higham et al. 2019; King et al. 2017). While certain risks would likely be common to all inhabitants of Non Ban Jak (e.g., exposure to parasites in food), individuals undertaking agricultural activities potentially suffered greater exposure to these pathogens via their occupation. Furthermore, evidence for animal husbandry in this period suggests the possibility of zoonotic transfer of infectious diseases through ingestion of contaminated animal products and exposure to cough spray among agricultural workers (e.g., Cossivi et al. 1998).

In contrast, disease profiles observed among the inhabitants of the west mound may relate to greater disease exposure through trade, as proposed for the presence of leprosy and tuberculosis at Noen U-Loke (Tayles and Buckley 2004). A preliminary analysis of pathology at Non Ban Jak has indicated the presence

of at least two possible cases of leprosy and nine cases of possible tuberculosis, all but one of which are found in west mound individuals (Buckley et al. in press).

To summarize, evidence for variation in grave goods quantities by sex and mound suggests the presence of status differentiation at Non Ban Jak, while variation in stress suggests that the site's inhabitants experienced variable health based on social identity. Gendered divisions of labor, diet, and health have previously been identified elsewhere in the region, suggesting that the foundations of unequal societies may have been established earlier and built upon in the Iron Age (Douglas 1996; Newton et al. 2013; Pietruszewski and Douglas 2002).

Conclusion

This article presents an assessment of the relationship between social status and health in prehistoric north-east Thailand. This assessment, limited previously by poor bone preservation in the Iron Age of Southeast Asia, is one of very few focusing on health and status in this region and time period. We have demonstrated, on the basis of a grave goods analysis, that there may be sex- and class-related status differences at Non Ban Jak. Previous archaeological studies and epigraphic evidence support these interpretations, demonstrating the presence of sex and class differentiation in prehistoric and historic Southeast Asia, while the concept of a house society may provide a mechanism for the development of a class society at the site. The analysis of non-specific stress indicators suggests that stress burdens varied according to social identity and social status and that low social status relates to poorer health in this community.

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Supplemental Materials

Supplemental tables may be found online with the electronic version of the article.

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