Trauma and conflict in prehistoric Southeast Asia: A life of war or peace?

Thesis submitted by

Lucille T. Pedersen BA (Hons)

March 2017

For the degree of

Master of Research (MPhil)

College of Medicine and Dentistry

James Cook University

Statement on the contribution of others

This thesis includes unpublished skeletal data collected by others such as A/Professor Kate Domett (James Cook University), Professor Hallie Buckley (University of Otago), A/Professor Nancy Tayles (University of Otago), Professor Marc Oxenham (Australian National University), and A/Professor Troy Case (North Carolina State University). I was responsible for analyzing and interpreting that data for the final synthesis of results.

Financial support for this thesis was provided by the James Cook University Research Training Program, and fieldwork funding came in the form of an Australian Research Council Grant (DP110101997 - Drs. D. O'Reilly and L. Shewan) and a Marsden Fund (Professors H. Buckley, C. F. W. Higham and Dr. S. Halcrow).

Statement of Sources

I declare that this thesis is my own work and has not been submitted in any form for another degree or diploma at any university or other institution of tertiary education. Information derived from the published or unpublished work of others has been acknowledged in the text and a list of references given.

Lucille T. Pedersen

09 March 2017

Acknowledgements

First and foremost I would like to thank my supervisors, A/Professor Kate Domett, Dr Nigel Chang and Dr Sian Halcrow for their support, encouragement and advice. Special thanks go to Kate for keeping me on track and motivated.

Thank you to Kate Domett, Professor Hallie Buckley, Dr Sian Halcrow, and Stacey Ward who conducted sex and age estimations on the Non Ban Jak skeletal sample, data which I could then use in this thesis. Thank you to Kate and Hallie for their valuable expertise in trauma analysis.

Professor Charles Higham was always willing to share knowledge and research, as well as a sense of humour. Thanks also to Dr Rachanie Thosarat and the amazing Thai excavation team at Non Ban Jak. Thank you to the National Research Council of Thailand and the Fine Arts Department for providing the research permit.

Valuable expertise in interpreting skeletal pathology from radiographs, photographs and notes was given by Dr Luke Watson from the University of Queensland. Much patience and endurance was shown by the radiography staff, Mr Anusak Thammaraksa & Mrs Jarungsri Boonkuson, at Phimai Hospital in Thailand where the radiographs of skeletal fractures were taken.

And of course, nothing could have been achieved without the support and care I received from my very understanding family.

Abstract

This study is the first comprehensive analysis of trauma prevalence representing a range of temporal and geographic contexts from eighteen sites across Myanmar, Thailand, Cambodia and Vietnam and includes new skeletal analysis data from Iron Age Non Ban Jak in northeast Thailand. The aim of this thesis is to use evidence of skeletal trauma combined with material evidence of defensive architecture, weapons and military paraphernalia to test if there was increase in trauma prevalence, especially resulting from interpersonal violence, from the Neolithic to the Iron Age.

A statistically significant increase in trauma prevalence was observed between the Neolithic and the Iron Age. The patterning of injuries and the similar prevalence of trauma in both sexes in the Neolithic is indicative of accidental mechanisms, with the exception of two cases of cranial trauma suggesting that interpersonal violence may have been experienced by at least some individuals. Trauma prevalence increased in the Bronze Age with males experiencing almost twice as many injuries as females. The presence of craniofacial injuries and defensive parry fractures to the distal ulna at some sites are indications of interpersonal violence but there is no evidence for large-scale warfare such as the mass production of weapons, fortification, and military paraphernalia that is present in the Iron Age. There is three times more craniofacial trauma in the Iron Age than the Bronze Age and eight times more than is present in the Neolithic. Several cases of violent trauma are present at the Iron Age site of Noen U-Loke in northeast Thailand and the majority of cranial injuries are observed at Phum Snay in northwest Cambodia, along with evidence of weapons in the burials of individuals identified as warriors.

A combination of sociocultural and environmental circumstances are considered to have stimulated the increasing prevalence of trauma and the development of several ‘hot spots’ of intense conflict in the Iron Age. These include the expansion of the Han Dynasty from China into northern Vietnam that coincided with the construction of military fortifications and mass production of weapons at the late Iron Age site of Co Loa. Historical records indicate military activity in the Greater Angkor region, northeast Thailand and northern Vietnam. During the same period, sociopolitical change was influenced by exposure to new ideologies, religion and technology during contact with

well-established state societies such as India and China through a maritime exchange network. Also, early complex polities were forming as part of the manufacturing and trading centres in northern Vietnam and the Mekong delta region. These factors, in conjunction with significant environmental changes, partly driven by human adaptations, increasing population density and climate change, likely led to competition over resources and territory that instigated cycles of peace and increasingly violent conflict in Southeast Asia. Future excavations that focus on areas around these ‘hotspots’ of conflict may assist in further determining the conditions for the development of violent conflict and/or warfare.

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Chapter 1

Introduction

The prehistoric period c. 4000 BC – 800 AD (Early Neolithic to the Late Iron Age) is an important period of transformation in Southeast Asia during which the region underwent increasing social complexity as a consequence of population increase, environmental shifts, the introduction of new agricultural practices and metallurgical technologies, trade with distant populations, and socio-political reorganisation. How individuals and whole populations are affected by, and respond to, these changes to their social, physical and cultural environment is in many ways reflected in their skeletal remains. These changes are often the catalyst for interpersonal violence, and the skeletal remains, combined with archaeological information can illuminate why conflict was enacted. Interpretation of trauma can indicate lifestyle choices, cultural practices, and human interactions between groups and with their environment, that may have been present in prehistoric communities exposing people to risk of injury (Lovell 2008; Scott & Buckley 2010).

Trauma is defined as "injury to living tissue that is caused by a force or mechanism extrinsic to the body, whether accidental or intentional" (Lovell 2008:341). To truly be able to determine the relationship between trauma and violent behaviour, a distinction must first be made between accidental and intentional injury. An injury caused by human hostility is considered to be intentional interpersonal violence (Walker 2001). The World Health Organisation defines interpersonal violence to include violence between kin and intimate partners (domestic violence), and community violence, such as brawls, between strangers and/or acquaintances (Waters *et al.* 2004). Suicides and collective violence such as war and state-sponsored conflict do not fall into the category of interpersonal violence. Warfare has been defined as "armed and potentially lethal encounters between groups of politically autonomous populations…that can plan and execute collective violent action." (Arkush & Tung 2013:4). Acts of war may range in scope from crusades, raids and ambushes, massacres, sieges, military incursions, and feuding between kin groups (Arkush & Tung 2013; Christensen 2004; Martin 2016).

In modern clinical and forensic studies depressed skull fractures, fractures to facial bones or ribs, and fractures of the middle and distal ulna shaft are commonly associated with violent behaviour, especially if multiple injuries occur from a single incident (Brook & Wood 1983; Lovell 1997). These types of injuries are often sustained in close combat, in an attempt to ward off blows or flee from an attacker (Juengst *et al.* 2015; Lovell 1997; Steyn *et al.* 2010; Walker 2001). Wounds from weapons, for instance, a projectile still embedded in bone, are a clear indication of conflict (Lessa & Mendonça de Souza 2004). A high prevalence of trauma in males is suggestive of a population experiencing conflict, as most cultures send their men off to fight (Lovejoy & Heiple 1981; Scott & Buckley 2014; Vencl 1984). Men are also found to be more likely to engage in high-risk activities and fights due to competition with each other, whilst in most societies fewer women are directly engaged in intergroup conflict (McCall & Shields 2008; Wagner *et al.* 2002).

In contrast, if random accidents are responsible for the injuries an equal ratio of male/female trauma is likely to be seen, as accidental trauma is typically the result of an unplanned and unexpected incident, usually with a single injury occurring (Walker 2001). Certain types of fracture, such as a transverse fracture of the distal radius, midshaft clavicle, or femoral neck are commonly associated with trips or falls and sporting injuries (Lovejoy & Heiple 1981; Smekal *et al.* 2009). Skeletal trauma patterns may reflect the variety of risks associated with participation in different activities. Reference is made to males participating in occupational activities with high-risks, such as felling trees, hunting wild animals, herding cattle, fishing at sea, and working further from home to conduct these activities, while females have been suggested to participate in less physically demanding activities within proximity to the home, such as gathering shellfish, pastoral duties, tending to domestic animals, and foraging (Djurić *et al.* 2006; Judd & Roberts 1999; Lessa 2011).

However, patterns in gender division of labour have been found to vary between cultures and are related to environment, subsistence practices and social complexity, and these can change through time (Johnson & Earle 2000; Shoocongdej 2002). Rock art in western Thailand sites dating from c. 2000 BC – 1 AD depict men hunting wild buffalo and cows, herding cattle and firing arrows. Females appear to have roles relating to ploughing fields and herding animals (Shoocongdej 2002). Males and females at Ban

Non Wat have been identified through skeletal analysis to have likely participated in similar levels of laborious activities but patterns of subsistence activities may have changed from the Neolithic to the Iron Age to include the introduction of metallurgy and the intensification of rice agriculture (Foster 2011). At Neolithic Man Bac in northern Vietnam, Foster (2011) identified gender divisions in labour that may have been related to subsistence strategies and socioeconomic specialisation associated with the way the population exploited the surrounding environment.

All fractures and lesions need to be examined in conjunction with contextual evidence and possible mechanisms of injury need to be identified to determine if the injuries are from an accidental or intentional incident. This information can then be used to ascertain if the trauma observed in prehistoric populations has a violent aetiology. Skeletal trauma, along with the archaeological evidence of conflict in past populations, has been suggested to be the result of a series of changes such as the migration of people into new territory, environmental insecurity, politically motivated violence stemming from increased social tension, amalgamation of nucleated settlements, and increased competition over resources (Christensen 2004; Domett *et al.* 2011; Martin 2016; McCartney 2012; O'Reilly 2008).

Gheggi (2016) observed that violence may have escalated in certain populations in the Ancient Andes of northwest Argentina (c. 900 – 1450 AD) due to a series of severe droughts. This led to increasing conflict, including raids and ambushes, over threatened resources and a period of social and political unrest. Lessa and Mendonça de Souza (2004) found an increase in violence between males during a period of social and economic transition. The skeletal trauma on the males suggested their participation in hand-to-hand combat that could have been due to socially endorsed ritual or intergroup conflict. In southeast Alaska and Queen Charlotte islands (c. 200 – 500 AD) evidence of warfare was seen in the fortification of settlements, the merging of settlements under one centralized rule, and skeletal evidence of violent injury and death that included wounds from weapons (Maschner 2014). However, Maschner (2014) concluded that the conflict was not the result of a single reason, such as a scarcity of resources, but rather the amalgamation many reasons that could result in conflict lasting many generations.

By combining the research of the prevalence of trauma in prehistoric Southeast Asian populations with analysis of archaeological evidence of conflict, and studies of the cultural environment, a more rigorous and complete picture of life and death in past societies will be gained, and may shed light on the causes of interpersonal violence and warfare.

The purpose of this study

This thesis will conduct new bioarchaeological research on a recently excavated late Iron Age skeletal series from Non Ban Jak in the upper Mun Valley, northeast Thailand (Figure 1.1) to examine the prevalence and patterning of traumatic injury combined with archaeological evidence for warfare such as weapons and defensive architecture. This new data will be combined with existing studies to holistically test the hypothesis that trauma prevalence increased over time. Attention will be focused on a broader regional bioarchaeological perspective as opposed to narrow localised studies to increase the understanding of past behaviours as well as the cultural and environmental stressors that lead to trauma and conflict in earlier societies. For instance, Underdown (2012) described how social play could be a reason for skeletal trauma in a population from Tierra del Fuego; Shimelmitz and Rosenberg (2013) investigated ritual fighting in prehistoric Southern Levant; and Šlaus *et al.* (2012) argue that a temporal increase in bone fracture rates recorded in the Eastern Adriatic indicate not only an increase in intentional violence but also a dramatic lifestyle change. Interpersonal violence and accidental injury are frequently discussed as causes of skeletal trauma in Southeast Asia, and although warfare has been discussed, most commonly on a local scale (Chetwin 2001; Domett & O'Reilly 2009; Li *et al.* 2009; O'Reilly 2003; Oxenham *et al.* 2001; White & Eyre 2011), conclusive evidence of warfare has been difficult to determine.

Study area

This study will focus on prehistoric mainland Southeast Asia, a region incorporating an area within the modern borders of Vietnam, Thailand, Cambodia, Laos and Myanmar (Burma) (Figure 1.1).

Figure 1.1. Topographic map of mainland Southeast Asia study area and major river systems

Background and significance

A number of skeletal assemblages, representing the Neolithic to the Iron Age, have recently received detailed analysis reviewing health, disease and lifestyle (for example Clark *et al.* 2013; Domett & O'Reilly 2009; Domett & Buckley 2012; Halcrow & Tayles 2008; Halcrow *et al.* 2008; Halcrow *et al.* 2013; Nelsen *et al.* 2001; Oxenham 2006; Oxenham *et al.* 2008; Oxenham *et al.* 2005; Oxenham & Domett 2011; Pietrusewsky & Douglas 2002; Pietrusewsky & Ikehara-Quebral 2006; Tayles 1999; Tayles *et al.* 2007). In comparison, trauma analysis in skeletal assemblages of prehistoric Southeast Asian populations has received far less attention, with the literature currently limited to a few bioarchaeological studies (Domett 2001; Domett & Tayles 2006; Domett & O'Reilly 2009; Domett *et al.* 2011; Oxenham 2006; Oxenham *et al.* 2001; Tayles 2003), along with observations of trauma briefly mentioned in further literature (Matsumura *et al.* 2011a; O'Reilly 2008; Oxenham & Matsumura 2011; Pietrusewsky & Douglas 2001; Pietrusewsky & Ikehara-Quebral 2006; Tayles *et al.* 1998). Of this literature, there are only a few researchers making in-depth comparisons of types of traumatic injury found in different skeletal series. The first published detailed comparative study of trauma in Southeast Asia was made by Domett and Tayles (2006) who tabulated adult fracture rates of four skeletal series in Thailand and made some synthesis of this information with other prehistoric sites from Thailand and Vietnam. Oxenham *et al.* (2001) and Oxenham (2006) compared fracture frequencies of sites from prehistoric northern Vietnam, Thailand and Japan; whilst Domett and O'Reilly (2009) and Domett *et al.* (2011) made trauma comparisons between Phum Snay and sites in northeast Thailand.

The study by Domett and Tayles (2006) compared the four prehistoric Thailand sites of Khok Phanom Di, Nong Nor, Ban Lum Khao and Ban Na Di and found a tenfold increase in long bone fractures between the Neolithic and Bronze Age. Domett and Tayles (2006) suggested this could be linked to a change in subsistence activities with the intensification of agriculture. Domett and Tayles (2006) also noted that the prevalence of distal ulna fractures and craniofacial fractures in the Bronze Age samples could suggest that interpersonal violence was experienced by low numbers of individuals. Oxenham *et al.* (2001) observed that in northern Vietnam, the Neolithic population of Con Co Ngua were more at risk of fracture to the major long bones than Metal Age populations. Overall, even though historical evidence suggests warfare in northern Vietnam, the skeletal evidence and lack of weaponry suggests that interpersonal violence was not common during the Metal period in Vietnam (Oxenham 2006). Oxenham (2006) suggests that serious traumatic injury from Con Co Ngua could be related to factors such as large-game hunting or misadventure and interpersonal violence could not be discounted.

The majority of archaeological excavations in Southeast Asia are concentrated in Thailand and Vietnam, and to a lesser extent, Cambodia. Due to long-standing political instability and remoteness, archaeological excavations are still very limited in Laos and Myanmar (Tayles *et al.* 2012). Man Bac is the most intensely studied Neolithic bioarchaeological site in Vietnam (n = >95), and Con Co Ngua, possibly the earliest Neolithic burial site in Southeast Asia, has shown increasing bioarchaeological potential with the recent discovery of a further 146 well preserved burials that are yet to undergo skeletal analysis. A few other prehistoric sites from Vietnam, such as Lung Hoa have produced only a small number of poorly preserved human remains (Oxenham *et al.* 2009). Until recently, the majority of the archaeological projects conducted in Cambodia were concerned with the late Angkorian period, post-800 AD rather than the prehistoric period (O'Reilly *et al.* 2006a). The Vat Komnou cemetery presently has the largest excavated archaeological skeletal assemblage from Cambodia with 111 human burials (Ikehara-Quebral 2010), whilst other prehistoric Cambodian sites have produced low numbers of provenanced skeletal samples that usually have very poor preservation (Phum Snay, n=23; Phum Krosaing Thmei, n=8; and Prei Khmeng, n=7 (Domett & O'Reilly 2009). Phum Snay and Phum Sophy also have skeletal remains from ossuaries (n= 134 and 37 respectively) but these are comprised of isolated bone elements that lack stratigraphic provenance. In comparison prehistoric Thailand has the largest excavated archaeological skeletal assemblage ever recovered in Southeast Asia, at Ban Non Wat (n = 696). Sites located within Thailand, such as Non Nok Tha, Nong Nor, Khok Phanom Di, Ban Chiang, Noen U-Loke, Ban Lum Khao, and Non Ban Jak have each recorded between 100 and 200 burials of varying states of preservation, whilst Ban Na Di, Ban Pong Manao and Phromthin Tai contain between 27 and 78 burials.

Although the majority of skeletal assemblages are relatively small, the human remains have provided a direct link to the life of individuals and communities in the past and information on prehistoric health, disease, and lifestyle and population history. Oxenham and Buckley (2015) recognised that the Southeast Asian region has its own complex characteristics but has been relatively ignored in world prehistory and the bioarchaeological record. They have combined the research of leading experts in mobility patterns, mortuary traditions and population relationships as well as health and disease, recognising that such a publication would encourage a wider interest in the bioarchaeology of prehistoric Southeast Asia. Direct evidence of prehistoric trauma and conflict however, is currently sparse in Southeast Asia and there is a need for a similar anthology of research to gain a regional context and contribute to the understanding of prehistoric societies worldwide.

Domett *et al.* (2011) provided a detailed examination of skeletal material and grave goods from Phum Snay in which the presence of warfare was suggested not only by the high prevalence of cranial trauma, but also by the increased frequency of trauma in males and the contextual evidence showing that the majority of military specific grave goods such as long and short swords, projectile points and epaulettes were buried with males. The size of the longest swords, over a metre in length, suggests their use was as weapons rather than for ceremonial purposes. There was very little evidence for disease in the skeletal remains, indicating the general health was adequate, leading to the conclusion that people were dying prematurely by accident or violence rather than through disease (Domett & O'Reilly 2009).

At Noen U-Loke in Thailand, trauma was observed in two individuals that possibly occurred in combat, an adult male who was found with an iron projectile point located *in situ,* lodged in his spine, and a female with her skull violently cleaved (Higham & Thosarat 2007; Tayles *et al.* 2007). There was also evidence of conflict through burial goods of iron spears and knives. Further cranial injuries were also observed at five other sites in Thailand, two sites in Vietnam and Vat Komnou in Cambodia also had one individual observed with cranial trauma. It has been suggested by Arkush and Tung (2013) that cranial trauma and defensive settlement patterns often align and are related to the scale and severity of conflict, however, only three of these sites (Phromthin Tai, Ban Non Wat and Noen U-Loke) are surrounded by moats, and defence has been one of the possible reasons given for their construction (Vencl 1984).

Currently there is much debate amongst researchers about whether or not the presence of moats indicates defensive settlement behavior (Kojo & Pheng 1998; Maschner & Reedy-Maschner 1998; Moore 1989; Moore 1988; Nitta 1991; O'Reilly 2014; Villabhotama 1984). Higham *et al.* (2014a) suggest that the moats surrounding late Iron Age settlements in the upper Mun Valley of northeast Thailand had a defensive purpose. Especially when they coincide with the increased production of iron projectile points and a possible rise in conflict between rival settlements (Higham & Rispoli 2014). Moore (1988) also suggested that the construction of moats can represent ownership over territory as well as provide a physical barrier that can protect the population from not only wild animals, but also human attackers. Dega (1999) similarly describes the embankments and ditches of the Neolithic circular mounds in Cambodia and Vietnam as a two-way defensive barrier that serves to protect livestock and the human inhabitants, whilst warding off undesirable animals and humans.

Other possible explanations for the role of moats in prehistoric Southeast Asia have been considered, such as religious or cult practices (Moore 1989; O'Reilly 2008); aquaculture (Higham 2011c; Mudar 1999); or to symbolise kinship relations (O'Reilly 2008). Boyd *et al.* (1999b) argue that the earlier sites of northeast Thailand utilised former river channels or natural wetlands that encircled naturally formed mounds. In later stages of development it appears that the inhabitants mimicked these natural features to establish artificial moats and embankments around settlements, most likely for water storage for domestic and agricultural use, or water control to mitigate against flooding in the monsoon season (Higham 1996; Higham 1998; Moore 1989; Moore 1988; O’Reilly 2014; Villabhotama 1984).

The main cause of disparity in determining the function of moats encircling mounded sites in Southeast Asia is that there are currently no standard criteria for identifying defensive features, which has led individual researchers to interpret the role of ditches and embankments in very different ways. According to Keeley *et al.* (2007) many authors insist that a ditch can only be defensive if it has a height and width greater than several metres. In contradiction, Dega (1999) believes that a height of 1.5 -2.0 metres is sufficient for defence, as is the case at the Neolithic Eastern Cambodian and Western Vietnamese settlements. But these ditches also have an average width of 22 metres which would assist with the defensive function, such as slowing down the advancement of attackers. Shallow moats can also be reinforced with wooden palisades (Blanchard 2011; Larson 1972; Malleret 1959; Peña-Monné *et al.* 2014; Stark & Sovath 2001) which would form a difficult obstacle for an enemy attacker to negotiate. The characteristics of a defensive structure will normally be determined by the type of perceived threat. For instance, ditches may not have been constructed to abate human invaders, but instead to deter wild animals, such as elephants from entering settlements or destroying crops (Fernando *et al.* 2008). The required geometry of the ditches and embankments would not necessarily be the same for each threat.

The time, energy and material resources that go into building defensive structures for protection of a settlement can indicate the level of threat perceived by the population (Golitko & Keeley 2007; Lambert 2002). In other words, the more elaborate the ditches and ramparts, the greater threat of attack and therefore a greater willingness to take into consideration not only the cost of labour and resources but also reallocating people away from subsistence activities to build these defences (Larson 1972; Milner 1999). The level of defences could also indicate the degree of competitiveness for local resources (Higham 2011c), and the need to protect these resources from an outside threat. For example, excavations at Iron Age Co Loa in northern Vietnam uncovered a defensive structure consisting of a ditch and platform system that may have functioned as a guardhouse, a watchtower, or even a firing platform for projectiles (Keeley pers. comm. in Kim *et al.* 2010:1017). To date, these are the earliest known fortifications within Vietnam (Kim *et al.* 2010). During the late Iron Age northern Vietnam was experiencing incursions by the more powerful Han China to the north and these defensive structures were likely constructed to counter this threat and from regional competition over territory, the best agricultural land and natural resources (Kim *et al.* 2010; Kim 2013a).

In central Myanmar, the Tircul (or Pyu) established themselves as the dominant population during 2nd – 9th AD (O'Reilly *et al.* 2006a). They created garrison towns and large fortified sites with religious and administrative centres, as well as impressive hydraulic works (O'Reilly *et al.* 2006a). Only a few publications (Moore & Win 2007; O'Reilly *et al.* 2006a) give any form of detailed analysis of Myanmar prehistoric settlements, and within those publications there are only four sites that are described as having moats and walls. It still remains to be seen how much of Southeast Asia was affected by conflict, and what the exact relationship is between rates of trauma, the fortification of settlements, and increasing social complexity. This will be investigated in the following chapters.

Higham and Rispoli (2014) suggest that the presence of spears and arrowheads indicate a rise in conflict, and while long swords found only in male burials may be easily interpreted as weapons for combat, other mortuary offerings such as projectile points, axes, knives, daggers, and spear-heads can be more difficult to interpret in terms of conflict. Knives and axes have been associated with domestic and agricultural use (Higham & Rispoli 2014), and projectile points have been described as possible hunting weapons (Matsumura *et al.* 2011a). However, in certain circumstances their use in violence can be implied, such as in the case of the young adult male found buried with a projectile point lodged in his spine (Higham & Thosarat 2007; Walker 2001). Other material items that could be interpreted as evidence of conflict, such as ceramic shoulder decorations (epaulettes) have been recovered as burial goods (Domett & O'Reilly 2009); and looters have found items they described as bronze helmets, however, none have been excavated in situ with burials (Domett *et al.* 2011).

Missing from the prehistoric archaeological record in Southeast Asia is armour, but this could have been made from biodegradable materials such as bamboo or hide (Chetwin 2001). Iconographic evidence of warfare from the Dong Son Iron Age culture centred in the Red River Valley of present day Vietnam (c. 100 BC – 1 AD) consists of decorated bronze drums and large vessels depicting scenes of warriors holding weapons (Chetwin 2001; Higham 1996). A bronze burial vessel containing the remains of an infant was recovered from another Dong Son site, Hop Minh. This was decorated with images interpreted to be of warriors in war canoes (Ha Van Phung 1995, cited in Higham 2002:174). Although the skeletal and artefactual evidence for violent trauma is currently minimal in Southeast Asia, there is enough to suggest that conflict was part of prehistoric life. Factors such as looting at excavated sites and taphonomic processes could explain the lack of substantial metal weaponry found. Weaponry may also have been omitted from the mortuary ritual (O'Reilly 2008).

Interpretation of historical and ethnographic evidence of conflict in the Iron Age and protohistoric period of Southeast Asia indicates that from the mid first millennium, many elites had formed polities in northern Vietnam that began competing for economic wealth and political dominance through military power (Kim *et al.* 2010). During this time ritual bronze drums from the Dong Son culture in northern Vietnam were depicting scenes with war canoes, warriors brandishing spears, bows and arrows and holding captives (Higham 2004; Millar 2012). Inscriptions from Late Iron Age/protohistoric Chenla period (c. 550-800 AD) document that elites from the first ruling Angkorian dynasty conducted military excursions up the Mun River, which Higham (2014c) suggests could possibly have induced the abandonment of many sites in northeast Thailand in the Late Iron Age. This military activity may also account for the most violent trauma observed in that region in the late Iron Age.

Aims, hypothesis and objectives

The aim of this study is to advance the understanding of the causes of violent conflict and traumatic injuries in prehistoric Southeast Asia and the sociocultural and environmental factors that shape these actions.

It is hypothesised that over time there will be an increase in trauma prevalence, as risk of injury increases in response to burgeoning population density, increasing socio-political complexity and environmental changes during the transition from the Neolithic to the Iron Age.

To test the hypothesis the following objectives will be addressed:

1. Complete a comprehensive review of published research on trauma and conflict in prehistoric mainland Southeast Asia,

2. Gather and analyse new evidence of trauma in the Late Iron Age skeletal sample from Non Ban Jak, northeast Thailand,

3. Conduct statistical and qualitative analyses on the combined data from each skeletal series. Existing literature and archaeological reports including indicators of warfare such as fortification, weapons and military paraphernalia will be studied and incorporated into a critical analysis.

By consolidating these studies into one thesis, a long-overdue and unprecedented regional synthesis will be compiled. This will represent a comprehensive resource for a comparative analysis of trauma and conflict in Southeast Asia, adding to the overall understanding of socioeconomic and cultural development within prehistoric societies.

Thesis outline

This chapter has explored the purpose of this study and provided background and significance. Chapter 2 will provide an overview of how the Neolithic, Bronze Age and Iron Age periods were defined by changes in material culture, technology, mortuary ritual, weapons and social complexity. Chapter 3 will introduce the archaeological site of Iron Age Non Ban Jak in northeast Thailand and the methods used to examine the new skeletal material, whilst Chapter 4 will discuss the skeletal trauma data collected from Non Ban Jak. Chapter 5 summarises the published research on skeletal trauma for Southeast Asia, which is followed by the results section, Chapter 6, where the new Non Ban Jak skeletal trauma data is combined with the published research for a temporal analysis of trauma prevalence. Chapter 7 is a discussion of the results, followed by suggestions for future research and the concluding remarks.

Chapter 2

Southeast Asia

Neolithic to the Iron Age

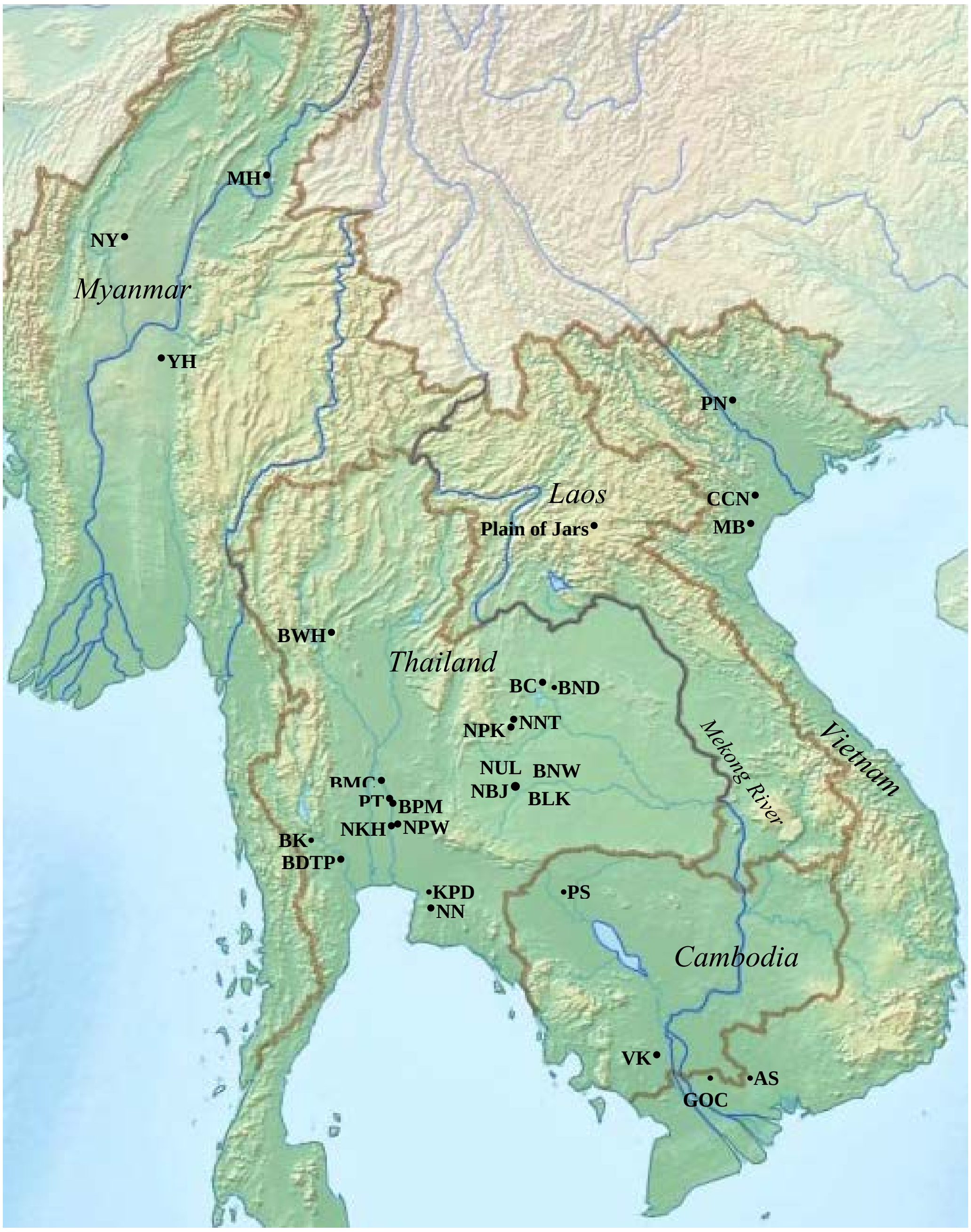
Introduction

This chapter focuses on the development of mainland Southeast Asia from the Neolithic to the Iron Age, which has been influenced by ecological diversity, population density increase, and cultural diffusion, ensuring that there is variation and flexibility throughout the region for the timing and degree of adoption of social and technological changes. Currently, the vast majority of available published archaeological research on Southeast Asia is heavily concentrated on central and northeastern Thailand, and Vietnam also comes under close inspection. Myanmar, Laos and Cambodia have not received as much attention, mostly due to their recently unstable political climate and wars experienced in recent decades (Stark & Allen 1998; Tayles *et al.* 2012).

Neolithic

Cultural and technological changes, as well as the arrival of farmers from China signified the beginning of the Neolithic during the first half of the 2nd millennium BC (Higham & Rispoli 2014). This period lasted until the advent of metal working technology, transitioning into the Bronze Age in the late 11th century BC (Higham & Rispoli 2014). Copper and tin were mined and then smelted and cast into a variety of copper and bronze ornaments, tools and weapons (Higham 2004). During the Neolithic small, autonomous settlements started to be built on top of mounds or terraces (Oxenham *et al.* 2015) with a preference to be located along inland tributary valleys (Higham 2002). Along with the introduction of domesticated pigs, cattle and dogs, the adoption of rice cultivation was flexible. Populations did not have to depend on rice or livestock as a food staple as wild plant and animal resources were readily available (Higham 2002). There does not appear to be any archaeological evidence, such as skeletal trauma and military material culture, that socioeconomic changes and shift in settlement behavior caused any degree of social pressure requiring conflict to resolve.

Figure 2.1. The location of the sites mentioned in the study.



Cambodia: PS – Phum Snay, VK – Vat Komnou
Myanmar: MH – Myo Hla, NY – Nyaunggan, YH - Ywa Htin
Thailand: BC - Ban Chiang, BDTP – Ban Don Ta Phet, BLK - Ban Lum Khao, BND – Ban Na Di, BNW - Ban Non Wat, BMC – Ban Mai Chaimongkol, BPM – Ban Pong Manao, BWH – Ban Wang Hai, KPD - Khok Phanom Di, NBJ – Non Ban Jak, NKH – Nil Kham Haeng, NN - Nong Nor, NNT – Non Nok Tha, NPK – Non Pa Kluay, NPW – Non Pa Wai, NUL – Noen U-Loke, PT – Phromthin Tai
Vietnam: AS - An Son, CCN – Con Co Ngua, GOC - Gò Ô Chùa, MB – Man Bac, PN – Phung Nguyen

Mortuary ritual

During the Neolithic interring infant burials in ceramic jars was a common practice. More unusually, at Ban Non Wat (see Figure 2.1) two adults were also interred in elaborately decorated ceramic vessels (Higham & Rispoli 2014). The usual practice was to place adults in an extended, supine position with the body typically on an east/west or north/south axis (Higham 2004; Higham & Rispoli 2014). Several infants at Man Bac had received special mortuary treatment, lying in an extended position either encircled with stones or with stones places to one side next to the body (Oxenham *et al.* 2008). Some flexed burials were still being found within the Neolithic mortuary ritual at sites such as Man Bac, Ban Non Wat (Foster 2011), and Ban Kao in a possible overlap of the hunter-gatherer and Neolithic periods (Higham & Rispoli 2014). Adults and children were mostly buried in clusters within close proximity of each other, in apparent family groups (Oxenham *et al.* 2008). The amount and variety of mortuary offerings increased in the Neolithic Period compared to the hunter-gatherers' offerings and high quality stone adzes and fine ceramic vessels were introduced.

Material culture

Bellwood *et al.* (2011) have noted that contemporaneous settlements in southern Vietnam, central and northeastern Thailand - areas that are connected by the Mekong River - have many similarities in material culture. This indicates that early in the Neolithic, during the transition to an agricultural economy, small settlements throughout the region were in contact and exchanging ideas and culture. For instance, baked clay pellets used as projectiles for a hunting bow or slingshot are present in southern Vietnam at An Son, northern Vietnam within Phung Nguyen sites, northeastern Thailand at Ban Non Wat and Ban Chiang, northern Thailand at Ban Wang Hai, as well as the Mimotien sites of southern Cambodia and southwestern Vietnam (Bellwood *et al.* 2011; Coupey 2006; Gorman & Charoenwongsa 1976; Haidle *et al.* 2010; Higham 2011a). Ban Non Wat has been extensively excavated (Higham & Kijngam 2011) and an array of burial artefacts, typical of many Neolithic sites, were noted including whetstones, bivalve shells, stone beads, shell discs, and pig bones placed on or beside individuals. Other sites also had animal bones as offerings, such as a dog mandible and pig tusk tool at An Son; and pig bones at Man Bac. Adzes were also present throughout the region and were likely used for wood working activities (Albrecht *et al.* 2000). Almost all burials contained at least one or two pottery vessels, usually placed around the head or feet. At Man Bac semi-precious stone nephrite jewellery and ornaments, or cowrie shells were placed with some burials. Marine shell jewellery found at inland sites within central and northeastern Thailand indicate long-distance trade with coastal communities (Higham 2002, 2011b). No region stands out as having any mortuary offering, or pottery and stone tool technology that is radically different from the others.

Weaponry

Within the archaeological record of the Neolithic Period in Southeast Asia there is no evidence of in-situ artefacts that can be unambiguously defined as weapons. Stone points, spear points and arrowheads were rare, but a range of stone adzes and axes were manufactured throughout the region (Higham 2002). These implements could have the potential to inflict harm, however there is nothing in the skeletal record to suggest they were used in this way.

Social complexity

On the whole, mortuary offerings seem to indicate that egalitarian societies were the norm in Neolithic mainland Southeast Asia. However, there are examples of subtle differences in mortuary treatment of males and females or individuals of different ages within some populations. Females at Man Bac are more likely to be distinguished by burial goods that have an association with economic roles, also the number of ceramic vessels placed within a burial increases in conjunction with the individual's age (Oxenham *et al.* 2008). Burials at Man Bac that are distinguished by having more impressive mortuary offerings are believed, by Huffer (2005) and Oxenham *et al.* (2008), to be for individuals who were recognized for their social role and level of participation within the community. This is also seen at Khok Phanom Di, a community that highlights the social changes occurring in the transition from small hunting and gathering communities to farming economies with a sedentary lifestyle in larger and more complex populations. Individuals were then able to focus on specialized occupations such as ceramic manufacture, farming and animal husbandry (Higham & Thosarat 2012). Bentley *et al.* (2007) conducted a study on the isotopic signatures from

Khok Phanom Di skeletons to reveal an initial strong female immigration into the community followed by a period of matrilocality. They concluded that this is likely a result of the women's increasingly important role in the community as makers of prestige ceramic vessels, which coincides with an increase in female mortuary wealth at the site. Isotopic evidence from Ban Chiang shows a similar pattern in migration, leading Bentley *et al.* (2007) to suggest that social transitioning is likely to be seen throughout the region as individual and kinship responsibilities change.

Bronze Age

The Bronze Age is a term used to describe a period defined by a technological sequence that includes archaeological evidence of ore-crushing tools and crucibles used in copper and tin ore processing, metal slag left over from the smelting process, and/or the presence of copper-base artefacts (Eyre 2010; Higham & Higham 2009; White & Hamilton 2009). Current evidence places the appearance of metal technology in Thailand during the 11th century BC (Higham *et al.* 2015) and the Bronze Age period continued in the region until c. 500 BC, when iron technology first appeared (Higham & Rispoli 2014; White 2006; White & Hamilton 2009). There are opposing views of what life was like in Bronze Age Southeast Asia, some believe that life was peaceful whilst others point to weapon manufacture; the possible fortification of sites using moats and ramparts; and evidence of skeletal trauma as indications of conflict (see Pietrusewsky & Douglas 2001).

Bronze casting techniques were used by localised specialist craftsmen to create surpluses for exchange and there is some suggestion that this is associated with increasing sociopolitical complexity (Higham 2012b). White and Eyre (2011) believe that Bronze Age settlements with evidence for stratification, such as an uneven distribution of mortuary wealth and exotic materials, were no longer egalitarian. However, they also argue that there is no evidence that communities were under the control of a centralized polity. Instead, populations were small and autonomous, with settlements usually widely distributed. By the Bronze Age, communities were building permanent structures and were largely reliant on a rice agricultural economy and raising domesticated animals, however hunting, fishing and gathering still supported these activities (Higham 2002; White 1995). The majority of settlements were situated on top of low mounds that were adjacent to water courses, usually positioned on the middle terraces but sometimes the higher terraces, depending on location of resources and suitable land for agriculture (Higham 2002). During the Bronze Age and Iron Age the intensification of agriculture would have required that a great deal of time and energy was expended in farming and land clearance activities. Pietrusewsky and Douglas (2001) believe that sedentary populations would have needed to protect their resources and this may have increased the likelihood of interpersonal conflict and injury. Pietrusewsky and Douglas (2001) also discuss the opposing views of Higham (1996), who argues that the presence of spear points and arrows in the mortuary contexts is also an indication that conflict was experienced; and White (1982), who proposes the Bronze Age was a relatively peaceful period with low levels of conflict.

Mortuary ritual

Overall, the mortuary ritual is similar in all Bronze Age sites found in Thailand, but with some local variation (Higham 2012c). Adults, subadults and some infants, were usually interred in an extended and supine position, predominantly with the graves in rows, such as Non Nok Tha, Ban Non Wat, Nong Nor, Ban Lum Khao (Higham 2012c), and Nyaunggan in Upper Myanmar (Tayles *et al.* 2001). Studies on mortuary practices by Harris and Tayles (2012) and Willis and Tayles (2009) show that burial container variety peaked in the late Bronze Age and early Iron Age. The infant jar burial tradition carried on from the Neolithic, and was seen in Vietnam, Laos, Myanmar and in northeast Thailand (Coupey 2006). Trace remains of possible material shrouds and/or wooden coffins are found in parts of northern Thailand, Vietnam and Myanmar (Coupey 2006; Higham & Higham 2009). Placement of animal remains (pig and bovine limb bones, and dog skulls) beside human burials was also a common practice in Thailand (Higham 2002), and is seen in Myanmar (Tayles *et al.* 2001). There was no evidence that cemeteries were divided by gender. Males, females and the young were all interred within the same area (Higham 2012c). It was usual practice for graves to be placed either in a north/south orientation, such as Ban Na Di and Ban Lum Khao; or an east/west orientation as is seen at Nong Nor (Higham 2002). The lack of published material on Bronze Age mortuary rituals in Cambodia and Laos is noticeable and can only be addressed when more sites are excavated in these areas.

Material culture

There is a pattern of commonality in the type of burial goods in much of Southeast Asia. Multiple pottery vessels are almost always present, placed close to the head, next to or over the body, and at the feet. Also common are stone and shell jewellery, clay spindle whorls and lithic tools. Cowrie and trochus shell bangles at Ban Na Di and Ban Na Wat are evidence of long-distance trade with a coastal settlement (Higham 2012f). Bronze mortuary artefacts in the form of jewellery, bells, axes, spears and points were regionally relatively uncommon. Nong Nor mortuary offerings featured a unique array of artefacts, including tin and shell jewellery, a tiger's tooth pendant, and bull horns (Higham 2002).

When comparing the Neolithic burial phases with the Bronze Age phases at Ban Non Wat, if wealth is assessed by the amount and type of burial offerings placed with individuals, then there is a marked increase in wealth at this site (Higham & Higham 2009). There was also an increase in mortuary offerings between the earliest and the later Bronze Age burial phases. This is in contrast to the final two Bronze Age burial phases that contained few bronze offerings or shell jewellery and beads. Comparisons between contemporaneous sites in northeastern Thailand reveal that Ban Non Wat has the most elaborate collection of burial goods placed with both adults and infants compared to Non Nok Tha, Ban Na Di and Ban Chiang (Higham 2012c). The material evidence recovered from other regions of mainland Southeast Asia is not as extensive, perhaps due to the fewer number of sites that have been excavated.

Weaponry

White and Hamilton (2009) state that no artefacts from Bronze Age Thailand could 'unambiguously' be considered a weapon. They further argue that even implements commonly associated with conflict, such as spear points could have a use unrelated to warfare, such as hunting or ritual. Spears and/or bronze projectile points were included as mortuary offerings at numerous sites such as Ban Chiang, Ban Na Di, Non Nok Tha, Nil Kham Haeng and Ban Don Ta Phet (Higham 2002). Villagers also reported bronze spearheads and axe-casting moulds from the looted site of Non Pa Kluay. Barbed and non-barbed arrowheads and/or moulds for casting arrowheads, axes and projectiles were found at Ban Na Di (Higham 2002). Ban Lum Khao and Non Pa Wai also had moulds for bronze projectile points (Higham & Thosarat 2012). Axes are implements that could potentially be used as weapons to inflict serious injury. Socketed axes are present at numerous sites in northeast and central Thailand (Higham & Thosarat 2012).

Social complexity

The number of mortuary offerings and the presence of exotic materials placed with individuals is the only way to assume status and wealth in these burials as no other evidence has survived. Differences in these could be an indication of social organization developing in the Bronze Age. White and Eyre (2011) have suggested that variation in grave wealth at sites in Bronze Age Thailand is subtle evidence of some hierarchy within cemeteries, but this is ‘episodic and short lived’. For instance, at Ban Non Wat early Bronze Age graves have substantial burial goods and this level of wealth was not repeated in the following burial phases (Higham & Kijngam 2012). White and Eyre suggest this is an indication that these communities were not egalitarian, nor was there an elite class, however, individuals could achieve a high status. Clusters of burials with the same mortuary ritual could be from a defined social or descent group who achieved this higher status (Higham 2002).

Task-specific mortuary artefacts interred with burials could possibly indicate the daily activities undertaken by individuals, such as spindle whorls that were used to produce thread for weaving and grey clay that was used to dye cloth (Higham 2012c); a ceramic anvil together with clay, may indicate they were potters (Higham 2012e). At Ban Non Wat one male burial prominently featured 29 clay moulds, the type used for casting socketed axes and bangles. Such a large number of moulds with one individual leads to a likely conclusion that this man was involved in the manufacture of bronze artefacts (Higham 2012d).

Iron Age Period

Evidence for iron technology first appeared in the Southeast Asian archaeological record c. 500 BC (Higham 2002). During this period there were numerous examples of Iron Age burials containing an increase in the quantity and quality of burial offerings; more artefacts were manufactured from exotic glass, gold, silver and carnelian; and exchange networks continued to grow and reach further afield (O'Reilly 2007b). The emerging iron technology and improved bronze casting techniques had a great impact on regional culture, economic industries and trade networks. For example, the advent of the buffalo-drawn iron plough share meant more land could be prepared for cultivation than by a person with a hoe, allowing agricultural intensification and the production of surplus food stocks (Higham & Rispoli 2014). Bronze metallurgy techniques improved to a new level of sophistication as evidenced in the range of mortuary offerings and ritual vessels that were more abundant than in the Bronze Age (Higham 2002).

By the Late Iron Age c. 100 – 500 AD there was a well-established maritime trade network moving goods between India, China and Rome, with coastal settlements of Vietnam, Cambodia and Thailand participating in the exchange of goods and culture (Chang 2001; Stark 2007). Higham and Rispoli (2014) credit India with having introduced iron forging expertise via a maritime trade network.

Characteristics of the Iron Age in Southeast Asia include increasing site size and density correlating with increasing population levels, with some suggesting there is evidence of a shift from unranked social organisations of the Bronze Age to clustered and stratified societies (Boyd & McGrath 2001a; O'Reilly 2007b) that experienced a rise in social unrest (O'Reilly & Sytha 2001). Settlements in northeast and central Thailand grew in size, from less than five ha with low population density in the Bronze Age (Higham 2002), to more than fifty ha during the Iron Age (Higham & Rispoli 2014). Cambodia's earliest polities started to develop in the Mekong delta and increasing population density instigated the development of new inland and coastal settlements (Stark 2007). This population expansion occurred in conjunction with the ability to produce surplus rice crops. In the Iron Age there is definitive evidence for the duel use of settlements for domestic activities and manufacturing industries (Higham & Higham 2009). According to Higham and Rispoli (2014) and O'Reilly (2007b) the higher number of weapons in Iron Age burials in comparison to the Bronze Age is an indication of increased social stress and conflict within and/or between settlements, especially when viewed in conjunction with traumatic injuries and the construction of moats and banks around settlements.

Mortuary ritual

Mortuary rituals in mainland Southeast Asia took on many varied forms during the Iron Age. Extended and supine inhumation was the dominant mortuary tradition for adult burials (Higham 2002), often placed within a wooden coffin or tightly wrapped in a fibrous material, or a combination of both (Coupey 2006; Harris & Tayles 2012; Pautreau *et al.* 2003; Willis & Tayles 2009). Prominent log coffin ‘boat’ burials, up to five metres long, were featured in some of the cemeteries in the Red River Delta region in northern Vietnam (Higham 2002). The practice of infant jar burial continued but became even more widespread than it was during the Bronze Age (Coupey 2006; Higham 2002; Karlstrom 2008). The Plain of Jars in upland Laos is possibly a cemetery, however only a few burials have been located and this area is still undergoing excavation (N. Chang, pers. comm.).

Material culture

From the Bronze Age to the Iron Age, there is a general pattern of increasing quality and quantity of burial goods, and amount of exotic materials such as glass, agate and carnelian, which signify long-distance trading relationships throughout mainland Southeast Asia (Boyd & Chang 2010; O'Reilly & Sytha 2001; O'Reilly 2007b). Iron implements and ornaments became part of the mortuary ritual throughout Southeast Asia. In Thailand, agricultural tools such as socketed hoes and spades, billhooks, and tool kits including knives and awls (Higham & Rispoli 2014) were offered as burial goods alongside bangles, weapons and wooden bowls, trays and carved human figures (Higham 2002). Animal bone of pig and cow were also still included as mortuary offerings (Bentley *et al.* 2005). The Dong Son cultures in northern Vietnam produced unique artefacts, most impressive of which were the large bronze drums that were traded throughout much of Southeast Asia, they also produced bronze bells, utensils and daggers (Higham 2002).

Spindle whorls are a common mortuary offering, just as they were in the Bronze Age and there is evidence for cloth production as woven fabric and cordage were partially preserved at a number of sites in northeast Thailand and northern Vietnam (Higham 2002) and fabric stamp rollers at sites in Laos (Karlstrom 2008). Almost every type of mortuary offering found in the Samon Valley, Upper Myanmar is common to cemeteries elsewhere in Southeast Asia (Coupey 2006) and there is evidence for well-established trade and military routes passing through Upper Myanmar to connect with India and China (Moore & Win 2007).

Weaponry

In comparison with the Bronze Age, burials in the Iron Age contained more artefacts that could be considered to function as weapons (O'Reilly 2007b). One factor for this is that new iron technology and improved bronze casting methods provided the means to produce a wider range of weapon types. New production techniques also led to proficiency in manufacturing higher numbers of metal weapons and artefacts. The numerous trade networks that connected coastal and inland areas and linked Southeast Asia to India and China allowed for a commonality in material culture and weapon production, however, local variation was still seen in the mortuary offerings (White 1995).

In Thailand typical mortuary offerings that could function as weapons include axes, iron points, tanged sickles, tanged knives, spear points (Higham & Rispoli 2014), lances, barbed spear heads, and halberds (Sørensen 1973). The Iron Age cemetery and unprovenanced remains from looted burials at Phum Snay in Cambodia featured a wide array of weapons, including large iron swords over one metre in length, short swords, projectile points and spear heads (Domett *et al.* 2011). There were more weapons here than any other site in mainland Southeast Asia (O’Reilly 2006) and grave looters also reported finding artefacts resembling bronze helmets and breastplates (O'Reilly & Sytha 2001). These unprovenanced artefacts and the abundance of weapons led O'Reilly and Sytha (2001) to suggest that Phum Snay was a militarised society. Similar mortuary offerings of bronze weapons such as swords, paring knives, spears and arrowheads were found at cemeteries in northern Vietnamese Dong Son sites (Higham 2002). In southern and central Vietnam, regular mortuary offerings include swords, scythes, axes and knives (Chinh & Van Tien 1980). Swords, spear heads and arrowheads were also common to sites in Upper Myanmar (Moore 2003). A crossbow trigger mechanism found at a northern Vietnam site c. 100 BC, imitates Chinese technology (Higham 2002). Also common at these sites were halberds and bronze cast daggers with decorated hilts. Dong Son bronze drums often depicted images of warriors and individuals wearing daggers on belts as a form of personal weaponry (Higham 2002). According to Chinh and Van Tien (1980) almost 50 percent of bronze artefacts recovered from Dong Son sites were weapons, and the type of weapons suggests to them that warfare was frequent in these settlements.

There is also mortuary evidence of children being interred with weapons. For instance, Coupey (2006) found references to children and adolescents being buried with weapons in Vietnam: a baby burial containing a bronze dagger, and a socketed bronze axe and short-sword with a child under four years of age. Coupey (2006) suggests that the weapons found with adolescents at sites in the Samon Valley could mark their coming of age into the adult world, whilst the weapons in infant burials likely are regarded as a symbol of kinship status. In Thailand, child burials sometimes contained knives, but nothing that was unambiguously a weapon (Coupey 2006), and there is so far no evidence of weapons in child mortuary ritual in Laos.

Social complexity

The increase in the quantity and quality of burial goods of some individuals and kin groups, and increasing population density during the Iron Age is interpreted by some as evidence of a shift from unranked social organization to hierarchical societies (O'Reilly 2007b; O’Reilly 2014). There was also a suggestion that restricted access to specialist-produced and exotic items, or water and food surpluses, could be a sign of elite control and dominance (Higham & Rispoli 2014; O’Reilly 2014). However, White (1995) argues that most settlements in this period lacked the centralized political power needed to sustain continuous hierarchical societies. Instead, there is evidence of heterarchy in the form of flexible social status, cultural pluralism and cooperative community formed economies (White 1995). In contrast Bentley *et al.* (2009) suggest that at least some communities in Iron Age Mun River Valley showed signs of non-egalitarian treatment in their cemeteries. For instance, only some individuals at Noen U-Loke were buried with rare gold items, exotic carnelian and agate beads, or large quantities of domesticated rice (Bentley *et al.* 2009). Clustered burial patterns were found in the early Iron Age phases of Noen U-Loke, with noticeable fluctuations in the amount and variety of burial goods within and between the clusters, but by the late Iron Age the differences were less noticeable and the burials were no longer clustered (Boyd & Chang 2010; Willis & Tayles 2009). In the Samon Valley, Upper Myanmar, the cemeteries at Ywa Htin and Myo Hla graves are clustered in an obvious grouping of up to ten or more (Coupey 2006). Kinship or community relationships are also suggested by the presence of unique grave goods within neighbouring burials (Coupey 2006). The Dong Son cultures in northern Vietnam also had burials that contained more elaborate types and greater quantities of mortuary offerings than others in the same burial phase, such as several opulent boat burials (Higham 2002).

Summary: Neolithic to the Iron Age in Southeast Asia

There is substantial evidence for the early Neolithic Period being a transitional phase whereby populations practiced a hunter-gatherer economy mixed with farming as they adjusted to a sedentary lifestyle. The adoption of an agricultural economy was followed by regional changes in mortuary practice so that all groups buried their adults in an extended position. Pottery traditions also became more complex in both form and decoration, with widespread similarities influenced by trade networks and exchange. There is no definitive evidence of interpersonal violence nor the aggressive use of implements as weapons, or intercommunity conflict. Examples of traumatic injury within Neolithic skeletal assemblages are rare, although this may be in part because there are small skeletal samples from this period and preservation is often very poor.

By the Bronze Age settlements, were widely distributed and appeared to be autonomous. Regional similarity in material culture was likely a result of interaction over extensive trading networks, but local variation was also apparent. Whilst communities appear for the most part to be peaceful, there are some signs in the archaeological record that conflict was part of Bronze Age life. For example, with the advent of copper base metallurgy and casting moulds there is a definite increase in the production of weapons such as spear points and arrows. Some populations showed evidence of increasing social complexity and possible hierarchical structure through the uneven distribution of both the quantity and quality of mortuary offerings. Populations became focused on an agricultural economy and specialist artisans were producing surplus pottery and ornamentation. The rate of trauma noticeably increased in the Bronze Age, most cases however, have been attributed to accidental injury. But some individuals exhibited the hallmark signatures of violent aetiology such as combined craniofacial and lower arm injuries.

It is evident from the archaeological record that during the Iron Age period mainland Southeast Asia experienced major developments in agricultural innovation, settlement patterns, economic industries and advanced metallurgical techniques, however, there is still variation in the degree of complexity between settlements. Settlements that had control of metal ores, salt mines, the best agricultural land, or were in strategic locations along international trade routes, could rapidly grow a larger population and develop a complex social, political and economic presence. A great many sites became considerably larger and were encircled by a series of moats.

The function of these moats could vary between water retention and flood control, to an unambiguous fortification role as was the case at the Late Iron Age site of Co Loa. During this period, weapons development and manufacture proliferated. Not only could individuals be buried with several types of weapons but sites such as Co Loa produced thousands of surplus iron points and caches of crossbow bolts. This coincided with an increase in the amount of trauma seen in the Iron Age burials. A number of traumatic injuries have been attributed to a likely accidental cause or the result of an active agricultural lifestyle. However, there are also several cases of violent trauma resulting in death, and an increase in cranial trauma, that when combined with the archeological evidence of the use of weapons and settlement fortification, suggests a definite rise in social conflict.

Chapter 3

Non Ban Jak

Materials & Methods

This chapter will describe the bioarchaeological analysis conducted on a new skeletal sample from the Late Iron Age to early historic period (220 – 820 AD) (Higham *et al.* 2014a) settlement of Non Ban Jak, upper Mun Valley, northeast Thailand. The skeletal assemblage was examined for signs of antemortem and possible perimortem trauma, such as fractures, cuts, and dislocations to allow the assessment of differential exposure to risk of trauma between the sexes and between mortuary phases.

Non Ban Jak materials

The site

This site was first discovered during a 1996 area survey (reported in Higham *et al.* 2014a) and mentioned in several reports investigating moat stratigraphy, palaeovegetation and palaeodrainage of prehistoric ditched sites in the Upper Mun River Valley (Boyd *et al.* 1999a; Boyd *et al.* 1999b; Boyd & McGrath 2001b; McGrath & Boyd 2001). These publications had referred to the site using the name of the nearby village of Ban Non Khrua Chut(e), however, during later excavations it was realised that the local villagers have always identified the mounds with the name of Non Ban Jak (N. Chang, pers. comm.).

Non Ban Jak is located within the upper Mun catchment on the Khorat Plateau, northeast Thailand (Figure 3.1). The site measures 360 m in length by 170 m in width, and is comprised of two broad moats and banks surrounding an eastern and western mound that are separated by a low lying central region (Figure 3.2). Studies of the palaeoenvironment (Boyd *et al.* 1999a; Boyd & McGrath 2001b; Boyd & Chang 2010) indicate that the landscape of the early Holocene was transitioning from a period of stability with a warm and humid environment to one that was becoming increasingly drier by the late Holocene (c. 200 AD to present). This environmental change was driving a requirement for more intense landscape management and suggested a greater need for a mixed subsistence economy (Boyd & Chang 2010). The floodplain biosphere surrounding Non Ban Jak would have provided ample natural resources, and there is evidence for rice cultivation in the form of rice straw temper in the kilns, concentrations of rice grains in occupation contexts and the presence of iron sickles as mortuary offerings (Higham *et al.* 2014a).

Figure 3.1. Thailand, with the location of Iron Age sites mentioned in the text.

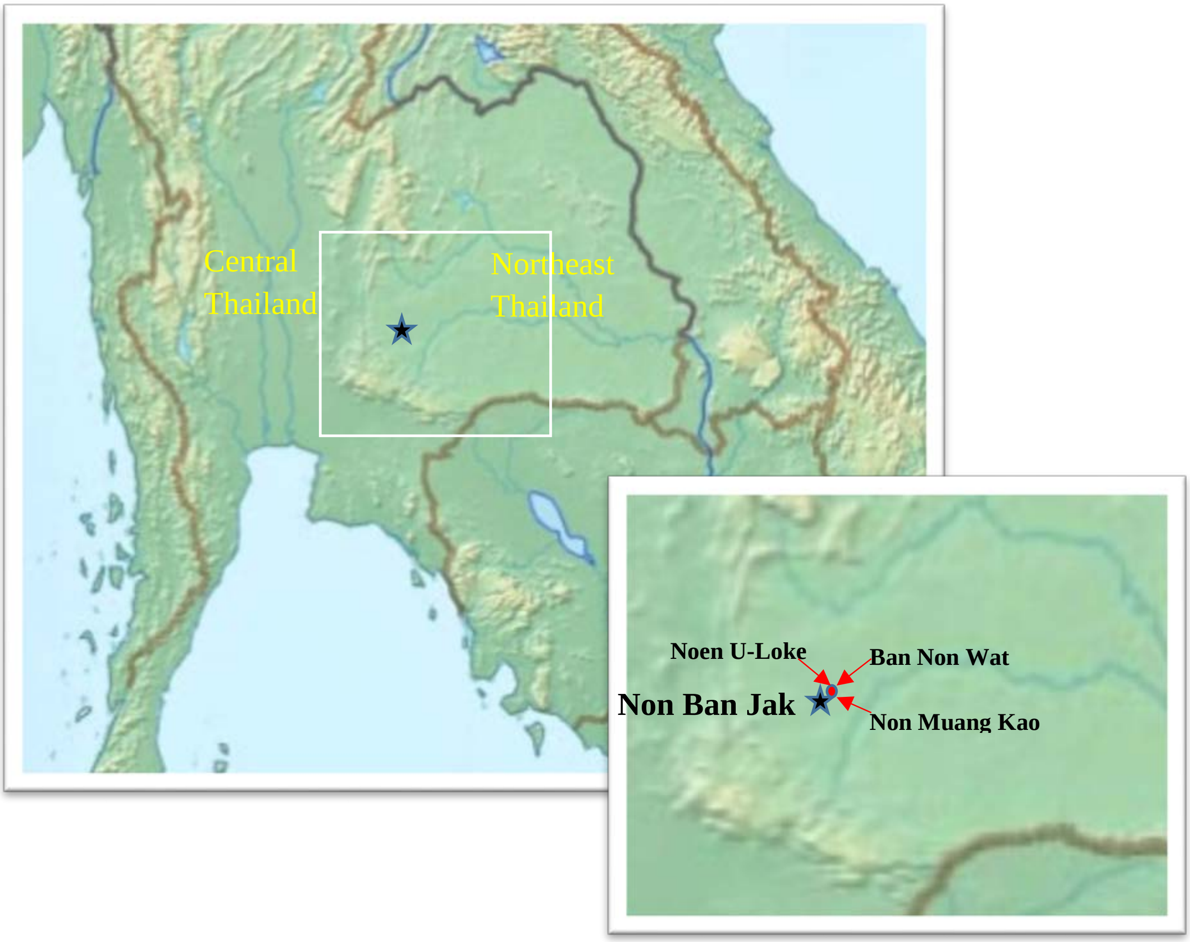


Figure 3.2. Current satellite view of Non Ban Jak, showing the location of the 2011 – 2015 excavation areas of the western mound (A) and eastern mound (B). (The white square shows one of the locations of the 2016 excavation that was in progress when the satellite image was taken).

Excavations have revealed remnants of mortuary phases, residential and industrial complexes and activities such as kiln firing of ceramic vessels, iron smithing or smelting, and cooking of food (Higham 2012a; Higham *et al.* 2014a; Higham 2015). Higham *et al.* (2014a) have identified clearly defined town lanes separating building structures, and residential burials which were cut through the clay floors of buildings, in alignment with the walls. Close and long-lasting affiliation with neighbouring regions and settlements are suggested by similarities in the appearance of pottery vessels from the last occupation layer of Non Ban Jak to those of the Dvaravati states of Central Thailand, and similar evidence for domestic dwellings at Non Muang Kao (Higham *et al.* 2014a; O'Reilly 2007a). Higham *et al.* (2014a) have recorded many similarities in mortuary ritual and material culture of Non Ban Jak with Iron Age three and four phases (c. 200 – 400 AD) of close neighbours Noen U-Loke and Ban Non Wat. This has led Higham *et al.* (2014a) to suggest the strong possibility that the inhabitants of Non Ban

Jak could have originated from the same general population that occupied these earlier settlements.

Site chronology

Radiocarbon dates have determined that the western mound was first occupied during the period of the 3rd – 4th century AD (AD 220 – 380), while the final phase of occupation of the western mound ended around the 8th century AD (AD 700 – 820) Higham *et al.* (2014a). This shows that the site was still in use during the early historic period. Current dating evidence from the eastern mound indicate that this part of the site was not occupied until the 5th century AD (390 – 530 AD) and Higham *et al.* (2014a) verified that the mortuary phases were concurrent with occupation layers on the eastern and western mounds during 4th – early 6th century AD. The preliminary investigations into moat stratigraphy revealed the moats and banks were constructed within the period of c. 400 – 500 AD (McGrath & Boyd 2001).

Population demography

This present study looks at the burials uplifted from the site during four excavation seasons from 2011 – 2015. All human remains were assessed in Phimai, northeastern Thailand where the remains are currently housed at a property operated by the University of Otago. The only exceptions are burials 1 to 9, which are curated at the Phimai Fine Arts Department in the prehistoric skeletal remains storage facility. The number of individuals analysed is 137, with subadults (< 15 years of age) representing 56.9 percent (78 burials), and adults 40.1 percent (55 burials). Four burials (B53, B67, B88 and B116) did not have enough skeletal elements present to be able to determine if they were subadults or adults. The sample of 55 adults consists of 23 females, 18 males, and 14 individuals of indeterminate sex (Table 3.1). Age at death estimation of the sample revealed ten young adults, 16 mid aged adults, 13 old aged adults, and 16 of indeterminate age. A number of individuals could not have their sex estimated due to factors such as poor bone preservation, poor representation of bone elements of individual skeleton, or specific skeletal morphology obscured by a layer of hardened calcitic concretion deposit.

Table 3.1. The sex and age at death distribution of the Non Ban Jak sample

	Male	Female	Unsexed	Total	
Indeterminate age			4	**4**	
Subadult (<15 y)			78	**78**	
					(%)*
Young Adult	4	2	4	10	(18.2)
Mid Aged Adult	7	8	1	16	(29.1)
Older Adult	6	7	0	13	(23.6)
Adult	1	6	9	16	(29.1)
Total Adults	18	23	14	**55**	
(%)	(32.7)	(41.8)	(25.5)		
Total				**137**	

Adult = unable to estimate age
*Percentage calculation for adult sample only

It should be noted that the following burials were excavated from the site but the skeletal remains currently cannot be located: the burial record of B50 notes that it is an adult with only two fragments of leg bone surviving; B52 burial records indicate it consists of a single leg bone from an infant; B54 consisted of a few fragmentary remains of an infant; B90 was also indicated as an infant on burial records; and no burial record or skeleton could be found for B109 which was noted as an infant in the excavation report published by Higham *et al.* (2014a). This material will no doubt be recovered as the full bioarchaeological analysis continues. Burial 44 was identified as an infant burial and consisted of a few bones and teeth only, however, once cleaned up for analysis the remains were identified as animal bones, probable canine, by H. Buckley. There is also no record of burial number 63 being assigned to any remains.

Eastern mound

A sequence of six occupation layers were identified from residential, industrial and mortuary activity, and contrasts in stratigraphy (Higham 2012a; Higham *et al.* 2014a). Fourteen burials (B1 – B14) were identified on the eastern mound, located within occupation layers two and five (Figure 3.3). The burials consisted of 11 subadults and three adults (two females and one male).

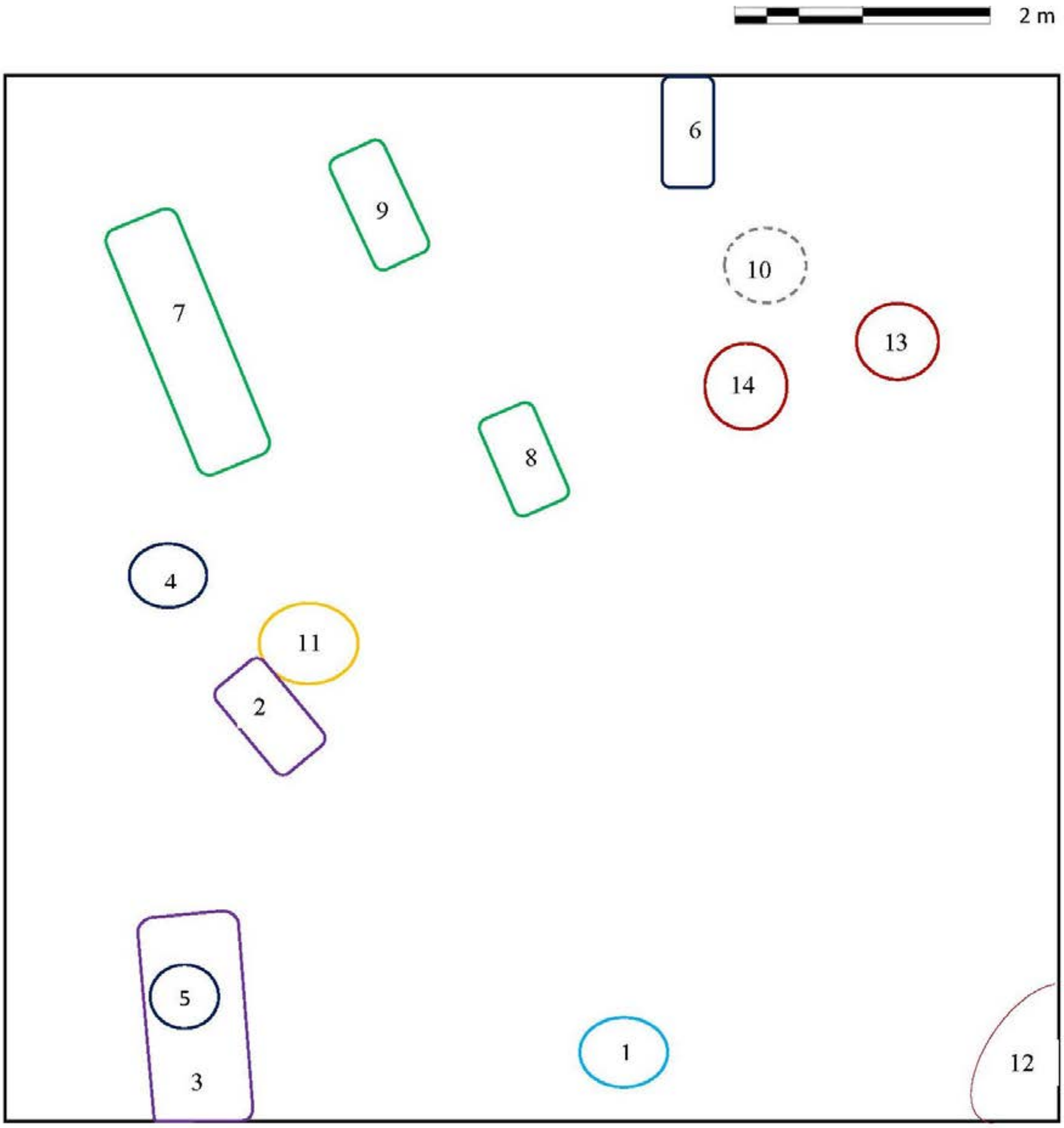


Figure 3.3. Eastern mound burials from the 2011 excavation season.

The graves of B7, a female old aged adult, B8 an infant and B9 a child, were cut through a clay floor in alignment with structural walls of what is most probably a burial chamber (Higham 2012a; Higham *et al.* 2014a). Burial 9 was interred supine, its head within one pot and feet in another, a practice also seen on the western mound with four other infant burials from mortuary phases three and four. Adult B2 and infant B4 have been disturbed by historic pits cut into the upper layers of the site stratigraphy. All other burials are found within the floors of buildings or adjacent to walls, suggesting the practice of residential burial at this part of the site (Higham *et al.* 2014a). Mortuary offerings were absent or few. Out of the three adults, only the grave of B7 contained mortuary offerings as B2 was heavily disturbed and B3 was only partially excavated. Most burials had a few pots placed on or adjacent to the body and other mortuary offerings catalogued were a lead earring, a bimetallic ring, a variety of bronze jewellery, an iron sickle and an iron knife. An iron artefact, found inside the remains of a kiln, was identified as a ploughshare. This item, in combination with the concentrations of rice remains found lining graves or in the residential areas, indicates the settlement's agricultural economy (Higham *et al.* 2014a).

Western mound

Four distinctive occupation layers were identified within the western mound and burials were separated into four successive mortuary phases (Figures 3.5 and 3.6), located either within a cemetery or the residential zone (Higham *et al.* 2014a; Higham 2016b) (Note: Assigning the eastern mound burials to mortuary phases requires further analysis and may even prove impossible to accomplish with precision (C.F.W. Higham, pers. comm.). For the purpose of research within this thesis, these occupation layers and mortuary phases will be used as guidelines to assist in observing relationships between burials.

Western mound mortuary phases

Mortuary phase 1 (MP1) burials were concentrated in the eastern part of the excavation area and these appeared to be in two distinct groupings, separated by a four metre buffer zone (Higham 2012a; Higham *et al.* 2014a). The mortuary offerings were sparse in both groups - usually one or two pots, bronze jewellery, glass beads, agate or shell pendants, and one adult had silver coil earrings (Higham *et al.* 2014a). A detailed bioarchaeological analysis of the human remains may enable further differences or similarities to be distinguished and thus possibly enabling confirmation of two distinct groups.

In MP1 group A consisted of 16 subadult burials, 13 of which were infants, and seven adults. Group B had two infant burials and six adults. This reflected a high degree of infant mortality (48.0%) which was also repeated in several of the following mortuary phases. Higham *et al.* (2014a) have reported this site as having one of the highest infant mortality rates yet recorded in prehistoric Southeast Asia. The subadults (<15 years old) are currently undergoing a full bioanthropological analysis on health and disease, which will offer insight into infant mortality at this site.

MP2 was located in the western part of the excavation. There were a total of 16 adult and 26 subadult burials. The adults had similar mortuary goods to those in MP1 but the subadults (infants) in MP2 had more varied grave goods and Higham *et al.* (2014a:20) note that some would be considered "moderately wealthy" as one infant in particular stood out with nine gold beads, and another infant wore numerous agate and glass beads and bronze jewellery. An iron knife and sickle were found in this mortuary phase.

MP3 had 13 adult and 19 subadult burials. Higham *et al*. (2014a) reported that most adults were now interred with an iron sickle and/or knife, one adult had a gold ring, and bronze jewellery was more abundant than previous mortuary phases but glass beads were rare. The infants in this mortuary phase received less ornaments than previous phases.

MP4 burials are mostly disturbed as they were close to the surface and modern farming activity such as bulldozing had removed much of the topsoil (Higham 2014b). There were five subadult burials and ten adult burials. In comparison to MP3, there was less variety of mortuary goods in MP4, bronze jewellery was scarce but iron sickles or knives were buried with most adults and one wore a gold earring (Higham *et al.* 2014a).

Burial orientation varied only slightly during the four mortuary phases. Most burials in MP1 were orientated with the head to the north, only one burial had the head in a southern orientation. Through the other mortuary phases the graves were orientated with a preference for the head to be NW or SE but there were several anomalies with the head either to the east, north or south (Higham *et al.* 2014a). Overall, the mortuary offerings at Non Ban Jak were sparse when viewed in comparison to the more elaborate and contemporaneous burial offerings at the nearby site of Noen U-Loke (Higham *et al.* 2014a). There was no obvious difference in wealth between the mortuary phases at Non Ban Jak to indicate dominant social groups, however, there were differences in the types of items interred with individuals of each mortuary phase. The presence of marine species shell pendants from MP1 and MP2 at Non Ban Jak indicated trade and exchange over a long distance with coastal communities (Higham *et al.* 2014a). Ornaments made of gold (MP's 2, 3 and 4), silver (MP1), agate and carnelian beads (MP's 1 and 2) and glass beads (all MP's) indicate the establishment of a number of long distance exchange networks and suggest economic and social changes in the Iron Age (Higham *et al*. 2014a). Iron sickles are predominantly found in MP3 and MP4 and suggest an intensification of rice cultivation during the latter part of occupation at this site (Higham *et al*. 2014). Iron knives are found with a number of adults (Higham *et al.* 2014a), one of which has been identified as a possible spear tip (C.F.W. Higham, pers. comm.). It is unknown if the iron knives were utilised as just tools or could have also been used as weapons (Figure 3.4).

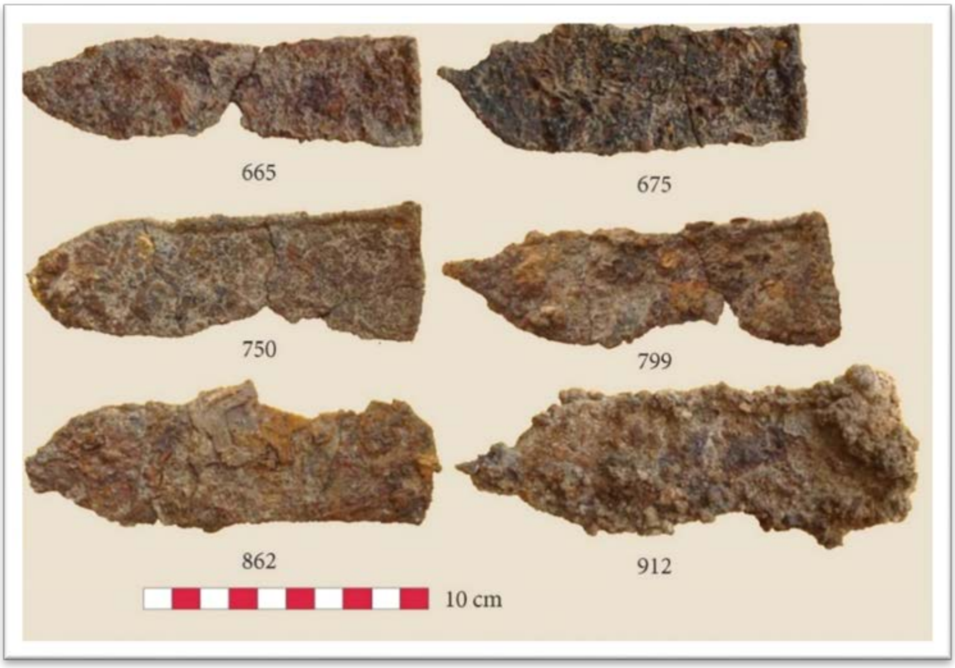


Figure 3.4. Iron knife blades were common mortuary goods. (Picture: Higham *et al.* (2014a)).

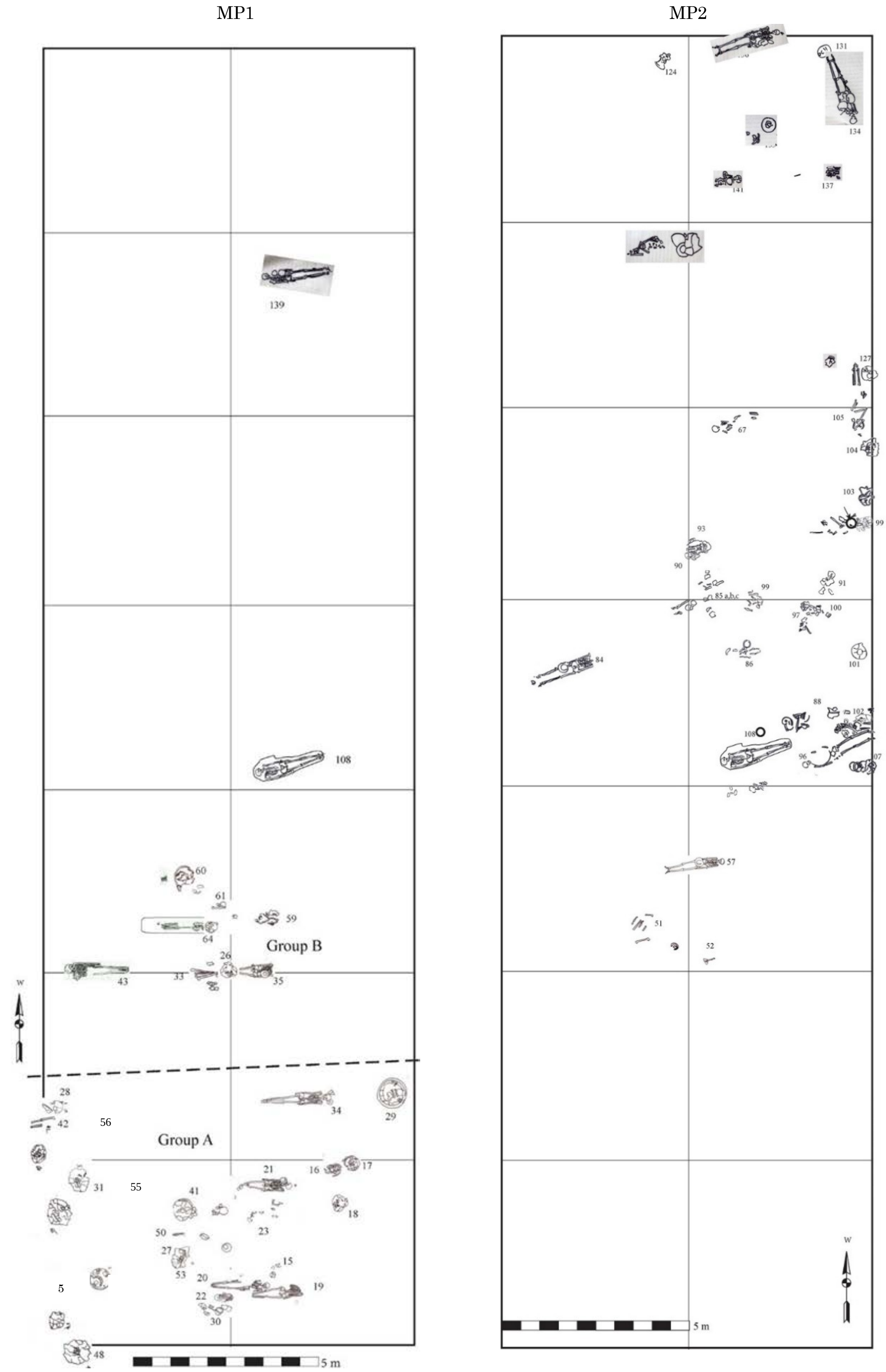


Figure 3.5. Western mound mortuary phases 1 & 2 (MP plans provided by C.F.W Higham).

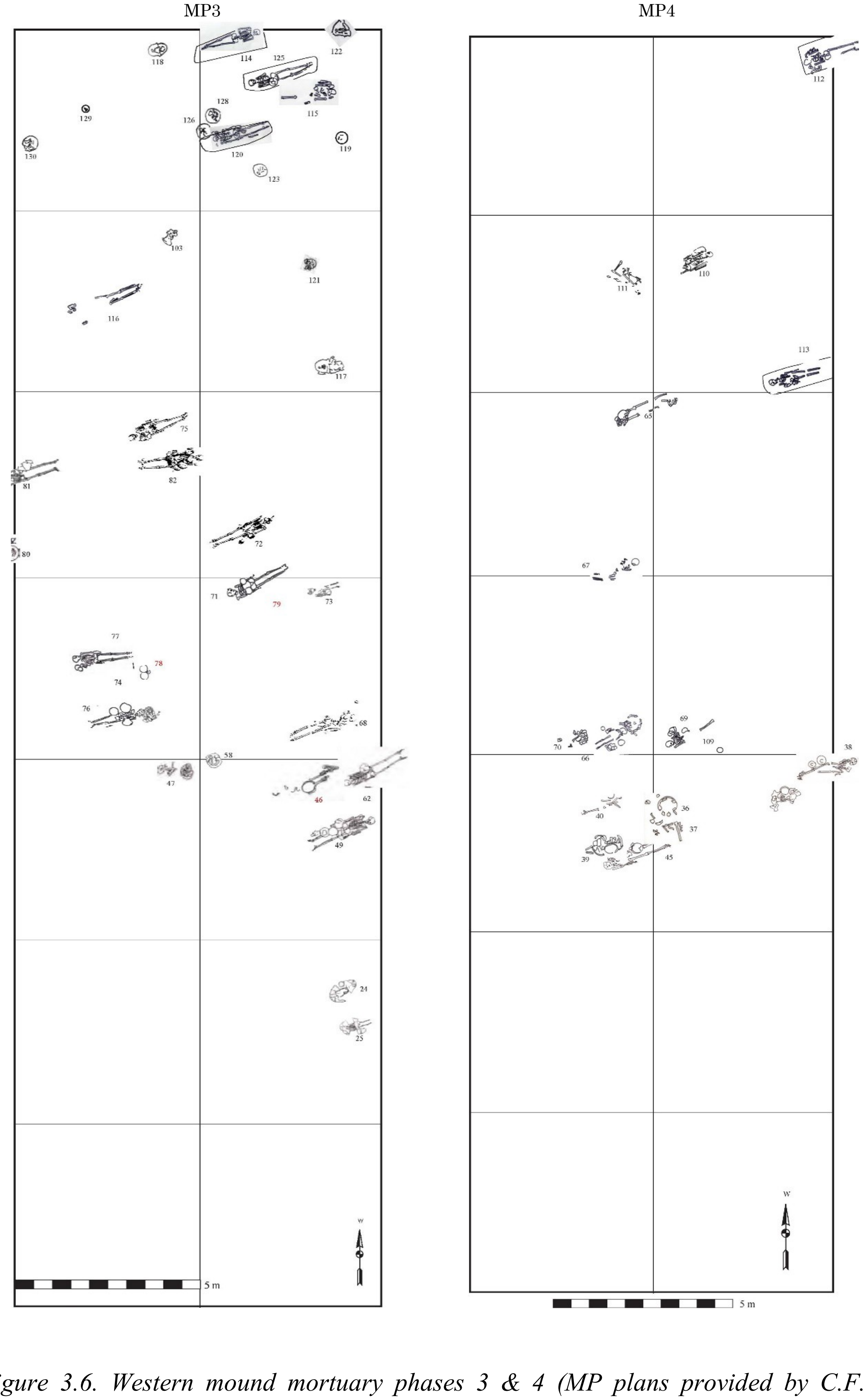


Figure 3.6. Western mound mortuary phases 3 & 4 (MP plans provided by C.F.W Higham).

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Skeletal analysis

Skeletal census, sex and age data was collected using a File Maker Pro program devised by K. Domett. Sex determination and age at death estimation were completed by K. Domett, H. Buckley, S. Halcrow and S. Ward according to commonly used standards published in Buikstra and Ubelaker (1994). These sex and age results differ slightly to those published by Higham (2012a, 2014 & 2016) and Higham *et al.* (2014a) who used the assessments made primarily by N. Harris in field conditions. In this thesis the updated data collected by Domett, Buckley, Halcrow and Ward were used. Adult sex estimation was based on assessment of macroscopic analysis of pelvic and cranial morphology. Metric analysis of long bone lengths and/or femoral and humeral head diameters were also used if the pelvis or skull were not available for examination. Sex was then determined when individual measurements were compared to a population specific table devised by K. Domett using section point analysis from a range of prehistoric Thai samples. Subadult sex estimation was not attempted due to the lack of sexual dimorphism in the immature skeleton of infants and children.

Current methods for reliably estimating the sex of an individual rely on pelvic and cranial morphological changes that occur as the result of the hormonal secretions at puberty (Scheuer *et al.* 2000). Age at death estimates for adults relied on late-fusing epiphyses and pubic symphysis morphology, but in some cases it was necessary to use molar wear analysis for age estimation using the method of Smith (1984). Subadult age at death estimates were achieved with a preference for observing dental formation and eruption using the standards detailed in Buikstra and Ubelaker (1994). If dentition was not present then long bone lengths were used, and if the individual was older than 12 years epiphyseal fusion rates could also reliably be used based on the methods published in Buikstra and Ubelaker (1994). Age categories were defined as subadult (<15 years), young adult (15 – 29 years), mid aged adult and older adult. (Tayles *et al.* 2007).

Due to the nature of local taphonomic processes such as soil acidity, an individual burial may at times only be represented by a few bones. Some burials were cut by historic pits, in one case a burial was disturbed by a sequential burial, and mortuary phase four burials were so close to the surface that they were highly disturbed by modern land clearance activities with a bulldozer. All individuals were included in the assessment for trauma types, regardless of the level of completeness. The level of bone preservation in each skeletal element (bone) was determined using methods adapted from Buikstra and Ubelaker (1994). Long bones were separated into five segments: proximal epiphysis, proximal third of shaft, midshaft third, distal third of shaft, and distal epiphysis, to assist in determining bone preservation, reporting trauma location and prevalence by bone element. Each segment was assessed as complete (fully preserved), near complete (almost complete segment), partial (more than half the segment preserved), incomplete (less than half the segment preserved), and fragmented (only fragmentary bone pieces preserved). Long bones represented by at least three complete segments, or 75% of the element, were included for analysis in this study.

Non Ban Jak methods

Trauma analysis

The trauma data for this thesis was collected by the author with a detailed description and photographic record. Each bone with macroscopic evidence of fracture was taken to Phimai Hospital in Thailand to be radiographed in both anterioposterior and mediolateral projections to gain the best perspective to view the fracture. Radiographs assisted in the evaluation of fracture healing and to identify deformities or displacement under a callus (Lovell 2008). The location and type of pathologies, such as trauma-induced degenerative joint disease or bone-weakening disease such as osteoporosis, were also recorded so as to identify any factors that may directly or indirectly affect the presence of fractures (Krakowka 2015; Lovell 1997).

Evidence of trauma was identified from the skeletal remains by examining the presence and type of fractures, abnormal displacement or dislocation of joints, and sharp force trauma. Recorded for each lesion were:

1) bone element;
2) side (left or right);
3) segment (i.e. distal 1/3 of shaft);

4) aspect (i.e. superiolateral);
5) the appearance of the injury;
6) dimensions, including length, width & depth of the wound;

Also recorded was the proximate cause of injury, if it could be ascertained, using the criteria from Lovell (2008). For example, an impaction fracture occurs when fragments of bone at the fracture site are firmly driven into each other, such as when an individual falls from a great height, attempting to land on both feet (Lovell 2008).

Antemortem, perimortem or postmortem injury

To help distinguish the differences between violent and non-violent trauma it is necessary to identify fundamental differences between antemortem, perimortem and postmortem trauma, and also the differences between trauma and disease; and taphonomic processes versus bone lesions that occurred during life. Antemortem injuries were recognised by evidence of active or completed bone remodeling, such as a callus of woven or lamellar bone, or bone resorption (Aufderheide & Rodriguez-Martin 1998; Ortner 2003; Sauer 1998). Antemortem injuries were also distinguished by the uniform colour staining at the trauma site and the surrounding bone, as opposed to recent postmortem breaks which will have a lighter colour (Lovell 1997). This identified trauma that was sustained whilst the individual was still living. Perimortem injuries that happened at the time or death or very soon after were differentiated from antemortem trauma by the absence of any stage of healing or infectious response (SWGFA 2011).

This still leaves the difficulty of correctly differentiating perimortem trauma from postmortem breakage which results from taphonomic processes (SWGFA 2011). However, the organic component of perimortem bone gives it a level of elasticity and it will react differently to ‘dry’ post mortem bone (Aufderheide & Rodriguez-Martin 1998). Perimortem injuries were further identified by observing the following: colouration of the wound edges, for example recently exposed surfaces will be a lighter colour than the prehistoric injury edges; and by the presence of fresh bone characteristics such as adhering bone to the edges of the wound, inner beveling and sharp edges (Facchini *et al.* 2008; Sauer 1998; Wheatley 2008).

Dislocations

Only unset dislocations with osteogenic changes to an articular surface can be seen in the archaeological record. Dislocated joints that return to their normal position soon after the injury occurred will not leave any trace of the injury as there needs to be instability in the joint for some time prior to death for osteogenic changes to be seen (Lovell 1997). For this type of injury the affected bone elements and articular joints were recorded, along with a description of the displacement and any associated complications such as osteoarthritis or fracture and whether there was luxation (complete dislocation) or subluxation (partial dislocation) (Lovell 1997).

Sharp force trauma

All bone elements were macroscopically inspected for signs of sharp force trauma (SFT) using the cut mark morphology terminology described by Lewis (2008). Wounds could be described as chop marks, linear cuts, scrape marks, percussion marks or perforating injuries (Stodder 2008). Characteristics evaluated were linear lesions with well-defined sharp edges and V-shaped cross section (Šlaus *et al.* 2012) with striations parallel to the kerf (Shaw *et al.* 2011). Any blunt force injuries such as crushing to the edges of the wound were recorded as they may be associated with the force of the weapon blow (Shaw *et al.* 2011). The location, dimensions, number and orientation and patterning of cuts was also noted. Sharp force injuries can be inflicted by many different implements and a good description of the injury may lead to an identification of the weapon used (Lewis 2008).

Fractures

All postcranial elements were macroscopically examined for any signs of healed or unhealed trauma. Evidence of complications in bone remodeling was noted, in particular if there was any nonunion, malunion or delayed union of healed bone, or secondary infection (Judd 2002). For long bones, the affected limb was compared to the unaffected side for malunion deformities such as shortening, lengthening, angular or rotational displacement of the fractured ends (Grauer & Roberts 1996; Lovell 1997). Radiographic observation of the fractures was used to assist in identifying fracture type and degree of healing (Lovell 2008). Only fractures with evidence of antemortem healing were used in the trauma analyses.

Cranial trauma

Traumatic lesions on the crania were recorded by element, location (left/right, anterior/posterior, inferior/superior), whether the injury was present on the ectocranial and/or endocranial surface, and if beveling was observed. Injuries were classified as either blunt force trauma (BFT) or sharp force trauma (SFT). Depression fractures to the cranium are a common result from BFT, and are consistent with direct localized trauma (Djurić *et al.* 2006). These can be identified by a circular, oval or linear fracture depression at the point of impact with the plastic properties of antemortem bone producing an outward bulging around the edges of the depression (Berryman & Haun 1996). SFT to the cranium was identified as a puncture or incision (Djurić *et al.* 2006; Grauer & Roberts 1996). The size and shape of any lesion, and any sign of healing was noted in this study.

Statistical analysis

Due to the small sample sizes, statistical analysis for significance was carried out using Fisher's Exact Test (FET) with two-tail p value and a confidence interval of 95%. A significance level of 0.05 was used to determine if there was notable differences in the rates of trauma between males and females, and between mortuary phases. When a hypothesis is tested by statistical analysis, there are two types of errors possible as the results are based on probabilities. Type I error occurs if it is concluded that there is a difference between skeletal samples when there is none, and type II error is the opposite, failing to observe a difference between the samples when there actually is one (Cannon 2001). A traditional significance level of 0.05 was chosen to accept a 5 in 100 chance that the variability, or difference, would be due to random chance.

Chapter 4

Results

Non Ban Jak

This chapter will begin with the descriptions of the types of trauma found in the Non Ban Jak population (dislocation, fractures, cranial trauma and cuts). The second part of the results section presents qualitative data of the frequency of postcranial and cranial trauma according to individual and bone element and statistical analyses comparing the prevalence of trauma between males and females. Comparisons are also made of the trauma prevalence between the mortuary phases of the western mound. This will be followed by a discussion of the results.

For the most part, this study focuses on healed (antemortem) trauma as it is known to have been inflicted during the individuals' life. Only one case of probable perimortem trauma, an individual observed with unhealed penetrating cranial lesions alongside an antemortem cranial lesion was found in this study. Further unhealed lesions were observed on several individuals which could possibly be perimortem trauma that occurred close to the time of death. However, the lesion characteristics made it difficult to distinguish them from postmortem lesions caused by taphonomic processes occurring after death. Therefore these lesions have not been included in this study.

Appendix A provides details of possible perimortem or postmortem lesions in the skeletal assemblage, such as unhealed cuts and possible compression fractures to the vertebrae, which have an unknown aetiology. The appendix also provides more detailed trauma information for each individual, including the dimensions of the lesions and completeness and preservation of the skeleton.

No individuals younger than 15 years of age were found to have antemortem or perimortem lesions and so the trauma data tables represent adult individuals only. Age at death estimations were not included in the trauma analyses as it is not possible to ascertain when in the individual's life, or from what number of events, well-remodeled fractures occurred.

Trauma: Non Ban Jak

Dislocation

Burial 40 (B40), an adult of indeterminate sex and age, was the only individual to exhibit a dislocation in the Non Ban Jak sample (Figure 4.1). The radial fossa of the right humerus was enlarged, resulting from an anterior radial dislocation. This injury produced a lateral supracondylar crest that is thicker, wider, and more robust than is usual where the radial head was subsequently articulated. The muscle attachments on the right humeral diaphysis also appear more robust when compared with the left humerus. It is likely that this individual would have suffered from one or more of the common complications associated with an unreduced elbow dislocation, such as vascular or nerve injury which can lead to and elbow instability and stiffness, often with limitation of rotation (Apley & Soloman 2001; Huckstep 1995). Functional loss relating to radial and ulna nerve injury could have led to paraesthesia of the forearm and digits (Takebe *et al.* 1982) or 'wrist drop', a weakening of the forearm extensor muscles (Neal & Fields 2010). Injury to the ligaments could have caused long-term instability in the joint capsule, often causing the ossification of compensating muscle attachments (Lovell 1997) but there was no skeletal evidence of this in B40.

This individual likely received the injury at a young age as the radial fossa is quite well remodeled. This is also a rare injury that is most commonly seen in young individuals (O'Driscoll 2000). For such articular surface modifications to occur the bones must have remained in the abnormal position for a substantial period of time before death (Lovell 1997). An anterior radial dislocation can be associated with a Monteggia fracture of the shaft of the ulna (Huckstep 1995; Mostofi 2006), which is usually the result of a fall onto an outstretched hand when the forearm is in hyperpronation (Lovell 2008). However, in this individual, neither the ulna nor radius of the right forearm was preserved so this cannot be ascertained.

Figure 4.1. B40

Anterior view of right distal humerus with enlarged radial fossa and wider lateral supracondylar crest due to dislocation of the radius (not present).

Fracture

There were 13 observations of antemortem fractures in a total of 10 individuals. The majority of fractures were identified as transverse or oblique using macroscopic and radiological examination. Both transverse and oblique type fractures are common and can be the result of direct or indirect trauma (Lovell 1997). It must also be noted that underlying conditions such as tumour, infection, vitamin D deficiency and osteoporosis can compromise bone strength, which in turn can increase an individual's risk to fracture (Patel *et al.* 2011; Ruohola *et al.* 2006; Yun & Lee 2004).

Burial 21, a mid aged male adult, exhibited a healed transverse fracture to the distal third of the right ulna, with slight posterior displacement visible of the distal element (Figure 4.2). The radius was not affected. These lesion characteristics of an isolated fracture of the ulna are often used to define a Parry or 'night stick' fracture, an injury occurring when the arm is brought up to protect the face from a direct blow (Judd 2008; Richards & Deal 2014). Judd (2008) compiled the following quantitative criteria to recognize a Parry fracture: (1) an absence of radial involvement, (2) a transverse fracture line, (3) a location below the midshaft and (4) either minor unalignment (≤ 10°) in any plane or horizontal apposition from the diaphysis (<50%). Other possible mechanisms to consider for a distal ulna fracture are chronic stress fracture resulting from habitual or repetitive activities, or accidental injury (Judd 2008; Smith 1996). A violent aetiology for this type of fracture is more probable when it is accompanied by evidence of craniofacial trauma (Smith 1996), whilst B21 has not been observed with craniofacial trauma, perhaps due to successfully warding of blows aimed at the head, other individuals in the Non Ban Jak sample have.

Figure 4.2. B21 Medial view, healed fracture of right distal ulna (remodeled callus is visible to the right of the recent postmortem break).

Three individuals exhibited transverse fractures of the distal third of the radius, with posterior displacement of the distal fragment. These injuries are clinically described as Colles' fractures as they are identified by three features: (1) impacted transverse fracture, (2) affecting the lower fourth of the radius with (3) posterior displacement and/or angulation (Apley & Soloman 2001; Lovell 1997; Perkins 1958). This type of fracture is commonly caused by a fall onto an outstretched hand (Huckstep 1995; McQueen & Caspers 1988). However, in a prehistoric sample, the exact mechanism will never be known. For instance, a fall could be the result of the individual tripping, falling or being pushed. Serious complications can arise from such an injury, depending on the level of treatment received, and it is possible that any of these individuals could have been effected by persistent nerve damage, arthrosis or ruptured tendons, and these injuries could all lead to pain and dysfunction such as loss of finger or wrist motion (Cooney *et al.* 1980).

Burial 75, an old age adult female, has two fractures of the right radius. The first fits the description of a Colles' fracture (Figure 4.3A), it has a mostly well-remodeled callus just proximal to the distal epiphysis but there was still immature active bone remodeling the posterior side of the callus at the time of death. The other complete fracture is further proximal (Figure 4.3B). This injury appears to be an older lesion as the mature bone of the well-remodeled callus has a smooth surface and no angulation or displacement is evident. There is some postmortem damage to this region but the healed callus is still evident. Distal radial fractures are one of the most common fractures in children and adults (Apley & Soloman 2001), so it would not be that unusual for an individual to achieve two radial fractures in their lifetime. In postmenopausal women Colles' fracture is also one of the most common fractures (Cummings *et al.* 1985). Radial or ulnar nerve injury are relatively common complications with distal radial fractures, and tendon rupture or tendonitis may occur, impairing strength and function of the digits and forearm (Turner *et al.* 2007).

Figure 4.3A. B75

Medial view of right distal radius with fracture 'A' (circled) that was still remodeling at the time of death. Posterior (to the top of the picture) displacement of the distal epiphysis is evident.

Figure 4.3B. B75
Lateral view of the same right distal radius with healed fracture 'B' (circled) (recent postmortem break through the fracture site).

Burial 76 is also an old aged female adult with a Colles' fracture to the distal shaft of the left radius (Figure 4.4). The fracture site is well-remodeled, with the callus more prominent posteriolaterally. There is some lipping on the distal articular surface perhaps indicative of degenerative changes associated with the change in joint alignment postfracture.

Figure 4.4. B76

Lateral view of the left distal radius, with healed fracture. There is posterior displacement of the distal epiphysis and remodeling of the mature callus is visible.

B133, a mid aged female, exhibits posterior displacement of the distal segment of the right radius in a classic Colles' fracture (Figure 4.5). A well-remodeled callus is most evident on the lateral aspect. The left clavicle also has a transverse fracture mid-shaft. The callus is well-remodeled with a recent postmortem break through it. There are signs of osteolytic activity, particularly on the inferior surface, and this suggests infection. However it is not possible to determine if the infection was the mechanism for the fracture or if the infection was secondary to the fracture. No other bones in this individual show signs of infection. Figure 4.6 shows an obvious shortening of the left clavicle, thickening of the circumference and a pronounced curve to the lateral end. Mid-shaft clavicular fractures are a common injury, usually resulting from a direct force or fall onto the shoulder (Denard *et al.* 2005; Khan *et al.* 2009). No treatment for such an injury would be required, however a slight but permanent deformity or shortening of the clavicle are common complication in adults post fracture (Apley & Soloman 2001; Huckstep 1995). There may be some shoulder pain and limitation of arm or shoulder movement in the worst of cases due altered anatomical relationships (Perkins 1958; Rasmussen *et al.* 2011).

Figure 4.5. B133

Medial view of right and left distal radius for comparison. Right radial distal epiphysis is fractured and the distal segment is displaced posteriorly.

Figure 4.6. B133 Superior view of right and left clavicle for comparison. The left clavicle is shortened as a result of a healed fracture and shows signs of infection.

Two burials exhibited an isolated oblique fracture to a toe phalanx. Toe fractures are very painful but would not usually be accompanied by any lasting disabilities unless infection enters the lesion (Huckstep 1995), of which there was no skeletal indication of in either individual. This type of fracture results from a depression force from above, for example, a crushing injury when a heavy object is dropped onto the foot, alternatively they can result from axial forces, usually when stubbing a toe (Hatch & Hacking 2003).

Burial 62, a mid aged adult male, presents with an oblique fracture distolaterally on the proximal phalanx of the second metatarsal on the left foot (Figure 4.7). There is a slight plantar angulation of the distal epiphysis and a callus of immature woven bone had formed over the fracture. The callus also appears to have incorporated the articulating middle phalanx so that the distal interphalangeal joint is now ankylosed.

Figure 4.7. B62
A) Dorsal view of second toe proximal phalanx with oblique fracture of distal epiphysis.

B) Lateral view of oblique fracture. Distal epiphysis of the proximal phalanx is displaced in a plantar direction and fused with articulating epiphysis of the middle phalanx.

Burial 140, an adult of undetermined sex and age, has a remodeled fracture to the distal diaphysis of a right proximal toe phalanx. The oblique fracture line is still visible (Figure 4.8). This individual also has a fracture to a possible lower left rib which has a well-remodeled callus of smooth bone. The callus is located anteriorly (Figure 4.9).

Figure 4.8. B140

Dorsal view of right proximal toe phalanx, with oblique healed fracture visible above the white line.

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Figure 4.9. B140

External view of left lower (?) rib, with healed fracture (callus visible). Sternal tip of rib broken off postmortem.

There are four other individuals who have sustained rib fractures (described below). Rib fractures are a common injury that may cause pain and discomfort but do not usually require treatment to heal (Perkins 1958). Multiple rib fractures, however, can be the result of a severe chest injury or non-accidental trauma (Barsness *et al.* 2003), resulting in death or the need for extended care should pulmonary complications develop (Ziegler & Agarwal 1994). Individuals are particularly vulnerable if multiple ribs are fractured (Sirmali *et al.* 2003). The level of healing observed in the four individuals mentioned here indicate they have lived for some time after sustaining rib trauma. They are therefore unlikely to have suffered from serious complications such as laceration of the spleen, liver or kidneys, which is possible if the lower ribs are fractured (Huckstep 1995; Sirmali *et al.* 2003). In clinical studies the majority of rib fractures result from traffic accidents, followed by falls and less commonly assaults, and industrial or farming accidents (Bulger *et al.* 2000; Sirmali *et al.* 2003; Ziegler & Agarwal 1994).

B43, a young adult female, exhibits a transverse fracture of a possible 8th rib (left) with non-union of the fracture edges which show signs of healing (Figure 4.10). This rib has been ossified to what is possibly the 7th rib. The fracture is positioned close to the angle of the rib. Lytic lesions were also observed on thoracic vertebrae T6 & T10, which suggests the likelihood that the fracture is secondary to the pathology. Even if the rib shaft was weakened by pathology, it would still require some force for a fracture to occur.

Figure 4.10. B43 External view of left ribs (rib 8 with non-union fracture circled). The two ribs have joined by ossification (antemortem).

Burial 64 is an old aged adult female who sustained a complete mid-shaft fracture of a left lower rib (likely 10th or 11th). This looks to be an oblique fracture with non-union of the fracture ends. The appearance of new woven bone in the rib interior suggests the bone was actively remodeling at the time of the individual's death (Figure 4.11). Non-union of a rib fracture would likely cause on-going pain and discomfort, exacerbated by the movement of the rib ends such as during physical activity or coughing (Nirula *et al.* 2009). Spondylolysis was noted in the 4th lumbar vertebra by K. Domett, and this could also be the result of trauma. Bone pathology is also present in this individual, with a reactive pathological lesion on S1 and L5 vertebrae. It is possible therefore that the spondylolysis and rib fracture have resulted from bone weakening due to possible infection.

Figure 4.11. B64 Inferior view of left rib (10th or 11th), fracture with non-union.

B82, an old adult male, has a malaligned complete fracture observed on a rib fragment from the left-hand side of the body (Figure 4.12). It cannot be ascertained which rib this is, or the exact location on the shaft that the fracture occurred. The bone has completely remodeled and the likelihood is that this individual lived with this injury for some time before their death.

Figure 4.12. B82

External view of rib fragment, with malaligned healed fracture.

B98, an adult of undetermined sex and age, has a well-remodeled fracture of a right, possible upper rib, on the lateral aspect. The callus is of mature lamellar bone (Figures 4.13 & 4.14).

Figure 4.13. B98 External view of right rib with healed fracture.

Figure 4.14. B98 Radiograph image of the healed fracture site.

Burial 7, an old adult female old, has a healed depressed cranial fracture, located on the right frontal bone, vertically in line with the right supraorbital notch (Figure 4.15 A & B). The irregular circular fracture site has remodeled, with mature bone present. The floor of the depression is an uneven surface. There was no inward displacement of bone fragments observed endocranially. A depressed cranial fracture may be associated with a cortical laceration, cerebral contusion or haematoma (McBride *et al.* 1988) which, depending on the severity of the injury, may have affected the individual's memory or co-ordination and movement temporarily.

Figure 4.15 B7

A) Depressed cranial fracture.

B) Close-up of the healed fracture.

B96, an adult of indeterminate sex and age, has a healed blunt force trauma fracture to the maxillae which affects the left and right frontal processes and nasal bones (Figure 4.16). The right nasal and medial side of the left nasal appear depressed, while the lateral side of the left nasal and medial side of the left frontal process appear to bulge outward. This makes it appear as if the individual has been hit on a downward oblique angle from superiolaterally to inferiomedially. This individual may have sustained a permanent facial deformity as a result of the fracture.

Figure 4.16. B96 Black arrows point to healed depressed fracture affecting the left and right nasal bones and frontal processes of the maxillae.

Cuts: incision and penetrating

Burial 3 is a young adult male exhibiting cut marks, both healed and unhealed on the cranium. Unfortunately the cranium is incomplete and fragmented due to postmortem damage. Some of the cranial fragments were temporarily reconstructed to be able to distinguish the location of the cuts. A healed cut is located on the posterioinferior aspect of the right parietal (Figure 4.17 A & B). The wound edges are smooth and well remodeled. Three other unhealed linear, v-shaped cuts are present on the inferior aspect of the left parietal (Figure 4.18). All three cuts pierce completely through the parietal bone and beveling is present on the endocranial surface. The edges of the cuts are clean and smooth and there are no signs of healing. A possible fourth cut is located on the left temporal but it is likely that this is the inferior end of one of the parietal cuts. However, parts of the cranium are missing and so continuity of the cut cannot be clarified. Due to these cuts piercing the cranium and there is no sign of healing, it is likely that these are perimortem injuries occurring at the time of death, and possibly even contributed to the cause of death due to shock and/or hemorrhage. It is also possible that the cranium was cut postmortem soon after death.

Figure 4.17. B3

A) Lateral view of healed cut on the posterio-inferior aspect of the right

Figure 4.17. B3

B) Close-up of the healed cut.

Figure 4.18. B3 Lateral view of left parietal with three unhealed cuts highlighted by arrows. (Coronal suture is to the left of the image).

Trauma prevalence by individual

A total of 14 adults, 25.5 percent of the total adult sample of 55 individuals (which is 10.2 percent of the total Non Ban Jak sample of 137 individuals), displayed evidence for traumatic antemortem and perimortem lesions in the form of a dislocation, fractures and Sharp force trauma (SFT). There were a total of 20 traumatic lesions observed, including one individual with an antemortem cut and a series of three perimortem cuts. Four individuals (two females, one male and one of indeterminate sex) exhibited two or more lesions each (Figure 4.19).

Six females, 10.9 per cent of the adult sample (n = 55), were observed with a traumatic lesion, as were five males (9.1%), and three of unknown sex (5.5%) (Table 4.1). By looking at frequency of trauma by sex, it can be seen that almost one third of males (27.8%, 5/18) were affected, a quarter of females (26.1%, 6/23), and 21.4 per cent (3/14) of unsexed individuals. There was no statistically significant difference between the number of females and males with trauma (FET p value = 1.0000).

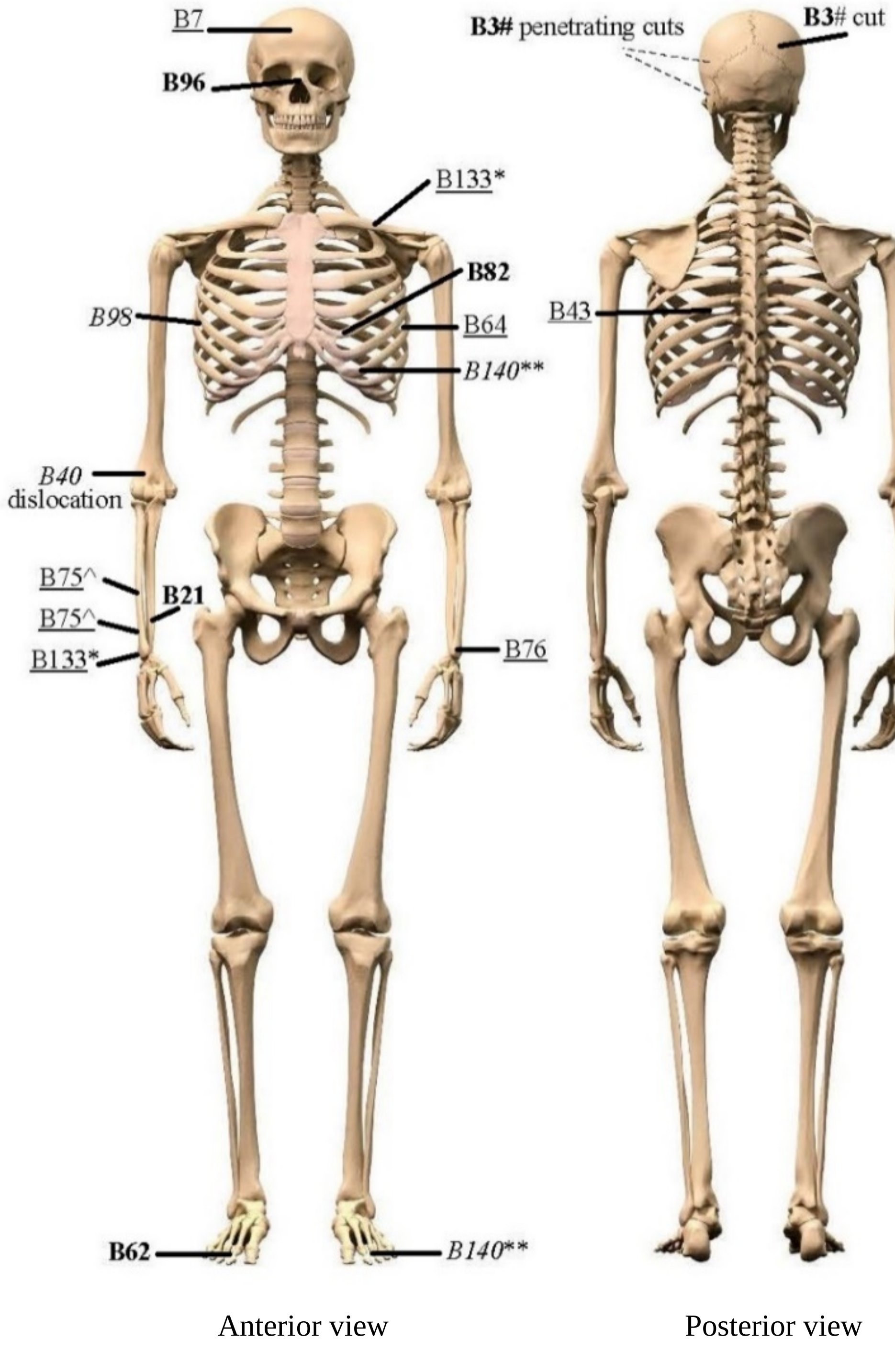
Table 4.1. Sex distribution of trauma by adult individual

	Within the adult population		Within each sex category	
	a/A	%	n/N	%
Male	5/55	9.1	5/18	27.8
Female	6/55	10.9	6/23	26.1
Unsexed	3/55	5.5	3/14	21.4
Total	14/55	25.5	14/55	25.5

a, n = number of individuals exhibiting one or more traumatic lesions
A = total number of adults in the sample
N = number of adult individuals of that sex

A predominance of forearm fractures are found on females (3 females, and one male) (Table 4.2). Rib fractures are found on two females, one male, and two individuals of indeterminate sex. There is one male and one individual of indeterminate sex with a foot injury but no females, and there is only a female with a fractured clavicle. There are two males with cranial trauma (parietals and nasals) and one female (depression fracture to top of right forehead) (Table 4.3). There are no individuals presenting with both cranial and postcranial trauma.

Figure 4.19. Location of antemortem and perimortem trauma in adults.



All lesions are fractures, except where indicated otherwise.

*Trauma in the same individual indicated by * or ** or ^ or #*
----- dashed line indicates probable perimortem trauma.

Burial numbers that are underlined indicate females, in bold indicate males, italics indicate unsexed adults.

Table 4.2. Postcranial trauma by adult individual

Sex	Burial No.	Element	Side	Part	Trauma
M	21	ulna	R	distal 1/3	fracture (transverse)
M	62	toe phalanx	L	distal epiphysis	fracture (oblique)
M	82	rib	L	shaft	fracture (malaligned)
F	43	middle rib	L	posterior shaft	fracture (non-union)
F	64	lower rib	L	lateral shaft	fracture (non-union)
F	75	radius radius	R R	distal 1/3 distal 1/3	fracture (transverse) fracture (transverse)
F	76	radius	L	distal 1/3	fracture (transverse)
F	133	clavicle radius	L R	shaft distal 1/3	fracture (transverse) fracture (transverse)
?	40	humerus	R	distal epiphysis	(radial) dislocation
?	98	rib	R	lateral shaft	fracture (transverse?)
?	140	lower (?) rib toe phalanx	L R	anterior shaft distal epiphysis	fracture (transverse) fracture (oblique)

Table 4.3. Cranial trauma by adult individual

Sex	Burial No.	Side	Part	Trauma
M	3	R L	parietal (lateral) parietal	SFT (shallow cut) SFT (piercing cuts, perimortem?)
M	96	L/R	nasals/frontal processes	fracture
F	7	R	frontal	depressed fracture

Overall, the number of lesions are only slightly more prevalent on the right-hand side (right = 10; left = 9). Forearm injuries consist of fractures to the ulna (one) or radius (four), four of which are on the right-hand side and one on the left-hand side. All forearm fractures were to the distal 1/3 of the diaphyses. One distal humerus presents with an enlarged radial fossa which is due to a dislocation of the radius, however, the radius was not present in the sample. A left clavicle was also fractured. There were no lesions to the long bones of the thigh or lower leg, however, there were two fractured toe phalanges, one on the left-hand side and one on the right-hand side.

There were five individuals (9.1%) with fractured ribs (one middle rib, two lower ribs and two indeterminate ribs), all but one of the rib fractures are on the left-hand side. The fracture locations on the rib shaft varied from two fractures occurring laterally on the shaft, one posteriorly, one anteriorly and one unknown shaft location. Cranial trauma was evident on three individuals, with a frequency of 11.5 percent (3/26) of individuals with at least 75% of the cranium present. B3, a young adult male had a shallow and well-healed cut to the right parietal occurring before the three unhealed cuts that pierced straight through the left parietal bone. It is likely that these are perimortem injuries occurring at the time of death, and possibly even contributed to the cause of death due to shock and/or hemorrhage. B7, an older adult female had a healed circular depressed fracture to the top right of the forehead, and B96, a mid aged adult male, sustained a fracture across the left and right nasals.

Fracture prevalence by long bone

The number of antemortem fractures in complete or near complete long bone elements (at least 75% preservation of the element) were compared by individual and also compared by each element. Both left- and right-side elements are included when present in the sample. The fracture prevalence for the small and fragile bones of the hands, feet, ribs and cranium could not be calculated as the total number of complete bones were difficult to ascertain. This was due to a lack of preservation and a tendency for the small and fragile bones to be lost due to taphonomic processes such as animal burrowing and water movement.

The total prevalence for all long bone fractures in males is 0.6 percent, and for females it is 3.9 percent (Table 4.4). However, this difference is not statistically significant (FET p value = 0.6177). Only one male in the Non Ban Jak sample has trauma observed in a long bone. The ulna fracture rate for males is 3.6 per cent. In the female sample the fracture prevalence rate for the clavicle is 5.9 percent and the radius is 25.0 percent. There are no observable differences between males and females for the trauma prevalence rates of a particular element as there are no long bone elements with traumatic lesions represented by both sexes.

Radii represent the most frequently fractured long bone element with a fracture prevalence of 7.0 percent, even though it was represented by the least number of complete or near complete elements (n= 57). There is one fractured clavicle and ulna in the sample, with each of these elements having a less than two per cent fracture prevalence. There were no observable fractures in the long bones of the thigh or leg (femur, tibia and fibula), even when these elements were represented by a preservation rate similar to most other elements.

Table 4.4. Adult long bone fracture prevalence (% by bone element)

Element	Male n/N	%	Female n/N	%	?sex n/N	%	Adults n/N	%
Clavicle	0/29	0.0	1/17	5.9	0/23	0.0	1/69	1.4
Humerus	0/27	0.0	0/22	0.0	0/28	0.0	0/77	0.0
Radius	0/27	0.0	*4/16	25.0	0/14	0.0	*4/57	7.0
Ulna	1/28	3.6	0/16	0.0	0/16	0.0	1/60	1.7
Femur	0/23	0.0	0/22	0.0	0/20	0.0	0/65	0.0
Tibia	0/24	0.0	0/19	0.0	0/23	0.0	0/66	0.0
Fibula	0/22	0.0	0/17	0.0	0/23	0.0	0/62	0.0
Total	**1/180**	**0.6**	***5/129**	**3.9**	**0/147**	**0.0**	**6/456**	**1.3**

(n/N) n = number of fractures to element, N = total complete (≥75%) element present
* = Three individuals with fracture to radius but one of these individuals has two fractures of the same radius

Eastern and Western mound comparisons

Once trauma had been assessed in the overall adult sample, focus was placed on observing possible spatial differences of trauma rates at the site by making comparisons between the eastern and western mound burials. Only three adults have so far been excavated from the eastern mound, two of which were observed with trauma (2/3, 66.7%) whilst 12 individuals from the total of 52 adults (12/52, 23.1%) of the western mound were observed with trauma. No meaningful statistical comparisons could be made between the two mounds as the burial numbers are too low from the eastern mound. The smaller number of burials on the eastern mound could be due to the eastern mound excavation being a smaller area than that of the western mound, or the majority of burials are in locations yet to be excavated.

The Non Ban Jak population may also have had two very different mortuary rituals for each mound. The 2016 and 2017 excavations have uncovered more burials from both mounds, however time constraints during the skeletal examination phase in Thailand meant that the 2016 and 2017 burials could not be included in this thesis. More individuals for inclusion in any further skeletal analysis, will assist in determining if there were spatial differences in rates of trauma at the site.

Western mound trauma prevalence by individual

As discussed in the materials section, the four mortuary phases are identified by differences in mortuary ritual, cultural layers and stratigraphy, and they can be used to identify possible temporal changes in the prevalence of trauma. However, there are overlapping transition periods between the layers and this blurs the distinction between mortuary phases. Complex statistical analysis would be ineffective on such a small sample size when comparing trauma prevalence between mortuary phases. However, simple statistical analysis is still useful to highlight any possible patterns to changes in trauma prevalence in individuals for the time the cemetery was in use.

Across all the mortuary phases (MP's) four of the 17 males were observed with trauma (23.5 %), five of the 21 females (23.8%), and three of the 14 unsexed individuals (21.4%) (Table 4.5). During MP1 and MP2 the female trauma prevalence was between 16.7 – 22.2%. There was a spike of 50% female trauma rate in MP3, and this is just under twice as much as the male trauma rate of 28.6% in MP3 (no significant difference, FET p value = 1.000). The prevalence of trauma for males was highest at 33.3% in MP1, but MP2 & MP3 had similar prevalences of trauma (25.0% and 28.6% respectively). In the final mortuary phase (MP4) no adults were observed with antemortem trauma. No significant differences in trauma prevalence between the successive mortuary phases of the western mound could be identified (FET p values ranged from 0.3394 to 1.0000).

Table 4.5. Sex differences in antemortem trauma rates among mortuary phases of the western mound by individual

	MP1		**MP2**		**MP3**		**MP4**			
Sex	n/N	(%)	n/N	(%)	n/N	(%)	n/N	(%)	Total	(%)
Male	1/3	(33.3)	1/4	(25.0)	2/7	(28.6)	0/3	(0.0)	4/17	(23.5)
Female	2/9	(22.2)	1/6	(16.7)	2/4	(50.0)	0/2	(0.0)	5/21	(23.8)
Unsexed	0/1	(0.0)	2/6	(33.3)	0/2	(0.0)	1/5	(20.0)	3/14	(21.4)
Total	3/13	(23.1)	4/16	(25.0)	4/13	(30.8)	1/10	(10.0)	12/52	(23.1)

n = number of adult individuals exhibiting one or more traumatic lesions
N = total number of adult individuals of that sex

Discussion

One quarter of the adults (25.5%, 14/55), exhibited antemortem trauma and no subadults were observed with trauma. The risk of injury is very similar in males and females. Two of the females were observed with multiple fractures (two), whereas all males presented with a single fracture only. There was a slight bias for injuries to be on the right-hand side.

Compared to the males, females are more affected by injuries in the forearm (4:1), the clavicle (1:0), and ribs (2:1), while the three males received an injury to either the forearm, a rib, or foot. This pattern of trauma is slightly suggestive of occupational or lifestyle risk differences in females and males. More males than females in the Non Ban Jak sample are buried with iron sickles, and both men and women are buried with iron knives and spindle whorls (Higham *et al.* 2014a), which does not indicate to an obvious gender division in economic roles. However, any future detailed examinations on identifying activity-related skeletal modifications, such as osteoarthritis and entheseal degeneration, would be helpful in determining a correlation trauma and occupation.

The characteristics of the distal ulna fracture sustained by a mid aged male suggest it is a Parry fracture. This type of injury is often categorised as a defensive wound resulting from interpersonal violence where the person raises the forearm to protect their face, rather than accidental injury such as a fall (Apley & Soloman 2001; Lovell 1997). However, chronic stress fracture from daily activities or sports could also have caused such a lesion (Judd 2008). The pattern of forearm fractures in the females suggest an accidental aetiology, such as a Colles' fracture to the distal radius. This type of fracture can be attributed to indirect trauma, likely from the reflexive action of falling onto an outstretched hand (Lovell 1997; Sigurdardottir 2014). This could also explain why forearm injuries are predominantly on the right hand side. Populations are usually dominated by right-handers, and a person falling would reflexively put their dominant hand out to save themselves. Fractures to the clavicle can also be caused by a low-impact fall onto the shoulder or the outstretched hand, or it can be caused by moderate to high energy impact trauma such as a sports injury or a high-impact fall from a height (Andermahr *et al.* 2014; Apley & Soloman 2001; Perkins 1958).

Rib lesions were observed on both males and females. Possible mechanisms for rib fractures in prehistory include direct blunt trauma, penetrating trauma, and crush injuries (Morgan-Jones & Mackie 1996; Ziegler & Agarwal 1994). Typical scenarios in which fractured ribs result are falling from a height or onto an object, assaults, and being crushed or kicked by an animal (Björnstig *et al.* 1991; Byun & Kim 2013; Marasco *et al.* 2015).

An unsexed adult sustained a radial fossa dislocation on the right humerus. Dislocations can be congenital, a secondary injury to diminished growth of the ulna, or the result of trauma (Burge 2010; Lovell 1997), such as a fall onto the hand or wrist (Apley & Soloman 2001; O'Driscoll 2000). Interestingly no injuries were sustained to the thigh or leg, however there are two individuals with a fractured foot phalanx. Toe fractures most frequently are caused by crushing or stubbing injuries; stress fractures are also possible but less common (Hatch & Hacking 2003; Van Vliet-Koppert *et al.* 2011).

Two males and one female were observed with cranial trauma. Males are more prone to experiencing cranial trauma due to a culture of participating in fighting and hostile activities (Cohen *et al.* 2014). A young adult male (15 – 18 years of age) exhibited a healed cut to the right side of the head but also later in life sustained a series of cuts that pierced the left side of the head at or around the time of death. The cranial penetrating lesions and incision could possibly have been inflicted with a spear, machete, iron point or knife, such as the type found as mortuary offerings at this site (Higham *et al.* 2014a). A mid aged adult male was observed with a healed depressed fracture to the nasal bones. This type of injury can occur as a result of boxing or fighting injuries or a fall from a height (Perkins 1958). An old aged adult female sustained an antemortem depressed fracture to the right side of the forehead. This healed blunt force trauma could be the result of accidental injuries sustained from a fall or ‘other mishap’ (Walker 1989:318), such as a direct blow from a falling object. The injury could also have been from intentional mechanisms including a hammer-blow from a fist, a thrown rock or a blunt weapon from a left-handed attacker in face-to-face conflict (Walker 1989). Baked clay pellets used as projectiles for a hunting bow or slingshot were recovered from Iron Age burials at Ban Wang Hai in northern Thailand, as well as Ban Non Wat and Ban Chiang (Coupey 2006; Gorman & Charoenwongsa 1976; Higham 2011b) and such an implement could possibly have caused a depressed skull fracture.

Cranial trauma is predominantly recorded on the left side of the skull during face-to-face conflict as most attackers are right-handed (Cohen *et al.* 2014; Djurić *et al.* 2006). In this sample, cranial lesions were predominantly on the right hand side. If the injuries were from intentional violence, the female with the depressed fracture on the right frontal bone could have been attacked by a left-hander, the male with the antemortem cut to the right parietal was likely attacked from behind, and the male with the nasal fracture would likely have received the blow from above or from an attacker standing to the front.

Interpersonal violence at Non Ban Jak?

The presence of individuals with head, neck and facial injuries, ulna parry fractures, or multiple lesions are strong indicators of the presence of interpersonal violence (Brink *et al.* 1998; Judd 2006; Pechenkina *et al.* 2007; Walker 2014), with blunt force trauma resulting from kicks and punches being the primary mechanism (Brink *et al.* 1998). In the Non Ban Jak sample, four individuals exhibiting either cranial trauma or a defensive (Parry) forearm injury, and four individuals with multiple lesions suggest that there was some level of violent conflict within the settlement.

There were a number of Colles’ fractures to the forearm, and fractured toes, ribs and clavicle that were likely sustained by accident or as an occupational or environmental hazard. Osteoporosis is also a risk factor that may have predisposed old aged females to Colles' fracture (Cummings *et al.* 1985). Common mechanisms for accidental injury in hunting and foraging and agricultural populations are wide-ranging and these could have been experienced by the Non Ban Jak population. In rural Melanesia head injuries and long bone fractures are associated with falls from trees or being struck by a falling branch or coconut (Barss *et al.* 1984; Gupta & Reeves 2009). A high fracture prevalence in long bones, particularly of the forearm in a mediaeval Nubian skeletal sample were attributed to falling on uneven and rugged terrain (Kilgore *et al.* 1997).

Farming is a hazardous activity and a leading cause of fractures in individuals in prehistoric times resulting in injury mechanisms that include falls from height and direct contact with large animals (Judd & Roberts 1999; Jurmain 2001; Virtanen *et al.* 2003). Head-butting and trampling injuries from cattle are reported to be similar to high-velocity injuries and are particularly associated with long bone fractures, as well as head and chest trauma, trauma to toes and fingers and soft tissue (Murphy *et al.* 2010; Watts & Meisel 2011).

Summary

The archaeological evidence at Non Ban Jak suggests a population experiencing economic and cultural growth, as indicated by an increase in mortuary wealth from MP1 to MP4, evidence of metal working activities, agriculture, trade of exotic materials and the construction of surrounding moats. As yet there is no archaeological evidence of social tension or warfare, such as the destruction of buildings or large caches of weapons.

Approximately one quarter of the Non Ban Jak adults (25.5% of the adult sample of 55 individuals) experienced antemortem or perimortem trauma. No subadults were observed with antemortem or perimortem lesions. The prevalence of trauma was similar for males and females, however, the pattern of trauma was different between the sexes. Females were more likely to have fractures to the forearm, clavicle and ribs, whilst males have slightly higher incidences of foot or cranial trauma. Mortuary goods hinted that males and females had similar economic roles but differences in trauma patterns may instead by associated with activities not indicated by the items buried with them.

Twelve of the 52 adults (23.1%) from the western mound were observed with trauma. There were no statistically significant differences between male and female trauma rates between the four the mortuary phases, however female trauma rates did double in MP3, whilst male trauma rates remained steady, until MP4 when there was no males or females observed with trauma.

Rib fractures were found on five individuals (9.1% of adults). Radii represent the most frequently fractured long bone (7.0%) in Non Ban Jak adults, and all four radii fractures were observed on females. Two toe phalanges were fractured but only one clavicle, humerus and ulna had a lesion. There was no trauma observed on any lower limb elements. Trauma to the cranium or face was observed on three individuals, 11.5 percent of individuals with at least 75 percent of the cranium present.

The majority of antemortem trauma is suggestive of accidental injury through occupational hazards and lifestyle activities such as a sporting injury, slipping or falling, or crushing injuries from falling objects. These are injuries that are expected within a population engaged in agriculture, animal husbandry, hunting and foraging, but it is not likely they were engaged in warfare. However, the incidences of craniofacial trauma, a probable parry fracture sustained in self-defense, and multiple fractures are injuries indicative that there was some degree of interpersonal violence within the settlement.

Chapter 5

Methods and Summary

Southeast Asian trauma

This chapter provides the observations of trauma and details of population demographics that are available in current publications, for the skeletal samples that have been included in this study. The sites are presented by region. The variation in the level of bone preservation and the completeness of individual burials from the skeletal samples is also summarised. The following results chapter will then compare temporal patterns of individual prevalence of trauma and long bone fracture prevalence from the Neolithic to the Iron Age.

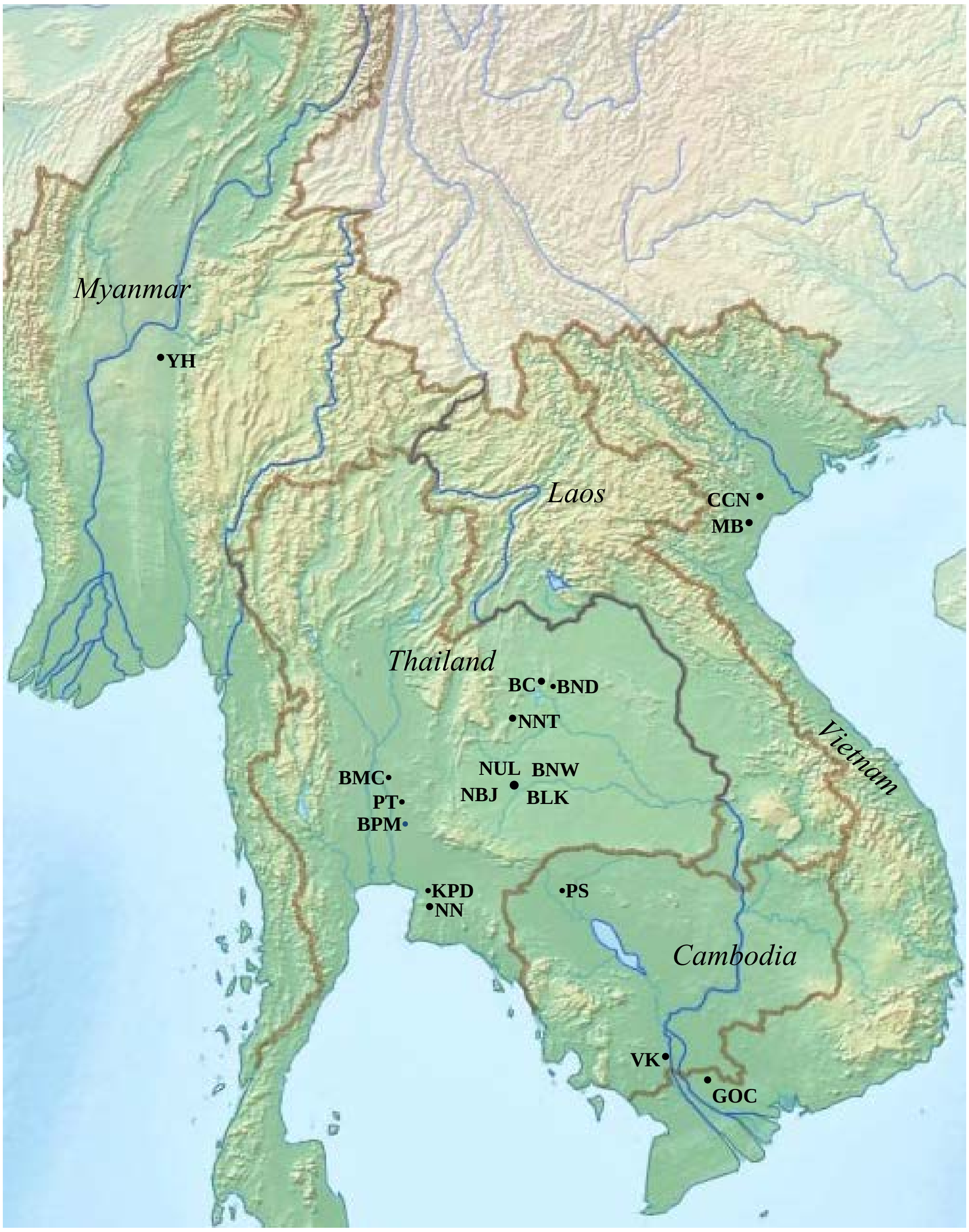
Excluded sites

There are many prehistoric sites in mainland Southeast Asia that have had burials exposed during excavations, however, if trauma was observed, the results may only be recorded in local journals that have not been translated into English. These sites are not included in this study. It must be remembered that only a fraction of each site has been excavated to date. It is possible that some incidences of trauma in mainland Southeast Asia have so far remained unobserved or unreported but it is hopeful that this will become the focus for future studies.

Mainland Southeast Asian sites with trauma

Eighteen sites are included in this study, from four regions on the mainland of Southeast Asia (Table 5.1). One site is located in Myanmar, 12 sites are in Thailand (two from southeast Thailand, seven from the northeast Thailand and three from central Thailand), two sites are from Cambodia (northwest and southern Cambodia) and three are from Vietnam (two from northern Vietnam and one from southern Vietnam) (see Figure 5.1). No trauma has, up to this date, been recorded in sites from Laos.

Fig. 5.1. Map of Southeast Asia indicating the sites included in trauma analyses.



Myanmar: YH - Ywa Htin
Thailand: KPD - Khok Phanom Di, NN - Nong Nor, BC - Ban Chiang, BNW - Ban Non Wat, BLK - Ban Lum Khao, NNT – Non Nok Tha, BND – Ban Na Di, NUL – Noen U-Loke, NBJ – Non Ban Jak, BMC – Ban Mai Chaimongkol, BPM – Ban Pong Manao, PT – Phromthin Tai
Cambodia: PS – Phum Snay, VK – Vat Komnou
Vietnam: CCN – Con Co Ngua, MB – Man Bac, GOC - Gò Ô Chùa,

Table 5.1. Study sample of sites with trauma in mainland Southeast Asia

Site	Region	Period	Date of burials	Sample size	Dating reference
Ywa Htin	Myanmar	IA	400 - 200 BC	76	Pautreau (2007)
Khok Phanom Di	SE Thailand	Neo	2100-1500 BC	154	Bentley *et al.* (2007)
Nong Nor	SE Thailand	BA	1100-700 BC	155	Higham (2014a)
Ban Chiang	NE Thailand	Neo-LIA	1600 BC -200 AD	140	Higham *et al.* (2015)
Ban Non Wat	NE Thailand	Neo-LIA	1750 BC - 500 AD	696	Higham (2015)
Ban Lum Khao	NE Thailand	BA	1400-300 BC	110	Higham *et al.* (2015)
Non Nok Tha	NE Thailand	Neo-BA	1400 - 500 BC	180	Higham *et al.* (2015)
Ban Na Di	NE Thailand	LBA	800-400 BC	78	Higham *et al.* (2015)
Noen U-Loke	NE Thailand	IA	450 BC - 600 AD	120	Higham & Rispoli (2014)
Non Ban Jak	NE Thailand	LIA	300 - 750 AD	137	Higham (2016a)
Ban Mai Chaimongkol	C Thailand	BA-IA	2000 BC - 1 AD	38	Liu (2012)
Phromthin Tai	C Thailand	IA	500 BC - 500 AD	49	Lertcharnrit (2014)
Ban Pong Manao	C Thailand	LIA	50 BC - 450 AD	27	Liu (2012)
Phum Snay	NW Cambodia	LIA	350 BC - 200 AD	160	O'Reilly *et al.* (2006a)
Vat Komnou	S Cambodia	LIA	200 BC - 200 AD	111	Stark (2007)
Con Co Ngua	N Vietnam	Neo	4000 - 3500 BC	96	Oxenham *et al.* (2005)
Man Bac	N Vietnam	LNeo	1800 - 1500 BC	95	Oxenham *et al.* (2011)
Gò Ô Chùa	S Vietnam	EIA	400 - 100 BC	52	Francken (2012)

SE = southeast, NE = northeast, C = central, NW= northwest, S = southern, N = northern
Neo= Neolithic, BA= Bronze Age, IA= Iron Age, E= early, L= late

Methods

Skeletal samples from published prehistoric Southeast Asia research were included in this present study if trauma was reported to have been observed in one or more individual. Skeletal elements were included in fracture prevalence analysis if at least 75 percent of the bone was present for examination. The statistical analyses were conducted using the same methods as for the Non Ban Jak data analysis in the previous chapter. However, whilst Fishers Exact Tests were used for the majority of analyses, chi-squared tests were used when large sample sizes were large.

Individuals aged between 15 – 19 years may be viewed by some as children who are in an ‘in-between’ phase – no longer a child but also not yet an adult (Coupey 2007:32). Different cultures, in both modern and prehistoric times, also independently determine the chronological age of maturation into adulthood and we have no way to determine for certain how the prehistoric populations included in this study viewed this. For the purpose of consistency in this study, subadults are determined to be individuals under 15 years of age at the time of death. Most of the authors of the publications used in this study observed the subadult/adult changeover to be 15 years of age, when the majority of epiphyseal fusion begins. A few studies reported the changeover to be 20 years of age, however, using the demographic data they provided, all individuals with ages estimated to be greater than 15 years were selected to be included as adults in this present study. Although five subadults in the Southeast Asian sample were observed with trauma (see the following trauma tables for details), they are not part of the trauma analysis in this thesis as not all authors included subadults in their trauma analysis and skeletal census, either because trauma was not observed or due to preservation issues where the smaller and more fragile subadult bones did not preserve as well as the adult bones. Subadult bones may not show visible indications of fracture as they are still undergoing growth and development and injury sites will remodel very well (Ubelaker & Montaperto 2011).

To test the hypotheses the samples will be analysed for statistically significant differences in trauma prevalence at the individual level, and differences in the fracture prevalence at the skeletal element level.

To examine the trauma prevalence for individuals, the proportion of individuals with one or more lesions, on any skeletal element, was calculated as a proportion of the total number of individuals in the sample (calculated separately for males, females and all adults). All types of trauma were included, ranging from fractures (including wedge fractures of vertebrae, long bone fractures and depressed cranial fractures), blunt force trauma (BFT), sharp force trauma (SFT) (which includes cuts and piercing wounds), dislocation, contusions, hematoma ossification and *myositis ossificans traumatica)*.

Fracture prevalence was calculated by determining the proportion of long bones with at least one healed fracture to the total number of observed complete long bones in the sample. Long bone elements (clavicle, humerus, radius, ulna, femur, tibia and fibula) are the elements most likely to survive the archaeological record with the most amount of preservation, in comparison with the small bones of the hands and feet and fragile bones of the pelvis, ribs and vertebrae (Underdown 2012). This is the main reason why they are used to determine fracture prevalence within a sample. Fractures are some of the most common types of trauma and are easily recognised by macroscopic analysis, even to observers with little experience in trauma analysis, which is another reason fracture prevalence is chosen to be studied.

Limitations and general observations

It is likely that the lack of sufficient preservation and completeness in a portion of the skeletal samples meant that some evidence of trauma would have been obliterated. The rates of skeletal preservation and completeness of human burials varied greatly from site to site and this has produced a small observable sample size at many sites. Burials were often disturbed post-depositionally by postholes, present-day plowing, insect burrowing, and commonly from intercutting of later prehistoric burials. High soil acidity and waterlogging affected multiple sites, especially in Myanmar, leaving either no traces of bone within burials, or if the bone was present, they were very fragile and crumbled easily when handled. Looting by relic hunters had resulted in extensive damage at the Iron Age sites of Phum Snay and Vat Komnou in Cambodia; Ywa Htin in Myanmar; Ban Chiang in Northeast Thailand, Ban Pong Manao in Central Thailand and Bronze Age Nong Nor. The action of looters removing human remains from their archaeological context has damaged a large portion of skeletal remains and many, especially small and fragile bones, have been lost. This has reduced the number of elements that could be observed and included in skeletal analysis.

Estimating the level of completeness of elements can be subjective as personal judgment affects how each researcher determines the degree of preservation, and therefore the number of ‘complete’ elements included in each study. This becomes a concern when comparing the fracture prevalence for elements between sites when the data is produced by different authors. Small discrepancies in fracture rates will likely occur until a universally used methodology for calculating the amount of surviving bone is produced. Most authors of research used in this present study established element completeness by dividing each element into five segments and estimating that at least 75 percent of the total element be present.

However, there were some exceptions. Oxenham (2000) only included the diaphysis in the Con Co Ngua skeletal census, the epiphyses were excluded due to his observation that most fractures are reported to occur in the diaphysis of the long bones (Oxenham *et al.* 2001). Ikehara-Quebral (2010) calculated the fracture prevalence for the ulna and fibula (the only elements observed with fractures) using the distal third of the elements but complete elements for the rest of the long bones. These differences in data recording will have some effect when comparing prevalence rates. Some skeletal samples used in this study have not had the level of preservation of elements published, for example, Ban Mai Chaimongkol, Ban Pong Manao and Promin Tai (Liu 2012), Ywa Htin (Pautreau 2007) and Gò Ô Chùa (Francken 2012). This is due to several factors such as extremely poor levels of preservation; or trauma analysis was not the primary aim of the author's study, and therefore it was not necessary for the authors to know the number of complete elements to determine fracture prevalence. These sites with no denomination data had to be omitted from the fracture prevalence analysis.

To enable Non Nok Tha fracture prevalence to be compared with other studies, the skeletal inventory in the appendix of Douglas (1996) was used in this present study to determine the number of complete bones (> 75 % of element present) observed for each element type. This enabled the denominator for the fracture prevalence calculations to be based on complete bones and not the partial skeletal elements that Douglas used in her fracture prevalence tables. The same was done for the Ban Chiang sample, however it was noticed that four pages of data had been (accidently) omitted from the published Ban Chiang skeletal inventory in Douglas (1996). Thirty-six burials were missing the skeletal census for the left and right clavicles and the right humerus. Thirty-two individuals were missing skeletal census data for the left and right tibia and fibula. Therefore the fracture prevalence for these elements will be slightly inflated as the number of complete bones used as the denominator value is lower than it actually should be.

Trauma summaries by region

Laos

Archaeological surveys have been steadily on the increase in Laos since the few conducted in the early 1900s. This is due to a change in political circumstances, decolonization and the end to armed conflict which previously made access for international researchers virtually impossible (Zeitoun *et al.* 2012). Exploratory surveys conducted since the beginning of the 21st century have located over fifty archaeological sites in the Middle Mekong Valley of northern Laos, the majority of which are rock shelters or caves from the Late Pleistocene to mid Holocene periods (White *et al.* 2009). Prehistoric copper mining sites have been excavated in Central Laos (Tucci *et al.* 2014), and extensive excavations are currently underway on sites in the Plain of Jars plateau, northeastern Laos. There are currently no published observations of trauma at any of these sites.

Myanmar

Ywa Htin

Ywa Htin is an Iron Age village cemetery in the Samon Valley of Upper Myanmar, c. 400 – 200 BC (Pautreau 2007). It was partially excavated in 2002 & 2003. Skeletal analysis has so far been limited to a detailed report on subadult burial rituals (Coupey 2006) and a brief mention of trauma observed in the adult sample (Pautreau 2007). The demographic and trauma information for this study is from these two publications.

Sample demography

A total of 76 burials with skeletal remains were present in the sample. Thirty-three subadult burials under fifteen years of age were identified but only 17 of these graves actually contained skeletal material for analysis (Coupey 2007). Due to very poor preservation, in some cases distinguishing adults from adolescents was only possible by assessing bone size. This led to several individuals being listed as children but Coupey (2007) noted that they could possibly be gracile young adults. From the burial descriptions provided by Mornais (2007) it was difficult to discern the total number of adults observed in the sample. Approximately 59 adults were recorded, however, some burial descriptions were unclear if the individuals were adults or subadults. The extremely fragmentary nature of many burials meant that only one individual could have their sex accurately estimated (burial S132, female).

Trauma

The very poor levels of bone preservation found at this site hindered the observation of trauma. Only three lesions were recorded on two individuals (Table 5.2). Trauma analysis was not a focus of any previous reports associated with Ywa Htin, and only a few sentences on adult trauma have so been published (Mornais 2007).

Table 5.2. Ywa Htin trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
?	S74	humerus	R	?	fracture
		mandible	?	?	fracture?
?	S121	humerus	R	?	fracture

Source: Mornais (2007)

Southeast Thailand

Khok Phanom Di

Neolithic burials, c. 2100 – 1500 BC (Bentley *et al.* 2007) were excavated at Khok Phanom Di and have been reported on in detail by (Domett & Tayles 2006). The majority of skeletal remains were quite well preserved with many individuals near complete.

Sample demography

The Khok Phanom Di sample contained 154 individuals and comprising 86 subadults (55.8%) and 68 adults (44.2%) (Domett & Tayles 2006). There was an almost even distribution of males (n = 32, 47.1%) and females (n = 36, 52.9%).

Trauma

Five individuals were affected by trauma, three of which are females and two are males (Table 5.3). Two fractures are present on the left-hand side and three on the left. The fractures are all in small bones of the hands and feet and clavicles, and no trauma was observed in any of the quite well-preserved long bones of the individuals from this sample (Domett & Tayles 2006).

Table 5.3. Khok Phanom Di trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	44	5th metatarsal	R	distal 1/3	fracture (transverse?)
M	91	5th metacarpal	L	midshaft	fracture (oblique)
F	61	clavicle	L	midshaft	fracture (oblique)
F	110	clavicle	L	midshaft	fracture (oblique)
F	142	4th metacarpal	R	midshaft	fracture (oblique)

Source: (Domett & Tayles 2006)

Nong Nor

Nong Nor is a Bronze Age cemetery, c. 1100 – 700 BC (Higham 2014a). The individuals in this skeletal assemblage were mostly poorly preserved and fragmented.

Sample demography

This site is represented by a Bronze Age skeletal assemblage of 155 individuals. Subadults comprised 21.3 percent (n = 33) and adults 78.7 percent (n = 122), 44 of which are males (36.1%) and 49 are females (40.2%). Twenty-nine of the adults could not have their sex estimated (Domett & Tayles 2006).

Trauma

Five individuals were observed with trauma at this site, two males and one female and two unsexed individuals (Table 5.4). Three lesions were located on the left-hand side, one on the right and one unsided. The lesions were located on the mandible and postcranially, affecting several long bones and the smaller bones of the foot and a clavicle.

Table 5.4. Nong Nor trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	32	mandible	L	body	fracture
M	47	clavicle	R	midshaft 1/3	fracture (transverse?)
F	6	ulna	L	distal 1/3	fracture (oblique?)
?	27	foot phalanx	?	proximal 1/3	fracture
?	53	ulna	L	midshaft 1/3	fracture (oblique or spiral)

Source: (Domett & Tayles 2006)

Northeast Thailand

Ban Chiang

Excavations in the 1970's revealed a village cemetery and habitation zone, 1600 BC – 200 AD (Higham *et al.* 2015). The good preservation and size of the Ban Chiang village cemetery, spanning from the Neolithic to the Iron Age attributed to the large number of traumatic lesions observed.

Sample demography

The sample contained a total of 140 individuals, of which 38 were subadults under 15 years of age (27.1%) and 102 were adults (72.9%) (Douglas 1996). In the adult sample there were 51 males (50.0%) and 47 females (46.1%), whilst four adults could not have their sex estimated (3.9%). Sixteen of the adults were from the Neolithic period, 58 from the Bronze Age and 27 from the Iron Age. No trauma was observed in the Neolithic burials.

Trauma

Eighteen adults were observed with trauma (Table 5.5), with three individuals exhibiting multiple lesions (Douglas 1996, 1997) (Douglas also included four individuals with spondylolysis but these cases are not included in this present study). There were a total of 28 lesions on the adults. Two subadults were also observed with fractured clavicles but this study will concentrate on adult trauma and these individuals will not be included in any further analysis. The types of trauma varied from fractures, a dislocation, and tibial contusions. More than twice as many males (13) than females (5) suffered from traumatic lesions. There are a total of 13 left-side lesions compared to just seven on the right side. Interestingly, all rib fractures were located on the left side of two females and three males. Four of those individuals had multiple rib lesions. Two individuals presented with a combination of cranial and vertebral fractures.

Table 5.5. Ban Chiang trauma by individual

Period	**Sex**	**Burial No.**	**Element**	**Side**	**Part**	**Trauma**
BA	M	BC-5	femur	R	midshaft	fracture (oblique)
	M	BC-20	C7 vertebra		spinous process	fracture
			cranium	R	frontal	depressed fracture
	M	BCES-35	radius	L	proximal 1/3	fracture
	M	BCES-45	6th & 12th ribs	L	shaft/head	fracture
	M	BCES-47	9th & 10th ribs	L	apex	fracture
	M	BCES-50	C6 & C7 vertebrae		spinous process	fracture
			cranium	L	frontal	depressed fracture (perimortem?)
	M	BCES-53	humerus	R	apex medial	fracture
	M	BCES-65	tibia	L	distal 1/3	contusion
	M	BCES-76	4th metacarpal	L	proximal 1/3	fracture
	F	BC-8	12th rib	L	shaft (axial end)	fracture
	F	BC-31	radius	R	distal 1/3	fracture
	F	BCES-34	humerus	L	distal epiphysis	fracture (avulsion)
	F	BCES-46	2 x mid-ribs	L	shaft	fracture
	SA*	BCES-44	clavicle	R	shaft	fracture
IA	M	BCES-7	hamate	L	hook	fracture
	M	BCES-24	5th metacarpal	R	shaft	fracture
	M	BCES-40	9th, 10th & 11th ribs	L	apex	fracture
	M	BCES-73	5th metatarsal	L	?epiphysis	fracture (avulsion)
			scapula	L	glenoid	chronic dislocation
			hyoid	?R	horn	fracture
	F	BC-2	tibia	R	proximal 1/3	contusion
	SA*	BCES-12	clavicle	R	shaft	fracture

Source: Douglas (1996)
BA= Bronze Age, IA= Iron Age
*SA = subadult, not included in trauma analysis, C6 & C7 = 6th & 7th cervical vertebrae.

Ban Non Wat

The settlement and cemetery of Ban Non Wat was in use from the Neolithic to the Iron Age, 1750 BC – 600 AD (Higham & Rispoli 2014). Almost 50 percent of the individuals from Ban Non Wat were complete or near complete but a majority of bones were covered by a concretion or were demineralized, making them fragile and fragmented.

Sample demography

The skeletal remains of 696 individuals could be analysed from a total of 708 burials (Tayles & Domett pers.com.). The sample comprised of 227 subadults (32.6%) and 469 adults (67.4%). The number of male adults (178, 38.0%) was almost equal to the number of adult females (181, 38.6 %). One hundred and ten individuals could not have their sex determined (23.5%).

Trauma

Tayles and Domett (pers. comm.) have observed and described trauma from this site but the data is currently unpublished. Some lesions had to be excluded from this study as the determination of trauma was inconclusive, mostly due to the bone surface being obscured by concretion or because of poor preservation.

Sixty-five lesions were observed on 45 individuals, 15 of whom had multiple lesions (Table 5.6). Five individuals with trauma were from the Neolithic period, 33 from the Bronze Age, three from the Iron Age and four individuals with trauma could not have their provenance determined. There was an almost even distribution of males (n = 22) and females (n = 20) affected with lesions, and three unsexed individuals were observed with trauma. Thirty-five lesions were on the right-hand side of the body and 25 were on the left-hand side. Almost twice as many forearm injuries occurred on the left-hand side (n = 9) compared to the right-hand side (n = 5), and more males (n = 8) than females (n = 5) were observed with fractured radii or ulnae. Both the left and right radii had healed fractures on B154, a female. This individual had also sustained healed wedge fractures to two vertebrae and a perimortem depressed cranial fracture. The trauma description provided by Domett and Tayles (pers. comm.) did not specify if the injury could have contributed to this female's death. Other perimortem injuries include B26, a female, with SFT and BFT to the left and right ilia, and B660, also a female, with SFT to the ilium. Both these injuries have characteristics pointing to possible wounds from either a projectile or a spear (Domett & Tayles, pers. comm.). B180, of unknown sex, has two possible perimortem depressed fractures on the right parietal.

Altogether, six individuals were observed with cranial trauma, and one individual with a fractured mandible. The lesions were evenly distributed on both the left and right-hand sides. Three of these lesions were to the frontal bone and five to the parietal. In addition to B154, two other individuals were observed with combinations of skull and arm trauma. B431, a male, had a fractured mandible and ulna; and B672, a male, sustained SFT to the left frontal, a rib and right humerus.

Table 5.6. Ban Non Wat trauma by individual

Period	**Sex**	**Burial No.**	**Element**	**Side**	**Part**	**Trauma**
Neo	M	24	tibia	R	midshaft	contusion
	F?	16	4th metacarpal	R	midshaft	fracture (angulation)
	F?	26	ilium	L	iliac blade	SFT (perimortem)
			ilium	R	iliac spine	BFT (perimortem)
	F	32	2 x ribs	R	shaft	fracture (displacement)
	F?	286	5th metacarpal	R	distal 1/3	fracture
BA	M	17	ulna	R	shaft	fracture
	M	29	radius	L	distal 1/3	fracture (angulation)
			ulna	L	distal 1/3	fracture
	M?	123	fibula	L	proximal 1/3	fracture (transverse)
	M?	150	2 x ribs	L	shaft	fracture
	M	155	clavicle	L	lateral shaft	fracture
	M	219	humerus	L	proximal 1/3	fracture (oblique)
			radius	L	distal 1/3	fracture (angulation)
	M?	230	radius	R	distal 1/3	fracture (angulation)
	M?	270	5th metatarsal	R	proximal epiphysis	fracture
	M	306	clavicle	R	acromial end	fracture (impaction?)
	M	408	hand phalanx	R	distal epiphysis	fracture (crush?)
	M?	431	ulna	R	distal 1/3	fracture
			mandible	L	condyle	fracture
	M	446	4th metatarsal	L	proximal 1/3	fracture (impaction?)
			5th metatarsal	L	proximal 1/3	fracture (impaction?)
	M	455	radius	L	distal 1/3	fracture
	M?	571	2nd metatarsal	R	proximal 1/3	fracture
			3rd metatarsal	R	proximal 1/3	fracture
			tibia	R	midshaft	fracture
	M	671	femur	L	proximal 1/3	fracture
	M	672	cranium	L	frontal	SFT
			rib	?	shaft	SFT
			humerus	R	distal epiphysis	SFT
	M	679	cranium	L	frontal	depressed fracture
			12th rib	L	shaft	fracture (malunion)

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Cont….

Period	Sex	Burial No.	Element	Side	Part	Trauma
	M?	690	cranium	L	frontal	depressed fracture
			cranium	R	parietal (superior)	depressed fracture
	M	696	cranium	R	parietal (posterior)	SFT
	F?	151	finger phalanx	R	shaft	fracture
	F	154	radii	L&R	distal 1/3	fracture (angulation)
			cranium	L	parietal & temporal	depressed fracture (perimortem)
			L1 & T12		body	wedge fracture
	F	160	rib	R	head	fracture
	F	161	clavicle	R	acromial half	fracture (oblique)
	F	218	1st metacarpal	R	proximal 1/3	fracture
	F	257	radius	L	distal 1/3	fracture (angulation)
	F	273	5th metacarpal	R	distal 1/3	fracture (oblique)
	F?	385	clavicle	R	acromial half	fracture (angulation)
	F	456	clavicle	R	lateral shaft	fracture
	F	460	radius	L	distal 1/3	fracture (angulation)
	F	554	3rd metatarsal	R	midshaft	fracture
			ulna	R	midshaft	fracture
	F	660	ilium	R	?	SFT (perimortem)
			radius	L	distal 1/3	fracture
	F	688	1st hand phalanx	L	midshaft	fracture (angulation)
	?	661	1st rib	R	medial end	fracture (with pseudo joint)
IA	M	333	ulna	L	shaft	fracture (oblique?)
	F	540	5th metacarpal	R	distal 1/3	fracture
	?	575	rib	R	shaft	fracture
?	M	325	4th metatarsal	R	distal 1/3	fracture
	F	171	hand phalanx	?	shaft	fracture
	F	471	rib	?	shaft	fracture
	?	180	cranium	R	parietal - central	depressed fracture (perimortem?)
			cranium	R	parietal - medial	depressed fracture (perimortem?)

Source: Domett & Tayles (unpublished)
Neo= Neolithic, BA= Bronze Age, IA= Iron Age, ?period= burial could not be assigned to a chronological period, or unknown side. BFT = Blunt force trauma, SFT -= Sharp force trauma, L1 = 1st lumbar vertebra, T12 = 12th thoracic vertebra.

Ban Lum Khao

Ban Lum Khao is dated to 1400 – 300 BC (Higham *et al.* 2015), but current evidence suggest it was only used as a cemetery in the Bronze Age after 1050 BC (Bentley *et al.*

2009). A third of the burials were highly disturbed or partially mineralized, however, the overall preservation of the sample was quite good.

Sample demography

A total of 110 individuals were identified in the skeletal assemblage, this comprised of 51 subadults (46.4%) and 59 adults (53.6%). In the adult sample there were slightly more females (n = 31, 52.5%) than males (n = 28, 47.5%) (Domett & Tayles 2006).

Trauma

There are nine individuals with a total of thirteen lesions (six male and three female) (Table 5.7). Lesions are almost evenly distributed on the left (n = 7) and right-hand side (n = 6). The majority of forearm fractures (ulna and radius) are recorded on males (n = 5), whilst two females have a fractured ulna. Burial B28, a male, was observed to have a combination of facial and forearm fractures and this was discussed by Domett and Tayles (2006) to have a possible violent causation. Complications in healing are evident in two individuals, one with non-union in the ends of a radial fracture and another with the formation of a new articular surface on the humerus due to a dislocation of the radial head associated with a radial shaft fracture.

Table 5.7. Ban Lum Khao trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	22	2nd metatarsal	L	proximal 1/3	fracture
M	28	ulna	R	distal 1/3	fracture (oblique)
		nasals	L/R		fracture
M	30	fibula	R	proximal 1/3	fracture
		ulna	L	proximal 1/3	fracture (oblique?)
		radius	L	proximal 1/3	fracture (transverse?)
M	48	mandible	L	body	fracture
M	65	radius	R	distal 1/3	fracture (impacted)
		L4 vertebrae		body	wedge fracture
M	67	radius	L	midshaft	fracture (non-union)
F	7	ulna	R	distal 1/3	fracture
F	64	clavicle	L	lateral 1/3	fracture (crush)
F	98	ulna	R	proximal 1/3	fracture (oblique)

Source: (Domett & Tayles 2006), K. Domett (pers. comm)
L4 = 4th lumbar vertebra.

Non Nok Tha

The cemetery of Non Nok Tha was utilized from the Neolithic to the Bronze Age, 1400 BC – 500 AD (Higham *et al.* 2015). Overall, the skeletons are near complete with a fair to good level of preservation.

Sample demography

A total of 180 individuals were present in the Non Nok Tha sample (Douglas 1996). This comprised of 49 subadults/fetal individuals (27.2%) and 131 adults (72.8%). There were 60 male adults (45.8%) and 67 female adults (51.1%), a lack of preservation in the skeletal remains of four adults meant their sex could not be determined (3.1%). A total of 19 adults were from the Neolithic, 111 were from the Bronze Age and one individual could not be assigned to a chronological period.

Trauma

Twenty-one lesions were observed on sixteen adults (Table 5.8). Nine males and seven females were affected. Five of those individuals were observed with multiple lesions. More than half the trauma was located on the left-hand side (n = 13), compared to just six on the right-hand side. A combination of hand and cranial (parietal bone) fractures were recorded on a male. Two fractures show healing occurred with complications such as malunion of a rib shaft and non-union of a clavicle.

Table 5.8. Non Nok Tha trauma by individual

Period	Sex	Burial No.	Element	Side	Part	Trauma
Neo	M	2.42	3rd metacarpal	L	proximal epiphysis	fracture (?)
			cranium	L	parietal	depressed fracture
	M	2.89	scapula	R	glenoid	fracture
	F	2.4	C7 vertebra		lamina	fracture
			rib	?	shaft	fracture (malunion)
	F	2.78	hamate	L	hook	fracture
	F	2.117	clavicle	L	lateral 1/3	fracture
BA	M	1.22	middle rib	L	shaft	fracture
			cranium	L	parietal	depressed fracture
	M	1.51	tibia	R	midshaft	fracture (angulation)
	M	2.27	humerus	L	distal epiphysis	fracture
	M	2.33	tibia	L	distal 1/3	contusion
	M	2.47	clavicle	R	midshaft	fracture (?) (non-union)
			1st rib	R	neck	fracture (oblique)
	M	2.7	1st metacarpal	R	distal epiphysis	fracture
	M	2.9	C2 vertebra	L	superior facet	fracture (?)
	F	1.8	radius	R	distal 1/3	fracture
	F	1.28	clavicle	L	medial	fracture (?)
	F	2.60	tibia	L	midshaft	fracture
			fibula	L	midshaft	fracture
	F	2.124	clavicle	L	shaft	fracture (?)

Source: Douglas (1996) and Douglas (1997)
Neo= Neolithic, BA= Bronze Age, C2 & C7 = 2nd & 7th cervical vertebra.

Ban Na Di

This settlement was occupied during the Late Bronze Age to the Iron Age, 800 – 400 BC, but only Bronze Age burials have been excavated to date (Higham *et al.* 2015). The level of preservation varied greatly, with many skeletons incomplete.

Sample demography

A total of 78 individuals were excavated from the site, of which 28 were subadults (35.9%) and 50 were adults (64.1 %). Males made up half of the adult sample (n = 25, 50.0%) and 20 were females (40.0%) and a further five adults (10.0%) could not have their sex estimated with any accuracy (Domett & Tayles 2006).

Trauma

Only two incidences of trauma were observed in this sample, and both were on males and both were on the left-hand side (Table 5.9). Domett and Tayles (2006) noted that there was no statistical significance to the exclusion of females from episodes of trauma. The level of preservation was moderate at this site, however many of the skeletons of the 78 individuals were incomplete and this would likely have affected the number of observable lesions.

Table 5.9. Ban Na Di trauma by individual

Sex	**Burial No.**	**Element**	**Side**	**Part**	**Trauma**
M	M.17	femur	L	proximal 1/3	fracture (partial spiral?)
M	M.35	3rd metatarsal	L	midshaft	fracture (oblique?)

Source: Domett and Tayles (2006)

Noen U-Loke

Noen U-Loke is a large site dating from the Iron Age, 450 BC – 600 AD (Higham & Rispoli 2014). The skeletal preservation varied from almost perfect to a virtual absence of bone, due largely to the inclusion of unthreshed rice as a burial offering. The rice chemically reacted with the human remains to cause demineralization of the bone. Less than a third of the burials at this site were complete.

Sample demography

Although 127 graves were observed at the site, only 120 individuals could be included in any skeletal analysis (Tayles *et al.* 2007). There were 53 subadults (44.2%) and 67 adults (55.8%) in the sample. The adult sample was predominantly female (n = 27, 40.3%), with 21 males (31.3%) present and 19 unsexed individuals (28.4%).

Trauma

The majority of trauma at this site is located on the cranium, whilst one lesion is observed on a long bone (tibia) and one on a thoracic vertebra. Four individuals in total were observed with fractures, SFT, BFT or a contusion (one male, two females and one of unknown sex) (Table 5.10). Four lesions are on the right side and two are on the left side. Also of note is a young adult male (B61) who was buried prone with an iron projectile point lodged in-situ next to the 12th thoracic and 1st lumbar vertebrae. There was no skeletal evidence of trauma, but it is likely that this individual suffered a soft-tissue projectile wound that would have been fatal (Tayles *et al.* 2007). This Iron Age site has produced one of the most interesting cases of severe trauma seen in prehistoric mainland Southeast Asia. B99, an older age female, appears to have had her head cleaved from side to side by a heavy and sharp-edged implement. The right side of her skull and the midface appear to have sustained blows with a blunt implement. Tayles (2003) has produced an in-depth case study on the fatal trauma suffered by this individual.

Table 5.10. Noen U-Loke trauma by individual

Sex	**Burial No.**	**Element**	**Side**	**Part**	**Trauma**
M	42	cranium	R	parietal	depressed fracture
		cranium	?	frontal	depressed fracture
F	99	skull	L & R	frontal	SFT (perimortem)
		cranium	R		BFT (perimortem)
F	108	T12 vertebrae		body	fracture (wedge)
?	78	tibia	L	shaft	contusion

Source: Tayles *et al.* (2007). ? = unknown sex or side.

Central Thailand

Currently three prehistoric sites from Central Thailand (Ban Mai Chaimongkol, Phromthin Tai and Ban Pong Manao) have been reported to include individuals with definite trauma. Liu (2012) has compiled trauma data for these three sites from unpublished sources. Several cases of possible lesions discussed by Liu (2012) are not accompanied by enough information to make a formative decision to include them in the trauma analysis. A fourth site (Non Mak La) was also discussed by Liu (2012), but was not included in this study as the ‘lesions’ observed on the bones could very well be from taphanomic processes not trauma (Angelarakis 2010). Dr. Troy Case, from the North Carolina State University provided more recent observations of trauma from the Phromthin Tai sample (T. Case, pers. comm.).

Ban Mai Chaimongkol

Ban Mai Chaimongkol is a small Bronze to Iron Age site, c. 2000 BC – 1 AD (Liu 2012), It is situated on a low mound that was used for both habitation and as a cemetery. Overall, the skeletal remains were well-preserved and were excavated from the site during the 1995 excavation season. The majority of individuals are stored at Silpakorn University, Phetchaburi, near Bangkok. However, a small number of burials were delivered to the Bangkok campus of Silpakorn University for curation. The Bangkok individuals could not be accessed for skeletal examination by Liu (2012) and are not included in this analysis.

Population demography

A total of 38 individuals were available for analysis, eight were subadults (21.1%) and 30 were adults (78.9%) (Liu 2012). There were an equal number of male and female adults (11, 36.7% of each sex) and also eight unsexed adults in the sample (26.7%). Twelve adults were assigned to the Bronze Age, seven to the Iron Age and 11 individuals could not be assigned to a chronological period.

Trauma

Only one individual, a male, was observed with trauma in this sample (*Table 5.11*).

Table 5.11. Ban Mai Chaimongkol trauma by individual

Site	Period	Sex	Element	Side	Part	Trauma
Ban Mai Chaimongkol	BA	M	clavicle	R	?	fracture

Source: Liu (2012)

Ban Pong Manao

Ban Pong Manao is a Late Iron Age site, 50 BC – 450 AD (Liu 2012), located 120 km southeast of Ban Mai Chaimongkol. Excavations were conducted from 2000 to 2004 and in 2007. A designated cemetery and habitation zones were discovered during these excavations. A majority of the bones at Ban Pong Manao were coated with a preservation which was noted to have likely obscured some evidence of trauma (Liu 2012).

Sample demography

The overall Ban Pong Manao burial sample size was >60, however, Liu (2012) has reported that there were many issues with provenance and this is due to several compounding factors, such as some burials remaining *in situ*, incorrect labeling and packaging of individual burials and widespread grave looting. Only 49 individuals actually had clear provenance and burial designations, and these were the burials Liu (2012) assessed for palaeopathology. The sample comprised of three subadults (6.1%) and 46 adults (93.9%). There are almost twice as many adult males (n = 21, 45.7%) as there are adult females (n = 13, 28.3%), and 12 individuals (26.1%) could not have their sex ascertained.

Trauma

One male was observed with a fractured left ulna. No burial numbers were provided by Liu (2012) (Table 5.12).

Table 5.12. Ban Pong Manao trauma by individual

Site	Period	Sex	Element	Side	Part	Trauma
Ban Pong Manao	LIA	M	ulna	L	distal 1/3	fracture

Source: Liu (2012)

Phromthin Tai

Promthin Tai (also known as Promtin Tai) is a semi-circular shaped moated settlement with archaeological evidence of occupation from the Late Bronze Age up until the Dvaravati period, 500 BC – 500 AD (Lertcharnrit 2014). Excavations revealed one burial possibly associated with the Late Bronze Age (c. 700 – 500 BC but dating is tenuous. All other burials have been assigned to the Iron Age (Lertcharnrit 2014). This site suffered from very poor preservation rates due to issues with acidity and high moisture levels in the soil. Many of the bones also underwent fossilization which could hinder the observation of trauma (Liu 2012).

Sample demography

Some individuals were left *in situ* by the excavation teams and are not included in the population demography as the skeletal remains could not be thoroughly examined.

A total of 27 individuals could be included in skeletal analysis (T. Case pers. comm), seven of which were subadults (25.9%) and 20 were adults (74.1%). The number of males (n = 9, 45.0%) is higher than females (n = 6, 30.0%).

Trauma

Two males (2/9, 22.2 %) and one female (1/6, 16.7 %) were observed with trauma (Table 5.13). Two individuals had several fractured ribs and one male had a fracture to the cranium. A more detailed report will soon be published by T. Case (T. Case pers. comm.).

Table 5.13. Phromthin Tai trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	8	ribs 11 & 12	R	sternal end	fracture
M	22	cranium	L	parietal	fracture
F	20	clavicle	L	shaft	fracture
		ribs 2 & 3	L	near tubercle	fracture

Source: T. Case (pers. comm.)

Northwest Cambodia

Phum Snay

Phum Snay is an Iron Age village and cemetery, c. 350 BC – 200 AD (O'Reilly *et al.* 2006b), situated close to the Thai border in northwest Cambodia. This site was heavily disturbed by a period of grave looting in modern times which resulted in a large portion of human remains being displaced from graves and scattered on the ground surface. Local monks later collected these unprovenanced bones, which mostly consisted of crania, to be stored in ossuaries at temples in Phum Snay and Siem Reap (Matsumura *et al.* 2011a).

Domett and O'Reilly (2009) examined the skeletal remains excavated from the graves to study the health of the prehistoric community, and also included a description of the postcranial fractures in the sample. Domett *et al.* (2011) described the trauma observed on crania from both the excavated burials and the unprovenanced material.

Sample demography

A total of 160 individuals were included in the Phum Snay census (Domett & O'Reilly 2009; Domett *et al.* 2011). This included 138 individuals from the unprovenanced material, and 22 individuals excavated from the cemetery (although only 21 could be analysed for trauma). The report on the 2007 excavation of Phum Snay by Lapteff (2013) did not include observations of sex or age at death estimations. There is also no published evidence that these remains have been analysed for pathology, including trauma, therefore these 35 burials are not included in this current study.

A total of 12 subadults are present in the sample (7.5%), and 148 adults (92.5%). There are an almost equal amount of male (n = 63, 42.6%) and female (n = 65, 43.9%) adults in the sample, and 20 adults could not have their sex determined (13.5%).

Trauma

The following lesions are a summary of the extensive trauma reported by Domett and O'Reilly (2009) and Domett *et al.* (2011). Thirty-nine individuals were observed with a total of 48 lesions, with seven individuals observed with multiple lesions (Table 5.14). Almost twice as many males (n = 20) as females (n = 12) were affected by trauma, as well as seven individuals of unknown sex. Lesions are predominantly found on the right-hand side (n = 27), with another 17 located on the left-hand side. Seven postcranial fractures and an exceptionally high number of cranial injuries were observed at this site, overall 39 lesions were located on the crania and two mandibles also displayed lesions. The parietal bone (n = 25) was most predominantly affected. However, frontal lesions (n = 11) were significantly more common in males than females (9:1). The crania were equally affected by blunt force trauma (BFT) and sharp force trauma (SFT). Significantly more males (n = 13) than females (n = 4) suffered BFT to the cranium but SFT was equally distributed amongst the males and females. Perimortem head trauma to burial PSL17, a male, was likely fatal. Severe SFT suffered by WLC73, which included a possible decapitation attempt and SFT to the crania from a large bladed instrument, would also have been fatal. However, the perimortem depression fracture on burial WBC82, a female, was most probably not the cause of death for this individual. WBC6, a male, may have received a penetrating injury to the eye. This trauma left the individual with a gross deformity to the right orbit.

Table 5.14. Phum Snay trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	PS01B6	clavicle	R	midshaft	fracture
M	PSL10	frontal	R	midline	BFT
M	PSL16	frontal	R	midline	SFT
M	PSL17	frontal	R	posterior	BFT - perimortem
		frontal	R	?	SFT (penetrating?) - perimortem
M	WBC6	orbit	R		SFT? (penetrating?)
M	WBC8	frontal	R	superior	BFT
M	WBC29	frontal	L	posterior	BFT
M	WBC30	parietal	L	posteriosuperior	SFT
M	WBC32	parietal	L	posterior	BFT
M	WBC35	parietal	R	?	BFT
M	WBC36	frontal	L	lateral	SFT
		parietal	R	posterior	SFT
M	WBC38	parietal	L	posterior	BFT
M	WBC56	parietal	R	posterior	SFT
M	WBC80	parietal	R	posterior	BFT
		frontal	R	anterior	BFT
M	WBC88	parietal	L	posterior	SFT
M	WLC10	parietal	L	posterior	BFT
		frontal	R	midline	BFT
M	WLC95	parietal	R	superior	BFT
M	WLC96	parietal	L	posterior	BFT
M	WLC105	parietal	R	posteriosuperior	BFT
M	WLC108	parietal	R	posterior	BFT
		parietal	L	anterior	SFT
F	PS01B9	metacarpal	?	midshaft	fracture
F	PS03B7	clavicle	R	midshaft	fracture
F	PS03B13	4th metacarpal	R	midshaft	fracture

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Sex	Burial No.	Element	Side	Part	Trauma
F	PSL11	parietal	R	posterior	SFT
F	WBC10	parietal	L	superiomedial	BFT
F	WBC66	parietal	R	posterior	SFT
F	WBC70	parietal	R	superior	SFT
F	WBC75	parietal	R	posteriosuperior	BFT
		frontal	L	anterior	SFT
F	WBC82	glabella	?		BFT - perimortem
F	WLC73	parietal	L	?	SFT - perimortem
		parietal	L	?	SFT - perimortem
		parietal	R	predominantly R side	SFT - perimortem
		occipital	L	?	SFT - perimortem
F	WLC75	parietal	L	posterior	SFT
F	WLC91	parietal	L	posterior	SFT
?	PSL4	mandible	?	condyle	?fracture
?	WBC18	clavicle	L	shaft, lateral	fracture
?	WBC77	frontal	R	lateral	SFT
?	WBC81	parietal	R	posterior	BFT
?	WBM28	mandible	?	condyle	?fracture
?	WBR4	radius	R	distal epiphysis	fracture
?	WBR6	radius	R	distal epiphysis	fracture (angulation)
SA*	BCES-12	clavicle	R	shaft	fracture
SA*	BCES-44	clavicle	R	?	fracture

Source: Domett and O'Reilly (2009) and Domett *et al.* (2011)
BFT= blunt force trauma, SFT= sharp force trauma
*SA not included in trauma analysis, ? = unknown sex, side or part.

<u>Southern Cambodia</u>

Vat Komnou

Vat Komnou (also referred to as Angkor Borei) is a Late Iron Age cemetery in use from approximately 200 BC to 200 AD (Stark 2007). Excavations were undertaken in 1999 and 2000. Skeletal preservation overall was poor to fair with only a few well preserved individuals in this densely packed cemetery. Mineralisation of the bone matrix was also an issue at this site, this natural process could obscure subtle signs of trauma and pathology.

Pietrusewsky and Ikehara-Quebral (2006) made a brief mention of the few examples of cranial and limb bone fractures that were observed in the sample. Ikehara-Quebral (2010) later completed a detailed analysis of the trauma and this is where the trauma and demographic data for this study is obtained.

Sample demography

A total of 111 individuals were present in the Vat Komnou sample (Ikehara-Quebral 2010). This comprised 31 (27.9%) subadults and 80 (72.1%) adults. Twice as many males (n = 51, 63.8%) than females (n = 26, 32.5%) were in the adult sample. Three adults could not have their sex estimated (3.8%).

Trauma

Eleven individuals were affected by a total of 18 lesions (Table 5.15). Four individuals had multiple lesions. The type of trauma ranged from fractures, hematoma ossification, *myositis ossificans traumaticas* and an injury described by Ikehara-Quebral (2010) as localized bone swelling. Predominantly more males (n = 8) than females (n = 3) were affected and the majority of lesions are located on the left-hand side (n = 8), with only three located on the right-hand side. Complications in healing were observed in one individual with malunion of fractured rib ends.

Table 5.15. Vat Komnou trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	AB10	C5, C6 vertebrae		centra	fracture (crush/wedge)
		tibia	L	midshaft	hematoma ossification
M	AB13	T2, T3 vertebrae		spinous process	fractures
M	AB27	tibia	L	proximal 1/3	myositis ossificans
M	ABM31B	parietal	L	mid-section	depressed fracture
M	AB37	fibula	R	distal 1/3	fracture (angulation)
M	AB39A	4th metatarsal	R	shaft	fracture (longitudinal)
M	AB43B	hyoid	R	greater horn	fracture
		rib	?	neck	fracture
M	AB55	ulna	L	distal 1/3	fracture
		10th – 12th ribs	L	anterior to the angle	fracture (malunion)
F	AB28	scapula	L	coracoid	fracture (avulsion?)
F	AB39	tibia	L	midshaft	localized bone swelling
F	AB44	ischiopubic ramus	L	midsection	fracture (avulsion)

Source: Ikehara-Quebral (2010)
C5 & C6 = 5th & 6th cervical vertebrae, T2 & T3 = 2nd & 3rd thoracic vertebrae.

<u>Northern Vietnam</u>

Oxenham (2000) discussed trauma observed in a skeletal sample compiled from 14 Metal Age sites in northern Vietnam. The burials from these sites were interred during the Bronze Age and Iron Age but the published data did not discern how many adult burials came from each period and a skeletal census was not published. Therefore the Metal Age burials could not be included in the temporal statistical analysis.

Con Co Ngua

The site of Con Co Ngua, 4000 – 3500 BC (Oxenham *et al.* 2005), contains archaeological evidence of Neolithic occupation activity alongside a cemetery. The level of cranial preservation was generally good but there was quite a range of preservation rates in the postcranial remains Oxenham (2000).

Sample demography

Ninety-six individuals were excavated with enough skeletal material to allow analyses to be conducted. There were seven subadults (7.3%) and 89 adults (92.7%), with more male adults (n = 43, 48.3%) than females (n = 31, 34.8%) as well as 15 unsexed adults (16.9%) (Oxenham 2006). An additional 146 burials were excavated in 2012, and whilst there have been observations of trauma observed, a detailed skeletal analysis is currently not available.

Trauma

Six adults were discussed by Oxenham (2000) to have possible traumatic lesions. However, only four fractures are included in this study as the other two lesions possibly do not have a traumatic aetiology, or are described as pathologies possibly secondary to trauma. Burial 80CCNMX4 a male adult, was observed with possible *myositis ossificans traumatica* to the right humeral deltoid insertion. However, this is the only surviving bone from the burial and Oxenham (2000) cannot discount the possibility that this condition could be hereditary (*myositis ossificans progressiva*). A more complete skeleton is needed be certain.

There are four adults with fractures in the Con Co Ngua sample (two males and two females) (Table 5.16). Three fractures are situated on the right-hand side, and two on the left. Burial 80CCNM47a, a subadult, was observed with a transverse fracture to the midshaft of the right femur. 80CCNM57a has two fractures to the distal 1/3 of the left humerus. Oxenham (2000) could not ascertain if the two fractures occurred at the same occasion.

Table 5.16. Con Co Ngua trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	80CCNM35a	femur	R	distal 1/3	fracture (malunion)
M	80CCNM57a	humerus	L	distal 1/3	fractures (1 x oblique, 1 x transverse)
F	80CCNMX5	femur	R	distal 1/3	fracture (malunion)
F	80CCNM54a	humerus	L	distal 1/3	fracture (oblique)
SA*	80CCNM47a	femur	R	midshaft	fracture (transverse)

Source: (Oxenham 2000)
*SA = subadult, not included in trauma analysis

Man Bac

Man Bac is a Late Neolithic site dated between 1800 – 1500 BC (Oxenham *et al.* 2011) located in northern Vietnam. The total size of the site has been difficult to determine due to possible intrusions from an historic period cemetery and farming activity (Matsumura & Oxenham 2011). Current analysis places habitation zones in two upper stratigraphic levels and a cemetery in the lowest stratigraphic level. Palaeohealth, including observations of pathology, were recorded at Man Bac (for example, Huffer 2005; Oxenham & Domett 2011) however, trauma analysis was not a focus of these studies and has not been published. A list of observed individuals with observed trauma was provided by Oxenham (pers. comm.). Oxenham (2000) noted that the skeletal preservation was excellent by Southeast Asian standards with nearly 54 percent of the sample complete or near complete, and the rest of the burials were incomplete or fragmented.

Sample demography

The population census data for individuals from the 1999 and 2001 excavations were obtained from burial descriptions written by Huffer and Hiep (2011), whilst demographics for the individuals from the 2004/5 and 2007 excavations were provided by Domett and Oxenham (2011). There were a total of 100 burials, four of which could not be excavated and one burial consisted of a few isolated teeth only, so that the skeletal remains of 95 individuals were included in further analysis. The sample comprised of 57 subadults (60.0%) and 38 adults (40.0%), of which 18 were males (47.4%), and 15 were females (39.5%) and five of unknown sex (13.2%).

Trauma

Four individuals were observed with trauma, three males and an infant with a rounded ‘depression like’ perimortem break on the posterior aspect of the right ilium (Oxenham, pers. comm.) (Table 5.18). Only very limited trauma analysis data is currently available for this site, but a more thorough trauma analysis may be carried out in the near future.

Table 5.17. Man Bac trauma by individual

Sex	Burial No.	Element	Side	Part	Trauma
M	MB05M11	cranium		frontal	SFT (perimortem?)
M	MB07H1M5	clavicle	L	shaft	fracture (angulation)
M	MB07H1M8	radius	L	proximal 1/3	fracture (oblique)
SA*	MB07H1M8	ilium	R	posterior	BFT (depressed fracture, perimortem?)

Source: Oxenham (pers. comm.)
*SA = subadult, not included in trauma analysis, BFT= blunt force trauma, SFT= sharp force trauma

Southern Vietnam

Gò Ô Chùa

The excavations from 2003 to 2006 revealed a Bronze Age settlement layer and an Early Iron Age cemetery that was in continuous use from 400 – 100 BC (Francken 2012). The three-mound site is located in southern Vietnam, close to the border of Cambodia. The majority of the densely-packed burials were very well preserved.

Sample demography

Sixty-four burials were excavated, with 52 individuals able to be included in the skeletal analysis, 45 of which were inhumations and seven were jar burials. Seven subadults (13.5%) were present in the sample, and 45 adults (86.5%). The adult sample comprised of 23 males (51.1%), 20 females (44.4%) and two unsexed individuals (4.4%).

Trauma

Three males (3/23, 13.0%) and three females (3/20, 15.0%) were affected by trauma, with a total of nine lesions observed (Table 5.19). However, Francken (2012) did not published details on the part of the element affected or the side.

Table 5.18. Gò Ô Chùa trauma by individual

Sex	Element	Trauma
F	clavicle	fracture
F	clavicle	fracture
F	ulna	fracture
F	radius	fracture (non-union)
M	vertebrae	fracture (compression)
M	sacrum	fracture (compression)
M	rib x 2	fracture

Source: Francken (2012)

The next chapter will present the results of statistical analyses of the trauma data from these samples.

Chapter 6

Results

Mainland Southeast Asia

This chapter presents the analyses conducted on the trauma observed in skeletal samples from prehistoric mainland Southeast Asia. The analyses are designed to test if there are any statistically significant differences in the level of risk from serious injury between the Neolithic, Bronze Age and Iron Age periods of Myanmar, Thailand, Cambodia and Vietnam. Individual trauma prevalence and fracture prevalence of long bones are investigated to gain an understanding of the level of risk experienced by the sample populations in this study and to examine the relationship that trauma has to natural and cultural environments, and to examine the potential origins of warfare in Southeast Asia.

A total of 18 sites in prehistoric Southeast Asia were observed to have individuals with trauma (see Appendix B, Tables B1 & B2, sites by region), however not all of these sites could be included in temporal analyses. Ywa Htin (Myanmar), Ban Mai Chaimongkol, Phromthin Tai, Ban Pong Manao (central Thailand) and Gò Ô Chùa (southern Vietnam) are sites that had to be excluded from comparisons of fracture prevalence as their skeletal census were not adequate enough to be able to count the total number of complete bone elements to be used as the denominator in fracture prevalence calculations for each long bone element. These sites will still, however, be included in the analysis of trauma prevalence in individuals.

Ban Chiang, Ban Non Wat, Non Nok Tha, and Ban Mai Chaimongkol were settlements inhabited over several periods and the burials for each site were grouped and analysed according to the period in which they were interred. There are also a number of burials from these sites that do not have enough archaeological evidence to assign them to a time period, and these individuals could not be included in the temporal comparisons: Ban Chiang and Non Nok Tha each have one unprovenanced individual, Ban Non Wat has a total of 56 individuals currently not assigned to a temporal phase and Ban Mai Chaimongkol has 11 unassigned burials.

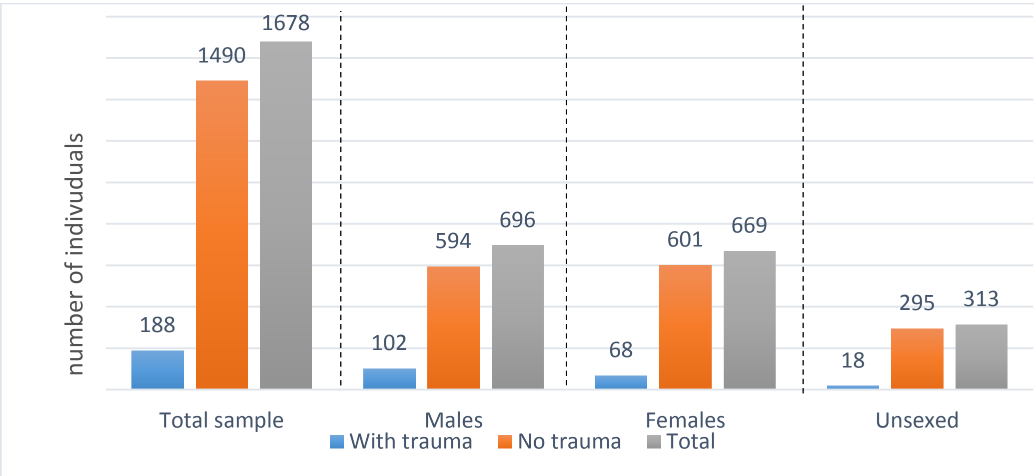
Temporal analysis: Individual trauma prevalence

The results in this section include observations of all types of trauma on the cranial and post cranial elements in the samples, including fractures, sharp force trauma (SFT), blunt force trauma (BFT), dislocations, contusions, hematoma ossification and *myositis ossificans traumatica*. Individual trauma prevalence was then calculated for adults, males and females using the number of individuals affected by the trauma divided by the number of observed adult individuals.

A total of 18 sites were used in the temporal comparisons of individual trauma prevalence. The adult sample is 1,678 (males, females and unsexed adults combined from all 18 sites), in which 188 (11.2%) were observed with trauma (Table 6.1 and Figure 6.1).

There were a total of 696 males in the combined sample, of which 102 were observed with trauma (102/696, 14.7%). The total adult female sample was 669, of which 68 had trauma (68/669, 10.2%), whilst trauma was observed in 18 of the unsexed adults (18/313, 5.8%). Overall, males had a statistically significant higher prevalence of trauma observed compared with females in the total sample (χ^2 6.309, p = 0.0120).

Figure 6.1. Individual trauma in the Southeast Asian skeletal samples (sites suitable for temporal analysis)



Neolithic Period

Six sites contain burials from the Neolithic period, three of these sites are from northeast Thailand, one from southeast Thailand and two from northern Vietnam (Table 6.1). Twenty-two individuals from a combined sample of 283 adults were observed with trauma for an overall trauma prevalence of 7.8 percent for the Neolithic period.

Bronze Age

Seven sites contain Bronze Age burials, five of these sites are from northeast Thailand, one from southeast Thailand, and one from central Thailand. When the adult individuals from the Bronze Age sites are combined there is an overall trauma prevalence rate of 11.8 percent (74 out of 629 adults).

Iron Age

A total of 11 sites contain Iron Age burials. Four of these sites are from northeast Thailand, three from central Thailand, one from Myanmar, one from northwest Cambodia, one from southern Cambodia, and one from southern Vietnam. When these samples are combined the overall prevalence of trauma for the Iron Age is 12.6 percent (88/697).

Neolithic to the Iron Age: Adult trauma

When the combined adult samples (males, females and unsexed individuals) from each of the periods were compared, there appeared to be an increase in trauma prevalence from the Neolithic (7.8%), to the Bronze Age (11.8%) and to the Iron Age (12.6%). The rise in the levels of trauma between the Neolithic and the Iron Age was to a significant level (FET p-value = 0.0334) (Table 6.2).

Table 6.1. Individual trauma prevalence by adult and temporal period

Neolithic burials		**Individual prevalence of trauma[1]**							
Site	**Region**	**Male n/N**	**%**	**Female n/N**	**%**	**Unsexed n/N**	**%**	**Adults n/N**	**%**
Khok Phanom Di[a]	SET	2/32	6.3	3/36	8.3	0/0	-	5/68	7.4
Ban Chiang[b]	NET	0/6	0.0	0/9	0.0	0/1	0.0	0/16	0.0
Ban Non Wat[c]	NET	1/21	4.8	4/25	16.0	0/7	0.0	5/53	9.4
Non Nok Tha[b]	NET	2/10	20.0	3/9	33.3	0/0	-	5/19	26.3
Con Co Ngua[d]	NV	2/43	4.7	2/31	6.5	0/15	0.0	4/89	4.5
Man Bac[e]	NV	3/18	16.7	0/15	0.0	0/5	0.0	3/38	7.9
Total		**10/130**	**7.7**	**12/125**	**9.6**	**0/28**	**0.0**	**22/283**	**7.8**
Bronze Age burials									
Nong Nor[a]	SET	2/44	4.5	1/49	2.0	2/29	6.9	5/122	4.1
Ban Chiang	NET	9/33	27.3	4/23	17.4	0/2	0.0	13/58	22.4
Ban Non Wat	NET	19/92	20.7	13/95	13.7	1/30	3.3	33/217	15.2
Ban Lum Khao[a]	NET	6/28	21.4	3/31	9.7	0/0	-	9/59	15.3
Non Nok Tha	NET	7/49	14.3	4/58	6.9	0/4	0.0	11/111	9.9
Ban Na Di[a]	NET	2/25	8.0	0/20	0.0	0/5	0.0	2/50	4.0
Ban Mai Chaimongkol[f]	CT	1/4	25.0	0/4	0.0	0/4	0.0	1/12	8.3
Total		**46/275**	**16.7**	**25/280**	**8.9**	**3/74**	**4.1**	**74/629**	**11.8**
Iron Age burials									
Ywa Htin[g]	M	0/*	*	0/1*	*	2/58	6.9	2/59	3.4
Ban Chiang	NET	4/12	33.3	1/14	7.1	0/1	0.0	5/27	18.5
Ban Non Wat	NET	1/51	2.0	1/49	2.0	1/43	2.3	3/143	2.1
Noen U-Loke[h]	NET	1/21	4.8	2/27	7.4	1/19	5.3	4/67	6.0
Non Ban Jak[i]	NET	5/18	27.8	6/23	26.1	3/14	21.4	14/55	25.5
Ban Mai Chaimongkol	CT	0/4	0.0	0/2	0.0	0/1	0.0	0/7	0.0
Phromthin Tai[f]	CT	2/9	22.2	1/6	16.7	0/5	0.0	3/20	15.0
Ban Pong Manao[f]	CT	1/21	4.8	0/13	0.0	0/12	0.0	1/46	2.2
Phum Snay[j]	NWC	20/63	31.7	12/65	18.5	7/20	35.0	39/148	26.4
Vat Komnou[k]	SC	8/51	15.7	3/26	11.5	0/3	0.0	11/80	13.8
Gò Ô Chùa [l]	SV	3/23	13.0	3/20	15.0	0/2	0.0	6/45	13.3
Total		**45/273**	**16.5**	**29/246**	**11.8**	**14/178**	**7.9**	**88/697**	**12.6**
Unprovenanced burials									
Ban Chiang	NET	0/0	-	0/1	0.0	-	0.0	0/1	0.0
Ban Non Wat	NET	1/14	7.1	2/12	16.7	1/30	3.3	4/56	7.1
Non Nok Tha	NET	0/1	0.0	0/0	-	0/0	-	0/1	0.0
Ban Mai Chaimongkol	CT	0/3	0.0	0/5	0.0	0/3	0.0	0/11	0.0
Total		**1/18**	**5.6**	**2/18**	**11.1**	**1/33**	**3.0**	**4/69**	**5.8**
Total for SEA		**102/696**	**14.7**	**68/669**	**10.2**	**18/313**	**5.8**	**188/1678**	**11.2**

[1] (n/N) n = number of individuals affected by trauma, N = number of observed individuals.

% = trauma prevalence. *Poor bone preservation limited sex estimation to only one individual.

Region: M= Myanmar, SET= southeast Thailand, NET= northeast Thailand, CT= central Thailand, NWC= northwest Cambodia, SC= southern Cambodia, NV= northern Vietnam, SV= southern Vietnam, SEA = Southeast Asia.

Reference:[a]Domett & Tayles (2006), [b]Douglas (1996), [c]Domett & Tayles (unpublished), [d]Oxenham (2000), [e] Domett & Oxenham (2011) and Huffer & Hiep (2011) and Oxenham (pers. comm.), [f]Case (pers. comm.) and Liu (2012), [g]Pautreau (2007), [h]Tayles *et al*. (2007), [i]Domett & Buckley (unpublished), [j]Domett *et al*. (2011) and Domett & O'Reilly (2009), [k]Ikehara-Quebral (2010), [l]Francken (2012).

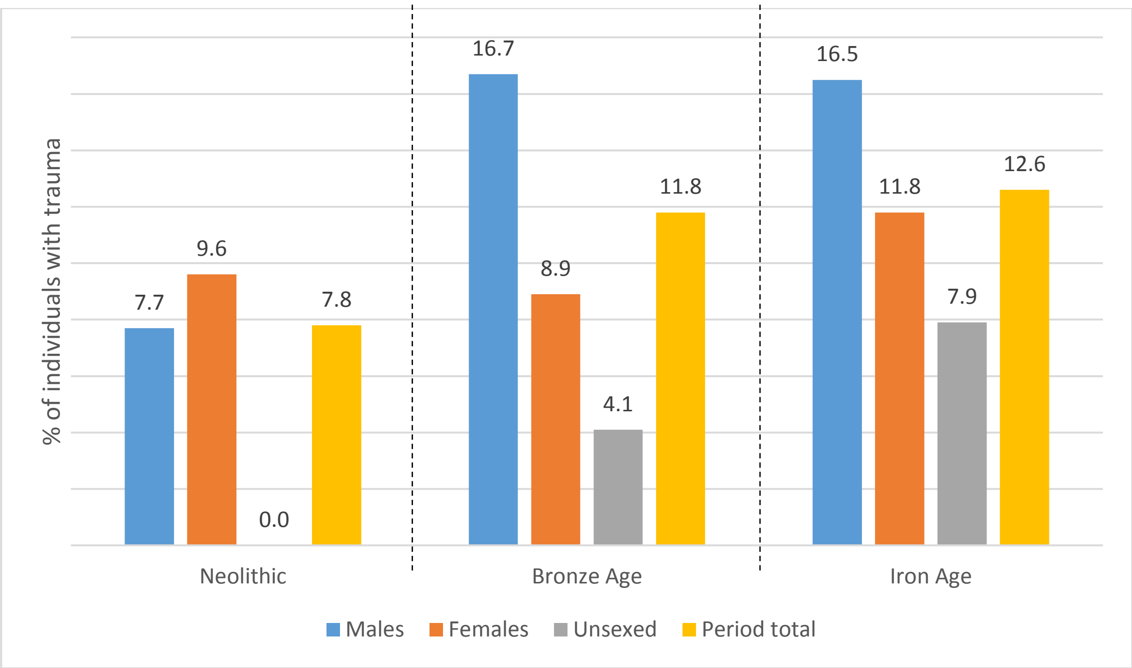
Table 6.2. Statistical values (FET p-value) for the temporal comparisons of trauma prevalence in adults (males, females & unsexed)

	n/N	%	Bronze Age	Iron Age
Neolithic	22/283	7.8	0.0799	**0.0334**
Bronze Age	74/629	11.8	n/a	0.6748
Iron Age	88/697	12.6	n/a	n/a

(n/N) n = number of individuals affected by trauma, N = number of observed individuals. % = trauma prevalence. Bold numbers indicate statistically significant *p*-values (<0.05)

The female sample from the Neolithic period has a slightly higher prevalence of trauma (9.6%) than the male sample (7.7%) (Figure 6.2) but this is not statistically significantly different (FET *p*-value = 0.6588). Bronze Age males (16.7%) were observed with almost twice as much trauma than Bronze Age females (8.9%), which is statistically significantly different (FET *p*-value = 0.0073). Iron Age males (16.5%) also have a higher prevalence of trauma than Iron Age females (11.8%) but this is not statistically significant (FET *p*-value = 0.1333).

Figure 6.2. Adult trauma prevalence by sex: temporal comparison



Neolithic to Iron Age: Male adult trauma

The male adult sample sizes and number of individuals observed with trauma were almost identical for the Bronze and Iron Ages, and these periods experienced very similar prevalences of trauma (16.7% and 16.5% respectively). The level of trauma observed in males from the Neolithic period (7.7%) was less than half that experienced by Bronze and Iron Age males and this difference was statistically significant (Table 6.3).

Table 6.3. Statistical differences (FET p-value) in males: inter-period comparison

	n/N	%	Bronze Age	Iron Age
Neolithic	10/130	7.7	**0.0136**	**0.0192**
Bronze Age	46/275	16.7	*	1.0000
Iron Age	45/273	16.5	*	*

(n/N) n = number of individuals affected by trauma, N = number of observed individuals. % = trauma prevalence. Bold numbers indicate statistically significant *p*-values (<0.05)

Neolithic to Iron Age: Female adult trauma

The prevalence of trauma for females was marginally lower in the Bronze Age (8.9%) compared to the Neolithic (9.6%) and then increased again in the Iron Age (11.8%) but the differences between the three periods was not statistically significant (Table 6.4).

Table 6.4. Statistical values (FET p-value) of inter-period comparisons

	n/N	%	Bronze Age	Iron Age
Neolithic	12/125	9.6	0.7102	0.6015
Bronze Age	25/280	8.9	*	0.2494
Iron Age	29/246	11.8	*	*

(n/N) n = number of individuals affected by trauma, N = number of observed individuals. % = trauma prevalence. Bold numbers indicate statistically significant *p*-values (<0.05)

Inter-site comparison of individual trauma prevalence

To understand why there are temporal differences in trauma prevalence, a closer look will be taken at each site to see variation of trauma prevalence among the sites influences the degree of trauma observed in each period.

For a majority of the sites (13/18) males have a higher prevalence of trauma compared to females (Figure 6.3), whereas at Khok Phanom Di (Neolithic southeast Thailand), Noen U-Loke (Iron Age northeast Thailand), Con Co Ngua (Neolithic northern Vietnam) and Gò Ô Chùa (Iron Age southern Vietnam) females have a slightly higher prevalence of trauma than males. However, within each site, these differences in trauma prevalence between the sexes are not statistically significant (Appendix, Table B3).

The adult sample (males, females and unsexed individuals) from each site was analysed in an intersite comparison (Figure 6.3), it can be seen that Phum Snay adults have the highest prevalence of trauma (39/148, 26.4%). This prevalence is statistically significantly higher than the adult samples of 12 other sites (Appendix, Table B4). The adults of Non Ban Jak had the second highest trauma prevalence of 25.5 percent (14/55), which was statistically higher than ten other sites. Statistically significantly more trauma was experienced by the adults of Ban Chiang (18/102, 17.6%) compared with seven other sites

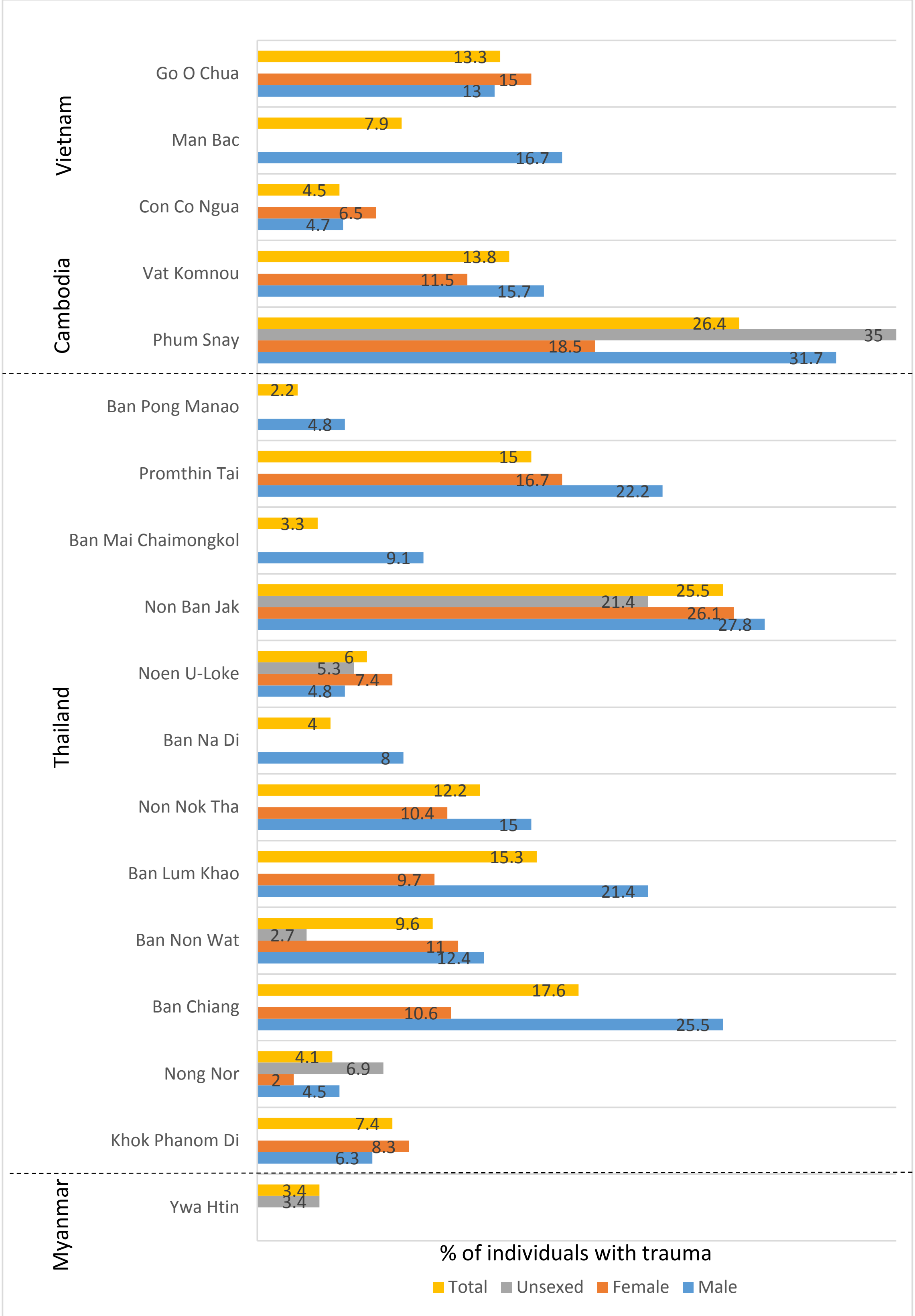
In the Neolithic samples (see Table 6.1), Non Nok Tha (northeast Thailand) has a relatively high prevalence of trauma in both the females (33.3%) and males (20.0%). Man Bac (northern Vietnam) males also have a relatively high prevalence of trauma (16.7%) but no trauma is observed in the Man Bac females. No trauma was observed in the adults of Ban Chiang (northeast Thailand).

The trauma prevalence for males was relatively high at Bronze Age Ban Chiang (27.3%), Ban Mai Chaimongkol (25.0%), Ban Lum Khao (21.4%) and Ban Non Wat (20.7%). All these sites were either from northeast or central Thailand. In comparison, the lowest prevalence of Bronze Age male trauma was 4.5 percent at Nong Nor (southeast Thailand). The trauma prevalence for females was highest at Ban Chiang

(17.4%), followed by Ban Non Wat (13.7%). Neither the Ban Na Di nor Ban Mai Chaimongkol female samples were observed with trauma.

A very high prevalence of trauma in males was found at Iron Age Ban Chiang (33.3%), Phum Snay, northwest Cambodia (31.7%) and Non Ban Jak, northeast Thailand (27.8%). A relatively high prevalence of trauma for females is also found at Non Ban Jak (26.1%) and Phum Snay (18.5%). No adults were observed with trauma at the central Thailand site of Ban Mai Chaimongkol.

Figure 6.3. Adult trauma prevalence by sex (% of individuals with trauma): intersite comparison



Temporal analysis: Long bone fracture prevalence

Table B2 in the Appendix lists the long bone elements observed with fractures and the total number of complete elements that could be observed at all 18 sites sampled in prehistoric Southeast Asia (listed by region). However, only 13 sites had sufficient skeletal census data to allow the calculation of fracture prevalence useful for temporal comparisons. Table 6.5 lists these sites by temporal period. Seven sites are from northeast Thailand, two from southeast Thailand, two from northern Vietnam, and one each from northwest and southern Cambodia.

A total of 7,249 long bones were considered to be observable for trauma (at least 75% of each element present) from the 13 sites (Neolithic, Bronze Age, Iron Age and unprovenanced burials). Seventy-two long bones had healed fractures, accounting for an overall fracture prevalence of 1.0 percent (72/7249) for Southeast Asia.

In the total adult sample (Neolithic, Bronze Age, Iron Age and unprovenanced burials combined) the element with the highest fracture prevalence was the radius (22/1001, 2.2%) and this was followed by the clavicle (19/1028, 1.8%) and ulna (13/985, 1.3%), then the humerus (6/1116, 0.5%). The thigh and leg elements had a much lower fracture prevalence compared to the upper body: fibula (4/881, 0.5%), femur (5/1156, 0.4%) and tibia (3/1082, 0.3%).

Table 6.5. Adult long bone fracture prevalence (% by bone element): sites suitable for temporal comparisons

Neolithic burials		**Major long bone fracture rates (% by bone element)[1]**															
Site	**Region**	**Clavicle %**		**Humerus %**		**Radius %**		**Ulna %**		**Femur %**		**Tibia %**		**Fibula %**		**Total %**	
Khok Phanom Di[a]	SET	2/106	1.9	0/104	0.0	0/102	0.0	0/74	0.0	0/85	0.0	0/90	0.0	0/48	0.0	2/609	0.3
Ban Chiang[b]	NET	0/3#	0.0	0/7#	0.0	0/4	0.0	0/3	0.0	0/12	0.0	0/9#	0.0	0/7#	0.0	0/45	0.0
Ban Non Wat[c]	NET	0/52	0.0	0/46	0.0	0/43	0.0	0/46	0.0	0/37	0.0	0/43	0.0	0/47	0.0	0/314	0.0
Non Nok Tha[b]	NET	1/7	14.3	0/16	0.0	0/8	0.0	0/9	0.0	0/18	0.0	0/8	0.0	0/9	0.0	1/75	1.3
Con Co Ngua[d]	NV	0/*	0.0	2/45[2]	4.4	0/27[2]	0.0	0/21[2]	0.0	2/45[2]	4.4	0/29[2]	0.0	0/12[2]	0.0	4/179[2]	2.2
Man Bac[e]	NV	1/26	3.8	0/51	0.0	1/48	2.1	0/51	0.0	0/53	0.0	0/45	0.0	0/23	0.0	2/297	0.7
Total		**4/194**	**2.1**	**2/269**	**0.7**	**1/232**	**0.4**	**0/204**	**0.0**	**2/250**	**0.8**	**0/224**	**0.0**	**0/146**	**0.0**	**9/1519**	**0.6**
Bronze Age burials																	
Nong Nor[a]	SET	1/18	5.6	0/19	0.0	0/13	0.0	2/9	22.2	0/17	0.0	0/13	0.0	0/0	-	3/89	3.4
Ban Chiang	NET	1/38#	2.6	2/45#	4.4	2/48	4.2	0/51	0.0	1/57	1.8	0/44#	0.0	0/39#	0.0	6/322	1.9#
Ban Non Wat	NET	5/329	1.5	1/304	0.3	9/305	3.0	4/308	1.3	1/325	0.3	1/310	0.3	1/292	0.3	22/2173	1.0
Ban Lum Khao[a]	NET	1/39	2.6	0/37	0.0	3/48	6.3	4/40	10.0	0/37	0.0	0/34	0.0	1/29	3.4	9/264	3.4
Non Nok Tha	NET	3/67	4.5	1/82	1.2	1/72	1.4	0/66	0.0	0/100	0.0	2/90	2.2	1/76	1.3	8/553	1.4
Ban Na Di[a]	NET	0/15	0.0	0/15	0.0	0/18	0.0	0/10	0.0	1/13	7.7	0/11	0.0	0/4	0.0	1/86	1.2
Total		**11/506**	**2.2**	**4/502**	**0.8**	**15/504**	**3.0**	**10/484**	**2.1**	**3/549**	**0.5**	**3/502**	**0.6**	**3/440**	**0.7**	**49/3487**	**1.4**
Iron Age burials																	
Ban Chiang	NET	0/16#	0.0	0/17#	0.0	0/18	0.0	0/22	0.0	0/17	0.0	0/23#	0.0	0/20#	0.0	0/133	0.0
Ban Non Wat	NET	0/122	0.0	0/97	0.0	0/95	0.0	1/100	1.0	0/108	0.0	0/108	0.0	0/88	0.0	1/718	0.1
Noen U-Loke[f]	NET	0/44	0.0	0/59	0.0	0/45	0.0	0/45	0.0	0/66	0.0	0/64	0.0	0/48	0.0	0/371	0.0
Non Ban Jak[g]	NET	1/69	1.4	0/77	0.0	[3]4/57	7.0	1/60	1.7	0/65	0.0	0/66	0.0	0/62	0.0	6/456	1.3
Phum Snay[h]	NWC	3/52[4]	5.8	0/70	0.0	2/24[4]	8.3	0/26	0.0	0/76	0.0	0/60	0.0	0/21	0.0	5/329	1.5
Vat Komnou[i]	SC	0/6	0.0	0/9	0.0	0/10	0.0	1/29[5]	3.4	0/2	0.0	0/8	0.0	1/31[5]	3.2	2/95	2.1
Total		**4/309**	**1.3**	**0/329**	**0.0**	**6/249**	**2.4**	**3/282**	**1.1**	**0/334**	**0.0**	**0/329**	**0.0**	**1/270**	**0.4**	**14/2102**	**0.7**

Continued on next page

Unprovenanced burials																	
Site	**Region**	**Clavicle %**		**Humerus %**		**Radius %**		**Ulna %**		**Femur %**		**Tibia %**		**Fibula %**		**Total %**	
Ban Chiang	NET	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-
Ban Non Wat	NET	0/19	0.0	0/16	0.0	0/16	0.0	0/15	0.0	0/23	0.0	0/27	0.0	0/25	0.0	0/141	0.0
Non Nok Tha	NET	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-	0/0	-
Total		**0/19**	**0.0**	**0/16**	**0.0**	**0/16**	**0.0**	**0/15**	**0.0**	**0/23**	**0.0**	**0/27**	**0.0**	**0/25**	**0.0**	**0/141**	**0.0**
SEA total		**19/1028**	**1.8**	**6/1116**	**0.5**	**22/1001**	**2.2**	**13/985**	**1.3**	**5/1156**	**0.4**	**3/1082**	**0.3**	**4/881**	**0.5**	**72/7249**	**1.0**

[1](n/N) n = number of fractures to element, N = total complete elements (>75% element present).
% = fracture prevalence.
#Two pages of skeletal census data omitted from Douglas (1996), printing error during publication – so denominator (N) count is incomplete.
*No denominator data published for the clavicle.
[2]N = preserved diaphysis.
[3]One individual has two fractures on a single radius.
[4]Unprovenanced individuals could only have the left or right element counted (due to minimum number of individuals).
[5]N = distal third of the ulna and fibula.
Region: SET = southeast Thailand, NET = northeast Thailand, CT = central Thailand, NWC = northwest Cambodia, SC = southern Cambodia, NV = northern Vietnam.
Reference: [a]Domett and Tayles (2006), [b]Douglas (1996), [c]Domett & Tayles (unpublished), [d]Oxenham (2000), [e]Huffer & Hiep (2011) and Matsumura *et al.* (2011) and Oxenham (pers. comm), [f]Domett & Tayles (unpublished), [g]current study, [h]Domett (unpublished), [i] Ikehara-Quebral (2010).

Neolithic Period

Six sites contain burials from the Neolithic Period (Table 6.5). The sites are located in northern Vietnam, southeast and northeast Thailand. The overall prevalence of fractured elements (total number of fractured elements/total number of observed complete elements) for the Neolithic period is just 0.6 percent (9/1519). The clavicle is the most commonly fractured bone in the Neolithic (4/194, 2.1%). No fractures are observed on the leg bones (tibia and fibula) or the ulna. The two sites from northern Vietnam (Con Co Ngua and Man Bac) are the only sites to feature fractures to more than one element type. The other sites are observed with fractures to just a single element, or no fractures at all. The long bone sample size is particularly small at Ban Chiang, however it should be noted that four of the elements have skeletal census data missing from the published skeletal census (Douglas 1996).

Bronze Age

The Bronze Age is represented by six sites (Table 6.5). These sites are all located in Thailand (southeast, northeast and central). The overall fracture prevalence for the combined Bronze Age sample is 1.4 percent (49/3487), which is significantly higher than the Neolithic (0.6%, 9/1519) (χ^2 5.414, p = 0.0200) and the Iron Age (0.7%, 14/2102) (χ^2 5.783, p = 0.0162) (Table 6.6). The radius is the most commonly fractured bone in the Bronze Age, with 15 out of the 504 complete radii observed to have fractures (3.0 %). All but one of the Bronze Age sites contains fractures to the clavicle, for a fracture prevalence of 2.2 percent (11/506). The other five elements have a fracture prevalence at or below 0.8 percent.

Iron Age

A total of 6 sites contain Iron Age burials suitable for temporal fracture analysis. These site are located in northeast Thailand, southern Cambodia and northwest Cambodia (Table 6.5). The overall prevalence of fractures for the combined Iron Age sample is 0.7 percent (14/2102). The radius has the highest overall fracture prevalence of 2.4 percent (6/249) and the clavicle has the second highest fracture prevalence of 1.3 percent

(4/309). Low fracture prevalence was observed in the ulna (1.1%, 3/282) and fibula (0.4%, 1/270). No fractures are observed on any of the humerii (0/329), femora (0/334) or tibiae (0/329) from the six Iron Age sites.

Table 6.6. Statistical differences (χ^2 p-value) in fracture prevalence for all long bone elements combined: inter-period comparison

All elements	Bronze Age	Iron Age
Neolithic	$\boldsymbol{p = 0.0200}$ **(χ^2 = 5.414)**	p = 9498 (χ^2 = 0.004)
Bronze Age	*	$\boldsymbol{p = 0.0162}$ **(χ^2 = 5.783)**

Bold numbers indicate statistically significant p-values (<0.05)

When the fracture prevalence for each element is compared between the Neolithic, Bronze Age and Iron Age (Figure 6.4 and Table 6.7) it can be seen that only the radius and ulna have statistically significant differences in fracture prevalence. In the Bronze Age, 15 of the 504 observed radii are fractured (3.0%) and this fracture prevalence is statistically greater than the Neolithic, where only one out of a total 232 radii (0.4%) are fractured. The fracture prevalence for ulnae in the Bronze Age (10/484, 2.1%) is statistically significantly higher than in the Neolithic Period (0/204, 0.0%).

Figure 6.4. Fracture prevalence (%) by period and element

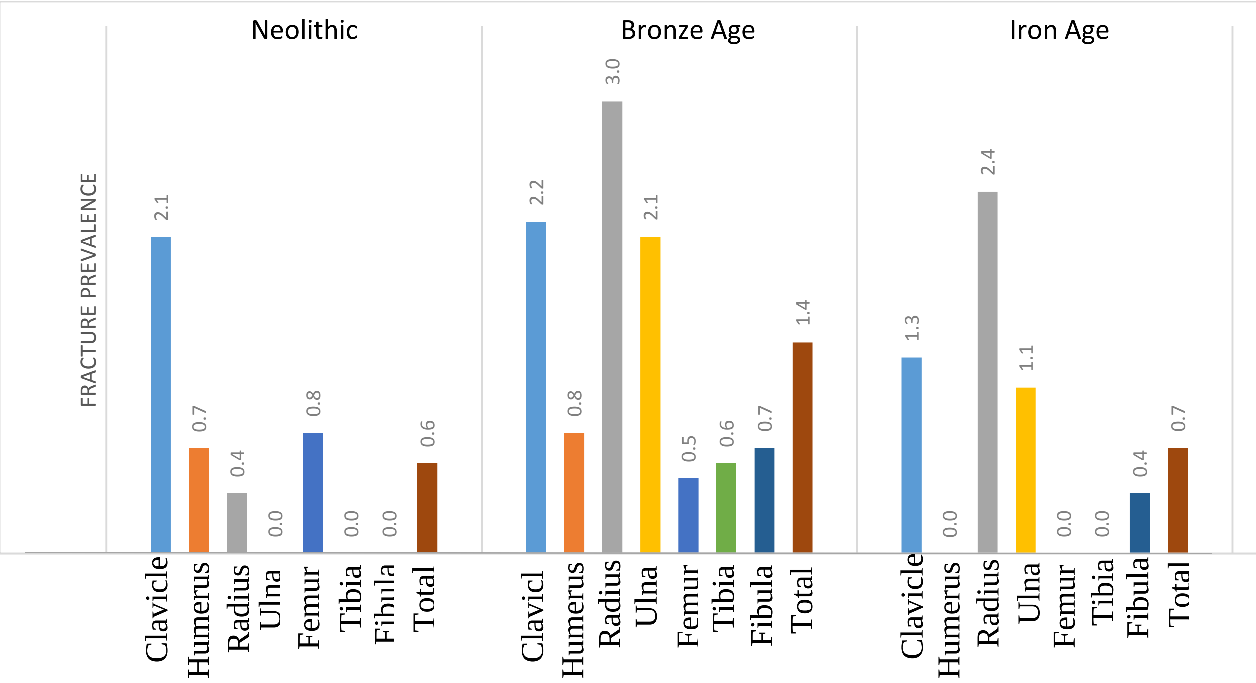


Table 6.7. Statistical values (FET p-value) of inter-period comparison in fracture prevalence by element

Clavicle	Bronze Age	Iron Age
Neolithic	1.0000	0.4924
Bronze Age	*	0.4317

Femur	Bronze Age	Iron Age
Neolithic	0.6507	0.1828
Bronze Age	*	0.2937

Humerus	Bronze Age	Iron Age
Neolithic	1.0000	0.2019
Bronze Age	*	0.1568

Tibia	Bronze Age	Iron Age
Neolithic	0.5565	1.0000
Bronze Age	*	0.2816

Radius	Bronze Age	Iron Age
Neolithic	**0.0283**	0.1239
Bronze Age	*	0.8153

Fibula	Bronze Age	Iron Age
Neolithic	1.0000	1.0000
Bronze Age	*	1.0000

Ulna	Bronze Age	Iron Age
Neolithic	**0.0383**	0.2678
Bronze Age	*	0.3922

Bold numbers indicate statistically significant *p*-values (<0.05)

Summary

There was a steady increase in adult trauma prevalence from the Neolithic (7.8%), to the Bronze Age (11.8%) and to the Iron Age (12.6%). The difference between the Neolithic and the Iron Age samples was statistically significant.

In the combined Southeast Asia sample, trauma prevalence is statistically significantly higher in males compared with the females. Within the Neolithic sample, females have a slightly higher prevalence of trauma than males. Bronze Age males had almost twice the prevalence of trauma than Bronze Age females and this was statistically significant. Iron Age males also experienced more trauma in comparison to females but the difference was not significant.

When comparing the female samples to one another, the prevalence of trauma was marginally lower in the Bronze Age compared to the Neolithic and it then increased again in the Iron Age but the differences were not statistically significant. When comparing the male samples to one another, there is a slightly higher prevalence of trauma prevalence in the Bronze Age males than the Iron Age males, but this difference is not significant. The level of trauma observed in males from the Neolithic period was half that experienced by Bronze Age males and Iron Age males and these difference are significant.

The overall long bone fracture prevalence was statistically significantly higher (twice as much) in the Bronze Age than both the Neolithic and the Iron Age. The radius was the most prevalently fractured element in the Southeast Asia sample, closely followed by the clavicle and then the ulna. Lower prevalences were observed in the humerus and lower body elements (femur, tibia and fibula). Both the radius and ulna fracture prevalence in the Bronze Age was significantly higher than in the Neolithic period.

The following chapter will discuss the temporal changes in trauma prevalence and long bone fracture prevalence and how the sociocultural environment has changed as the settlements transition through the periods, and influenced exposure to injury risk.

Chapter 7

Discussion

This chapter will discuss the results of the statistical and qualitative analyses conducted on the Neolithic, Bronze Age and Iron Age skeletal assemblages of Southeast Asia, compiled from published trauma research and new trauma data gathered from Iron Age Non Ban Jak in northeast Thailand. Contemporaneous skeletal samples from the world will be incorporated into the discussion for cultural comparisons. This data will be discussed in light of archaeological evidence for conflict such as fortification, weapons use and military paraphernalia to investigate temporal fluctuations of trauma prevalence to examine the risk of injury. The intent is to test the hypothesis that trauma prevalence would increase from the Neolithic to the Iron Age in response to population increase and changes to the sociopolitical sphere.

Limitations

Interpreting the behaviour of a prehistoric population through skeletal remains and artefacts that are thousands of years old is not without limitations and challenges. Many sites in Southeast Asia have not had trauma observed in the samples. However that does not mean that it is not present. Even when skeletal sample sizes appear large, the interpretation of evidence is complicated by widely varying levels of bone preservation among populations. The skeletons excavated are usually only a small portion of the total burials that are likely present at a site, and do not necessarily accurately represent the population that once lived (Lambert & Welker 2016). It would be highly beneficial if more extensive excavations could be conducted at each site to uncover larger skeletal samples, the human remains carefully recorded in-situ and excavated and analysed by biological anthropologists to get the most information possible from the remains. However, this brings up ethical and logistical issues as excavating larger areas means more of the site's context will be destroyed and huge samples of archaeological materials such as pottery, animal bones and shells will need to be stored, conserved and analysed.

Soft tissue injuries are more common than fractures (Sugiyama 2004) but in a skeletal sample, soft tissue injuries will only be seen in the rare cases where the traumatic event caused ossification of the damaged muscles or tissue (Walker 2001). Fractures to the bone can usually be seen macroscopically, however, in cases of advanced healing they may only be detectable via radiography. Due to the cost and/or lack of access to specialized radiographic equipment, this is not a common practice when analyzing prehistoric Southeast Asian skeletal samples and some fractures may have gone unnoticed.

Several sites, such as Phum Snay, Non Ban Jak, Noen U-Loke and Nong Nor, have a large percentage of adults of unknown sex. This may cause bias in the potential differences in trauma and fracture prevalence between the sexes, as it is unknown how many of these individuals are actually male or female.

Addressing the hypothesis

The hypothesis stated that over time there would be an increase in trauma prevalence, as the risk of injury increases in response to the burgeoning population density, increasing socio-political and technological complexity and environmental changes during the transition from the Neolithic to the Iron Age.

The trauma prevalence for individuals across the Southeast Asia samples supports this hypothesis. When the total adult sample (males, females and unsexed individuals) are compared between each of the periods, it is evident that there is an increase in trauma prevalence from the Neolithic (7.8%), to the Bronze Age (11.8%), and to the Iron Age (12.6%). While the increase from one consecutive period to the next is not statistically significant, the difference in trauma prevalence between the initial Neolithic and the final Iron Age is statistically significant and supports the hypothesis.

Part of the aim of this thesis is to determine if interpersonal violence was committed against individuals, a group or a community, and if it escalated into warfare. If so, to what extent, and what factors influenced violence to be enacted. The focus will be on trauma to the cranium, face, neck and forearms as they are suggested to be strong indicators of interpersonal violence (Lessa & Mendonça de Souza 2004; Lessa 2011;

Scott & Buckley 2014). The head and face are likely targeted to cause great pain or to cause permanent or temporary disfigurement, or death which Walker (2014) suggests would assert the aggressor's power over the victim. Fractures to other areas of the body can also be the result of violence, however it would be necessary to take a closer look at the context to understand the mechanism of injury (Lessa & Mendonça de Souza 2004).

Neolithic

The clavicle was the most frequently fractured long bone in the Neolithic, but more people received injuries to the hands. Much lower fracture prevalence is noted in the femur, humerus and radius, whilst no fractures were observed in the lower leg or ulna. Cranial trauma was experienced by just 0.7 percent of the adults (2/283). Fractures represent the majority of lesions, and there are two examples of sharp force trauma (SFT) and one contusion. Three individuals were observed with multiple lesions (1.1% of adults).

Results indicate that during the Neolithic, female trauma prevalence was slightly higher than it was for males. Injuries sustained by females included three individuals with a fractured metacarpal, one with a fractured hamate, three with a fractured clavicle and one with a fracture to the distal third of the humerus. These injuries typically result from indirect force; either a fall directly on to the shoulder or as the individual instinctively extends their arm to break a trip or fall (Judd & Roberts 1999; McCall & Shields 2008). Other injuries experienced by Neolithic females included a combination of sharp force and blunt force trauma to the ilium, and fractures to ribs and a vertebra. Only one female, from Con Co Ngua in northern Vietnam, was affected by trauma to the lower limbs; this individual had a fracture to the distal third of the femur. Fractures to the femoral shaft would normally require a high amount of kinetic energy for a fracture to occur, such as a fall from a tree or building, or contact from a heavy object (Lessa 2011).

Several males were observed with fractured metacarpals, and injuries to the upper body consisting of fractures to a clavicle, to the distal third of a humerus, the proximal third of a radius and a fractured glenoid. Only one fracture to the femur was observed, and one to a metatarsal. Just as it was for the females, these type of fractures can be the result of shock transference during a fall (Lessa 2011). Injury to the foot bones is quite common and can be the result of direct trauma such as objects falling on the foot, from falls, or from accidental collisions with a variety of everyday objects (Rogers & Campbell 1978).

Only two individuals in the Neolithic were observed with cranial injuries. At Man Bac in northern Vietnam a male was affected by sharp force trauma (SFT) to the frontal bone, and a male from Non Nok Tha in northeast Thailand was observed with a depressed cranial fracture. In modern and prehistoric studies, head trauma is mostly reported to occur during assaults, rather than from accidental mechanisms (De La Cova 2010; Gardner 2001; Lambert & Welker 2016; Lovell 1997; Scott & Buckley 2010). However, caution must be exercised when attempting to interpret violent behaviour in a population from just a few examples of trauma. Berger and Trinkaus (1995) have indicated that one possibility for the head and neck injuries they observed in a Neanderthal sample could be contact with wild animals during hunting. A wide variety of large animals were present in prehistoric Southeast Asia that could be prey for humans, for instance, faunal remains recovered from sites in northeast and central Thailand and northern Vietnam include bears, wild pigs, deer, crocodile, rhinoceros, elephants, tigers, panthers, leopard cats, and serow (Douglas 1996; Oxenham 2006; Sawada *et al.* 2011). Close encounters with domesticated animals such as buffalo, pigs and cattle could also increase the risk of injury from kicks, bites or trampling (Jones 1990; Judd & Roberts 1999). The need to protect domestic animals from wild predators would also increase the risk of injury to humans (Vencl 1984).

Weapons, or possible hunting implements, that were found within the Neolithic mortuary ritual include stone tools such as ground axes, hoes, spear heads and arrowheads that all have the potential to be used to inflict harm on humans but there is no direct evidence to suggest they were used in this way. Also part of the mortuary ritual were small spherical baked clay pellets that were likely used as missiles (perhaps with a pellet bow) to hunt small birds and animals. These were offered as grave goods at the Neolithic northern Vietnam sites of An Son and Man Bac, and also in northeast Thailand at Ban Non Wat, and later at Bronze Age Ban Lum Khao (Bellwood *et al.* 2011; Bentley *et al.* 2009; Matsumura *et al.* 2011b). There is a possibility that some depressed cranial fractures in this study could have been caused when accidentally, or intentionally, struck by clay pellet fired from a pellet bow. Items such as wood or bamboo used to make bows and spear shafts, or another type of weapon, are perishable materials in Southeast Asia that would leave no visible trace in the archaeological record (Junker 2006). Therefore it is possible that evidence of some weapons cannot be observed.

Whilst Non Nok Tha, Ban Chiang and Ban Non Wat from northeast Thailand are located in an inland riverine area, Man Bac and Con Co Ngua from northern Vietnam, and Khok Phanom Di from central Thailand are coastal estuarine settlements. Inland riverine areas are predominantly located in low-lying plains, with nearby low hills, subtropical forests and seasonal watercourses. The coastal estuarine sites also have access to subtropical forests nearby but they also may have mangrove swamps, rocky shores and marine resources. A difference in physical location and foraging strategy between these two environmental zones could explain the differences in trauma prevalence as each environment has its own associated risks. For instance, coastal populations may be at increased risk of injury from falls off coastal cliffs, slipping off wet rocks and boulders when collecting shellfish (Lessa 2011), while inland populations may have more injuries associated with a reliance on hunting terrestrial animals (Lambert & Welker 2016).

Domett and Tayles (2006) had previously compared two northeast Thailand inland riverine sites, Ban Lum Khao and Ban Na Di, with two southeast Thailand coastal sites, Khok Phanom Di and Nong Nor. They found that trauma prevalence was higher in the inland riverine region compared to the coastal estuarine region. Khok Phanom Di was a Neolithic site, the other three sites were from the Bronze Age. Therefore, cultural and technological change may also have had an impact on the comparison, as it was found that the combined Bronze Age sample (Ban Lum Khao, Ban Na Di, and Nong Nor) had significantly more long bones with fractures than the Neolithic sample (Domett & Tayles 2006). Other studies show a different trend. Lessa (2011) found Pre-colonial coastal populations from Brazil had a much higher prevalence of trauma compared from other regions, including the northeast Thailand sites in the study by Domett and Tayles (2006). Lessa (2011) determined this was due to the extremely rugged coastline compared to other regions that put them at increased risk when collecting marine resources.

Studies indicate that changes in social stratigraphy and the natural environment that put demands on the population with regard to food production and choice of settlement location, may be linked to an increase in social tension (Boyd & Chang 2010; Domett 2001; Eyre 2010; Higham 1989, 2004; Higham & Thosarat 2007; Higham 2015; O'Reilly 2000; Torres-Rouff & Costa Junqueira 2006; Zhang *et al.* 2007). Non Nok Tha adults did not stand out as being particularly wealthy in terms of burial goods (Higham *et al.* 2014b), however Bayard (1984) argues that the richness of mortuary goods in child burials at Non Nok Tha is evidence of ascribed status. Some Neolithic burials from Man Bac and Khok Phanom Di are distinguished by having more opulent mortuary offerings, and this could be linked to their perceived economic role in the society and status differences (Bentley *et al.* 2007; Oxenham *et al.* 2008).

The adults at Non Nok Tha in northeast Thailand had a statistically significantly higher trauma prevalence (26.3%) than any other Neolithic site, except for Ban Non Wat (Appendix B5). However, the sample size of just 19 adults at Non Nok Tha is very small and sampling error may account for the high prevalence. Douglas (1996) determined that the trauma observed at both Non Nok Tha and Ban Na Di was attributable to accidental mechanisms, and given the context of the trauma, mortuary ritual and archaeological record, there was no evidence of warfare. However, the presence of at least four individuals at Non Nok Tha buried with disarticulated crania led Douglas (1996) to suggest that head-hunting raids may have been practiced, but more analysis would need to be conducted to confirm this interpretation. If raids or ambushes were regularly conducted by the population of Non Nok Tha it could explain the elevated trauma prevalence at that site. Ban Non Wat (9.4%) had the second highest prevalence of trauma, followed by Man Bac (7.9%) and Khok Phanom Di (7.4%). In contrast, Con Co Ngua had very low prevalence of trauma (4.5%), and no trauma was observed in the Neolithic burials of Ban Na Di. Oxenham *et al.* (2001) has suggested accidents due to movement over rough and elevated terrain and hunting large animals are likely to have put the Con Co Ngua individuals at risk of injury. Domett and Tayles (2006) could not attribute any of the trauma at Khok Phanom Di to interpersonal violence. No detailed trauma analysis reports have yet been published for the Man Bac and Ban Non Wat skeletal samples.

Summary

Females had only marginally higher trauma prevalence than males in the Neolithic. A similar prevalence of trauma suggests females and males experienced similar risks from daily activities. Fractures to the upper body, mostly to the clavicle and hand bones, are much more common than injuries to the lower limbs. The majority of injuries are from single events, and are most likely due to accidental mechanisms such as falls, tripping over uneven ground or close encounters with animals. The two males with cranial trauma suggest there is a possibility that some individuals experienced interpersonal violence, however it is just as likely that these injuries were accidental. Social stratigraphy was evident in some of the Neolithic sites but this could not be correlated with an increase in trauma prevalence as the two sites with the highest trauma prevalence also had no evidence of individuals with obvious wealth in mortuary goods.

Bronze Age

All long bones, except for the femur, were calculated to have a higher fracture prevalence in the Bronze Age than either the Neolithic or Iron Age. The fracture prevalence for the femur was highest in the Neolithic and second highest in the Bronze Age. The radius was the most commonly fractured bone, followed by the clavicle and ulna. Trauma to the hands and feet was also relatively common. There was a much lower fracture prevalence for the humerus and lower limbs. Just 1.9 percent (12/629) of adult individuals experienced craniofacial trauma. Multiple lesions are observed on nineteen adults (3.0%). The majority of injuries are fractures but three individuals were observed with sharp force trauma and two were observed with contusions.

In the overall Bronze Age sample, males (16.7%) were observed with a statistically significantly higher trauma prevalence than the females (8.9%). Males are affected more by trauma to the lower limbs, feet, humerus and vertebrae. However, males and females are almost equally likely to have trauma to the forearm and hands. Females are observed with more fractures to the clavicle and ribs than males. Bronze Age males have statistically significantly more craniofacial trauma than females. Intentional injury is suggested if the trauma is predominantly observed in one group of the society, for instance a high prevalence of cranial trauma in males is generally considered to indicate interpersonal violence (Lessa & Mendonça de Souza 2004).

Only one female, from Ban Non Wat in northeast Thailand, was observed with cranial trauma. This individual had several perimortem depressed cranial fractures as well as healed fractures to both the left and right distal radii. No females were observed with facial trauma. In contrast eleven males were observed with craniofacial trauma. A male from Ban Lum Khao was affected by fractured nasal bones and a fractured distal ulna, which had the characteristics of a parry fracture. This fracture was possibly sustained when the arm was brought up across the face to fend off a blow to the head (Judd 2008; Lambert & Welker 2016; Richards & Deal 2014). However, Domett and Tayles (2006) who analysed the trauma at this site, are unsure if the injuries both happened in the same event. If this was the case, then this individual was unsuccessful in fully protecting his face from the attack. A distal ulna fracture can also result from an accident, such as an individual putting their arm out to protect themselves from a fall onto the ground or against a falling heavy object (Lessa & Mendonça de Souza 2004). However, parry fractures that are found in high frequency or combined with cranial trauma are a good indicator of involvement in conflict (Lessa & Mendonça de Souza 2004; Scott & Buckley 2014). Seven individuals, three males, three females and one unsexed adult, have possible parry fractures. These are distributed between Ban Lum Khao (3.4% of adults), Nong Nor (1.6%) and Ban Non Wat (1.5%).

A male from Ban Lum Khao was observed with a mandibular fracture, as was one male from Nong Nor and Ban Non Wat. In relation to prehistoric populations, fractures such as these to the body and condyles of the mandible can most commonly be attributed to interpersonal violence followed by falls and sports related incidences (Domett & Tayles 2006; Ellis *et al.* 1985; Fridrich *et al.* 1992; Silvennoinen *et al.* 1992). A further four males at Ban Non Wat were affected by either sharp force cranial trauma or depressed cranial fractures in combination with trauma to the humerus and/or a rib. At Ban Chiang, two males were observed with a depressed cranial fracture and fractured cervical vertebrae, and a male from Non Nok Tha was observed with a single depressed cranial fracture. The cranial trauma at Ban Chiang and Non Nok Tha was noted to likely not be caused by interpersonal violence, rather Pietrusewsky and Douglas (2002) suggested the cranial and postcranial trauma at these sites was attributable to lifestyle and occupation activities associated with a rural environment. But, depending on the context, a combination of cranial and facial trauma, distal ulnar fractures, and sharp force trauma (SFT) are relevant indications that the population likely experienced interpersonal violence (Scott & Buckley 2014; Walker 2001). The low prevalence of perimortem cranial injuries suggests that the majority of individuals who suffered such violence survived. It may be tha, in any cases of such violence, the intention was to injure rather than to kill (Gheggi 2016). This is suggestive of conflicts being settled by less violent means such as ritualised violence (McCall & Shields 2008).

Other types and patterns of trauma in the Bronze Age are more indicative of accidental injury, for instance transverse fractures to the distal third of the radius with posterior displacement or angulation have been described in the literature as possible Colles' fractures (Apley & Soloman 2001; Lovell 1997; Perkins 1958). This radius fracture is commonly caused by a trip, fall or being pushed onto an outstretched hand (Huckstep 1995; McQueen & Caspers 1988). The fractured radius from the Neolithic burial discussed above did not have the characteristics of a Colles' fracture but in the Bronze Age there are ten individuals with fractures to the distal radius that are suspected to be Colles' fractures, seven of which are found at Ban Non Wat (3.2% of adults at this site).

The humerus is a stronger bone and less likely to fracture compared to the thinner and less robust bones of the forearm and clavicle (Domett & Tayles 2006). Fractures to the humeral shaft can be caused by direct or indirect impact (Lovell 1997), such as a kick by an animal or a fall onto an outstretched hand (Chitnavis *et al.* 1996; Scott & Buckley 2010). But injuries to the brachium should also be considered as potential defence wounds as they can be used to block blows to the head and upper body (Brink *et al.* 1998).

Fractures have been observed in all three of the thigh and leg bones, albeit at a lower prevalence than the clavicle, arm and forearm bones. Fractures to the lower limbs are more commonly associated with accidental injury rather than intentional (Lambert & Welker 2016). In fisher/hunter and gatherer communities from coastal Brazil, the second most common fractures were those to the lower limbs, caused by falls down rocky coastal cliffs and slips on wet rocks in intertidal areas (Lessa 2011). The clavicle is the second most common long bone to be fractured in the Bronze Age. These usually result from a direct force or fall onto the shoulder (Denard *et al.* 2005; Khan *et al.* 2009). Most sites would have experienced similar environments as only Nong Nor is a coastal site to the southeast, all other sites are inland in the northeast, and one in central Thailand. Any differences in trauma prevalence are therefore unlikely to be due to subsistence activities.

The introduction of metals during this period meant that weapon types could be more diverse in design than stone tools in the Neolithic. Bronze spears, projectile points and axes were found at numerous sites including Noen U-Loke, Ban Chiang, Ban Na Di, and Non Nok Tha (Higham 2002; Higham & Thosarat 2012). Copper axes are present at Non Nok Tha and Ban Non Wat and moulds used for the production of bronze points were found at Ban Lum Khao (Higham & Thosarat 2012; Higham 2013). These implements were part of the mortuary ritual and could be associated with hunting animals or have ritual use. There is no direct contextual evidence that they were used as weapons to inflict trauma on Bronze Age people.

Higham *et al.* (2015) argue that bronze technology was likely introduced to Southeast Asia via Lingnan in southern China and copper base metallurgy appears to have been established simultaneously in northeast Thailand sites of Ban Non Wat, Ban Lum Khao and Noen U-Loke. Copper was traded into sites such as Ban Chiang and Ban Non Wat from distant mines, in upland Laos to the east, on the banks of the Mekong to the south and central Thailand to the west (Higham *et al.* 2015). In traditional arguments, the supply of copper might be expected to become vital for commercial and economic reasons and securing trade routes and access to the mineral resources would likely be considered important for these populations. Thus conflict over resources or territory may have become an issue. Ban Chiang had the highest prevalence of trauma (22.4%), followed by Ban Lum Khao (15.3%) and Ban Non Wat (15.3%). It would be impossible at this stage to link the prevalence of trauma at certain sites to the metal trade with any certainty as environment and other cultural factors also play a part. The economic role that bronze would have in a community could be linked to social status, for example, an early Bronze Age group of burials at Ban Non Wat showed 'outstanding' mortuary wealth that may have indicated they had higher status in the community (Higham 2014a). Higham (2014a) suggests this wealth was likely achieved through the ownership and control of copper and exotic shell items. Ban Non Wat's location close to a mountain pass to central Thailand would have allowed them to oversee the trade of such items (Higham & Rispoli 2014). This is the only site in the region to have shown such significant social change, most Bronze Age sites in northeast Thailand display only modest variations in mortuary wealth and lack evidence of such obvious status (Higham *et al.* 2015). However, this wealth was short-lived and only apparent over several generations (Higham 2015), which could point to Ban Non Wat having the advantage of access and control for only a short period of time.

Summary

The pattern and type of some trauma suggests that interpersonal violence was experienced by Bronze Age populations. This is supported by the statistically significantly greater amount of trauma in males and the presence of cranial trauma, facial injuries and parry fractures at some sites. There was no archaeological evidence of military paraphernalia or stockpiling of weapons. Bronze weapons are part of the mortuary ritual, however, there is no direct evidence to match them to a particular traumatic injury. Ban Non Wat, which had the third highest prevalence of trauma, was the only site reported to have social stratigraphy in the Bronze Age, the other sites had no obvious differences in mortuary wealth. No correlation can be made to the prevalence of trauma. Accidental mechanisms of trauma could be attributed to daily living activities and occupation, for instance, land clearance for rice fields would have put the population at increased risk of injury from falling branches or falling from trees, close encounters with wildlife, slips and trips and using wood cutting tools.

Iron Age

As was the case in the Bronze Age, in the Iron Age the radius is the most frequently fractured long bone, followed by the clavicle, then the ulna. The fibula was the only bone of the lower limb to be fractured and in only one individual. Trauma to the hands and feet is not as common in the Iron Age as it is in the Bronze Age and Neolithic.

In the Iron Age there was a greater diversity in the type of bones affected by trauma (feet, hands, pelvis, scapula, vertebra, hyoid, mandible, craniofacial, ribs, as well as major long bones) compared with the other two periods. For instance, no trauma was observed to the face or neck (mandible, hyoid or facial bones) from the Neolithic sample, nor was trauma observed to the hyoid or scapula in the Bronze Age sample.

There was also a greater diversity in type of injury identified in the Iron Age sample (fractures, dislocation, contusion, SFT, BFT, hematoma ossification, *myositis ossificans traumatica*, and localised bone swelling), however the reporting of less common types of trauma may be due to the observers' level of experience and knowledge in identifying different types of trauma.

The results show that Iron Age males had a higher prevalence of trauma (16.5%) than females (11.8%) but the difference was not statistically significant. Just over twice as many males than females were observed with craniofacial trauma. More males than females received injuries to the ulna, ribs, hyoid, vertebrae, feet, and fibula. Marginally more females have trauma observed on the clavicle, hands, scapula and pelvis.

Three males have possible parry fractures. These are found at Ban Pong Manao (2.2% of all adults), Non Ban Jak (1.8%) and Vat Komnou (1.3%). As these fractures are only found in one individual per site the fracture frequency per site is actually very low and therefore not likely to be from interpersonal violence.

Three females from Non Ban Jak (5.5% of all adults) and two adults of unknown sex from Phum Snay (1.4%) have Colles' fractures of the distal radius, which as discussed earlier, are most commonly associated with falls or trips onto an outstretched hand.

At Iron Age Non Ban Jak, five out of 55 adults (9.1%) have experienced rib fractures. This is the highest percentage in any skeletal sample in Southeast Asia. Fracture to a single rib commonly indicates a direct hit, whereas multiple rib fractures are associated with violent blunt force trauma from a large object or compressive force (Rodríguez-Martín 2006). In modern clinical studies, blunt force trauma resulting in rib fractures were most commonly caused by motor vehicle accidents, falls and assaults (Byun & Kim 2013; Marasco *et al.* 2015). Violence may be suspected if rib injuries are accompanied by upper body injuries, involving the clavicle, cranium and parry fractures (Judd & Roberts 1999). Two males from Vat Komnou were observed with either a combination of a fractured rib and hyoid; or two fractured ribs and a possible parry fracture to the distal ulna. A female from Phromthin Tai in central Thailand was observed with a fractured clavicle and multiple rib fractures.

There was a particularly high rate of cranial trauma at Iron Age Phum Snay, northwest Cambodia (Domett *et al.* 2011), where 21.6 percent of the adults (32/148) displayed evidence of craniofacial lesions (affecting the cranium, face and mandible), this is the highest of any individual site from any period. Eight other Iron Age sites had individuals observed with craniofacial trauma. The overall proportion of adult individuals experiencing craniofacial trauma from the total Iron Age sample is 5.7 percent (40/697).

The cranial trauma at Phum Snay was a mixture of blunt force trauma and sharp force trauma. Almost all the cranial trauma is located on the frontal or parietal bones. This suggests an attack from the front, with the perpetrator up close to the victim (Lessa & Mendonça de Souza 2004). Depressed fractures to the frontal bone are often an indicator of hand-to-hand combat (McBride *et al.* 1988). The most severe case of trauma at this site, to a possible female (Figure 7.1), was the result of multiple perimortem blows to the head with a straight edged instrument, and these are the likely cause of death (Domett *et al.* 2011:447). There was also a cut mark on the left side of the head of this individual, as well as an unhealed cut mark to the occipital that was noted by Domett *et al.* (2011:447) to be possibly from a decapitation attempt. Decapitation is often associated with trophy-taking, sacrifice, punishment, and execution (Dougherty & Friedman 2008; Kanjou *et al.* 2015; Khudaverdyan 2014). Disarticulated skulls were found in four Non Nok Tha burials, however it is not known whether the heads were removed as part of the mortuary ritual or taken as trophies (Douglas 1996:482). There are no other records of decapitation discussed in prehistoric Mainland Southeast Asia, however, in Island Southeast Asia (not part of this study) two pre-Neolithic (c. 5500) burials and a small number of Neolithic burials at Niah Cave in Borneo (Sarawak) were reported to have possibly been decapitated (Lloyd-Smith 2014). It has been suggested by Lloyd-Smith (2014) that their burial ritual may symbolise dividing the social identity into parts, and may symbolise the need for social separation in death.

Figure 7.1. Burial WLC73 from Phum Snay. Perimortem cuts and blows to the cranium (Picture: (Domett et al. 2011)).

Domett *et al.* (2011) suggest that the high prevalence of cranial trauma at Phum Snay, the majority of which was present in males, and the inclusion of weapons in mortuary rituals (Figure 7.2) is highly indicative of interpersonal violence or warfare during a period of emerging political friction and social tension. Brink *et al.* (1998) studied modern patterns of injury associated with assault and found that fractures to the face and mandible were significantly more prevalent in males compared to females. In most cultures, warfare is considered a male activity (Burbank 1992; McCall & Shields 2008). Phum Snay males were buried with swords and knives (Domett *et al.* 2011). These weapons would have been too unwieldy for use in hunting, and so it can be assumed they were produced specifically for war. To maintain specialist warriors at Phum Snay would have required time and resources dedicated for training in military tactics and maintenance of fitness and equipment. These weapons and the cranial trauma suggests that male roles focused on training for and participating in socially sanctioned warfare. A few females were buried with projectile points (Domett *et al.* 2011). Their burial with weapons and the high prevalence of cranial trauma, indicate their role as possible participants in conflict. Outside of the sample recovered from formal archaeological excavations, ceramic shoulder decorations resembling military style epaulettes (Figure 7.3) have been found in the mortuary ritual at Phum Snay and looters have reported sighting bronze helmets on the skulls (Domett *et al.* 2011; O'Reilly *et al.* 2006a). Military paraphernalia and weapons in burials have been interpreted as representing the social and economic role that individuals played in society (Earle 2004; Härke 1990) and may indicate social stratification exists at Phum Snay. O'Reilly and Sytha (2001) have suggested the abundance of military paraphernalia and weapons indicate a competition for resources and this could be a contributing factor for the later development of the strongly hierarchical capital of Angkor in this region.

Figure 7.2. B5, young adult male buried with iron sword and projectile points (circled) (Picture: Domett et al. (2011)).

Figure 7.3.

Unprovenanced artefact that is a Possible epaulette (Picture: Domett et al. (2011)).

Three unsexed individuals were observed with a mandibular fracture, one from Ywa Htin in Myanmar, and two from Phum Snay. Fractures to the face, particularly the nasal bones and mandible are associated with violent assaults as the head and neck is most targeted in fist-fights (Cohen *et al.* 2014; De La Cova 2010; Lessa & Mendonça de Souza 2004). Accidental falls may also account for facial fractures, especially in regions with rough terrain (De La Cova 2010).

Fractures to the hyoid were observed in two males from the Iron Age - Ban Chiang in northeast Thailand and Vat Komnou in southeast Cambodia - but no females from any period were observed with an injury to the hyoid. Fractures to the hyoid bone are rare in the archaeological record as this bone is rarely retrieved from an excavation (Lovell 2008). If the individual is a victim of assault, a hyoid fracture will seldom be in isolation, it is frequently associated with injuries to adjacent structures such as nasal bones and/or the mandible (Dunsby & Davison 2011; Gupta *et al.* 1995). Both the males have other fractures, such as to the foot and shoulder or rib, but it is difficult to tell if the multiple injuries on the one individual happened in the one incident, or if the injuries were the result of several events. Most commonly, it is direct force from strangulation or hanging that fractures the hyoid (Chowdhury *et al.* 2005; De La Cova 2010; Dunsby & Davison 2011; Szeremeta & Morovati 1991). Other mechanisms include a direct hit to the throat, falls from a height, and there has been a reported case of hyoid fracture from induced vomiting (Chowdhury *et al.* 2005; Dunsby & Davison 2011; Gupta *et al.* 1995). Both of the hyoid fractures show signs of healing which indicates the individuals survived the traumatic event, whatever the cause.

The most severe case of head trauma yet observed in Southeast Asia was discovered at Noen U-Loke, Iron Age northeast Thailand (Figure 7.4). An elderly woman received several hits to the face and side of the head, some of which resulted in crushing injuries. Her skull had also been cleaved across the centre from side to side. Tayles (2003) suggests this injury was the likely cause of death as such violent trauma would be fatal. The positioning of the cut indicates the victim was upright when the blow was received and thus the trauma is likely to be perimortem (Tayles 2003). Her burial ritual was also unusual in that her ankles were crossed and her head was placed inside a large pot, which may have been done to mask the severe head trauma (Tayles 2003). She had a similar quantity and type of mortuary goods to other individuals in the large cluster of graves that she was interred within, therefore it can be assumed that she was not buried with haste or treated differently to others in the community. The trauma to this elderly woman was inflicted by a very sharp and heavy instrument, possibly a sword or iron spear (Tayles 2003). Swords were not found at Noen U-Loke, but they are found at Phum Snay and further away at Ban Wang Hai in northern Thailand (Domett *et al.* 2011; Pautreau *et al.* 2003). Other implements that could have caused such a traumatic wound are sickles, hoes, digging sticks and the heavy iron spear heads that are part of the mortuary ritual at Noen U-Loke and the nearby, contemporaneous site of Ban Non Wat (Higham & Rispoli 2014; Tayles 2003). An exchange network is suggested to have existed between Phum Snay, Noen U-Loke and Ban Non Wat due to a similarity in mortuary ritual and material artefacts (O'Reilly & Sytha 2001; O'Reilly *et al.* 2006b). This trauma could indicate that there was possibly a rise in social tension between these settlements.

Figure 7.4.

Left lateral aspect of the cranium with arrows showing the cut (Picture: (Tayles 2003)).

At Noen U-Loke, a young adult male was found buried with an iron projectile point lodged in his spine (Figure 7.5 A & B) (Higham & Thosarat 2007). When projectiles are embedded in bone it is a strong indication that the person was the victim of violence (Gheggi 2016; Lessa & Mendonça de Souza 2004; Milner 1999). Two studies on projectile wounds indicate that only half to one third of projectiles fired at an individual would actually hit bone (Milner 1999; Walker 2001). This individual may been the victim of intentional violence or possibly a hunting accident, where the projectile was not intentionally meant to inflict harm. Milner (1999) suggests that hunting accidents would have been uncommon in prehistoric populations due to the high-degree of skill and accuracy generally attained by hunters. The use of projectiles is also noted to more likely be used on distant groups that are not related (Chagnon 2012).

A further two males at Noen U-Loke were buried in the prone position, they both have skeletal lesions that have been tentatively diagnosed as the result of leprosy (Tayles & Buckley 2004). No lesions have been observed on the poorly preserved skeletal elements of the individual with the projectile point (Tayles & Buckley 2004). But pathological changes do not always affect bone, especially in the early stages of infection (Judd & Roberts 1998), thus Tayles and Buckley (2004) are unable to ascertain if his prone burial was related to leprosy or if it was related to his possible injury. Prone burials are rare in the archaeological record worldwide and are suggested to signify low socio-economic status, social exclusion, non-membership in the community, captives of war, ritual sacrifice, the mark of a deviant or criminal social status, or either a fear of, or lack of respect for the deceased (Arcini 2009; Carver 2005; Duncan *et al.* 2008; Fowler Jr 1984; Handler 1996; Hawkes & Wells 1975; Saracino *et al.* 2014). Given the context of this man's burial, lying face-down, and the paucity of mortuary goods in comparison to those buried around him, we might suggest a hasty burial.

Figure 7.5 A. Iron projectile point lodged in the vertebrae

Figure 7.5 B. Prone burial of B61, a young male adult. Position of projectile circled.(Pictures: Higham and Thosarat (2007)).

Figure. A.

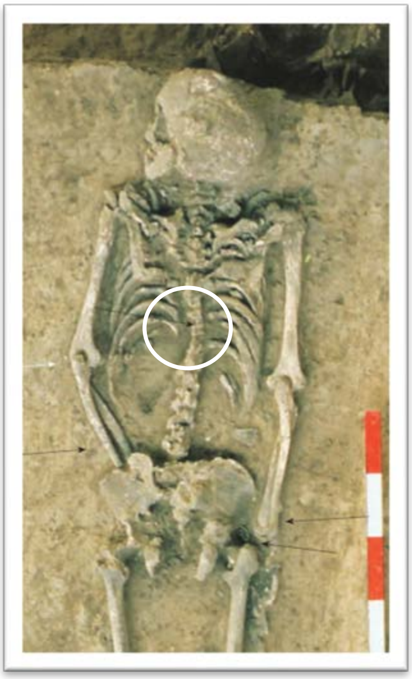


Figure B.

Material evidence of conflict in the Iron Age

The types of weapons became more diverse and weapons production notably increased in the Iron Age, especially the mass production of projectile points in northeast Thailand and northern Vietnam (Higham *et al.* 2014a; Kim 2013a). Socketed and bimetallic spears, heavy iron spears, and iron knife blades were excavated from Ban Non Wat Iron Age burials. Burials at Non Ban Jak contained iron knife blades and heavy iron spears were found at Noen U-Loke and Ban Chiang. Large bronze drums that originated from Dong Son cultures in northern Vietnam depicted images of warriors with spears, bows and arrows (Millar 2012). A large bronze drum that was excavated from within the ramparts at Co Loa contained, among other items, bronze spears, hoes, axes, daggers and projectiles (Higham 2002). A cache of 10,000 projectiles was found just outside the ramparts and bronze cross-bow bolts were being produced in large quantities (Kim 2013a).

Interpersonal violence and changes to settlement patterns has been linked to environmental pressures, for example, Zhang *et al.* (2007) have linked long-term climate change cycles from warmer to colder phases to decreased agricultural production and depleted resources. This depletion in resources has been linked to increasing social tension, uprisings, and a higher frequency of war as the population can no longer be sustained at the previous levels achieved with surplus food production in the warmer climate (Zhang *et al.* 2007). A change in the Mun River Valley, northeast Thailand, from the low density settlement patterns in the late Bronze Age to the high density settlement in the Iron Age, and the subsequent increase in the quantity and size of mounded settlements, has been linked to a shift to a drier and/or more strongly seasonal climate cycle (Boyd *et al.* 1999b; Boyd 2008). In Southeast Asia an increase in population density and intensive human impacts such as forest clearance, burning vegetation and wet-rice farming technology also strongly impacted the landscape and settlement patterns in the Iron Age (Boyd *et al.* 1999b; Boyd & Chang 2010).

However, it appears that possible resource stress in the Iron Age was being countered by an ability to produce surplus food as evident by the iron or bronze ploughshares that were found at Non Ban Jak and Noen U-Loke, and also Co Loa in northern Vietnam (Higham 2014c; Millar 2012). Further, images of water buffalo pulling ploughs were etched into drums produced in northern Vietnam Dong Son settlements (Millar 2012). Buffalo-pulled ploughs enabled more land to be cultivated in the same time than could be done manually by people with hoes, and this may have led to food surpluses (Higham 2014c; Higham & Rispoli 2014). Trauma prevalence has also been linked to an increased scale and intensity of farming, in contrast to earlier periods when farming was less central to society (Lambert & Welker 2016). By the mid Iron Age the environment had rapidly changed to a dry woodland, receiving less seasonal rainfall, and this likely required a greater degree of landscape management and maintenance (Boyd & Chang 2010). The more intensive farming practices may have led to increased injury risk associated with the cultivation of larger fields, extensive engineering work, land clearance activities, livestock handling and increased risk taking due to more extreme environment and social situations (Judd & Roberts 1999; Lambert & Welker 2016).

There is an increasing diversity of moated sites from the earlier, smaller eastern Cambodian and southwestern Vietnam circular sites to the large, multi-moated sites of late Iron Age Thailand and the heavily fortified site of Co Loa in northern Vietnam, Khao Sam Kaeo in the upper Thai-Malay Peninsula, (Kim *et al.* 2010) and the complex defensive structures surrounding urban centres in Myanmar (Moore & Win 2007). Many authors, (Higham 2011c; Kim 2013b; Kojo & Pheng 1998; Maschner & Reedy-Maschner 1998; Moore 1989; Moore 1988; Mudar 1999; Nitta 1991; Villabhotama 1984) have discussed the potential of moats as defensive structures and not just as water management devices. Co Loa was situated in a region that bordered the more powerful Han China to the north, but it was itself part of the prosperous Dong Son culture. This gave the site the means and the potential to expand at a rate not seen in other regions during the Iron Age. The sheer size of the site and the elaborate defensive features are an indication of the labour force and material resources that would have been required over many generations. This is not only a testament to the power of the ruling authority (Higham 1996; Zialcita 1995) but also an example of the emerging social complexity within the region. Kim (2013a) and Kim *et al.* (2010) also argue that the defensive features at Co Loa were likely constructed in response to threat from foreign powers to the north and intra-regional competition for agricultural land, and in turn this would have contributed to the formation of a central economic and state polity based at Co Loa. The ramparts and moats are described by Kim (2013a) as an empowering symbol of physical ownership, used to control access to resources, stored water, and also as a deterrent to potential threats.

Interpretation of historical and ethnographic evidence of conflict in the Iron Age and protohistoric period of Southeast Asia indicates that from the mid first millennium, many elites had formed polities in northern Vietnam that began competing for economic wealth and political dominance through military power (Kim *et al.* 2010). During this time ritual bronze drums from the Dong Son culture in northern Vietnam were depicting scenes with war canoes, warriors brandishing spears, bows and arrows and holding captives (Higham 2004; Millar 2012). Early complex polities were forming as part of the manufacturing and trading centres of the Funan and Oc Eo cultures in the Mekong delta, covering areas of southern Vietnam and Cambodia (Stark & Sovath 2001). It is suggested these sites were occupied until the late 7th century AD when organizational changes shifted the power north to where the Kingdom of Angkor was established in northern Cambodia (Stark & Sovath 2001). Inscriptions from Late Iron Age/protohistoric Chenla period (c. 550-800 AD) document that elites from the first ruling Angkorian dynasty conducted military excursions up the Mun River, which Higham (2014c) suggests could possibly have induced the abandonment of many sites in northeast Thailand in the Late Iron Age. This military activity may also account for the most violent trauma observed in that region in the late Iron Age. Stark and Sovath (2001) suggest that control over economic exchange networks likely kick-started the establishment of political centres around the 5th century AD. Southeast Asia was economically linked to India, China, Rome and the Mediterranean markets through a maritime exchange network that also extended up the inland via the Mekong and Red River systems for the exchange of goods (Boyd & Chang 2010; Higham 2014c; Rispoli *et al.* 2013; Stark & Sovath 2001).

Summary

The Iron Age was a period of intense social, technological and environmental change. There is an increased diversity in the type and trajectory of social and economic intensification across the region. There is ample evidence for interpersonal violence escalating into warfare, such as the high rate of cranial trauma in Phum Snay males, and the long swords and military paraphernalia within the mortuary ritual. At a different scale, the woman with violent cranial trauma and the young man with a projectile lodged in his spine indicate the (at least occasional) severity of conflict at Noen U-Loke. Military fortifications and mass production of weapons at the late Iron Age site of Co Loa in northern Vietnam indicate the need for the inhabitants to maintain an offensive and defensive posture at the southern borders of an expanding Han Dynasty China. Historical records also highlight military activity within the Greater Angkor region and in northern Vietnam.

Neolithic to the Iron Age summary

Not only was there an increase in trauma prevalence from the Neolithic (7.8%) to the Bronze Age (11.8%) and to the Iron Age (12.6%), but the pattern of trauma and archaeological evidence suggested that violent conflict also increased through the periods. In the Neolithic craniofacial trauma prevalence was just 0.7%, this increased by approximately two and a half times to 1.9% in the Bronze Age, but this is not a statistically significant difference. The amount of craniofacial trauma in the Iron Age (5.7%) was eight times more than the Neolithic, and almost three times more than the Bronze Age, and the differences are statistically significant. This trauma prevalence will be compared to global samples in the next section. The Neolithic appears to be a period of environmental and social stability with few examples of possible interpersonal violence. There is evidence of long distance exchange networks being extended in the Bronze Age as metallurgy is introduced and copper-based artefacts join shell as exchange items between coastal and inland settlements. There is minimal evidence of social stratigraphy in most regions. It is not until the Iron Age that we see a greater investment of time and resources towards complex defensive fortification, mass production of projectile points and the development of specialist weapons such as long swords. Early chiefdoms are emerging toward the mid Iron Age as a maritime trade network connects Southeast Asia with India and China. The intensity and direction of these sorts of changes varies across mainland Southeast Asia.

Global comparisons of trauma prevalence

It is useful to compare these results to other regions of the world to gain an understanding of how Southeast Asia (SEA) trauma patterns fit into the context of the development of violent encounters and warfare in other parts of the world.

The prevalence of intentional trauma observed in the unprovenanced remains (42%, 8/19) at the comparative early Bronze Age site of Sund (1500 – 1100 BC) in Norway (Fyllingen 2003) was much higher than the Southeast Asia sites. However, the remains at Sund are from within a mass grave where all the individuals are victims of a massacre. The closest comparisons from within the SEA sample comes are Iron Age Phum Snay in Cambodia (26.4%) and Non Ban Jak (25.5%) in northeast Thailand; Bronze Age Ban Chiang (22.4%) in northeast Thailand; and Neolithic Non Nok Tha (26.3%) in northeast Thailand. From this sample, Sund and Phum Snay are the only sites suggested to have specialized warriors and obvious weapons such as swords (Domett *et al.* 2011; Fyllingen 2003) and both may have been involved in military activity and perhaps ritualised violence. The Sund sample contained postcranial fractures, blunt force trauma and sharp force trauma observed to the forearms and hand, vertebrae, femur and pelvis. Injuries appear to have been inflicted by a wooden club, sword, metal blade or axe in hand-to-hand combat (Fyllingen 2003). Interestingly, there was no trauma observed to any of the crania, which would normally be expected in participants of hand-to-hand combat (Scott & Buckley 2014). Earlier reports that the early Bronze Age in this region was a peaceful period are contradicted by the patterning of old and new trauma in the remains at Sund, which Fyllingen (2003) suggests are evidence of a society under constant threat of ritualized violence as chiefdoms compete to gain or maintain power and status. The majority of trauma at Non Ban Jak, Ban Chiang and Non Nok Tha has been attributed to accidents but all these sites also contain cranial and rib trauma that could be the result of interpersonal violence. It does not appear that these three SEA sites suffered the same constant threat of violence as seems to be the case at Sund and Phum Snay.

Hand-to-hand combat and ritualistic duels are also suspected to be the reason for the trauma observed in the prehistoric Atacama Desert population in Chile (250 – 1240 AD). Overall, the trauma prevalence here was 25.0% (16/64) (Lessa & Mendonça de

Souza 2004). Craniofacial trauma, arrow penetration wounds and parry fractures were present but the vast majority of these injuries are found in the later occupation period. Lessa and Mendonça de Souza (2004) link the rise in trauma to social unrest as the Solcor-3 site came under the religious and political influence of the nearby hierarchical Tiwanaku Federation. This external influence may have broken social bonds within the Solcor-2 community, leading to interpersonal violence within the group and between them and the Tiwanaku Federation. There was no archaeological evidence of organized warfare but weapons such as bow and arrows, wooden and metal clubs, sling stones, axes and knuckle-dusters were found at Atacama Desert sites (Lessa & Mendonça de Souza 2004). The trauma prevalence at this site is on par with the above mentioned four SEA sites. The elevated trauma prevalence and mass production of weapons at Phum Snay could be the result of the population coming under the influence of foreign traders and the emerging Oc Eo and Funan polities in the Mekong delta region. Non Ban Jak, Ban Chiang and Non Nok Tha are inland sites that currently show no evidence of weapon production or coming under the same sociopolitical influence of dominant hierarchical societies.

The Jomon period site of Yoshigo in Japan (1400 – 400 BC) had evidence of trauma in 21 individuals from a sample of 166 adults (>20 years of age) (12.7%, 21/166). Almost all the trauma was found in the bones of the hands and feet, whilst two clavicles, two radii and a lumbar vertebrae also displayed healed fractures, but no cranial trauma was observed (Nakai *et al.* 1999). The type of bones observed with trauma is similar to Neolithic sites in Southeast Asia (SEA) in that there are few individuals with long bone and cranial fractures, but fractures to the hand bones are common. However, the Jomon trauma prevalence is higher than most Neolithic SEA sites, which have a trauma prevalence ranging from 0.0% – 7.9%. Only Non Nok Tha (26.3%) has a higher incidence of trauma. Yoshigo had a similar food gathering economy to Neolithic SEA sites, with no rice growing or metal working (Yamaguchi 1982). Nakai *et al.* (1999) suggest that the trauma at Yoshigo reflects a population with a relatively stress-free lifestyle, and they made no mention of interpersonal violence. Non Nok Tha and Man Bac from northern Vietnam are the only Neolithic sites with cranial trauma that could possibly be the result of interpersonal violence.

Jiménez-Brobeil *et al.* (2009) turned to the southeast Iberian Peninsula (5500 BC – 1300 AD) to study adult (> 13 years of age) cranial trauma from samples representing the Neolithic (17.1%, 7/41), Copper Age (5.5%, 6/110) and two Bronze Age samples – Grenada province (11.7%, 7/60) and Agar culture (10.7%, 12/112). They also included a rural sample from Medieval La Torrecilla (9.9%, 32/323). The results show an unexpectedly high prevalence of cranial trauma in the Neolithic which is traditionally deemed a peaceful period in this region (Jiménez-Brobeil *et al.* 2009). It was instead expected that the development of societies in the later periods would cause a rise in social conflict, and this is seen in the Bronze Age and Medieval samples but not the Copper Age sites. Cranial trauma prevalence from Neolithic (0.7%) and Bronze Age (1.9%) SEA is much lower than the Neolithic and Bronze Age groups of the Iberian Peninsula, reflecting that SEA populations did not experience the same level of social conflict. Jiménez-Brobeil *et al.* (2009) conclude that the high rate of Neolithic cranial trauma, especially in the males, when combined with evidence of cannibalism, is evidence of a social environment conducive of short episodes of interpersonal violence. The cranial trauma at the Bronze Age sites was due to their strong hierarchical structure and evidence of weapons and defensive structures. The Iron Age SEA cranial trauma prevalence (5.7%) would be expected to more closely reflect that of Bronze Age Iberian Peninsula samples as the level of social stratigraphy, defensive architecture and evidence of weapons is on par. However, Iron Age SEA cranial trauma is more similar to the Iberian Copper Age sites, which have lower than expected cranial trauma for that region. This discrepancy could be accounted for by the very poor preservation in the small Iberian sample, as the defensive structures in a nearby site reflect that conflict over territory is likely during this time. La Torrecilla was the only site with conclusive evidence of intentional trauma, which was not surprising as civil wars and conflicts with invading groups were frequent in the Medieval period (Jiménez-Brobeil *et al.* 2009).

The early Bronze Age site of Sund has far more trauma than any SEA site, but this is not surprising as the Sund sample consisted of massacre victims. There is no trauma or archaeological evidence to suggest that any SEA settlements were the site of a massacre. The Atacama Desert population shares similar trauma prevalence to Phum Snay, Non Ban Jak, Ban Chiang and Non Nok Tha, however, only Phum Snay appears to have the same degree of socio-political influence from external sources. The cranial trauma observed within the Neolithic, Bronze Age and Medieval sites from the

Mediterranean Iberian Peninsula is also much more prevalent than that experienced in the Neolithic, Bronze Age and Iron Age of SEA. Even the Jomon period site of Yoshigo has more trauma prevalence than the majority of SEA Neolithic sites (except for Non Nok Tha), even though it shares a similar subsistence economy without agriculture or metals.

Future directions

Currently there are large gaps in our ability to fully understand how the prevalence of trauma changes through time in Southeast Asia. The majority of sites that have been excavated, and the skeletal remains examined and reported on by biological anthropologists, are mostly concentrated in Thailand, particularly in the northeast. There is only one site from Myanmar that is known to have individuals with trauma, however this skeletal sample is very poorly preserved and can tell us very little. Very few prehistoric sites from Laos have been excavated, and very little skeletal analysis has been conducted or published. Currently there are no sites from Laos recorded to have trauma. At this stage, few sites from Cambodia and Vietnam have had a full skeletal analysis conducted. Therefore this thesis provides a thorough analysis of the change in trauma prevalence in Thailand, and the associated cultural and environmental changes from the Neolithic to the Iron Age. But it does not necessarily fully represent what is happening throughout mainland Southeast Asia. It is likely that given another five to ten years of excavations there will be enough skeletal material from all regions of Southeast Asia to be able to usefully revisit this topic.

Future excavations of sites around Co Loa and Phum Snay may assist in determining the full extent of the military activity that is evident in both northern Vietnam and Cambodia. Of particular interest is whether the trauma and proliferation of weapons at Phum Snay is connected to evidence of interpersonal violence seen in contemporaneous sites in northeast Thailand. More material evidence is required of any developing relationship between the two regions. In Myanmar excavations have uncovered Pyu culture sites with heavy fortifications, historical records also describe rebellions and the deliberate destruction of cities late in the Iron Age. However there has not been much emphasis placed on observing and recording skeletal trauma. Future research on this subject may be able to determine if the conditions for the development of violent conflict and/or warfare were different to the rest of Southeast Asia.

Turning to the analysis of human remains, the extremely high resolution that can be achieved with a Scanning Electron Microscope (SEM) would enable fracture mechanisms to be far more thoroughly examined than is possible with traditional macroscopic analysis. Some lesions may not be able to be seen with the naked eye so using a SEM would likely allow more trauma to be included in the analysis. It could be used to identify the implement or weapon used to inflict sharp force trauma or blunt force trauma, and this will in turn assist in identifying human behaviour. It would of course, not be financially feasible to examine all the skeletal material by this method, however much useful information could be gained by analyzing even a small amount of the skeletal remains this way.

Conclusion

It was hypothesised that over time there would be an increase in trauma prevalence as risk of injury increased in response to burgeoning population density, increasing socio-political complexity and environmental changes during the transition from the Neolithic to the Iron Age. It was predicted that these increasing pressures would mean greater conflict within and between settlements or regions. This thesis supports the hypothesis in that the results show a significant increase in trauma between the Neolithic and the Iron Age. The pattern of trauma and archaeological evidence suggested that violent conflict also increased as time progressed.

The Neolithic period is consistent with being a peaceful period, expressed by small autonomous groups in a stable environment and no material evidence of warfare. The trauma prevalence between the sexes is similar, albeit females have slightly higher amount of trauma than males, a scenario that reverses over the next two periods. The type and patterning of injuries indicates predominantly accidental mechanisms that would be influenced by lifestyle and occupation. A small degree of interpersonal violence is suggested by several cases of cranial trauma but these could just as easily have an accidental aetiology associated with their daily subsistence activities such as hunting wild animals.

The Bronze Age is interesting in that along with the introduction of the new technology of metallurgy we see an increase in trauma prevalence and evidence of some social stratigraphy. A small sample of individuals from Ban Non Wat in northeast Thailand have substantial mortuary wealth that has been associated with having higher status and alludes to these individuals having control over mineral resources and access to exotic materials (Higham & Rispoli 2014). This rise in status lasted several generations. However, it is not been repeated to the same degree at any other site and, this disparity between individuals' grave wealth does not appear to carry through to the Iron Age. Sampling error may account for the lack of high-status graves in the Iron Age at Ban Non Wat. The control of assets by one group of people could indicate a shift in power that could involve conflict over gaining status and influence.

Perhaps contact made through long distance exchange networks between settlements and regions was not always mutually beneficial and conflict may have arisen during negotiations. Significantly more trauma is observed in males and there is an increase in injuries likely sustained as a result of interpersonal violence, such as craniofacial injuries and parry fractures. This could be an indication that there was now a need to engage in conflict to protect natural and economic resources, perhaps through raids and ambushes. However, there is no evidence of large-scale warfare such as the mass production of weapons, fortification, military paraphernalia and warrior burials that are observed in the Iron Age.

When the archaeological, ethnographic and skeletal evidence was combined it can be seen that there are several 'hot spots' of intense conflict in the Iron Age. Noen U-Loke in northeastern Thailand had several cases of violent trauma suggestive of intense interpersonal conflict. It would appear that the inhabitants of Phum Snay were involved in warfare (Domett *et al.* 2011), and Co Loa was operating as a military establishment (Kim 2013a). Both settlements cached weapons and both projected a military presence by either having warriors equipped for fighting or maintaining massive defensive structures. This would suggest these two settlements were prepared for and involved in major conflict for some period of time. The Mekong delta region experienced periods of military activity late in the Iron Age. This likely influenced the need for warriors and mass weapons production at Phum Snay, and this conflict could have continued into northeast Thailand. Militarization of Co Loa was likely the result of ongoing harassment and control of the region by Han Chinese from the mid Iron Age until a successful rebellion by the people of Vietnam late in the Iron Age (Millar 2012). Yet there is no evidence of skeletal trauma exhibiting the effects of interpersonal violence and warfare in this region. If people were killed in warfare and their bodies were left on the battlefield, we would not see the evidence of this, as currently excavations have been concentrated on the mounded settlements and not the surrounding areas.

External influences from the established state societies of India and China appeared to have had the greatest and most long-lasting impacts on the coastal and Mekong delta settlements. This contact introduced new ways of thinking, manufacture and religion. These ideas eventually spread into the inland sites through the river trade network, but there is currently no evidence that the inland settlements were undergoing militarization as some coastal/Mekong settlements were. Environmental conditions were stable enough from the Neolithic through to the early Iron Age to allow optimal agricultural production with minimal human adaptation of the landscape, and social adaptation could be gradual (Boyd & Chang 2010). But, more intensive management of the landscape was required in the late Iron Age in response to a dry arid climate and increasing population density (Boyd & Chang 2010). These critical social and environmental developments are suggested to be factors that were the driving force behind cycles of peace and increasingly violent conflict in Southeast Asia.

By bringing together the skeletal trauma data from individual published studies with new and unpublished data, this thesis provides an unprecedented temporal and geographical record of the social and external influences that has led to evidence of major conflict and militarization in Southeast Asia prior to the formation of centralised polities such as Angkor in Cambodia and Dvaravati in central Thailand. Patterns of conflict and warfare can now be seen to be emerging in Cambodia, Thailand and Vietnam from at least the mid Iron Age. This pattern does not necessarily follow the same trajectory as samples from other parts of the world. It is evident that focussing future excavations around identified ‘hotspots’, and working to understand the variety of experience in different regions, will ensure that exciting discoveries of Southeast Asia’s social and political development can be expected in the near future.

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Appendices

Appendix A

Non Ban Jak
Burial descriptions of adults with lesions

SFT = Sharp force trauma
BFT = Blunt force trauma
YA = Young adult, MA = Mid aged adult, OA = Old aged adult

*A number of images of Non Ban Jak burials *in-situ* have been published by (Higham 2012a, 2016; Higham *et al*. 2014a) and other images will be included in a future book publication on the archaeology of Non Ban Jak (Higham *et al*.).

BURIAL ID: 2
SEX: Female
AGE: MA
COMPLETENESS/PRESERVATION: Some large skull fragments, part of the mandible & maxillae, most long bones, some foot and hand bones, ribs, scapula, pelvis, and only a few vertebrae. Long bones mostly near complete or incomplete. Most other elements fragmented.
PATHOLOGY: Sharp force trauma (SFT) - Shallow depression on proximal third of right femur, anterior aspect (see Figure A.1 below). Edges of depression are smooth, and the floor of the lesion is uneven. It appears as if the cut direction was proximal to distal, with distal edge flaked off. The distal end is shallower than the proximal end of the lesion. No sign of healing, or infection. Measurements: length 19.63 mm, width 9.81 mm, maximum depth 1.01 mm.
SFT - Shallow depression on distal third of left femur, anteriomedial aspect. Edges are rough, and the floor of the lesion is uneven. It appears like the cut direction is from proximal to distal (distal edge is smooth and shallow, and looks flaked off, whereas the proximal edge is jagged). Another much smaller depression above, midshaft of the femur. Measurements: length 7.98 mm, width 5.49 mm, depth is too shallow to measure.
COMMENTS: Nil.

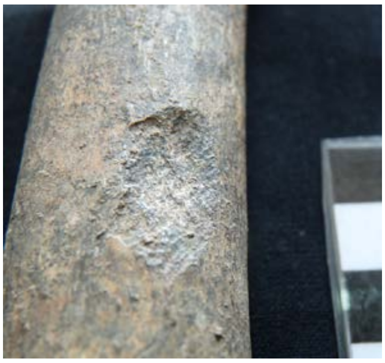

Figure A.1.Possible postmortem damage to proximal third of right femur B2

BURIAL ID: 7
SEX: Female
AGE: OA
COMPLETENESS/PRESERVATION: Foot and hand bones, some long bones that are near complete or fragmented. Most other elements, such as ribs, vertebrae, and clavicle are fragmented. Very little concretion covering the bones.
PATHOLOGY: Depressed fracture on the right frontal, in line with the right supraorbital notch (see Figure 4.15, Chapter 4). The skull has been flattened due to taphonomic processes, the cranium has been fractured postmortem and the facial bones have been skewed to the left in relation to the forehead. The depressed fracture has remodelled, lamellar mature bone is present. No sign of infection. No fracture lines emanating from the depression. Measurements: 16.53 mm (mediolateral) x 12.42 mm (posterioanterior), depth is approximately 0.47 mm. No inward displacement of bone fragments.
COMMENTS: Nil.

BURIAL ID: 21
SEX: Male
AGE: MA
COMPLETENESS/PRESERVATION: No mandible or foot bones, right tibia and fibula are missing, lumbar and thoracic vertebrae missing. Cranium has been squashed by postmortem taphonomic processes. Most elements that are present are near complete or partial. Some bones are covered in concretion.
PATHOLOGY: Transverse fracture of distal third of right ulna (see Figure 4.2, Chapter 4). No displacement or dislocation of joints. No joint involvement, and radius is not affected. No obvious angular deformity but distal third of shaft is possibly slightly displaced posteriorly. Callus present medial/posterior/anterior aspects, with less obvious callus formation to lateral aspect. Measurements: 20.3 mm (inferiosuperior) x 19.5 mm (lateromedial) x 20.0 mm (anterioposterior). Callus begins 39.0 mm up from the tip of the styloid process. Callus is well-remodelled, mature bone. No evidence of infection. No other injuries observed.
COMMENTS: Right ulna broken into four pieces - postmortem damage. The left ulna is not complete so no comparison in length could be made. Spinous process on C2 abnormal (congenital?).

BURIAL ID: 36
SEX: Indeterminate
AGE: Adult
COMPLETENESS/PRESERVATION: Incomplete. Heavily disturbed burial with elements found interred at different levels. Most of right forearm, and shaft of brachium, only a small piece of the left ulna, some foot bones and a few pieces of vertebrae.
PATHOLOGY: SFT - Shallow lesion on proximal third of right humerus, anteriolateral aspect. Oval in shape that is longer superioinferiorly (9.82 mm) than mediolaterally (7.38 mm). Depth is approximately 2.4 mm. No sign of healing, infection or fracture. Unknown if perimortem or postmortem trauma. Excavation damage?
COMMENTS: Nil

BURIAL ID: 38
SEX: Female
AGE: MA
COMPLETENESS/PRESERVATION: Skeleton near complete. Field notes: upper body was disturbed. Skull in very poor state, squashed and fragmented post-mortem. Foot and hand bones in good condition.
PATHOLOGY: SFT – Two small parallel and linear cut marks on proximal third of left tibia, posteriolateral aspect. Measurement: superior cut- length 5.27 mm and width 1.55 mm Inferior cut- length 6.27 mm and width 1.55 mm. Both approximately 0.9 mm deep, with a 1.53 mm distance between the superior and inferior cut. Positioned at the top of the interosseous crest on the neck of the tibia, the cuts are slightly angled downwards (superiolateral to inferioposterior). No signs of healing. Unknown if perimortem or postmortem. Proximal and distal epiphyses missing.
COMMENTS: Nil

BURIAL ID: 40
SEX: Indeterminate
AGE: Adult
COMPLETENESS/PRESERVATION: Incomplete. Few long bones and epiphyses partially missing, ribs and foot bones. Elements generally in good condition but incomplete and broken.
PATHOLOGY: Enlarged radial fossa (deeper and wider than usual) on right distal epiphysis of humerus, due to anterior dislocation of radial head (see figure 4.1, Chapter 4). The right radius is not present so cannot ascertain if it was a Monteggia fracture. Measurements: radial fossa width (mediolateral) 16.14 mm, height (inferiosuperior) 6.6 mm. Lateral supracondylar crest appears wider and thicker and more robust than usual (however, some of the distal epiphysis is missing on the left humerus so comparisons cannot be made). The medial supracondylar crest is not affected. On the right humerus the muscle attachments are more robust than the left humerus, in the distal third and mid shaft of the diaphysis. There is no difference in length between the right and left

humerii. This individual probably received the injury at a young age as the radial fossa is quite pathological.
COMMENTS: Olecranon fossa perforated (septal aperture).

BURIAL ID: 43
SEX: Female
AGE: YA
COMPLETENESS/PRESERVATION: Incomplete. Most long bones present, but some broken postmortem from taphanomic processes. Cranium and mandible broken and flattened, held together by dirt. Some foot and hand bones, vertebrae, ribs, clavicles and scapulae. Majority of bones are near complete or partial, others are fragmented. Some concretion on most elements, especially the vertebrae.
PATHOLOGY: Fractured rib, posterior aspect, possibly 7th and 8th. Rib 8(?) has a transverse fracture with non-union (near the angle), signs of healing with immature bone growth still remodelling (see Figure 4.10, Chapter 4). This rib has been ossified to what is possibly the 7th rib. Lytic lesions were also observed on thoracic vertebrae T6 & T10, which suggests the likelihood that the fracture is secondary to the pathology. Possibly rib fragment is ossified to the 8th rib.
SFT- Linear, v-shaped cut to anterior of capitulum on distal epiphysis of right humerus. Measurements: length (superiomedial/inferiolateral) 12.07 mm, width 1.70 mm, depth approximately 1.31 mm. No healing, unknown if trauma is perimortem or postmortem. Right radius and ulna are not present. When the right humerus was compared with the left there was no evidence of shortening.
SFT – Linear, v-shaped cut to superioanterior of trochlea. Edges appear crushed and adhering to the bone. Measurements; length 9.94 mm, width 1.85 mm, depth approximately 0.85 mm. No healing, unknown if trauma is perimortem or postmortem.
COMMENTS: Unknown if the ribs fractured because the bone was weakened by the pathology evident on the thoracic vertebrae, or if the pathology occurred secondary to the trauma.

BURIAL ID: 49
SEX: Male
AGE: YA
COMPLETENESS/PRESERVATION: Bones in very good condition, near complete skeleton. Skull complete and in relatively good condition.
PATHOLOGY: SFT – possible linear V-shaped cut on shaft of a left rib fragment. Cut is on the superioanterior aspect. No sign of healing. Not included in the trauma analysis as it is possible that this is postmortem damage.
SFT (?) – Postmortem. 2 x circular holes on body of upper thoracic vertebra (see Figure A.2 below, showing single hole). Unknown if penetrating trauma, taphonomic, or bite marks.
SFT (?) – Postmortem. 2 x piercing circular holes on left iliac crest (see Figure A.3 below), anteriolateral aspect and 1 x piercing circular hole on left iliac crest,

posteriolateral aspect. Penetrating trauma? Or taphonomic processes? Could be tooth bite marks from a carnivore?
COMMENTS: Nil

Figure A.2. Thoracic vertebra B49 with possible taphanomic process

Figure A.3. Left iliac crest B49 with possible taphanomic process

BURIAL ID: 61A
SEX: Female
AGE: YA
COMPLETENESS/PRESERVATION: Fragmented. Only mandible and right os coxae, incomplete.
PATHOLOGY: SFT – Small linear cut to superiolateral aspect of iliac crest. Measurements: length 7.70 mm (superioinferior), width 1.61 mm (anterioposterior), depth approximately 2.85 mm. No signs of healing so unknown if perimortem or postmortem.
COMMENTS: Nil

BURIAL ID: 62
SEX: Male
AGE: MA
COMPLETENESS/PRESERVATION: Near complete skeleton.
PATHOLOGY: Oblique fracture distolaterally on the proximal phalanx of the second metatarsal on the left foot (Figure 4.7, Chapter 4). There is a slight plantar angulation of the distal epiphysis and a callus of immature woven bone had formed over the fracture. The callus also appears to have incorporated the articulating middle phalanx so that the distal interphalangeal joint is now ankylosed.
COMMENTS: Nil

BURIAL ID: 64
SEX: Female
AGE: OA
COMPLETENESS/PRESERVATION: All lumbar vertebrae, sacrum fragments, left femur, tibiae, fibulae, left humerus, right os coxae (fragmented), some hand bones, left and right foot bones. Some of the long bones and foot bones are complete. All the other elements present are near complete, partial or fragmented.
PATHOLOGY: Complete fracture to shaft of left rib fragment (10th or 11th rib). Non-union of fracture ends. The appearance of new woven bone in the rib interior suggests the bone was actively remodeling at the time of the individual's death (Figure 4.11, Chapter 4).
COMMENTS: Spondylolysis was noted in the 4th lumbar vertebra (and sacrum) by K. Domett, and this could also be the result of trauma. Bone pathology is also present in this individual, with a reactive pathological lesion on S1 and L5 vertebrae, and possibly on right MT3. It is possible therefore that the spondylolysis and rib fracture have resulted from bone weakening due to possible infection.

BURIAL ID: 65
SEX: Female
AGE: Adult
COMPLETENESS/PRESERVATION: Heavily disturbed burial from the knees up. Some foot bones, right femur, left and right tibiae and fibulae, partial right humerus, partial left ulna and radius, and hand bones. Fragments of cranium, ribs and scapulae.
PATHOLOGY: SFT **–** proximal third of right femur (lateral aspect), just below the neck of the great trochanter is a cut with no sign of healing. Oval in shape. No measurements taken. From the position of the cut mark it would seem likely that this occurred postmortem, after disarticulation (?).
SFT (?) **–** Possible piercing cut through parietal fragment. Smooth edges, but looks odd. No sign of healing. Most likely postmortem damage.
COMMENTS: Excavation photos show several iron implements are positioned up against the proximal epiphysis of the right humerus. Humerus had been disturbed, likely after burial and was displaced laterally. Because the burial was heavily disturbed, this may not be the original position of the iron implements. Is it possible that the humerus was cut/pierced by this unidentified implement? The photographs and field notes are inconclusive. The epiphysis is too damaged to identify if there is a cut or piercing trauma.

BURIAL ID: 68
SEX: Indeterminate
AGE: YA
COMPLETENESS/PRESERVATION: Skull distorted postmortem by taphonomic processes, mandible complete. Long bones fragmented, vertebrae very fragmented, hand and foot bones mostly complete.

PATHOLOGY: SFT – proximal third of right femur has a small and shallow V-shaped cut on anterior aspect. Measurements: length 8.30 mm (lateromedial), width 1.32 mm (superiointerior), depth approximately 0.44 mm. Inferior edge has shallow flake of bone removed (2.51 mm wide). No sign of healing. Not included in trauma analysis as possibly postmortem.
COMMENTS: Nil

BURIAL ID: 75
SEX: Female
AGE: OA
COMPLETENESS/PRESERVATION: Skull mostly intact, all long bones present – near complete or incomplete/fragmented. Some foot and hand bones, ribs and clavicles.
PATHOLOGY: 2 x fractures of the right radius, both healed. One is a transverse fracture to the distal third of the radius, a possible Colles' fracture (Figure 4.3A, Chapter 4), it has a mostly well-remodeled callus just proximal to the distal epiphysis but there was still immature active bone remodeling the posterior side of the callus at the time of death. The other complete fracture is further proximal (Figure 4.3 B). This injury appears to be an older lesion as the mature bone of the well-remodeled callus has a smooth surface and no angulation or displacement is evident. There is some postmortem damage to this region but the healed callus is still evident.
COMMENTS: Right humerus has too much postmortem damage, especially to the epiphyses to determine if the capitulum or humeral head were affected by trauma.

BURIAL ID: 76
SEX: Female
AGE: OA
COMPLETENESS/PRESERVATION: Skull almost entire but lots of concretion covering the surface. Most long bones present but broken, near complete or incomplete. Some vertebrae but very fragmented and covered in concretion. Some fragments of ribs, scapulae and clavicle. Most hand and foot bones are in a good condition.
PATHOLOGY: Colles' fracture to the distal shaft of the left radius (Figure 4.4, Chapter 4). Epiphysis is posteriorly displaced. The fracture site is well-remodeled, with the callus more prominent posteriolaterally. There is some lipping on the distal articular surface perhaps indicative of degenerative changes associated with the change in joint alignment postfracture. The right distal epiphysis is not present so cannot compare length to see if the left radius was affected by shortening due to the trauma. No sign of infection. Left ulna does not appear to be affected by trauma, however, the distal epiphysis is not present. Left humerus not affected.
COMMENTS: Nil

BURIAL ID: 77
SEX: Male
AGE: OA
COMPLETENESS/PRESERVATION: Very good condition of long bones which are near complete. Skeleton mostly complete but fragmented. Vertebrae, ribs, clavicles and scapulae in good condition – near complete or partial.
PATHOLOGY: SFT – V-shaped cut on spine of left scapula, posterior aspect. Measurements: length 6.04 mm, width (mediolateral) 0.98 mm, maximum depth 1.57 mm. Bone crushed from impact and bone fragments still adhering to scapula. No sign of healing. Could be postmortem damage.
SFT - 2 x linear cuts on subscapular fossa, near the lateral border. Colouration of edges suggests these occurred postmortem.

BURIAL ID: 82
SEX: Male
AGE: OA
COMPLETENESS/PRESERVATION: Skull fragmented, held together by dirt. Mandible intact. Mostly entire skeleton, in good condition. Long bones are near complete.
PATHOLOGY: Malaligned complete fracture observed on a rib fragment from the left-hand side of the body (Figure 4.12, Chapter 4). It cannot be ascertained which rib this is, or the exact location on the shaft that the fracture occurred. The bone has completely remodeled and the likelihood is that this individual lived with this injury for some time before their death.
SFT (?) – Possible cut on the posteriomedial aspect of the right iliac crest. Measurements: length 10.51 mm, width 2.64 mm, depth 1.58 mm. V-shaped cut but some postmortem damage around surface of trauma so difficult to define as a definite cut. No sign of healing. Also, a depression inferior to the 'cut' is unusual, but probably just a musculature impression.
COMMENTS: Robust bones, short statured individual.

BURIAL ID: 84
SEX: Female
AGE: MA
COMPLETENESS/PRESERVATION: Mostly complete skeleton, but excavation photos show individual was not buried with skull. Most long bones are complete.
PATHOLOGY: Possible fracture to shaft of left middle rib? Appears to be some remodelled bone on the anterior surface, and a slight depression on the posterior surface. Just normal variation in bone? (Radiograph does not show signs of a fracture so this was not included in the trauma analysis).
COMMENTS: Robust muscle attachments. Osteoblastic pathology on right fibula. Eburnation on left MC1 distal epiphysis. Right navicular looks 'squashed' compared to the left navicular, it appears that it could be linked to some sort of muscle/tendon injury, a dislocation perhaps.

BURIAL ID: 89a
SEX: Male
AGE: Adult
COMPLETENESS/PRESERVATION: Disturbed burial, legs lower than upper body, some confusion with bones –whether they are from B89d and cranium from B89c? There was also an infant, B89b (just a tibia and a few fragments). Left tibia, right fibula, a few ribs and vertebrae, left clavicle, right radius, most foot bones and some hand bones. The long bones and feet are near complete, some complete. All other elements incomplete or fragmented.
PATHOLOGY: SFT – Long, deep, oblique cut on the proximal epiphysis of the left tibia, medial aspect. Measurements: length 20.78 mm, width 1.95 mm, depth approximately 1.34 mm. Straight-edges and very prominent cut. There is a second, very shallow oblique cut (barely marking the surface, but still obvious as a cut) on the proximal third of the shaft, lateral aspect. Measurements: length 11.13 mm, interrupted by a shallow depression, then continues a further 3.11 mm, width 0.65 mm, too shallow to accurately measure the depth. Neither cut shows signs of healing.
SFT – Oblique cut on midshaft of right rib, posterioinferior aspect. Cut does not go all the way through to the anterior side. Measurements: length 4.88 mm, width 0.69 mm, depth approximately 0.44 mm. No signs of healing.
SFT - Small oblique cut on midshaft of right rib, posterioinferior aspect. V-shaped, no sign of healing. Measurements: length 3.95 mm, width 0.46 mm. Depth cannot be measured due to the position of the cut.
SFT – Possible deep cut to proximal end (heel) of left calcaneous, medioplantar aspect. Measurements: length 9.84 mm, width 1.68 mm, depth approximately 1.45 mm. Cut goes through the cortical bone to the trabecular bone. No sign of healing. These cuts could be postmortem and have not been included in the trauma analysis.
COMMENTS: B89a has robust bones, but without overly prominent muscle attachments.

BURIAL ID: 89c
SEX: Indeterminate
AGE: Adult
COMPLETENESS/PRESERVATION: Cranium only for this burial. Complete and in good condition.
PATHOLOGY: Various shallow cuts on the cranium. One on the occipital, right side, superiolateral aspect. Also, a flake of bone was removed from superioinferior edge of occipital bone. The rest of the cuts are on the right parietal, posterior aspect. Several flakes of bone have been removed from this area. No signs of healing. It is possible that these cuts postmortem, therefore they have not been included in the trauma analysis.
COMMENTS: Nil.

BURIAL ID: 96
SEX: Male?
AGE: MA
COMPLETENESS/PRESERVATION: Cranium intact but the mandible cannot be found with the rest of the skeleton, even though excavation photos show it was present in the burial. Left and right tibiae and fibulae, foot bones are near complete or complete. Left humerus, scapulae, clavicles, some ribs and vertebrae, right hand bones and only a few left hand bones are present – most of these elements are near complete, partial or fragmented.
PATHOLOGY: Healed blunt force trauma fracture to the maxillae which affects the left and right frontal processes and nasal bones (Figure 4.16, Chapter 4). The right nasal and medial side of the left nasal appear depressed, while the lateral side of the left nasal and medial side of the left frontal process appear to bulge outward. This makes it appear as if the individual has been hit on a downward oblique angle from superiolaterally to inferiomedially. This individual may have sustained a permanent facial deformity as a result of the fracture.
SFT – Trauma on 1st lumbar vertebra could either be a possible burst fracture (further analysis required to confirm this) or it is possibly a cut to the superioanterior aspect of the centra (see Figure A.4 below). Measurements: length 13.04 mm (posteriomedial/anteriolateral), maximum width is 3.61 mm and the depth is approximately 2.15 mm. No sign of healing, could be postmortem.
SFT – 4 x cut marks on the distal epiphysis of the left humerus (see Figure A.5 below), anterior aspect. Cut 1 is on the medial side of the trochlea, it is the longest and deepest of the cuts (superioinferior), length 6.38 mm, width 1.55 mm and depth 0.72 mm. Cut 2 is V-shaped, with crushing on the edges. It is on an oblique angle (superiolateral-inferiomedial), length 6.10 mm, width 1.40 mm and depth 0.45 mm. Cuts 3 and 4 are on the capitulum, both are on an oblique angle (superiolateral-inferiomedial), length 5.94 mm and 5.73 mm, width 1.39mm and 0.87 mm, depth 0.45 and 0.26 respectively. There is no sign of healing on any of the cuts. Likely postmortem cuts, possibly perimortem, due to their position on the articular surface of the humerus. Left ulna and radius are missing so cannot compare to see if they were cut also. None of these lesions are included in the trauma analysis.
COMMENTS: Nil

Figure A.4.1st lumbar vertebra B96 with unidentified trauma or taphanomic process

Figure A.5. Distal epiphysis left humerus *B96 with possible SFT or postmortem damage (circled)*

BURIAL ID: 98
SEX: Indeterminate
AGE: Adult
COMPLETENESS/PRESERVATION: Heavily disturbed burial, only a few elements in articulation. Bones are in very good condition. Mostly upper body and a few foot bones, sacrum, left os coxae but no skull.
PATHOLOGY: Well-remodeled fracture of a right, possible upper rib, on the lateral aspect. The callus is of mature lamellar bone (Figures 4.13 & 4.14, Chapter 4).
SFT – Possible oblique cut, (4 cm superior to the inferior angle, medial edge) on the left scapula, anteriolateral aspect but does not go all the way through to the posterior side. Bone is depressed inwards on the sides of the cut. This bone is very fragile and it is likely that this is postmortem even although the colouration, and adhering flakes of bone suggest it could be perimortem. No sign of healing. Measurements: length 6.35 mm, width 0.23 mm.
SFT – Small v-shaped cut through lateral edge of left os coxae, below the iliac crest. No sign of healing. Measurements: length 3.23 mm, width 2.26 mm and depth is approximately 1.37 mm.
SFT – Small, shallow and thin oblique v-shaped cut to distal epiphysis of right humerus, anteriolateral aspect on capitulum. No sign of healing. Measurements: length 4.40 mm, width 0.71 mm and depth 0.27 mm. These cuts have not been included in the trauma analysis as they could be postmortem.
COMMENTS: Nil

BURIAL ID: 102
SEX: Indeterminate
AGE: YA
COMPLETENESS/PRESERVATION: Bones in good condition, sacrum, some long bones - a clavicle, humerii and ulnae. Most vertebrae, hand bones and some ribs. Most elements fragmentary, some near complete or incomplete.
PATHOLOGY: SFT – Cut marks on lower rib fragment (not possible to side rib). There are six cuts on the anterior surface, two cuts on the posterior surface. Varying lengths and widths. Maximum length 7.63 mm, maximum width 1.27 mm, maximum depth 0.37 mm. Cuts are oblique, not perpendicular to the rib shaft's superior edge. No sign of healing. Possibly postmortem.
SFT – Cut marks on distal third of left tibia, anterior aspect. The deepest and longest cut is oblique (proximomedial/distolateral). Measurements: length 13.52 mm, width 1.81 mm, depth 0.39 mm. The other three cuts are horizontal, varying in length. Maximum length 10.69 mm, maximum width 0.68 mm, maximum depth 0.19 mm. No sign of healing. Possibly postmortem. These cuts were not included in the trauma analysis.
COMMENTS: Nil

BURIAL ID: 105
SEX: Female
AGE: Adult
COMPLETENESS/PRESERVATION: Good condition. Most long bones near complete or fragmented. Most ribs, vertebrae, foot and hand bones, scapulae, clavicles and mandible are present and near complete or fragmented.
PATHOLOGY: SFT - The diaphysis of the right femur has a series of cut marks of varying widths, lengths, depths and directions (see Figure A.6 below). Also some flakes of bone have been removed. Some cuts are on the anteriolateral aspect, but most are medial and on the proximal third and midshaft of the diaphysis. Due to the position of the cuts on the inside of the thigh, they are perhaps not perimortem, more likely to be postmortem after disarticulation (??). No sign of healing. Not included in the trauma analysis.
COMMENTS: Nil

Figure A.6. Right femur B105 with possible postmortem damage

BURIAL ID: 108
SEX: Male
AGE: MA
COMPLETENESS/PRESERVATION: Skeleton in very good condition and mostly complete (missing left ribs). Most elements complete, near complete, some fragmentary. Skull intact.
PATHOLOGY: SFT – Oblique v-shape cut (superiomedial-inferiolateral) to the right brow ridge, medial to the supraorbital notch. Measurements: length 6.44 mm, width – cut is very slightly narrower at inferior end 1.64mm and 1.88 mm superior end, depth 1.64 mm. No sign of healing.
SFT – Oblique cut to distal third of right femur, lateral aspect. The superior edge has several small flakes removed. Measurements: length (superiomedial-inferiolateral) 13.20 mm, width of cut 1.44 mm, maximum width 4.0 mm, and maximum depth is 1.94 mm. No sign of healing. Cuts are possibly postmortem. Not included in the trauma analysis.
COMMENTS: Robust skeleton. Halley Buckley noted that the left humerus is 12 mm shorter than the right, and the humeral head is smaller. Otherwise the bone looks normal.

BURIAL ID: 110
SEX: Male
AGE: MA
COMPLETENESS/PRESERVATION: Long bones near complete. Most elements are present, in good condition, except the fragile bones i.e. scapula and vertebrae are fragmented.
PATHOLOGY: SFT – Small chunk of bone removed on the left scapula, on shoulder of glenoid fossa, medial, next to the nutrient foramen. Measurements: length (mediolateral) 7.76 mm, width (anterioposterior) 5.73 mm, and depth 2.53 mm. No sign of healing. Looks like the chunk of bone removed is from a series of small cuts.
COMMENTS: Very strong, robust bones.

BURIAL ID: 111
SEX: Indeterminate
AGE: YA
COMPLETENESS/PRESERVATION: Heavily disturbed burial. Almost all long bones are present, near complete but one or both epiphyses missing. Some ribs, fragments of vertebrae, clavicles, scapulae, pelves, sacrum, some hand and foot bones. No skull but some loose teeth.
PATHOLOGY: SFT – Goughing/scrape marks likely post-mortem damage, possibly from Iron Age disturbance of burial. Colouration suggests it was not recent (excavation) damage. Six bone elements show these marks – on distal third of both ulnae (lateral and medial aspects), both tibia (anterior aspect), distal third of right femur (medial aspect), and on a hand phalanx (see photo below). No sign of healing. Marks vary between

shallow ‘scrape’ marks to ‘gouging’ indentations, almost like lots of percussion points in the one spot.
COMMENTS: Nil

Figure A.7. Hand phalanx B111 with possible postmortem damage

BURIAL ID: 112
SEX: Indeterminate
AGE: YA
COMPLETENESS/PRESERVATION: Fieldnotes: Skull damaged by jop (metal hoe). Most of the skeleton is present, long bones and foot bones near complete, other elements fragmented.
PATHOLOGY: SFT – Chop marks on proximal third of left tibia, posteriolateral aspect. Numerous small chop marks have gouged a deep incision throught the inferior end of the soleal line. Measurements: length (mediolateral) 7.52 mm, width (superioinferior) 3.69 mm, maximum depth 0.40 mm. No sign of healing. Colouration suggest this is not new damage from excavation, and the repetitive chop marks over the one area suggest this is not from an excavators trowel or jop. Not included in the trauma analysis as these chop marks could be post-mortem.
COMMENTS: Nil

BURIAL ID: 116
SEX: Indeterminate
AGE: Adult
COMPLETENESS/PRESERVATION: Very disturbed burial, almost entire upper body destroyed when a historic pit was dug. Lower limbs, feet and left ulna only, near complete.
PATHOLOGY: SFT – Cuts on shaft of hand phalanx, palmer/medial aspect. It looks like most cuts are recent excavation damage, however two of the cuts are more difficult to tell due to the light colouration of the bone around the cuts. Due to this burial being disturbed by the digging of a pit, it is highly likely these cuts were all produced well after death. Not included in trauma analysis.
COMMENTS: Nil

BURIAL ID: 120
SEX: Male
AGE: YA
COMPLETENESS/PRESERVATION: Almost entire postcranial skeleton present and in good condition. Skull complete and in good condition but ‘squashed’ due to taphonomic processes.
PATHOLOGY: SFT – The midshaft of the right femur has one linear cut and three chop marks on the anteriolateral aspect. Measurements: linear cut length 4.3 mm, width 0.70 mm, depth approximately 0.60 mm. Chop marks 1) 4.39 x 4.61 mm, depth approximately 0.75 mm; 2) 3.62 x 2.14 mm; 3) 15.19 x 8.83 mm, depth approximately 0.85 mm. Colouration suggests that these are not recent damage. No sign of healing. Possibly post-mortem. Not included in trauma analysis.
COMMENTS: Robust bones and muscle attachments.

BURIAL ID: 125
SEX: Female
AGE: YA
COMPLETENESS/PRESERVATION: Almost entire skeleton, mostly in good condition. Skull intact but broken into pieces. Sacrum and vertebrae very fragmented.
PATHOLOGY: SFT – Slightly oblique v-shape cut on the left talus, laterodistal (toward the toes). Measurements: 7.83 mm, width 1.15 mm, depth 3.78 mm. Some erosion of the bone may make the cut appear deeper than it was originally. Position of the cut suggests the only was it occurred whilst bones were articulated was if the trauma was from a piercing wound from the dorsal surface downwards. Otherwise the other bones in articulation would prevent a slicing/cutting action from another direction. No sign of healing.
SFT (?) – Oval depression on the distal third of the left fibula, just superior to the epiphysis, anterior aspect. Shows signs of healing, immature bone is evident in the depression. The length and thickness of the left fibula is the same as the right.
COMMENTS: Bones gracile. Some pathological activity evident on the left and right clavicles. Both the left and right clavicle medial heads are misshaped compared to ‘normal’ clavicles, they are more teardrop shape than rounded, so that the inferiosuperior axis is elongated. This makes the alignment of the shaft and lateral end look twisted. No osteolytic activity in other bones. These lesions were not included in the trauma analysis.

BURIAL ID: 133
SEX: Female
AGE: MA
COMPLETENESS/PRESERVATION: Mostly entire skeleton in very good condition. Most long bones are complete. The cranium is in fragments, but the mandible is intact.
PATHOLOGY: Colles’ fracture of the right radius, posterior displacement of the distal segment (Figure 4.5, Chapter 4). A well-remodeled callus is most evident on the lateral aspect.

Transverse fracture of the mid-shaft, left clavicle (Figure 4.6, Chapter 4). The callus is well-remodeled with a recent postmortem break through it. There are signs of osteolytic activity, particularly on the inferior surface, and this suggests infection. However it is not possible to determine if the infection was the mechanism for the fracture or if the infection was secondary to the fracture. No other bones in this individual show signs of infection. There is an obvious shortening of the left clavicle, thickening of the circumference and a pronounced curve to the lateral end.
SFT – Both tibia have small oblique cuts, anterior aspect of the tibial tuberosity. The cut on the right tibia is more oblique, shorter and thinner. Measurements: length 7.74 mm, width 0.86 mm, and depth 1.17 mm. The cut on the left tibia is deeper, with some postmortem erosion of bone. No evidence of healing to either cut. The SFT has not been included in the trauma analysis as it is possible that it is postmortem.
COMMENTS: The distal third of the left femur looks 'twisted' medially. This gives a knock-kneed appearance. The tibiae and pelvis appear unaffected. Only the proximal third of the right femur is present so cannot confirm if the aversion is also on that side. No sign of infection in any of the bones.

BURIAL ID: 134
SEX: Male
AGE: OA
COMPLETENESS/PRESERVATION: Mostly entire skeleton in very good condition. Most long bones are intact. Skull intact but fragmented and held together by dirt.
PATHOLOGY:
SFT – Penetrating injury and several cuts in different directions on proximal third of left humerus, anterior aspect. No sign of healing. Measurement of penetrating injury: length 21.32 mm, maximum width 5.46 mm. V-shaped cuts vary in size. Maximum length 12.64, maximum width 1.91 mm and maximum depth 0.59 mm. Possibly postmortem.
Possible burst/crush fracture (?) to centra of 11th thoracic vertebrae (see photo below). There is a deep curved lesion from perhaps an 'incision' or crushing injury to the superior surface of the centra. No evidence of healing. These lesions are not included in the trauma analysis.
COMMENTS: Robust bones and muscle attachments. Looks like a short-statured individual.

Figure A.8. T11 B134 unidentified trauma or taphanomic process

BURIAL ID: 140

SEX: Indeterminate

AGE: Adult

COMPLETENESS/PRESERVATION: There are only a few elements present – foot bones, right fibula and patella, fragments of the 1st cervical vertebra and a rib.

PATHOLOGY: There is a remodeled fracture to the distal diaphysis of a right proximal toe phalanx. The oblique fracture line is still visible (Figure 4.8, Chapter 4). This individual also has a fracture to a possible lower left rib which has a well-remodeled callus of smooth bone. The callus is located anteriorly (Figure 4.9, Chapter 4).

COMMENTS: Nil

Appendix B

Table B.1. Individual prevalence of trauma (all types) by sex and adult (all sites)

Site	Region	Male n/N	%	Female n/N	%	Unsexed n/N	%	Adults n/N	%
[a]Ywa Htin	M	0/*	*	0/1*	*	2/58	3.4	2/59	3.4
[b]Khok Phanom Di	SET	2/32	6.3	3/36	8.3	0/0	0.0	5/68	7.4
[b]Nong Nor	SET	2/44	4.5	1/49	2.0	2/29	6.9	5/122	4.1
[c]Ban Chiang	NET	13/51	25.5	5/47	10.6	0/4	0.0	18/102	17.6
[d]Ban Non Wat	NET	22/178	12.4	20/181	11.0	3/110	2.7	45/469	9.6
[b]Ban Lum Khao	NET	6/28	21.4	3/31	9.7	0/0	0.0	9/59	15.3
[c]Non Nok Tha	NET	9/60	15.0	7/67	10.4	0/4	0.0	16/131	12.2
[b]Ban Na Di	NET	2/25	8.0	0/20	0.0	0/5	0.0	2/50	4.0
[e]Noen U-Loke	NET	1/21	4.8	2/27	7.4	1/19	5.3	4/67	6.0
[f]Non Ban Jak	NET	5/18	27.8	6/23	26.1	3/14	21.4	14/55	25.5
[g]Ban Mai Chaimongkol	CT	1/11	9.1	0/11	0.0	0/8	0.0	1/30	3.3
[h]Phromthin Tai	CT	2/9	22.2	1/6	16.7	0/5	0.0	3/20	15.0
[g]Ban Pong Manao	CT	1/21	4.8	0/13	0.0	0/12	0.0	1/46	2.2
[i]Phum Snay	NWC	20/63	31.7	12/65	18.5	7/20	35.0	39/148	26.4
[j]Vat Komnou	SC	8/51	15.7	3/26	11.5	0/3	0.0	11/80	13.8
[k]Con Co Ngua	NV	2/43	4.7	2/31	6.5	0/15	0.0	4/89	4.5
[l]Man Bac	NV	3/18	16.7	0/15	0.0	0/5	0.0	3/38	7.9
[m]Gò Ô Chùa	SV	3/23	13.0	3/20	15.0	0/2	0.0	6/45	13.3
All sites		**102/696**	**14.7**	**68/669**	**10.2**	**18/313**	**5.8**	**188/1678**	**11.2**

(n/N) n = number of individuals affected by trauma, N = number of observed individuals.

% = trauma prevalence. *Poor bone preservation limited sex estimation to only one individual.

Region: M= Myanmar, SET= southeast Thailand, NET= northeast Thailand, CT= central Thailand, NWC= northwest Cambodia, SC= southern Cambodia, NV= northern Vietnam, SV= southern Vietnam

Reference:[a]Pautreau (2007), [b]Domett & Tayles (2006), [c]Douglas (1996), [d]Domett & Tayles (unpublished), [e]Tayles *et al*. (2007), [f]Present study, [g]Liu (2012), [h]T. Case (pers. comm.), [i]Domett *et al*. (2011) and Domett & O'Reilly (2009), [j]Ikehara-Quebral (2010), [k]Oxenham (2000), [l] Domett & Oxenham (2011) and Huffer & Hiep (2011) and Oxenham (pers. comm.),[m]Francken (2012).

Table B.2. Adult long bone fracture prevalence (% by bone element): for all sites

Site	Region	Time Period	Clavicle %		Humerus %		Radius %		Ulna %		Femur %		Tibia %		Fibula %		Total %	
Ywa Htin	M	IA	0/*	0.0	2/*	*	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	2/*	*
Khok Phanom Di	SET	Neo	2/106	1.9	0/104	0.0	0/102	0.0	0/74	0.0	0/85	0.0	0/90	0.0	0/48	0.0	2/609	0.3
Nong Nor	SET	BA	1/18	5.6	0/19	0.0	0/13	0.0	2/9	22.2	0/17	0.0	0/13	0.0	0/0	0.0	3/89	3.4
Ban Chiang	NET	Neo-LIA	0/57#	0.0	2/69#	2.9	2/70	2.9	0/76	0.0	1/86	1.2	0/76#	0.0	0/66#	0.0	5/500#	1.0#
Ban Non Wat	NET	Neo-LIA	5/523	1.0	1/460	0.2	9/461	2.0	5/459	1.1	1/493	0.2	1/483	0.2	1/461	0.2	23/3340	0.7
Ban Lum Khao	NET	BA	1/39	2.6	0/37	0.0	3/48	6.3	4/40	10.0	0/37	0.0	0/34	0.0	1/29	3.4	9/264	3.4
Non Nok Tha	NET	Neo-BA	4/74	5.4	1/98	1.0	1/80	1.3	0/75	0.0	0/118	0.0	2/98	2.0	1/85	1.2	9/628	1.4
Ban Na Di	NET	LBA	0/15	0.0	0/15	0.0	0/18	0.0	0/10	0.0	1/13	7.7	0/11	0.0	0/4	0.0	1/86	1.2
Noen U-Loke	NET	IA	0/44	0.0	0/59	0.0	0/45	0.0	0/45	0.0	0/66	0.0	0/64	0.0	0/48	0.0	0/371	0.0
Non Ban Jak	NET	LIA	1/69	1.4	0/77	0.0	[2]4/57	7.0	1/60	1.7	0/65	0.0	0/66	0.0	0/62	0.0	6/456	1.3
Ban Mai Chaimongkol	CT	BA-IA	1/*	*	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	1/*	*
Phromthin Tai	CT	IA	1/*	*	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	0/*	0.0	1/*	*
Ban Pong Manao	CT	LIA	0/*	0.0	0/*	0.0	0/*	0.0	1/*	*	0/*	0.0	0/*	0.0	0/*	0.0	1/*	*
Phum Snay[3]	NWC	LIA	3/52	5.8	0/70	0.0	2/24	8.3	0/26	0.0	0/76	0.0	0/60	0.0	0/21	0.0	5/329	1.5
Vat Komnou	SC	LIA	0/6	0.0	0/9	0.0	0/10	0.0	1/29[4]	3.4	0/2	0.0	0/8	0.0	1/31[4]	3.2	2/95	2.1
Con Co Ngua[5]	NV	Neo	0/*	0.0	2/45	4.4	0/27	0.0	0/21	0.0	2/45	4.4	0/29	0.0	0/12	0.0	4/179	2.2
Man Bac	NV	LNeo	1/26	3.8	0/51	0.0	1/48	2.1	0/51	0.0	0/53	0.0	0/45	0.0	0/23	0.0	2/297	0.7
Gò Ô Chùa	SV	EIA	2/*	*	0/*	0.0	1/*	*	1/*	*	0/*	0.0	0/*	0.0	0/*	0.0	4/*	*

[1](n/N) n = number of fractures to element, N = total complete elements (>75% element present). % = fracture prevalence. #Two pages of skeletal census data omitted from Douglas (1996), printing error during publication – so denominator (N) count is incomplete. *No denominator data published. [2]One individual has two fractures on a single radius. [3]Unprovenanced individuals could only have the left or right element counted (due to minimum number of individuals). [4] N = distal third of the ulna and fibula. [5] N = preserved diaphysis. Region: SET = southeast Thailand, NET = northeast Thailand, CT = central Thailand, NWC = northwest Cambodia, SC = southern Cambodia, NV = northern Vietnam.

Table B.3. Statistical values for comparison of trauma prevalence between males and females in each site

	Males		**Females**		
Site	**n/N**	**%**	**n/N**	**%**	***p*-value**
Ywa Htin	0/*	*	0/1*	*	N/A
Khok Phanom Di	2/32	6.3	3/36	8.3	1.0000
Nong Nor	2/44	4.5	1/49	2.0	0.6013
Ban Chiang	13/51	25.5	5/47	10.6	0.0707
Ban Non Wat	22/178	12.4	20/181	11.0	0.7443
Ban Lum Khao	6/28	21.4	3/31	9.7	0.2851
Non Nok Tha	9/60	15.0	7/67	10.4	0.5935
Ban Na Di	2/25	8.0	0/20	0.0	0.4949
Noen U-Loke	1/21	4.8	2/27	7.4	1.0000
Non Ban Jak	5/18	27.8	6/23	26.1	1.0000
Ban Mai Chaimongkol	1/11	9.1	0/11	0.0	1.0000
Phromthin Tai	2/9	22.2	1/6	16.7	1.0000
Ban Pong Manao	1/21	4.8	0/13	0.0	1.0000
Phum Snay	20/63	31.7	12/65	18.5	0.1034
Vat Komnou	8/51	15.7	3/26	11.5	0.7410
Con Co Ngua	2/43	4.7	2/31	6.5	1.0000
Man Bac	3/18	16.7	0/15	0.0	0.2330
Gò Ô Chùa	3/23	13.0	3/20	15.0	1.0000

(n/N) n = number of adults affected by trauma, N = number of observed adults
% = trauma prevalence rate in adults

Table B.4. Statistical values for comparison of trauma prevalence in adults between the sites

Site	n/N	%	Ywa Htin	Khok Phanom Di	Nong Nor	Ban Chiang	Ban Non Wat	Ban Lum Khao	Non Nok Tha	Ban Na Di	Noen U-Loke	Non Ban Jak	Ban Mai Chaimongkol	Phromthin Tai	Ban Pong Manao	Phum Snay	Vat Komnou	Con Co Ngua	Man Bac	Gò Ô Chùa
Ywa Htin	2/59	3.4	*	0.4485	1.000	**0.0114**	0.1459	0.0533	0.0630	1.0000	0.6838	**0.0008**	1.0000	0.0999	1.0000	**0.0001**	**0.0429**	1.0000	1.0000	0.0739
Khok Phanom Di	5/68	7.4	*	*	0.3341	0.0676	0.6604	0.1700	0.3397	0.6972	1.0000	**0.0106**	0.6635	0.3748	0.3987	**0.0010**	0.2899	0.5023	0.4683	0.3411
Nong Nor	5/122	4.1	*	*	*	**0.0015**	0.0660	**0.0148**	**0.0225**	1.0000	0.7229	**0.0001**	1.0000	0.0846	1.0000	**0.0001**	**0.0167**	1.0000	1.0000	0.0706
Ban Chiang	18/102	17.6	*	*	*	*	**0.0235**	0.8277	0.2658	**0.0210**	**0.0346**	0.2999	0.0726	1.0000	**0.0075**	0.1258	0.5438	**0.0056**	**0.0024**	0.6316
Ban Non Wat	45/469	9.6	*	*	*	*	*	0.1745	0.4134	0.2966	0.4952	**0.0023**	0.3443	0.4330	0.1069	**0.0001**	0.3154	0.1522	0.0898	0.4314
Ban Lum Khao	9/59	15.3	*	*	*	*	*	*	0.6437	0.0619	0.1404	0.2431	0.1548	1.0000	**0.0401**	0.1021	0.8116	**0.0357**	**0.0281**	1.0000
Non Nok Tha	16/131	12.2	*	*	*	*	*	*	*	0.1621	0.2162	**0.0303**	0.2010	0.7195	0.0763	**0.0039**	0.8325	0.0579	**0.0460**	0.7992
Ban Na Di	2/50	4.0	*	*	*	*	*	*	*	*	1.0000	**0.0024**	1.0000	0.1367	1.0000	**0.0004**	0.0806	1.0000	1.0000	0.1439
Noen U-Loke	4/67	6.0	*	*	*	*	*	*	*	*	*	**0.0039**	1.0000	0.3444	0.6468	**0.0004**	0.1718	0.7257	0.7007	0.1966
Non Ban Jak	14/55	25.5	*	*	*	*	*	*	*	*	*	*	**0.0149**	0.5338	**0.0013**	1.0000	0.1143	**0.0004**	**0.0003**	0.2084
Ban Mai Chaimongkol	1/30	3.3	*	*	*	*	*	*	*	*	*	*	*	0.2885	1.0000	**0.0036**	0.1741	1.0000	1.0000	0.2315
Phromthin Tai	3/20	15.0	*	*	*	*	*	*	*	*	*	*	*	*	0.0795	0.4098	1.0000	0.1140	0.0857	1.0000
Ban Pong Manao	1/46	2.2	*	*	*	*	*	*	*	*	*	*	*	*	*	**0.0001**	0.0544	0.6610	1.0000	0.0585
Phum Snay	39/148	26.4	*	*	*	*	*	*	*	*	*	*	*	*	*	*	**0.0300**	**0.0001**	**0.0001**	0.0741
Vat Komnou	11/80	13.8	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	0.0553	**0.0256**	1.0000
Con Co Ngua	4/89	4.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.0000	0.0852
Man Bac	3/38	7.9	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	1.0000
Gò Ô Chùa	6/45	13.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*

(n/N) n = number of adults (male, female and unknown sex) affected by trauma, N = number of observed adults

% = trauma prevalence rate in adults

Bold text indicates statistically significant *p* values

Table B.5. Statistical values for comparison of trauma prevalence in adults between the Neolithic sites

Site	n/N	%	Khok Phanom Di	Ban Chiang	Ban Non Wat	Non Nok Tha	Con Co Ngua	Man Bac
Neolithic								
Khok Phanom Di	5/68	7.4	*	0.5779	0.7467	**0.0365**	0.5023	0.4683
Ban Chiang	0/16	0.0	*	*	0.5831	**0.0493**	1.0000	1.0000
Ban Non Wat	5/53	9.4	*	*	*	0.1158	0.2939	0.2613
Non Nok Tha	5/19	26.3	*	*	*	*	**0.0081**	**0.0053**
Con Co Ngua	4/89	4.5	*	*	*	*	*	1.0000
Man Bac	3/83	7.9	*	*	*	*	*	*

(n/N) n = number of adults (male, female and unknown sex) affected by trauma, N = number of observed adults. % = trauma prevalence rate in adults. Bold text indicates statistically significant *p* values