A bioarchaeological examination of the skeletal remains of Warring States period Tuchengzi, Inner Mongolia, China

by

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Abstract

Archaeological site Tuchengzi in Inner Mongolia, China presents a rich assemblage of human skeletal remains from the Warring States period (475-221 BCE). The assemblage most likely represents an early incarnation of the semi-military and semi-farming settlement system known as Tuntian. The Tuchengzi Tuntian settlement is believed to have been established by residents of the Zhao State to defend its northern border.

This study focuses on osteological and palaeopathological exanimations of 64 human skeletal remains from the site with an aim to better understand this unique population. Data from non-specific indicators of stress and dental pathology indicate the population suffered normal levels of systemic stresses when compared with other contemporary groups in the region, suggesting a normal farming community. However, abnormal age profile (fewer subadults and fewer elders) and a skewed sex ratio (3 males to 1 female) seem to reveal a possible military component to the population. However, low trauma prevalence, multiple cases of ankylosing spondylitis, and severe joint disease seem to imply a settlement that was involved in very infrequent combat.

This study demonstrates the usefulness of osteoarchaeological profiling of human remains to better understand skeletal populations and past lifeways.

Keywords: Bioarchaeology; Palaeopathology; Chinese Archaeology; Bronze Age; Warring States; Population Health

Dedication

To my mother, Glynis Finer, without whom none of this would be possible.

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List of Acronyms

AS   Ankylosing Spondylitis

AMTL   Antemortem Tooth Loss

EH   Enamel Hypoplasia

JLU   Jilin University

OA   Osteoarthritis

RA   Rheumatoid Arthritis

SA   Septal Aperture

SFU   Simon Fraser University

Chapter 1.   Introduction

Over the past few decades the study of human skeletal remains to address anthropological and archaeological questions has become increasingly more commonplace within the field of bioarchaeology. These questions range from how social factors impact human health and how post-processual topics such as gender, age, and identity can be examined in bioarchaeological records (Agarwal and Glenncross 2011; Baadsgraad *et al*. 2012). Investigating these questions through the analysis of ancient human remains requires an increased emphasis on cultural components such as archaeological context, ethnographic analogy, and when available, the historic record. The study of these factors not only facilitates a more thorough understanding of past cultures, but also increases the potential for bioarchaeologists to achieve a better understanding of archaeological sites and populations.

China's abundance of archaeological sites, and human skeletal remains provides bioarchaeologists with rather unique opportunities to examine impacts of social and cultural developments on skeletal populations. This can be significantly enhanced by the extensive written historic record available as early as 1200 BCE during the Shang Dynasty. Having realized this potential, China's bioarchaeological community has begun emphasizing bioarchaeological research with focus on more socio-cultural topics, such as health and diseases in ancient China (Pechenkina and Oxenham 2013).

This study examines health and lifeways of a skeletal population from the archaeological site Tuchengzi during the Warring States period (475-221 BCE). Although today the site is located in Inner Mongolia, during the Warring States period, the site was located on the northern border of the Zhao State, an area situated between two different cultural landscapes, northern nomadic groups and southern agriculturalists. The site is thought to be a settlement established by the Zhao state, as a means to defend the territory and the border to their state (Gu 2012). This assessment is

supported by historic evidence for northern migration during this period (Di Cosmo 1999). Segments of large defensive walls pre-dating the Great Wall have been documented in this region, the possibility exists that Tuchengzi was established as a settlement to man the defensive structure.

The skeletal remains of the Warring States Period from Tuchengzi are believed to represent those of a semi-military establishment, as suggested by archaeological context and the historic record (Gu 2012). Tuchengzi may represent one of the earliest Tuntian settlements in ancient China. Tuntian (屯田) in Chinese means a semi-military settlement (屯) with agricultural practice (田). The military nature is derived from the fact that this type of settlement is created by the state by moving people from the more occupied regions of the territory to border regions to defend their land. Inhabitants of the settlement could mobilize during periods of war. However, during periods of peace the site would operate as a regular self-sufficient agricultural settlement. The tuntian system was common practice during the Han Dynasty but its origin could possibly date back to the Warring States Period as represented by Tuchengzi.

Therefore, the study of these human skeletal remains offers an opportunity to document the palaeopathological profile of this ancient Chinese population to understand life-ways of this unique human population.

The underlying hypothesis of this study is that the effects of military service and combat should be visible in the skeletal remains of the population. More specifically, a high prevalence of trauma resulting from combat, overall higher mean stature due to military recruitment practices, and a population featuring a disproportionately high number of young-adult males are expected to be observed.

Since Tuchengzi is an early example of a settlement operating on the defensive wall and border of a Chinese state an argument can be made that Tuchengzi could provide an analogous site for later Great Wall defensive settlements. This study will allow us to gain insight into the health, and life-ways of later Great Wall soldiers in ancient China.

This study is focused on the examination of human skeletal remains currently curated at JLU, located in Changchun, China. Access to the collection was made possible through the SFU-JLU Joint Centre for Bioarchaeological Research, which was created to promote international collaborative research in the field of bioarchaeology and palaeopathology.

1.1.   Research Objectives

This study focuses on osteological examination of skeletal remains of 64 individuals from the Warring States period at Tuchengzi site. The remains were recovered from the archaeological site, Tuchengzi located near Hohhot, the modern capital of Inner Mongolia. The objectives of this research are to:

Use standard osteological methods to document the palaeopathological condition of 64 individuals to examine general patterns of pathology and stress present in the skeletal remains. Among many factors, sex and age will be carefully examined to reveal intra-population variations. Temporal stature trends between the Neolithic and Han Dynasty will be included to further contextualize health at Tuchengzi and in China.

Integrate the historic record and archaeological context of the region and time period, to examine if observed osteological patterns could be effectively interpreted, more specifically, to investigate if all lines of evidence can effectively be combined to enhance our ability to reconstruct the lifeways of this particular population, and investigate the possible designation of the site itself.

Compare the observed pattern from Tuchengzi with those from other archaeological skeletal populations of China and other parts of the world. This will be done to both contextualize health conditions at Tuchengzi, and to showcase how osteological profiling helps the study of human skeletal remains with information from social, cultural, political and environmental perspectives.

Chapter 2.   Background

Bioarchaeology and palaeopathology have grown both theoretically and methodologically since the first forays into human skeletal analysis made by naturalists. This chapter outlines the outcomes of the developments made in the associated fields, providing a necessary framework for a bioarchaeological examination of the skeletal remains excavated at Tuchengzi.

2.1.   The History of Palaeopathology and Bioarchaeology

Bioarchaeological research has expanded from simple description of medical anomalies to include holistic population level inquiries into the lifeways of past cultures (Armelagos and Gerven 2003). Aufderheide and Rodriguez-Martin divided palaeopathology research into four phases in their comprehensive volume The Cambridge Encyclopaedia of Human Palaeopathology. These phases appear very similar in trajectory and development to those previously defined for archaeology by Willey and Sabloff (1993) and Trigger (1996: 289) (Aufderheide and Rodriguez-Martin, 1998: 1-7). The phases of palaeopathology research consist of an antecedent phase (the renaissance to mid-nineteenth century), a genesis phase (mid-nineteenth century to WWI), a consolidation phase (WWI to WWII), and the "new" palaeopathology phase (WWII to present). Bioarchaeology shares a similar theoretical and methodological trajectory to palaeopathology, although with more recent origins (Armelagos 2003; Aufderheide and Rodriguez-Martin 1998: 1-7). Armelagos argues that bioarchaeology, by his definition, emerged out the combination of skeletal biology and archaeology, as archaeology transitioned between its descriptive phase and the "New Archaeology", or processual archaeology (2003). Since their inception fields have become highly inseparable, to the point now that palaeopathology is regarded as a subset of the larger umbrella of Bioarchaeology (Larsen 1999). Because of this a description of both histories is needed, and will be presented in chronological history.

Palaeopathology's origins date to the mid 18th century. For the next century physicians primarily conducted palaeopathological research. The antecedent phase of palaeopathology focused predominantly on the documentation and description of skeletal anomalies found in mummies and other human remains by physicians and naturalists. Ubelaker (1989) argues that the first example of palaeopathology did not involve human remains, but was the diagnosis of an osteosarcoma on the femur of a cave bear by the German naturalists Johann Friederich Esper in the mid-18th century (cited in Aufderheide and Rodriguez-Martin 1998:1). Other research during the antecedent phase includes the documentation and description of cranial deformation (what we now classify as intentional cultural cranial modification) in the indigenous peoples of North and South America, and the examination of Egyptian mummies by European pathologists and physicians (Aufderheide and Rodriguez-Martin 1998:2-4; Ortner 2011a).

Similarly, the genesis phase of palaeopathology (mid-nineteenth century to WWI) continued in this direction, focusing primarily on individual case studies. The analysis of osteoarthritic Neanderthal bones in the late-nineteenth century, as well as the documentation of trepanation in South American skeletal samples are examples of this period's research. While these examples are still primarily descriptive and focus of the individual, especially in the case of Neanderthal, researchers considered how lesions present on the skeletal remains would have affected the individual's life history (Aufderheide and Rodriguez-Martin 1998: 4). During the early 20th century however, research objectives began to expand out of the realm of being purely descriptions of medical oddities to an analysis of health.

The consolidation phase, which consists of the research that occurred between the First and Second World Wars, is highlighted by the progression towards using skeletal remains to assess overall human health. This is visible in the work of pathologist Marc Armand Ruffer, considered by many to be the pioneer of modern palaeopathology. In the late-nineteenth and early twentieth century Ruffer undertook an in-depth analysis of the health of Egyptian mummies based on his medical knowledge (Ruffer 1921 cited in Aufderheide and Rodriguez-Martin 1998:5-7; Ortner 2011a). Other research from this time included research into early syphilis in South America, as well as Hooton's analysis

of health in the Pueblo people of the American Southwest (Ortner 2011b). This period also marks the beginning of what is now considered North American bioarchaeology, that is, the examination of archaeological human remains to examine health and behaviour (Armelagos 2003).

The goal of early bioarchaeological research was to explore the biocultural processes that result from cultural and environmental change. Armelagos cites Hooton's use of skeletal lesions as a proxy for examining population health at Pecos Pueblo as one of the earliest examples of bioarchaeological research (Armelagos 2003; Hooton 1930). However, the use of skeletal lesions as an indicator of health did not become a common research technique until the 1970s (Armelagos 2003). Through the 1950s and 60s osteological research focused primarily on racial typology, population migration and population distribution (Armelagos 2003; Ruffer 1921 cited in Aufderheide and Rodriguez-Martin 1998:5-7).

Following the Second World War researchers began the process of standardizing research methods. This transition also led to the inclusion of methods and theory from other disciplines outside pathology, including demography, epidemiology, odontology, orthopaedics, and anthropology. Palaeopathologists began to focus primarily on population level analysis (Aufderheide and Rodriguez-Martin 1998: 7; Eshed *et al.* 2010; Ortner 2011b). Over the last three decades palaeopathology benefited greatly from the technological developments of the latter half of the twentieth century including aDNA analysis, isotopic analysis, complex imagining and dating techniques (Adler *et al.* 2011; O'Rourke *et al.* 2000; Ortner 2011b; Richards and Montgomery 2012; Ruhli 2012; Schoeninger and Moore 1992; Wilbur and Stone 2012).

Following the 1960s bioarchaeological research has distanced itself from race-based research for a variety of reasons. At a purely osteological level, the analysis of skeletal features as diagnostic features of population affinity has been shown to be problematic; an example being the "racial identification" program FORDISC, used by forensic anthropologists, and has been shown to perform consistently poorly (Albanese and Saunders 2006; Armelagos 2003). FORDISCS' poor performance is based on a number of factors. Firstly FORDISC was originally limited to the Howell data set which is

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limited to primarily to modern North American, European and African remains. While the program has expanded its sample in recent updates, and attempts to rectify this limited sample, and now allows for software users to add to their own data to establish local populations. This doesn't alleviate the fact that ancestral estimation is based on a limited sample that excluding many ancestral groups (FORDISC 3 Manual). Secondly, the software is based on an essentialist assumption that members of a "racial group" all share similar cranial structure that is inherent in the program. This does not factor the extreme variation of cranial morphology within any give regional or "racial" group, nor does it take into account other possible environmental, cultural or health factors that might ultimately influence cranial morphology. Racial typological studies are semantically and biologically viewed as problematic by majority of bioarchaeological researchers. Race is a historically loaded term that implies biological differences between populations. The study of this "phenomenon" by bioarchaeologists is not supported by biological and anthropological evidence (Armelagos 2003; Armelagos and Gerven 2003; Armelagos *et al.* 2005; Cartmill 1998). However it should be mentioned that racial identification still holds importance for forensic anthropological cases, as societally, race is a way of classifying people for identification purposes (Sauer 1992). Further discussion here of the issue of race in bioarchaeology and anthropology in generally is not necessary, as it has been covered extensively elsewhere (Albanese and Saunders 2006; Cartmill 1998; Lieberman *et al.* 1989; Sauer 1992), and is not the focus of this research.

In the late 1970s and early 80s, bioarchaeologists incorporated aspects of anthropology, and palaeopathology to transform into bioarchaeology that we know today. Much of the focus of this period was on human health during transitional periods of culture change. An early example of this is Palaeopathology at the Origins of Agriculture, edited by Cohen and Armelagos in the early 1980s (Armelagos 2003; Cohen and Armelagos 1984). This volume features population level analysis of health in the early agricultural periods of many regions around the world, and marked a major shift to population level analysis in bioarchaeology (Cohen and Armelagos 1984). The adoption of a population, or an epidemiological approach to bioarchaeology provides us with a more in depth understanding of health on a larger scale than did earlier case studies (Armelagos 2003; Cohen and Armelagos 1984).

Population health studies focus on one or more indicators of health in the past to assess temporal or regional patterns. These studies can examine periods of social and/or environmental changes. Demography can be incorporated with recent technological advancements such as aDNA studies and stable isotope analysis to examine diet, and migratory patterns (Montgomery 2010; Montgomery *et al.* 2007; O'Rourke *et al.* 2000; Schoeninger and Moore 1992). Population health studies frequently rely on non-specific indicators of stress to examine these larger questions. Non-specific indicators of stress is an umbrella term that consist of a variety of dental and osteological criteria. These indicators are considered non-specific because their aetiology cannot be specifically determined though they indicate of a period of growth cessation or morphological change stemming from a period of stress endured as a result of trauma, disease, nutritional deficiencies, and or psychological stress. Non-specific indicators of stress encompass EH, caries, ante-mortem tooth loss, and dental wear. Other indicators used by bioarchaeologists are stature, skeletal lesions, trauma, enthesopathies, musculoskeletal markers (MSM) and anthropometrics (Ahlstrom 2011; Alves-Cardoso and Henderson 2010; Cardoso and Gomes 2008; Dabbs, 2011; Larsen 1995; Walker and Eng 2007). The prevalence of non-specific indicators of stress are then compiled and examined at both the individual culture and the larger cross-cultural level of comparison (Ahlstrom 2011).

The advantage of the population approach, in comparison to that of the earlier palaeopathological and bioarchaeological research is that it provides a better understanding of behaviour, health and lifeways of the whole population, as opposed to solely focusing on elite individuals or case studies. However, this is not to say that case studies are not important and valid, an opinion held by some researchers (Weiss 2009: 2). Case studies play an important role in bioarchaeology conveying new and interesting osteological cases. To discount one or the other is to limit bioarchaeological and palaeopathological knowledge. To put it simply, strictly supporting population level studies has the risk of obscuring, or missing potentially new and undiscovered pathological conditions. Interesting case studies also have the ability of capturing the attention of the general public, which is an important part of what archaeologists do. A recent example of this is the book Bioarchaeology of Individuals written for both academics and the general public (Stodder and Palkovich 2012). Conversely, only

studying "special" or elite burials does not provide any information about the lives of average people in past societies.

Population level health studies facilitate regional and temporal comparisons, and permit hypothesis testing. They provide bioarchaeologists, as well as physicians, historians, and others who might value the research on how certain events impacted human health in the past. Studies on the adoption of an agricultural lifestyle have helped clarify the misconception that the transitionary period provided more health benefits. This is visible in general decrease in regional health from hunter-gatherer societies to sedentary agriculturists in a given region (Cohen and Armelagos 1984; Cohen and Crane-Kramer 2007: Pinhasi and Stock 2011). Compiling large-scale temporal evaluations of population health allows for researchers to examine how different cultural and environmental stress events impacted the health and behaviour of a region (Steckel and Rose 2005).

2.2   Health and Stress

Health is both a cultural and biological phenomenon referring to the biological and psychological condition of an individual (Bush and Zevelebil 1991:5: Stinson *et al.* 2012). As discussed previously, assessments of population health status using archaeological skeletal remains are based on specific and non-specific indicators of health. Lesions may have multiple causes; many lesions might be the result of one condition (Bush and Zevelebil 1991; Jackes *et al.* 1997; Milner et al. 2000; Roberts and Manchester 2007: 7-8; Wood *et al.* 1992; Wright and Yoder 2003). Thus, any skeletal indicator of health is contingent on the type, duration of exposure to a given pathogen or stressor, as well as the life stage of an individual when the health insult occurs (Bush and Zevelebil 1991). In addition, the relationships between skeletal indicators of health and human behaviour in the past are extremely complex (Bush and Zevelebil 1991; Larsen 1995, 1999; Milner and Katzenberg 1999; Ortner 1991; Wood *et al.* 1992; Wright and Yoder 2003). Integrating cultural context to bioarchaeological data can prove to be helpful in understanding possible cultural and environmental influences on individual health and stress.

2.2.1.   Effects of Stressors on Bone

Exposure to pathogens or other stressors such as starvation can occur either as adult during tissue maintenance and repair, or in adolescences during growth and development (which also includes tissue repair and maintenance) (Bozzoli *et al.* 2009; Moffat 2003; Norgan 2002; Prentice and Bates 1993; Young *et al.* 2008). These result in different physiological responses, which may ultimately be visible in osteological remains. If an insult to health occurs during growth and development, it may result in a period of temporary growth cessation. Osteological indicators of a period of growth arrest include Harris lines in long bones and linear EH in dentition (Mays 1995; McHenry and Schulz 1976). Stature estimates have also been used to estimate stress exposure (King and Ulijaszek 1999; Meiklejohn *et al.* 1984). Although catch-up growth may obscure evidence of stress through examination of stature in past skeletal samples (King and Ulijaszek 1999; Saunders and Hoppa 1993), studies on various vertebrates suggest that growth compensation following nutritional deficit may negatively influence later life trajectory and health status (Metcalfe and Monaghan 2001).

Cell and tissue maintenance and repair occur throughout life. Thus alterations in patterns of tissue repair may be observed in both non-adult and in adult skeletons. The prevalence of inflammatory processes such as periostitis on long bones (Larsen 1995) and in the maxillary sinuses (Merrett and Pfeiffer 2000) has been used as non-specific indicators of stress in past populations. Other health indicators include: dental caries, alveolar abscessing, and EH (Dabbs 2011; Eshed *et al.* 2006; Fabra and Gonzales 2015; Machicek and Beach 2013). Demographic data can also be used to examine levels of stress exposure, such as the age structure of a skeletal sample, and estimates of mean age-at-death for the population (Kowaleski 2014; Roksandic and Armstrong 2011).

2.2.2.   Lesions in Skeletal Remains

The application of clinical medical literature and research is necessary to fully evaluate pathological conditions in skeletal populations. However, in order to apply this academic resource to past human populations, the disease processes must include visible changes in skeletal morphology. For example, bone tissues, radiographs or MRI

or otherwise from individuals with documented medical histories may be used to establish links between disease processes in the living and skeletal lesions (Maksymowych *et al.* 2009; Monsees *et al.* 1985; Ragsdale 1993). If a causal relationship can be established in modern reference samples, then there exists a possibility that diagnosis of bone lesions in skeletal populations may be possible (Ortner 1991; Roberts and Manchester 2007: 5-6). However, the relationships between disease processes and the presence of diagnostic skeletal lesions, is not straightforward and individual variation in disease progression and the absence of diagnostic skeletal lesions may hinder diagnosis (Miller *et al.* 1996).

Morphological changes visible in skeletal remains however, may not be visible in living individuals, particularly if the diagnosis is contingent on radiographic identification of skeletal changes (Ortner 1991; Roberts and Manchester 2007: 5-6). For example, lesions on the pulmonary aspect of ribs, that may be associated with tuberculosis (Pfeiffer 1991), are not in the clinical repertoire of criteria for the diagnosis of tuberculosis. These rib lesions may not be recognized as possibly but not necessarily indicative of tuberculosis in skeletal samples but does reflect respiratory disease (Roberts *et al.* 1998). Thus, other criteria are required to diagnose a given disease or condition in past and in living populations (Ortner 1991; Roberts and Manchester 2007: 5-6).

Iindividuals who do not exhibit skeletal lesions may or may not have experienced episodes of illness or exposure to stressors (Wood *et al.* 1992). The absence of lesions may indicate no exposure to stressors, the "healthy but mortal" scenario (Jackes *et al.* 1997), exposure to stressors during a quiescent phase of the growth cycle (Lampl 2002), exposure to stress that results in no morphological change to bone or alternately may indicate exposure to stressors with death occurring prior to the stress episode being recorded in the skeleton (Goodman 1994; Roberts and Manchester 2007: 7-8; Wood *et al.* 1992). Some researchers suggest that bioarchaeological interpretation may be facilitated through the use of multiple indicators of health, at both the individual and the population level, and in conjunction with the archaeological, behavioural and cultural context of the sample (Goodman 1994). In contrast, Wood and colleagues (1992)

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suggest that estimations of health in past populations may be severely confounded as outlined in the "Osteological Paradox".

2.3. The Osteological Paradox

Wood *et al.* proposed the osteological paradox in 1992, which argues that there are inherent issues with representativeness of archaeological skeletal collections, as well as conceptual issues with bioarchaeological theory. Wood *et al.* (1992) highlight three areas which are conceptually problematic in bioarchaeological research: 1) skeletal collections represent populations that are demographically non-stationary 2) the samples contain selective mortality, and 3) the skeletons include heterogeneity of risk of death or illness (Wood *et al.* 1992). This is of particular importance when working with archaeological human remains, as these factors have to be taken into consideration when interpreting statistical results.

A demographically non-stationary population implies that populations are rarely static, which includes geographic location, and sample size. Small changes in fertility in non-stationary populations have a significant impact on age-at-death distributions of archaeological human skeletal populations. Wood *et al.* (1992) also argue that skeletal samples are intrinsically biased, as the samples only represent the individuals that died at a specific age, and thus are not representative of the individuals that lived to a greater age. Because of this, observed frequency of lesions overestimate the true prevalence in the general population, making past population appear less healthy (Wood *et al.* 1992). This bias cannot be avoided, as it is by its very nature built into the data.

Wood and colleagues (1992) also argue that skeletal samples are made from an unknown mixture of individuals who varied in their susceptibility to disease and death, resulting in an unknown number of both random and selective deaths. Heterogeneity arises from socioeconomic differences, microenvironmental variation and/or temporal variation of health and living conditions since skeletal samples generally represent a prolonged period of time. Because of this, they argue, it is impossible to obtain direct estimates of demographic or epidemiological rates from archaeological skeletal samples (Wood *et al.* 1992). Health data from a skeletal collection can be interpreted in different

ways. For example, the decline in mean age at death as interpreted by Cohen and Armelagos (1984) could be the product of increased fertility in agricultural populations, not the commonly argued deterioration of general health. Increased lesions could be indicative of a higher survival rate of individuals with infection, which would result in the presence of more individuals in a skeletal collection with more skeletal lesions (Wood *et al.* 1992).

The osteological paradox garnered criticism from Cohen and colleagues highlighted in his 1994 publication "The Osteological paradox reconsidered." This paper also features responses by both Wood and Milner (Cohen *et al.* 1994). Cohen was one of the early bioarchaeologists to argue for a decrease in health following the adoption of a sedentary agricultural lifestyle, thus he had a vested interest in defending the validity of his interpretations. Cohen *et al.* (1994) used a meta-analysis of hunter/gatherer and agriculturalist skeletal collections from around the globe that he did previously with Armelagos to argue his main points (Cohen and Armelagos 1984).

Cohen and colleagues (1994) argue that their data indicate several important points: an increase in nonspecific infection in agriculturists, tuberculosis and syphilitic like infection, more intestinal and parasite infection with increased sedentism (based on coprolites and mummified remains). Increased porotic hyperostosis and non-specific indicators of anemia in agriculturalists versus hunter-gatherers, as well as other indicators of stress and malnutrition such as a decrease in stature and increase in dental pathology were also noted (Cohen *et al.* 1994).

Cohen *et al.* (1994) argue that skeletal samples analyzed are reasonably representative of the living population, and therefore, morphological changes visible in the archaeological skeletal collections reflect real life changes in past populations. While they see the osteological paradox as theoretically valid, they do not agree that a reinterpretation of health in early agricultural societies is required. Cohen *et al.* (1994) argue their position is both in line with the ethnographic record and epidemiological theory. Epidemiological theory argues that the transition to agriculture coincided with the first epidemiological transition; this was the product of an increase in population density, size and sedentism, which resulted in an increase in the presence of infectious disease

in these populations (Armelagos 2003). Other data Cohen *et al,* (1994) use to defend their position is the increase in disparity between the prevalence of EH in lower status individuals versus higher status individuals following the onset of social stratification, as well as a decrease in diet breadth and quality following the adoption of an agricultural diet. They argue that ethnographic analogy also indicates an increase in the frequency of caries, as well as a more cariogenic diet with the adoption of an agriculturist lifestyle, versus that of a forager. And while they agree that mortuary samples are composed of heterogeneous individuals, both random and selective deaths should be relatively representative of those proportions in the past (Cohen *et al.* 1994).

Wood and Milner (in Cohen *et al.* 1994) have responded to Cohen *et al.*'s criticism of their theoretical work. While Wood and Milner agree that Cohen *et al.*'s proposed scenario is possibly a valid interpretation of the data, there exist other potentially equally valid interpretations. The problem is that it is difficult, if not impossible to determine which is ultimately correct. Wood and Milner use an analogy to illustrate how using Cohen *et al.*'s examples of declining health could argue the exact opposite is the case, and the transition to agriculture resulted in a healthier, more stable lifestyle. Wood and Milner argue that if an individual with a health condition does not die during childhood, or from the later effects of the disease, the individual should be considered healthy individual, as their condition did not affect their mortality (Cohen *et al.*1994). Wood and Milner argue that deaths prior to the industrial revolution were frequently the result of infection amplified by malnutrition (Cohen *et al.* 1994). However, Wood and Milner's statement appears more so to reinforce Cohen's position of decreased health, and nutrition following the adoption of an agricultural lifestyle than it does to counter it.

Wright's and Yoder's (2003) perspective on the osteological paradox outlines how recent research and technological developments can are used to curb possible issues with representativeness in skeletal collections. They call for more research into modern population frailty, specifically regarding the mechanisms that cause heterogeneity in population frailty, and how disease processes affect this (Wright and Yoder 2003). Wright and Yoder (2003) argue that more modern demographic research into how frailty contributes to the risk of death in modern populations is needed, and that ultimately, these results need to be analyzed in cultural context to understand how frailty

is affected by different cultural variables. The recent increases in accessibility to techniques such as isotopic analysis, and genetics provide researchers with the tools to better explore the interrelationships of these variables in past populations.

These techniques can be used to assess sex, socioeconomic status, age, individual and population movement, as well as used to examine health, and variables that may influence health in past populations. Wright and Yoder (2003) highlight emerging lines of inquiry such as dental calculus, starch granule and phytolith analyses as beneficial in understanding past diets. While these techniques will not replace traditional osteological analysis, they are useful in conjunction with both destructive (i.e.: thin sectioning of dentition and bone) and non-destructive analysis of crania, dentition, and post-cranial human skeletal remains. Wright and Yoder (2003) argue multivariate statistical methods can be used to garner a better understanding of population health, and although not mentioned by the authors, individual health. This, they argue can be used to avoid some of the representativeness issues outlined by Wood *et al.* (Wood *et al.* 1992; Wright and Yoder 2003). For the purposes of this study as much osteological data as possible was gathered on each individual to best estimate individual health, and in turn population health at the Tuchengzi site.

2.4.   Stature: As a Proxy for Population Health

Temporal studies, using stature as a proxy for population health provide an understanding of how health changes through time in a region. Studies have provided information about long-term health fluctuations between the Mesolithic or Neolithic and present day (Cardoso and Gomes 2008; Ozer *et al.* 2011). These studies have presented a common, but not universal pattern in regard to the effects of increased social complexity. For example, an increase in stature was documented in two different populations in Thailand following the reliance on intensive agriculture, and between the Bronze and Iron Age (Domett and Tayles 2007; Douglas and Pietrusewsky 2007). In contrast stature in New World populations in Ecuador and the Southern United States remained relatively static following the adoption of agriculture. The appearance of relatively temporally static population stature is likely due to continued reliance on wild

foods following the adoption of agriculture (Danforth *et al.* 2007; Ubelaker and Newson 2002). However this was not the case for other regions.

Alternatively, many other regions experienced a significant decline in health, visible in both a decrease in stature and an increase in non-specific indicators of health stress. Larsen has documented a decrease in quality of human health in Georgia, United States, following the adoption of agriculture, and later through contact with arriving European populations (Larsen 1984; Steckel *et al.* 2002). Smith *et al.* also reported a similar trend of decreased population health following the adoption of agriculture in the Levant (1984). Meiklejohn *et al.* (1984) documented a decrease in stature in Western Europe following the adoption of agriculture. However, later re-examination by Meiklejohn and Babb (2011) revealed the decrease to have occurred much earlier than previously thought, that is, during the Late Upper Palaeolithic period (Meiklejohn and Babb 2011). Pechenkina *et al.* (2007a) also reported a decrease in stature and an increase in the presence of non-specific indicators of health stress in the Yellow River region between Neolithic and Western Zhou. Pechenkina *et al.* (2007a) is one of few bioarchaeological papers published in English examining population health in ancient China.

Studies of stature at the population level provide what is ultimately a quantified representation of the biological stress influencing a given population during a given time period. This stress includes nutritional, disease, and scalar stress, it is difficult to parse out which one is ultimately impacting the population. However it manifests itself in a variety of physical or morphological ways that can be used to categorically examine the impact of a variety of stressors on a given population. While stature can inform researchers as to some aspects of health of a skeletal population, analysis of injury to bone can inform as to types of human behaviour of the past.

2.5. Injury to Bone

Injury to bone can provide bioarchaeologists with various types of information regarding behaviour in the past including, but not limited to, interpersonal violence, occupation, and lifeways (Judd 2004, 2008). Injury however is not limited to solely acute

trauma resulting from accident or violence, but also injury to joints resulting from other aetiologies such as repetitive use, age-related changes, genetics, occupation, or other injuries (Waldron 2008: 28). Whether acute or otherwise, traumatic change to the morphology of bone provides bioarchaeologists with information to interpret past behaviour from human remains.

2.5.1.   *Traumatic Injury*

Skeletal trauma provides bioarchaeologists with a record of interpersonal relationships, environmental and occupational hazards, medical knowledge, and ultimately, past lifeways (Judd 2004, 2008). Bioarchaeologists are uniquely positioned to examine violence and conflict in past cultures, as well as the more frequent accidental injury (Lovell 1997; Walker 2001). While material remains (i.e. weapons, defensive walls, armour etc.) provide a record of the perceived threat of conflict, they do not indicate physical violence. Alternatively, osteological remains provide a record of the individuals impacted by interpersonal conflict (Walker 2001). While interpreting patterns of trauma has the potential to explain past lifeways, diagnosis of individual traumatic incidents proves to be more complex. Without documented skeletal remains it proves difficult to determine whether an individual was involved in a violent event or suffered from an accidental injury (Wakley 1996). Certainly criteria can be used to parse out intentional from accidental injuries.

When attempting to determine the provenance of a traumatic injury it is important to include both qualitative and quantitative research elements (Judd 2008). Characteristics of fractures, including patterns at both the individual and population level are equally as important as contextualizing the peoples socially, culturally, historically and environmentally (Judd 2008; Lovell 1997; Wakley 1996). When compelling evidence for interpersonal violence, such as embedded projectile points or individuals suffering from multiple perimortem traumatic injuries to the craniofacial region are not available, the historic or ethnographic record can aid in bioarchaeological interpretation (Eng and Zhang 2013; Lovell 1997; Wakley 1996). Historic documentation can inform bioarchaeologists regarding conflict that may have affected a certain region or peoples, thus informing of potential incidents impacting individuals at a given site. Alternatively, information such as subsistence pattern at a site provides information regarding the

types of injuries one would expect to see in a population. For example both industrialized and non-industrialized agriculture carry a high risk of potential injury (Judd and Roberts 1999). Even with cultural context determining whether an injury is accidental or intentional is difficult, as accidental or stress fractures are frequently indistinguishable from interpersonal violence (Wakley 1996). For example, in parry fractures, the name itself implies the result of interpersonal violence resulting from blocking a direct blow with one's forearm, however the same transverse fracture of the ulna can occur with indirect force from forced pronation usually resulting from an outstretched arm attempting to break one's fall (Judd 2008; Lovell 1997). In clinical studies radius and ulna are most frequently fractured bones, though the injuries are rarely due to assault (Lovell 1997). While it is possible that more interpersonal violence with blade weapons occurred in the past, logically there was no less risk of falling resulting in a transverse ulna fracture. When classifying a traumatic injury like the parry fracture, or otherwise, as interpersonal violence it is important to follow criteria for such a diagnosis (Judd 2008). Even if an injury fits the criteria for interpersonal violence it is necessary to investigate other possibilities, so as to not over-represent the amount of interpersonal violence at a site or during a temporal period.

Assessment of skeletal healing is also an important component to the interpretation of skeletal trauma. Antemortem, and perimortem injuries, and post-mortem damage can appear morphologically different. These differences can be used to assess injury in relation to time of death (Lovell 1991; Martin and Harrod 2015; Walker 2001). Antemortem and perimortem can be differentiated from post-mortem damage with evidence of healing or inflammation, uniform presence of taphonomic staining, presence of greenstick, incomplete, and spiral fractures or fractures related to bone with organic material in it, or oblique angles on fracture edges (Lovell 1997). Post-mortem fractures are generally characterized by a number of features. Fragments are generally smaller, and non-uniformly coloured. Fracture edges are squared and lack patterning seen in fresh bone. In spite of these criteria for assessment, differentiation of perimortem from post-mortem damage is difficult (Lovell 1997). Perimortem fractures imply the injury occurred within 3 weeks of death, and the injury had little to no time to heal before the individual was deceased (Martin and Harrod 2005; Waldron 2008: 146-147; Walker 2001). This does not imply that the injury was the cause of death, but merely that the

injury occurred at or around the time of death. Antemortem trauma is classified as trauma occurring 3 weeks or more before death as indicated by the presence of new woven bone (Waldron 2008: 146-147). Acute trauma is only one type of injury that impacts the skeleton, accumulative trauma can result from many possible aetiologies including repetitive use, age, genetics, trauma, or disease conditions such as arthritis.

2.5.2.   *Joint Disease and Arthritis*

Joint Disease can result from a variety of possible causes. With the exception of dental disease, joint disease and arthritis are the most common pathological conditions visible in archaeological skeletal populations (Waldron 2008: 26). "Joint disease affects one or more joints of the body, usually in a clearly defined distribution pattern; it may destroy or form bone or promote both" (Roberts and Manchester 2007: 132). Numerous types of joint disease and arthritis exist such as: OA, RA, erosive OA, seronegative arthritis, AS, reactive arthropathy, psoriatic arthropathy, and enteropathic arthropathy, and gout, among others.

Arthritis can be divided in to two main categories, those that promote bone proliferation (OA), and those that promote bone erosion (erosive arthritis) (Waldron 2008: 47). OA, stimulates bone proliferation, and is the most common form of joint disease in living, archaeological, and paleontological samples. It affects all living organisms that possess synovial joints (Waldron 2008:26-27). OA is a disease that is characterized by the breakdown of articular cartilage (Waldron 2008: 26-27). Alternatively, erosive arthritis (RA, erosive OA, seronegative arthritis, and gout) results in bone erosion, among other symptoms (Waldron 2008: 47). Both of these disease processes have different aetiologies, and result in different morphological appearances. Through detailed observations of the bone, plotting of lesion locations within the skeleton and skeletal element and comparison of clinical data, a differential diagnosis can be performed on osteological remains.

OA can occur due to a variety of singular factors, or a complex combination of them. These factors include age, sex, genetics, obesity, trauma, and movement (Waldron 2008: 28). OA is considered primary OA when no direct cause is evident (Waldron 2008: 28). Alternatively in secondary OA a cause is evident, this could be, for

example, a traumatic injury that has left osteological evidence (Waldron 2008: 30). OA develops in three-stages, the first of which is the enzymatic breakdown of the cartilage. In stage two, cartilage begins to split into fibres, and erodes. This results in the release of collagen and proteoglycan into the synovial joint cavity causing the body to respond to foreign bodies in the synovial joint, thus triggering an inflammatory response including the production of inflammatory cytokines. The third stage is the body's attempt to repair the damage by forming new bone. New bone appears as marginal osteophytes, new bone on joint surfaces, pitting, changes to the overall joint contour, and eventually eburnation, and/or grooved eburnation (Waldron 2008: 27). OA generally affects individuals over the age of 40, and most frequently in areas in either weight bearing regions (such as the knees, hips and spine) or frequently used regions such as the hands (Waldron 2008: 32). For palaeopathological diagnosis of OA in archaeological remains certain features need to be present, either evidence of eburnation or two of the following: marginal osteophytes, new bone on the joint surface, pitting on joint surface, and/or alteration to joint contour (Waldron 2008: 33).

In contrast, RA development and occurrence is the result of both genetic and environmental factors (Waldron 2008: 48). Some researchers have argued that environmental factors such as infection could be responsible for the onset of RA (Mackenzie and Dawson 2005), however 60% of individuals suffering from RA possess the allele HLA DR4 and DR indicating a correlation between allele presence and RA development (Mackenzie and Dawson 2005). The onset of RA can occur at any age, but the peak rate of onset is between ages 40 and 70 years. RA also occurs more frequently in females than in males (Horst-Bruinsma *et al.* 2009). Other complications that have been associated with RA are osteoporosis (Horst-Bruinsma *et al.* 2009), and pressure erosion (Monsees *et al.* 1985). Similarly to OA, RA occurs in three phases. First cells derived from bone marrow infiltrate the synovial membrane; this process triggers an amplification phase resulting in further infiltration. The final step, inflammation, activates osteoclasts and increases vascularization (Waldron 2008: 49). The enzymes present result in erosion of osseous tissue, which progresses from cortical destruction to eventual exposure of the trabeculae (Waldron 2008: 51).

The origin and ultimate cause of RA is a source of debate within both the archaeological and rheumatological communities. Some researchers argue that the source of RA could be triggered by infection, specifically from a pathogen originating in the New World (Mackenzie and Dawson 2005) because of the presence of archaeological examples of RA in pre-European contact North America populations. Evidence of RA in the New World is abundant and dates back to as early as 4,500 BCE. This position is based on the fact that bone changes caused by a variety of infectious agents (bacteria, chlamydia, and some viruses) share traits with chronic erosive arthritis and RA. B19 parvovirus is more frequently present in the synovial fluid of individuals suffering from RA, than those suffering from OA (Mackenzie and Dawson 2005). It has also been suggested that RA could be also aseptic arthritis resulting from the presence of infectious agents inhabiting the body outside of synovial joint (Mackenzie and Dawson 2005). Other agents suggested have included but are not limited to, *Shigella dysentreriae, Treponema spp., Chlamydia trachomatis, Yersinia enterocolitica*, ulcerative colitis and Crohn's disease. Although no direct evidence has been found to support this, supporters of the hypothesis argue that it cannot be discounted (Mackenzie and Dawson 2005)

The presence and origin of RA in the archaeological past is still a point of contention. Some researchers believe that, as with other diseases such as Treponemal disease, RA originated in the New World spreading to the Old World post-contact (Rothschild 2005). Supporters of a New World origin of RA cite a number of factors such as, the minimal appearance of RA in the Old World prior to Columbian contact, and the subsequent increase in the presence of RA in the late 1700s, following increased travels between the Eastern and Western Hemispheres (Mackenzie and Dawson 2005). RA has a well-documented history in the New World dating as early as 4500 BCE (Mackenzie and Dawson 2005). However, archaeological evidence suggests at least 5 possible cases of RA in the Old World from between 70 and 1500 CE (Mackenzie and Dawson 2005), as well as examples from 7th to 9th century medieval France (Waldron 2008: 47). Evidence of RA presence in pre-Columbian contact Europe immediately discounts a New World origin. In spite of the apparent increase of RA occurrence in the late 1700s, correlation does not equal causation. A variety of possible explanations exist for its rarity. A variety of scenarios could explain RA being a rarity in the Old World skeletal

record. Poor preservation of deconstructed and fragile osteological materials, misdiagnosis in living individuals prior to 1785, or since RA occurs most frequently in individuals over 40 years of age, possibly a shorter life expectancy of the pre-contact Europeans limited its occurrence (Mackenzie and Dawson 2005). That being said, standard age estimation's upper category is generally 50+, limiting our understanding of age demographics in past populations (see Jackes (2000) and Aykroyd *et al.* (1999) for a discussion on life expectancy and age estimation in past populations). Since Tuchengzi predates the earliest examples of RA in the Old World by at the least 300 years, and at the most 1,000 years, it would make the possibility of individuals suffering from RA in Warring States period China of particular significance.

2.5.3.　　*Environment in Northern China During Warring States Time*

Information regarding Mongolian and Northern Chinese Holocene environmental change is rather scarce (Schwanghart *et al.* 2009). The late Bronze Age and early Iron Age (between 3550 and 2200 BP, including the time of Tuchengzi site occupation in the Warring States period and Han Dynasty) was a period of climatic improvement in Northern China, resulting in increased precipitation and more moist conditions allowing for northward expansion of agricultural. This period of amelioration was followed by a period of increased aridity (Huang and Su 2009). The Han Dynasty inhabitants of Tuchengzi would have experienced an environment similar to that of modern day conditions. The Chinese Meteorological Data Sharing Service currently describes the region of Tuchengzi as a steppe environment with a semi-arid climate with long, cold, and dry winters. Average temperature during the January is -11.6 °C. Summers are hot and slightly humid, with an average temperature of 22.6 °C during July (CMA 2014). Summers can be wet and are effected by Monsoon season. Modern conditions in the region evolved around 1100 BCE (Xiao *et al.* 2006). A cooling trend at approximately 2900 BP cal. resulted in deforestation, the steppe terrain, and the climate visible today (Xiao *et al.* 2006). Tuchengzi was not established until a few hundred years later during the Warring States period (approximately 2700 BP), and following this period the cold semi-arid environment visible today had already been formed. The peoples of Tuchengzi would have been subjected to long, cold, and dry winters, and warm, wet summers.

2.6.   Relevant Historic Periods

The changing social landscape during the Warring States period would have affected health at Tuchengzi in a variety of ways. Since health is a function of the interaction between cultural, environmental, and biological factors (Frisancho *et al.* 1970; Garn *et al.* 1964; Young *et al.* 2008) it is necessary to establish the social and political context of this time period before assessing levels of health in the people of Tuchengzi of the Warring States. This includes an introduction to the time periods before and after Tuchengzi occupation: the Spring and Autumn Period (770-476 BCE), and the subsequent Han Dynasty period (206 BCE-220 CE).

2.6.1.   *The Spring and Autumn Period*

The Spring and Autumn period directly preceded the Warring States period and ultimately shaped the political and social landscape in which the Tuchengzi site was established and situated. The Spring and Autumn Period (771-481 BCE) was an aristocratic society based on kinship (Lewis 1990). While authority was established by kinship, it was controlled by ritual violence. Violence was ritualized in the sense that it is primarily an act of defending family honour more so than for economic gain or increased social control. It was dictated by a set of guidelines that controlled when and how it could be exercised. Warfare during this period was between aristocratic families and was fought almost exclusively by the aristocratic class (Lewis 1990:17). Over the course of this period authority shifted first from Kings, to feudal lords (Lewis 1990: 28-29). Warfare was a part of life. Zuo Zhuan, a document compiled between 722 and 263 BCE, lists 540 interstate wars, and 130 major civil wars in the 259-year span. This document likely contains an incomplete list, as the Zuo Zhuan makes reference to conflicts not included in the tally (Lewis 1990: 36). During the transition into the Warring States period, violence and warfare changed from strictly ritualized behaviour of the aristocracy and the defense of family honour, to a tool to reinforcing authority, and securing group cohesion (Lewis 1990: 53). The transition was also marked by extension of military service from the aristocratic class to include the lower classes (Lewis 1990: 94). This facilitated the emergence of a new upper class whose authority was established by warfare, not by family lineage. By the end of the Spring and Autumn period political control had been consolidated in the hands of seven larger states.

2.6.2   *Warring States Period*

The 7 states of the Warring States period (475-221 BCE) were centralized around the drainage basin region of the Yellow River (Lewis 1999: 593). The states during this period were: Yan, Qi, Wei, Jin, Han, Qin, Zhao and Chu (Lewis 1999: 593-598). The slowly changing political climate permitted the formation of larger states; rulers began to appoint officials and dispatch them to control smaller regions under the authority of the larger state. Laws and punishments were imposed to control individuals and secure obedience over the growing population (Lewis 1999: 621). Technological and social developments played key roles in the turbulent political landscape of the time. Weaponry consisted of primarily bronze, but occasionally of stronger iron lances, daggers, halberds, complex arrow designs, and large swords. One of the most important technological developments was the crossbow as it permitted more efficient firing of projectiles (Lewis 1999: 622-623). Cavalry played an important role in Warring States warfare. Cavalry increased the speed at which armies could travel, and provided a novel manner in which they could engage in combat. The wearing of armour, including iron and leather body armour and helmets that increased military personnel's defense during combat, also became common in combat (Lewis 1999: 624). Other technological developments during this period include large blast furnaces, iron casting and metal mould technology resulting in more industrialized production of iron agricultural tools and coinage. This facilitated large-scale production of agricultural tools such as the iron tipped plough, mouldboard plough, seed drill, and chariot parts (Derui and Haiping 2011; Lin 1995; Wagner 1995). The development of more sophisticated and efficient agricultural tools would have provided the inhabitants of Tuchengzi the ability to practice agriculture at a larger scale, and increase overall crop yields.

Due to these technological developments, the scale of inter-state conflict dramatically increased. State colonialist activities also increased, with the Zhao State's expanse northward into what is now Inner Mongolia. Peoples were dispatched from the Central Plains to the North as means to establish and secure occupation of the Inner Mongolian plateau (Lewis 1999) where Tuchengzi was situated. Army size increased over 6 times, from the largest armies during the Spring and Autumn period of around 30,000 individuals to over 200,000 individuals with 6,000 cavalrymen, during the Warring States period (Lewis 1999: 625-626). This growth in army size was matched by

increased duration and spatial distribution of conflict. The extremely large size of armies allowed for states to be involved in multiple conflicts at any given time (Lewis 1999: 627-628). Defensive measures also increased. This resulted in walled cities, and the construction of large interstate defensive walls (Lewis 1999: 619). The warring eventually culminated when, over a 9-year period, the Qin state established a singular unified Chinese state (Lewis 1999: 598).

2.6.3 *The Qin and Han Dynasties*

While the Qin Dynasty (221-206 BCE) ruled the Chinese empire for a brief 15 years, it succeeded in establishing a unified Chinese state. This unification facilitated the standardization of systems of currency, weight and written language. The Qin Dynasty shifted power and social control from the aristocratic class to the government. This allowed for access to a greater pool of workers and enabled more large-scale construction of infrastructure. Despite these achievements, the Qin Dynasty's reign ended in a Han revolt that overthrew a weakened Qin Dynasty.

The Han Dynasty emerged as a unified imperial state, which governed for over 400 years, and resulted in expanded contact outside of the central Chinese region. The large state was divided into states that were each controlled by separate centralized government (Pingfang 2005). Establishment of the Silk Road facilitated long-distance trade, and the institution of an official language and currency bolstered this new larger scale interregional trade. Technological developments of the Han Dynasty included papermaking, rudder steering for sea craft, negative numbers in mathematics, astronomy tools, and a seismometer to measure ground movement (Pingfang 2005). The Han Dynasty was extremely peaceful in comparison to the previous 500 years. Warfare was drastically reduced, and focused primarily on defending the empire's northern border from invasion by the nomadic peoples of the Xianbei confederation, which occupied modern day Mongolia (Pingfang 2005). These conditions would have profoundly impacted health of the individuals living during this time. In both modern and archaeological populations increases in economic and social stability has shown to have an overall positive effect on health. A multigenerational study of individuals in postfamine Ireland found a significant correlation between stature and not only the individual's

socioeconomic status, but that of the their parents and the grandparents (Young *et al.* 2008). Other studies examining temporal changes in diet and economic growth have suggested a positive correlation between increased qualities of dietary intake and increased mean stature, and a decrease in the quality of diet followed by a decrease in mean stature (Larsen 1995; Salvatore 2004; Steckel *et al.* 2002).

Between 771 BCE and 220 CE substantial socio-political changes occurred in China. A large region of decentralized feudal control transitioned through conflict into a large state under centralized governmental control. Technological proliferation occurred as a by-product. Ultimately these changes would be reflected in the health of the individuals living at any given point, and while these trends may not be visible in the short term, they should be visible temporarily over a much longer term. We should expect to see an increase in stature between the Warring States and Han dynasty as a result of a less turbulent social climate that would be visible at both Tuchengzi as well as at the majority of other archaeological sites utilized by this study.

Chapter 3.   Materials and Methods

This chapter contextualizes the site and remains excavated at Tuchengzi for a more comprehensive analysis of the data. The data is analyzed using both descriptive and univariate statistics.

3.1.   Location of Tuchengzi Site

The site of Tuchengzi (112°E, 41°N) is located south of Horinger County approximately 40 km south of the modern day Inner Mongolian capital Hohhot of the autonomous region on the Hetao Plain (Fig. 3-1). Geographic barriers surround the site with the Yinshan Mountains to the north, and the Yellow River to the south. Between the Spring and Autumn period and the Han Dynasty Inner Mongolia was an area of two overlapping subsistence strategies: sedentary agriculturalist from the Central Plain region, and nomadic pastoralists in the north (Woodworth and Du 2011). While Tuchengzi is located in what is a semi-arid environment, generally occupied by pastoralists, it was established by emigrants from further south, from the northerly expanding Zhao State. These emigrants brought with them an agricultural lifeways and established a fortified sedentary site (Machicek and Beach 2013). It has also been suggested that site was a military base for the soldiers of the Zhao State taking part in northern expansion (Gu 2012). The region has an average altitude of 1050 m above sea level. The annual precipitation ranges from 300-500 mm. The region is semi-arid and temperate, with temperatures ranging from -17 $^{\circ}$C to +30 $^{\circ}$C with an average winter (January) temperature of -11.6 $^{\circ}$C, a summer average (July) of 22.6 $^{\circ}$C and an annual average temperature of 8 $^{\circ}$C (China Meteorological Administration 2014). The Tuchengzi site was occupied between the Warring States period (beginning in 475 BE) and the Liao Dynasty (ending in 1125 CE).
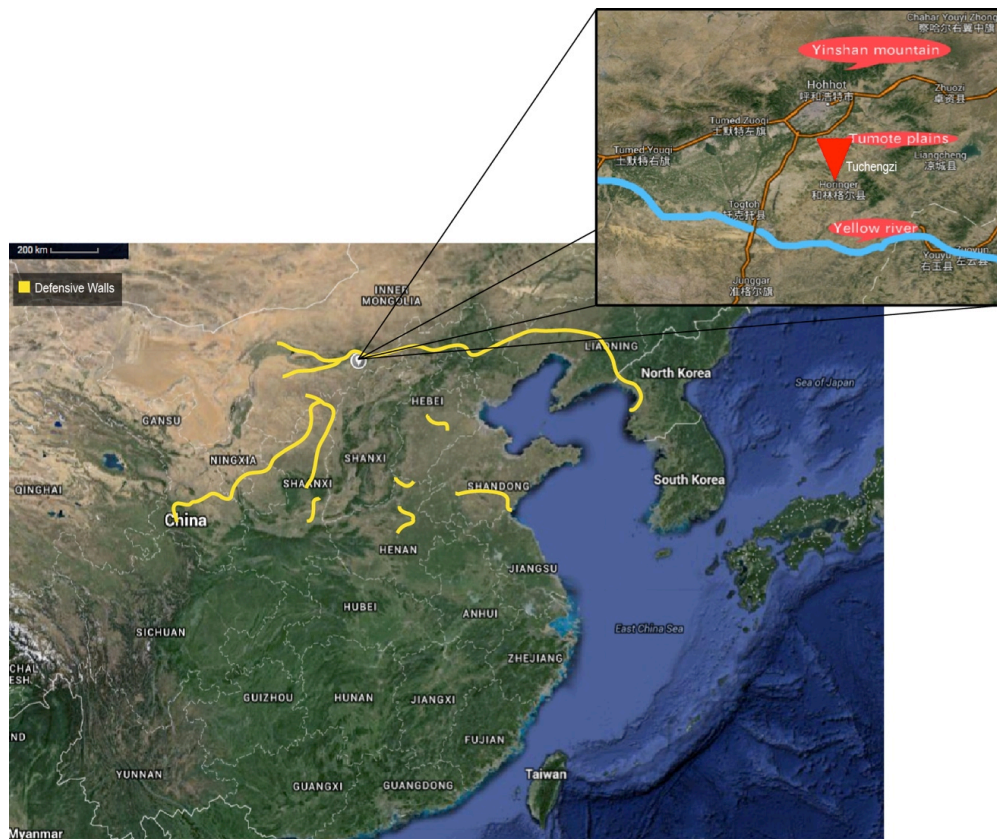
Figure 3-1 **Tuchengzi in Geographic context: The Tuchengzi site is marked with a red triangle in Horinger county, in the Tumote plains. The Yinshan mountain range and Gobi desert are visible to the north, and the Yellow river is visible to the south. Yellow lines represent defensive walls present during the Warring States period.**

3.2. Site Excavation History

The site of Tuchengzi was excavated on ten separate occasions between 1997 and 2005. In total, more than 2000 burials were identified, however only 289 burials from the Warring States period were excavated. The remains excavated at Tuchengzi appear to be almost exclusively the adult remains. However, in 2005 remains of children dating to the end of the Warring States, and start of the Han Dynasty were uncovered (China Post 2006). Twenty tombs were identified in an approximately 100m^2 cemetery and the children's remains were buried in earthen-wear jars. However, a formal publication regarding the sub-adult remains from the Tuchengzi children's cemetery has yet to published. .

During the 8 years of excavations over 5000 burial goods were excavated. These grave goods include a variety of pottery types drawing influence from Jin and Qin cultures to the south, as well as northern nomadic groups, highlighting the unique ecological and cultural landscape within which Tuchengzi is located. Other grave goods include copper coins, stone tools, and most commonly, weaponry, including bone and copper arrowheads, bronze swords, and bronze spears. Swords and halberds were common weapons recovered from the site.

Social stratification can be identified at Tuchengzi from the types of burials: presence or absence of a coffin. During excavation four tomb types were identified: 1) rectangular pit burial (with no stone reinforcement), 2) rectangular pit burial with stone reinforcement, 3) rectangular pit burial (no specification if these are reinforced or not) with small alcove for grave goods, and 4) rectangular pit burial with a stone ramp. Burial pit size was on average 2.5 meters long, and 1.5 to 2.5 meters wide. However graves varied with 4 m as the longest, and 3 m as the widest. Average burial depth was approximately 1.25 meters. Burials were generally oriented east to west. Higher status individuals were buried in a single wooden coffin, while the highest status individuals were buried in two coffins, an inner coffin, called a Guan, and an outer coffin called a Guo. Unfortunately a site report has yet to be published, so the data are not available to be used in this study to differentiate social status between individuals.

Military conflict was ubiquitous during the Warring States period. As a result, military service was predominately compulsory. There appear to be conflicting interpretations on the original intention of the settlement. While it has been argued by Chinese scholars to be a military garrison (Gu 2012), others, such as Machicek and Beach (2013), have considered it to be an agricultural settlement. Given the Tuchengzi's geographic location on the Northern border of the Zhao State, it seems unlikely that the site would have experienced as much conflict as sites near the Yellow River basin. This is due to the geographically separation from the other Warring States. However, these interpretations create a false dichotomy, these interpretations are not mutually exclusive and negate other possible intentions for the establishment of Tuchengzi including that of Tuntian.

The system of tuntian originated during the Han dynasty under the direction of Emperor Wu (Elvin 1973: 37). The policy began as a means to protect borders and produce agricultural products for the government. Military personnel and civilians were sent to uninhabited frontier land to establish settlements and grow crops. This provided the region with protection of stationed troops and made them remotely self-sufficient by growing their own food (Sines 2002). This system of tuntian was later expanded to include non-frontier regions as a means to increase government-controlled grain production (Elvin 1973: 37). The possibility exists that Tuchengzi was established as a proto-tuntian site. This would have been beneficial to the Zhao State, as it would create a self-sufficient means of occupying and defending territory that may have been recently acquired.

During this period large defensive walls called the Great Wall of Zhao were constructed to protect the state. Construction of rammed earth defensive walls in this region began in 307 BCE (Pingfang 2005). While this wall does not resemble the Great Wall with which we are familiar today, it served the same purpose of protecting the southern Chinese State from northern groups. It is possible that Tuchengzi was established as part of the defensive Great Wall system.

The site itself was occupied between the Warring States period and the Liao Dynasty (ending 1125 CE). Unfortunately due to the lack of absolute dating, no precise dates could be established. But the human skeletal remains analyzed in this study should be immigrants (or the descendants of immigrants) from the central part of the Zhao State, which originally covered parts of modern southern Inner Mongolia as well as Hebei, Shanxi and Shaanxi provinces.

Over time as people migrated from the north it became a more ethnically diverse community. This process began during the Han Dynasty (221 CE) and by the start of the Tang Dynasty (600 CE) the site was very mixed. This is based both on archaeological discoveries, and the historic record. This study does not involve those later human remains.

Agricultural production at the site of Tuchengzi focused primarily on millet, a C4 plant (Gu 2012). Both palaeobotanical and stable isotope analyses are consistent with

high C4 plant consumption at Tuchengzi. Irrigation does not appear in the region until approximately a century after the Warring States period during the reign of Han Wudi in the Han Dynasty (140-87 BCE) (Woodworth and Du 2011). Since there is very limited information published about Tuchengzi itself, information about the region will be used to supplement missing information regarding diet.

While palaeobotanical data from Tuchengzi is limited, the main plant domesticates in the region were foxtail and broomcorn millet. Agricultural tools have been recovered during excavation as well as remains of domesticated pigs and chickens (Nei 1989 cited in Machicek and Beach 2013). Inhabitants of Tuchengzi may have supplemented their diets with non-domesticated edible plants. The Book of Songs composed during the Spring and Autumn period identifies 55 different edible plant species (both cultivated and wild) used at this time (translated in Waley, 1987), with edible plants in the region consisting of Chinese cabbage, mallow (*Malva parviflora*), jujubes (*Ziziphus jujubes*), sow thistle (*Sonchus*), and dandelion-like plants, among others.

3.3. Recovered Human Remains

For the purpose of this study both cranial and post-cranial remains (N=64) were examined. The sample was limited to 64 individuals as these were the remains that could be reliably aged, and sexed for analysis. The Tuchengzi collection consists of 385 excavated burials (all dates at Tuchengzi are based on relative dating) between the Warring States period (475 BCE) and the Liao Dynasty (1125 CE). For this study, the focus will be on remains from the Warring States period (475-221 BCE) and Han Dynasty (206 BCE-220 CE) with the following considerations. Firstly, the sample sizes of the remains from the periods after the Han Dynasty are too small for statistical comparison (14 males and 0 females in total). Secondly, the Warring States period and Han Dynasty represent, as discussed above, two very different cultural landscapes that can be compared with respect to the impact of political and social unrest on health. The sample from Tuchengzi consists of 35 males and 16 females from the Warring States period, and 10 males and 1 female from the Han Dynasty occupation (for a total of 61

31

individuals). Further information regarding the archaeological background of Tuchengzi is available in Gu (2012).

Comparative stature data from this study come from published raw metrics from Chinese sites from the Neolithic and Han Dynasty. These data were collected in the spring of 2012 as part of my Honours Thesis (Hardy 2012). This study found a trend of increased stature during the Han Dynasty. The data are representative of 15 sites between the Neolithic and Han Dynasty (Fig. 3-2). These sites are located throughout China, however they are primarily centered around the Yellow River region.

Figure 3-2   Macroregional map highlighting temporal and spatial map location of the sites used for stature comparison. Sites range between the Neolithic and the Han Dynasty.

3.4.   Methods

Analyses of all samples included a gross examination of all preserved skeletal elements. Any elements that were damaged to a point of hindering measurement or proper identification of non-metric traits were photographed, and recorded, but not entered in to SSPS for final analysis. All samples were re-examined based on records and photographs following return to SFU to avoid intraobserver error. A photographic record of all skeletal elements was taken using a Nikon D40 digital camera, with a Nikon 50 mm f/1.4 lens. To address inter-observer error 20 Dr. Deborah Merrett examined

randomly selected photographs and her observations for each sample were recorded. These observations were then compared with the original data collection forms and the observations matched in all cases.

3.4.1. *Age assessment*

The majority of age estimations were based on the Lovejoy (1985) dental attrition method for aging individuals. In individuals with incomplete epiphyseal fusion, age was determined using both epiphyseal fusion (Buikstra and Ubelaker 1994: 40-43; White *et al.* 2012: 391), and Ubelaker's age assessments based on dental development (1989). Lovejoy's method of adult age assessment based on dental attrition may not be the most accurate method for age assessment (Lovejoy 1985) as it can be confounded by cultural practices and diet; unfortunately, the availability of skeletal elements necessitated us applying this method. With the exception of individual M5, no skeletal remains were associated with pelvis, auricular surfaces (Lovejoy *et al.* 1985; Meindl and Lovejoy 1989: 165), pubic symphyses (Brooks and Suchey 1990) or ribs (DiGangi *et al.* 2009; Kunos *et al.* 1999; Paine and Brenton 2006; Rios and Cardoso 2009) all of which can potentially provide more accurate age estimations. Age was the divided into the three categories: YA17-24, MA24-39, and OA40+. These age groupings were selected due to the size and nature of the sample.

3.4.2. *Sex assessment*

Sex estimation was based on cranial sex estimation, a qualitative method based on sexually dimorphic cranial features developed by Walker in Buikstra and Ubelaker (in Buikstra and Ubelaker 1994: 20), later revised by Walker (2008). The method uses (when available) four cranial traits scored in a 1 to 5 scoring system: 1 = hyper feminine, 2 = feminine, 3 = indeterminate, 4 = masculine, 5 = hypermasculine. The five cranial traits measured are the nuchal crest, mastoid process, supraorbital ridge (glabella), and the mental eminence of the mandible. This method, as with age assessment, was used due to a lack of other more informative bones such as innominate in the collection. The innominate bone provides a much more accurate method of sex assessment, however with the exception of individual M309 no skeletal remains retained the subpubic region needed for the Phenice method (Phenice 1969).Non-specific Indicators of Stress

Non-specific indicators of stress provide a quantifiable measurement of the amount of stress experienced by a population during a given time period which can be compared temporally. In this study non-specific indicators of are represented by stature and enamel hypoplasia.

3.4.3.   *Stature and Long Bone Measurement*

Long bone measurement was based on Moore-Jansen *et al.* (1994) method developed from forensic data. For the purpose of this research only maximum long bone lengths were recorded. Long bones that had been damaged post-mortem to the point where it would skew femur length results were not recorded. Individuals with healed ante-mortem fractures were recorded but were not used for comparative purposes, as they do not represent the individual's natural length. Femur length was recorded in CM as they are frequently used in stature estimation formulae. To limit intraobserver error all measurements were taken twice using the osteometric board provided by JLU.

Table 3-1   Samples used for temporal comparison of female right femur length between the Neolithic and Han Dynasty. For site locations please refer to Fig. 3-2.

Period	Date	All Other Samples (n)	Tuchengzi Sample (n)
Neolithic [a,b,c]	8500-1500 BCE	7	0
Early Bronze Age [d,e,f]	1499-771 BCE	37	0
Spring and Autumn/ Warring States [g,h,i]	770-221 BCE	21	15
Han Dynasty [j,k,f]	202BCE-220 CE	130	1
Total:		195	16

Note: a) Institute of Cultural Relics in Henan Province 2010; b) Fajun 2008; c) Kangxin and Qinfeng 1982; d) Qinfeng 1990; e) Qinfeng 2000; f) Archaeology and Cultural Relics 1985; g) Kangxin and Xinlin 1996; h) Kangxin and Jingze 2003; i) Zhang 2005; j) Han 2006; and k) Zhang 2009.

Table 3-2   Samples used for temporal comparison of male right femur length between the Neolithic and Han Dynasty. For site locations please refer to Fig. 3-2.

Period	Date	All Other Samples(n)	Tuchengzi Sample (n)
Neolithic [a,b,c,b,e]	8500-1500 BCE	36	0
Early Bronze Age [f,g,h,i]	1499-771 BCE	56	0
Spring and Autumn/ Warring States [j,k,l,m]	770-221 BCE	39	35
Han Dynasty [n,o,h]	202BCE-220 CE	144	10
Total:		265	45

Note: a) Yan *et al.,* 1960; b) Institute of Cultural Relics in Henan Province, 2010; c) Fajun, 2008; d) Kangxin and Qinfeng, 1982; e) Qinfeng, 1998; f) Qinfeng, 1990; g) Qinfeng, 2000; h) Archaeology and Cultural Relics, 1985; i) Jianing, 2001; j) Kangxin and Xinlin, 1996; k) Kangxin and Jingze, 2003; l) Xinmei and Jian'an, 1988; m) Zhang, 2005; n) Han, 2006 and o) Zhang, 2009.

3.4.4.   *Enamel Hypoplasia*

EH presence was recorded for all incisors and canine teeth. Presence or absence was recorded on the dental inventory sheet for each tooth individually. The number of linear hypoplasia present was recorded along with the number hypoplasiac lines per tooth following the methods of Buikstra and Ubelaker (1994) and Goodman *et al.* (1980).

3.5.   Palaeopathological analysis

Palaeopathological analysis with in the population will be discussed in 3 separate sections (excluding non-specific indicators of stress). Oral health will be discussed, followed by non-metric traits (septal apertures), and pathology, including trauma and spinal lesions. These will be analyzed for prevalence in both age and sex. While a variety of data were collected for each condition, for the purposes of this study analysis will be limited to strictly prevalence, not severity or location.

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3.6. Oral Health

3.6.1. *Caries*

The method for recording dental caries was proposed by Moore and Corbett (1971) and outlined in Buikstra and Ubelaker (1994: 54). Seven categories of caries are used to classify stages of cariogenic development (Table 3-3).

Table 3-3 **Classification criteria for caries used in the study ranging from no carious lesions present to large caries.**

Classification: Caries		
0	No lesion present	
1	Occlusal surface	All caries on occusal surface of molars
2	Interproximal Surfaces	Mesial and distal cervical caries
3	Smooth surfaces	Labial and lingual caries on smooth surface of teeth
4	Cervical caries	Caries at cement-enamel junction (CEJ) (except interproximal regions)
5	Root caries	Below the CEJ
6	Large caries	Caries that have destroyed so much of tooth origin cannot be assigned

3.6.2. *Abscessing*

Abscesses were recorded using the methods described in Buikstra and Ubelaker (1994: 55). Abscesses were recorded with presence and location. "1" was used to indicate buccal abscess and "2" was used to denote a lingual abscess. "0" was used in the absence of abscess.

3.6.3. *Antemortem Tooth Loss*

AMTL was recorded as part of the large dental inventory. AMTL was recorded as "4" in the dental inventory, indicating that the tooth is missing with partial or complete alveolar resorption. Cases where the alveolar bone is missing were recorded as "3". Teeth missing with no alveolar resorption, indicating the tooth was last post-mortem,

were recorded as "6", and neither were considered AMTL. This follows Buikstra and Ubelaker's categories of dental inventory (1994: 49).

3.7.   Nonmetric Traits

Non-metric trait analysis has been limited to prevalence of septal aperture, as its presence in the population was most apparent during data collection.

3.7.1.   *Septal Aperture*

SA is easily identified as an opening between the olecranon and coronoid fossae. It was recorded as "0" for absence and "1" for presence (White *et al* 2012: 184).

3.8   Pathology

3.8.1   *Trauma*

Following Lovell's definition, trauma is defined as injury to living tissue caused by force or mechanism extrinsic to the body" (1998). Trauma was recorded using the method proposed in White *et al.* 2012, antemortem trauma and perimortem trauma were recorded on data collection sheets, and "1" presence and a "0" for absence were used for SPSS analysis. The location of trauma, the type of trauma, and the level of healing were also recorded (Maples (1986) cited in White *et al.* 2012: 354). All bone surfaces were examined carefully and all examples of trauma were recorded and photographed for possible further analysis.

3.8.2.   *Spinal Lesions*

Few vertebral elements were collected in the Tuchengzi sample but those curated at JLU were primarily pathological. All lesions were recorded and photographed. Only individuals with a minimum of two fused vertebral bodies were selected for this analysis. Lesions were identified and they were then compared with Waldron's (2009: 58) differential diagnosis for AS and DISH.

3.9. Statistical Methods

This study employs two separate statistic methods to examine health at the site, and temporal stature trends in China. Stature trends are examined using an ANOVA test, where as population health at Tuchengzi during the Warring States period is analyzed using a Chi-Squared analysis. Preferably health at Tuchengzi would have been compared between the Warring States Period and Han Dynasty, but due to the nature of the sample this was not possible.

Stature trends were analyzed statistically using raw femur lengths as a proxy for stature. This method was chosen in lieu of comparing estimated stature to avoid the addition of unnecessary biases. Research has shown that femur lengths are sufficiently synchronized with stature estimations and can be used to examine temporal stature trends (Albanese 2010). Temporal stature trends were analyzed using femoral length samples for both females and males ranging between the Neolithic and Han Dynasty. These samples were analyzed independently and in comparison using univariate tests (ANOVA). These univariate tests employed multiple comparisons, with a 99% confidence and a Bonferroni's correction due to the nature of the sample. Discussion of stature trends will be done using stature estimations, as they prove easier for readers to conceptualize the trends the nature of stature changes through time. Chinese specific stature estimation formulae developed by Shao (1985) (males: 3.66(Femur)+5±5; females: 3.77(Femur)+5±5) were applied to the means from each time period (1985) for ease of comprehension, however estimations were not used for statistical testing.

For the purposes of examining population health during the Warring States Period the study employs Chi-Squared (χ^2) analysis to compare age and sex with all recorded pathological conditions. Fisher's Exact Test was used in association with the Chi Square test because of the relatively low sample size from the Tuchengzi Warring States period (Table 3-4).

Table 3-4   Tuchengzi sample age and sex distribution.

Tuchengzi Age Sample		Tuchengzi Sex Sample	
YA17-24	16	Female	16
MA25-39	36	Male	48
OA40+	11		
Total	63	Total	64

Chapter 4.   Results

This chapter reports results from the statistical examination of several markers of health and stress at Tuchengzi. These markers include non-specific indicators of stress, dental health, joint disease and their impacts on archaeological population of the Tuchengzi site.

4.1.   Demography

Demography
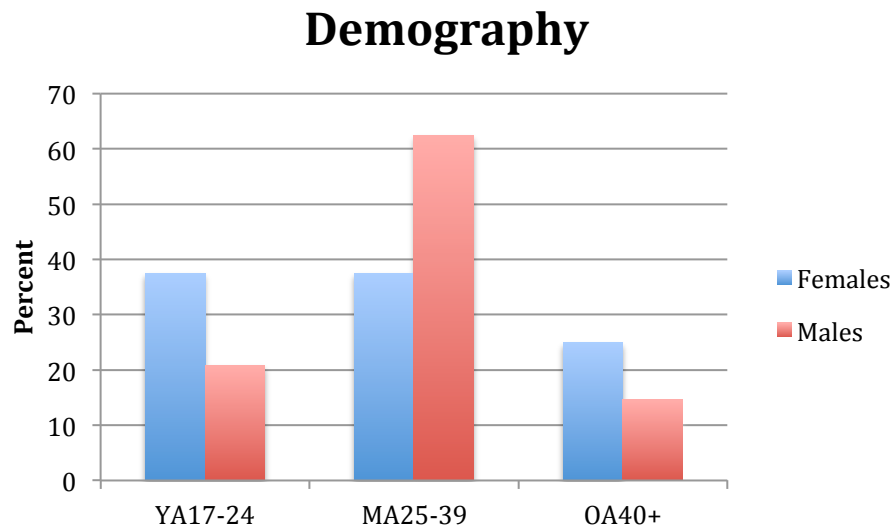
Figure 4-1   Age at death profile of Tuchengzi.

Table 4-1   Percentage of individuals in each age at death category.

Sex	YA17-24	MA25-39	OA40+	Total N
Females	37.5% (6)	37.5% (6)	25% (4)	100% (16)
Males	20.8% (10)	62.5% (30)	14.6% (7)	97.9% (47)

The age at death breakdown of the Tuchengzi population highlights the difference between male and female age at death. Female age at death is similar for both the young adult (37.5%) and middle adult (37.5%) categories, with a decline in the older adult category (25%) (Table 4-1; Figure 4-1). Male age at death appears to peak during the middle adult (62.5%) category, with young (20.8%) and older adult (14.6%)

being considerably lower (Table 4-1; Fig. 4-1). One male individual could not be aged resulting in the age based male sample adding up to 97.9% of the total sample.

4.2. Non-Specific Indicators of Stress: Stature

The mean femur length of female is 39.55 cm (std deviation 3.1) while the mean femur length for males is 3.89 cm longer with mean length at 43.44 cm (std deviation 1.50) (Table 4-2). Variability in femur length appears much higher in females with a standard deviation of 3.1 versus a uniform 1.5 in males (Table 4-2). When compared with other time periods, there seems to be an increase in femur length in the Han dynasty males with mean femur length at 44.02 cm, though standard deviation is higher in the Han sample at 2.91 (Table 4-3). Using Chinese specific stature estimation formulae for males and females, sexual dimorphism becomes more apparent with an approximately 10 cm difference between males and females (Shao 1985). Female stature is estimated to be 154.11±5 cm while male stature is estimated to be 163.99±5 cm (Table 4-2). An increase of 2.12 cm of mean male stature can be observed between the Warring States period and Han Dynasty. Han Dynasty male stature is estimated to be 166.11±5cm (Table 4-3).

Table 4-2   Mean right femur lengths of the Tuchengzi Warring States remains.

Sex	Mean (cm)	n	Std. Deviation	Stature Est.
Female	39.55	13	3.10	154.10
Male	43.44	36	1.50	163.99

Table 4-3   Mean right femur lengths of the Tuchengzi Han Dynasty remains.

Sex	Mean (cm)	n	Std. Deviation	Stature Est.
Female	42.20	1	0.00	164.10
Male	44.02	10	2.91	166.11

Mean femur length for ancient Chinese females follows an interesting pattern: 41.57 cm (std. deviation 1.91) for Neolithic, 40.54 cm (std. deviation 2.26) for Early Bronze Age, 40.69 cm (std. deviation 1.1) for Spring and Autumn/Warring States Period, 41.01 cm (std. deviation 1.9) for Han Dynasty (Table 4-4). Alternatively the male femur

length shows a steady increase from the Neolithic to Han Dynasty: 43.40 cm (std. deviation 2.77) for Neolithic, 43.60 cm (std. deviation 1.78) for Early Bronze Age, 43.69 cm (std. deviation 1.65) for Spring and Autumn/Warring States period, 45.15 cm (std. deviation 2.3) for Han Dynasty (Table 4-5).

Using Chinese specific stature estimation formulae (Shao 1985) for males and females to examine sexual dimorphism of archaeological skeletal remains (excluding Tuchengzi), a trend towards an increased sexual dimorphism is visible (Table 4-4; Table 4-5). The most dimorphic period is the Han Dynasty with a 10.64 cm difference of mean stature between males and females (Table 4-4; Table 4-5) with the least dimorphic time being the Neolithic with a difference of 1.76 cm (Table 4-4; Table 4-5).

Table 4-4 **Mean length of female right femora of ancient skeletal remains from other archaeological sites.**

Period	Date	(n)	Mean (cm)	S.D.	Stature Est.
Neolithic [a,b,c]	8500-1500 BCE	7	41.57	1.91	161.72
Early Bronze Age [d,e,f]	1499-771 BCE	43	40.54	2.26	157.84
Spring and Autumn/ Warring States [g,h,i]	770-221 BCE	15	40.69	1.10	158.40
Han Dynasty [j,o,k]	202 BCE-220 CE	130	41.01	1.90	159.61
Total:		195			

Note: a) Institute of Cultural Relics in Henan Province 2010; b) Fajun 2008; c) Kangxin and Qinfeng 1982; d) Qinfeng 1990; e) Qinfeng 2000; f) Archaeology and Cultural Relics 1985; g) Kangxin and Xinlin 1996; h) Kangxin and Jingze 2003; i) Zhang 2005; j) Han 2006; and k) Zhang 2009

When stature is examined between different periods of ancient China a temporal trend can be detected. From the Neolithic to the Bronze Age, female stature decreases by 3.88 cm. A trend towards a steady increase is also visible following the Bronze Age with a 0.56 cm increase during the Spring and Autumn/Warring States period. For skeletal remains from other Chinese archaeological sites (excluding Tuchengzi) an increase of 1.21cm in mean stature can be identified between the Spring and Autumn/Warring States and Han Dynasty (Table 4-4; Fig. 4-2). While this is the largest

increase in stature, none of the changes in female femur length (as a proxy for stature) between time intervals are statistically significant ($F=0.954$, $df=3$, $p=0.416$)(Table 4-6). When using Bonferroni's correction for multiple comparisons the relationships are not significantly different with all comparisons between all time intervals having a probability of 1.00 (Table 4-7). At Tuchengzi a similar trend can be seen in female stature with an increase of 10 cm between Warring States and Han Dynasty females, though this may not be a meaningful comparison as the Han Dynasty sample is only one individual (Table 4-2; Table 4-3; Fig. 4-2). While this is a large increase in stature, and in femur length the difference is not statistically significant ($F=0.966$, $df=1$, $p=0.342$)(Table 4-6).

Table 4-5   **Mean length of male right femur of human skeletal remains from other archaeological sites.**

Period	Date	(n)	Mean (cm)	S.D.	Stature Est.
Neolithic [a,b,c,d,e]	8500-1500 BCE	36	43.30	2.77	163.48
Early Bronze Age [f,g,h,i]	1499-771 BCE	56	43.60	1.78	164.58
Spring and Autumn/ Warring States [j,k,l,m]	770-221 BCE	29	43.69	1.65	164.91
Han Dynasty [n,o,h]	202 BCE-220 CE	144	45.15	2.30	170.25
Total:		265			

Note: a) Yan *et al.* 1960; b) Institute of Cultural Relics in Henan Province 2010; c) Fajun 2008; d) Kangxin and Qinfeng 1982; e) Qinfeng 1998; f) Qinfeng 1990; g) Qinfeng 2000; h) Archaeology and Cultural Relics 1985; i) Jianing 2001; j) Kangxin and Xinlin 1996; k) Kangxin and Jingze 2003; l) Xinmei and Jian'an 1988; m) Zhang 2005; n) Han 2006; and o) Zhang 2009

Unlike female stature at Chinese sites (excluding Tuchnegzi) there is no decrease in male stature following the Neolithic period. Male stature remains relatively static increasing only 1.43cm between the Neolithic and the Spring and Autumn/Warring States period. However during the Han Dynasty a large increase of 5.34cm in mean stature is visible (Table 4-5; Fig. 4-3). The increase in stature between the Neolithic and Han Dynasty is statistically significant ($F=12.407$, $df=3$, $p=0.000$)(Table 4-6).   When using Bonferroni's correction for multiple comparisons these relationships appear in

higher resolution. There is no significant difference between femur lengths during the Neolithic, Early Bronze Age, and Spring and Autumn/Warring States Period (p=1.00)(Table 4-8). Han Dynasty femur length however is statistically different than all previous periods: 8500-1500BCE mean diff.=1.85, std. error 0.40, p=0.000, 1500-771 BCE mean diff.=1.55, std. error=0.34, p=0.000, 771-221 BCE mean diff.=1.46, std. error=0.44, p=0.007)(Table 4-8). Tuchengzi follows a similar trend between these periods though the increase in stature is a less drastic 2.12cm (Table 4-2; Table 4-2; Fig. 4-3). This difference is however not statistically significant (F=1.16, df=1, p=0.287)(Table 4-6).
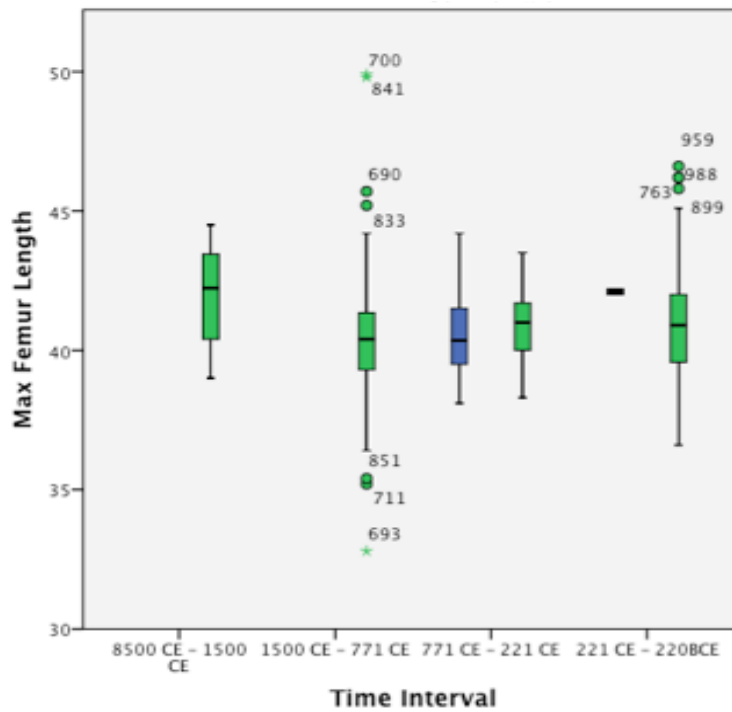
Figure 4-2   Temporal trend of female stature change: Tuchengzi (blue), and other Chinese sites (green). A sharp decrease in stature is visible following the Neolithic (8500-1500 BCE), however stature begins to rebound, with an increase following the Warring States period (771-221 BCE). Femur length at Tuchengzi follows a similar trend with a large increase in the Han Dynasty (221 BCE-220 CE).
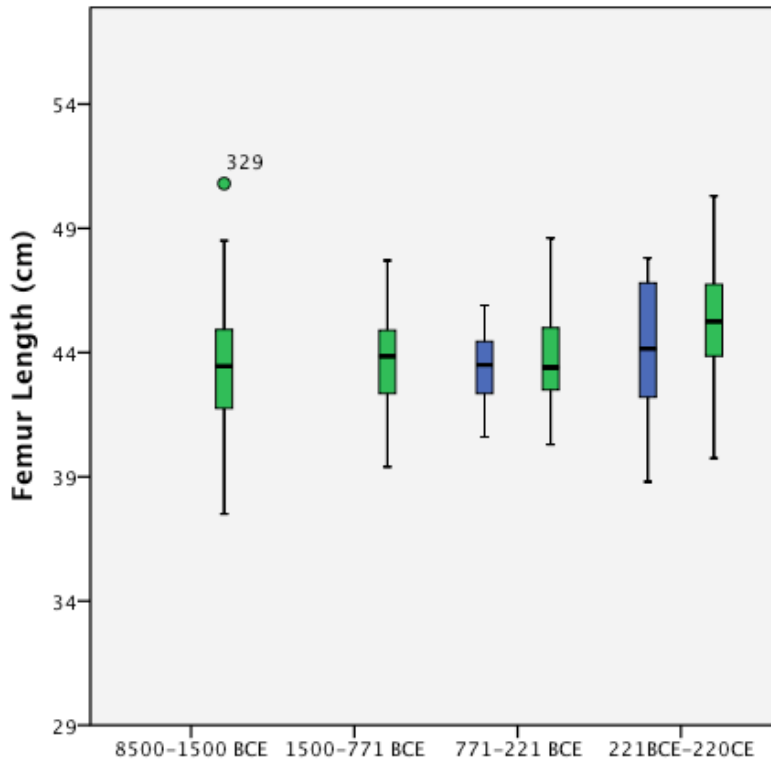
Figure 4-3   **Temporal trend of male stature change: Tuchengzi (blue), and other Chinese sites (green). An increase in stature following the Neolithic (8500-1500 BCE) is visible, with a significant increase in stature during the Han Dynasty (221 BCE-220 CE). Tuchengzi stature is shorter than the other Chinese sites.**

Table 4-6   **ANOVA results from right femur length comparisons**

ANOVA Test (Right Femur)	F	df	p
Tuchengzi Male: W.S. to Han	1.160	1	0.287
Tuchengzi Female: W.S. to Han	0.966	1	0.342
Chinese Sites Male: Neolithic to Han	12.407	3	0.000
Chinese Sites Female: Neolithic to Han	0.954	3	0.416

Table 4-7   ANOVA Post-Hoc Bonferroni correction results for female right femur (Non-Tuchengzi Sites)

Time Interval (1)	Time Interval (2)	Mean Diff.	Std. Error	p
8500-1500 BCE	1500-771 BCE	1.03	0.79	1.000
	771-221 BCE	0.88	0.89	1.000
	221BCE-220 CE	0.57	0.75	1.000
1500-771 BCE	8500-1500BCE	-1.03	0.79	1.000
	771-221 BCE	-0.15	0.58	1.000
	221BCE-220 CE	-0.46	0.34	1.000
771-221 BCE	8500-1500BCE	-0.88	0.89	1.000
	1500-771 BCE	0.15	0.58	1.000
	221BCE-220 CE	-0.31	0.53	1.000
221BCE-220 CE	8500-1500BCE	-0.57	0.75	1.000
	1500-771 BCE	0.46	0.34	1.000
	771-221 BCE	0.31	0.53	1.000

Table 4-8   ANOVA Post-Hoc Bonferroni correction results for male right femur (Non-Tuchengzi Sites).

Time Interval (1)	Time Interval (2)	Mean Diff.	Std. Error	p
8500-1500 BCE	1500-771 BCE	-0.30	0.46	1.000
	771-221 BCE	-0.39	0.54	1.000
	221BCE-220 CE	-1.85	0.40	0.000
1500-771 BCE	8500-1500 BCE	0.300	0.46	1.000
	771-221 BCE	-0.09	0.46	1.000
	221BCE-220 CE	-1.55	0.34	0.000
771-221 BCE	8500-1500 BCE	0.39	0.55	1.000
	1500-771 BCE	0.09	0.50	1.000
	221BCE-220 CE	-1.46	0.44	0.007
221BCE-220CE	8500-1500 BCE	1.85	0.40	0.000
	1500-771 BCE	1.55	0.34	0.000
	771-221 BCE	1.46	0.44	0.007

4.3.   Population prevalence of pathology

The overall prevalence of pathology and non-specific indicators of stress at Tuchengzi provide information regarding genetic predisposition to different conditions, as well as diet, and exposure to stressors. Enamel hypoplasia is visible in 39.7% (25 of 63) of people at the site. For dental pathology caries are visible in 61.9% (39 of 63), abscessing in 28.6% (18 of 63), and AMTL in 42.9% (27 of 63) of the population. Non-metric trait SA is visible in 13.4% (7 of 63) of the population. Trauma and spinal lesions are both visible in 4.8% (3 of 63) of individuals at Tuchengzi. These prevalences will be examined in further detail by analyzing by age and sex below. But, firstly the types of trauma visible within the Tuchengzi population will be examined to further contextualize their analysis.

4.3.1. *Traumatic injuries visible in the Tuchengzi population*

Trauma patterns can inform researchers about behaviour and lifestyle of past cultures (Judd 2004). Three types of trauma are visible at Tuchengzi: perimortem sharp force trauma, linear, and an impact fracture.

Two examples of cranial trauma are visible at Tuchengzi. The first is exhibited in individual M357, a 24-30 year old male featuring perimortem direct trauma to the occipital bone as the result of a projectile point. Although the projectile point is no longer embedded in the occipital bone the trauma matched the distinct shape and size of a warring states period arrow (Gu 2012: 162). No healing is visible in the wound, as would be expected from a fatal projectile point impact (Fig. 4-4) (Berryman and Symes 1998; Steadman 2008).

Figure 4-4   Posterior view of cranium of individual M357 with the projectile trauma to the occipital bone (black arrow).

Individual M89, also a male aged 24-39, features a healed linear fracture on the posterior portion of the right parietal. The lesion is completely healed. It is approximately 3cm long by 1cm wide. The healed bone is the same colour as the surrounding osteous tissue, with the exception of a half circle of greyish discolouration. Whether the

discolouration is taphonomic or the result of healing cannot be determined. Whether the traumatic injury was accidental or resulted from interpersonal conflict also cannot be determined (Fig. 4-5).

Figure 4-5   Cranium of individual M89 with a large healed traumatic injury to the right parietal bone (white arrows).

One example of long bone trauma is visible at the site in individual M338, a 20-24 year old female. The trauma is a fully healed impacted fracture to the proximal humerus. The head of the humerus has been displaced distally and head has been angled to face more superiorly. These fractures frequently occur when falling backward onto an outstretched hand (Fig. 4-6) (Lovell 1997).

Figure 4-6   Right humerus of individual M338 highlighting a fully healed impact fracture to the proximal humerus that resulted in displacement of the humeral head (white arrows). This fracture likely had years to heal as no callus is visible on the bone.

4.4. Results by Age

4.4.1. *Nonspecific Indicators of Stress and Age: Enamel Hypoplasia*

Prevalence

Figure 4-7   **Bar graphs showing the prevalence of EH in the Tuchengzi population divided into the three age groups YA17-24, MA25-39, and OA40+. The graph highlights the decreased prevalence with increased age.**

Table 4-9   **Prevalence of enamel hypoplasia by age group.**

	YA n (%)	MA n (%)	OA n (%)	Total N (%)	x^2	df	p	Exact p
EH	9 (56.3)	12 (33.3)	4 (36.4)	25 (39.7)	2.492	2	0.288	0.246
Total (n)	16	36	11	63				

Table 4-9 shows the prevalence of enamel hypoplasia in the Tuchengzi population during the Warring States Period. There is a pattern of decreasing enamel hypoplasia prevalence with age (Fig. 4-7). Total prevalence of enamel hypoplasia in the Tuchengzi population is 39.7%. (25 of 63) (Table 4-9; Fig. 4-7). Chi square test indicates

there is no significant difference between these groups (χ^2 = 2.492, df-2, p=0.288; Fisher's Exact (2 Sided) p= 0.246) (Table 4-9).

4.4.2.   *Oral health and Age: Caries, Abscessing, and AMTL*

Table 4-10 shows the prevalence of all dental pathologies (abscessing, AMTL, and caries) of the three age categories and total population prevalence. In general the table highlights a trend of increase in dental pathology prevalence as age increases. Descriptions of trends will be discussed below in more detail.

Table 4-10   Prevalence of oral pathologies by age group.

	YA n (%)	MA n (%)	OA n (%)	Total N (%)	x^2	df	p	p F. Exact
Caries	7 (43.8)	23 (63.9)	9 (81.8)	39 (61.9)	4.146	2	0.126	0.048
Abscessing	2 (12.5)	10 (27.8)	6 (54.5)	18 (28.6)	5.672	2	0.059	0.031
AMTL	4 (25.0)	15 (41.7)	8 (72.7)	27 (42.9)	6.112	2	0.047	0.017
Total (n)	16	36	11	63				

4.4.3.   *Caries*

Prevalence

Figure 4-8   **Bar graph showing the prevalence of caries in the Tuchengzi population divided into the three age groups YA17-24, MA25-39, and OA40+. Caries prevalence increases between the YA and MA groups, however there is an increase in OA group.**

Table 4-10 shows the prevalence of caries (1 of more per individual) in the Tuchengzi population during the Warring States Period. There is a trend of increasing caries prevalence with age (Fig. 4-8). One or more caries are visible in the dentition of 43.8% of young adults (17-24) (7 of 16). Prevalence increases with middle-aged adults (25-39) to 63.9% (23 of 36). Caries prevalence is the highest in older aged adults (40+) with 81.9% (9 of 11) of individuals in this category having one or more caries. Caries are the most common dental pathology with a total prevalence of caries at Tuchengzi of 61.9% (39 of 63) (Table 4-10; Fig. 4-8). There is a significant difference between caries prevalence in the three groups (χ^2 = 4.146, df-2, p=0.126; Fisher's Exact (2 sided) p= 0.048) (Table 4-10).

4.4.4. *Abscessing*
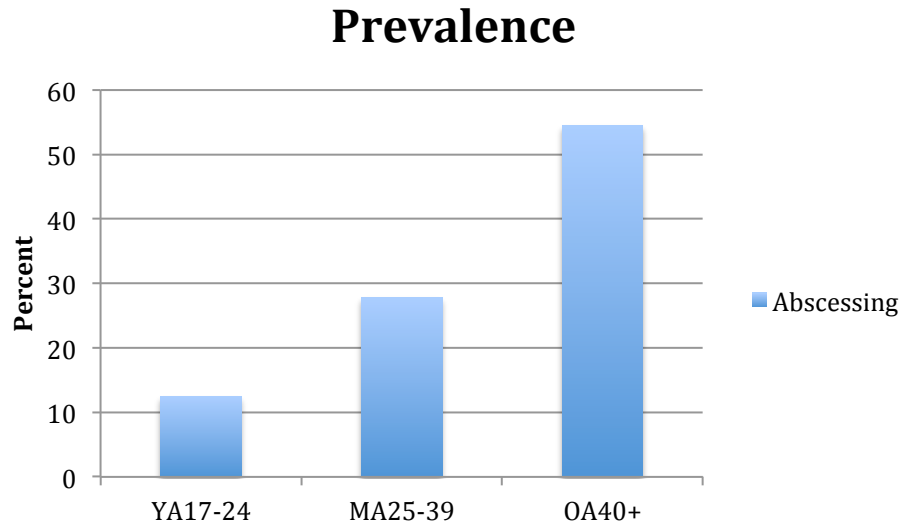
Prevalence

Figure 4-9 **Bar graph showing the prevalence of abscessing in the Tuchengzi population divided into the three age groups YA17-24, MA25-39, and OA40+. The increase in abscess prevalence with increased age is highlighted.**

Table 4-10 shows the prevalence of abscessing in the Tuchengzi population during the Warring States Period. There is a trend of increased abscess prevalence with increased age. In young adults 12.5% (17-24) (2 of 16) possessed one or more abscesses. This increases in middle-aged adults (25-39) to 27.8% (10 of 36). Abscessing prevalence is the highest in older aged adults (40+) with 54.5% (6 of 11). Total prevalence of abscesses at Tuchengzi is 28.6% (n=18) (Table 4-10; Fig. 4-9). This trend of increasing abscess prevalence is significant ($\chi^2 = 5.672$ df= 2 p=0.059; Fisher's Exact (2 sided) p=0.031) (Table 4-10).

4.4.5. *Antemortem Tooth Loss*
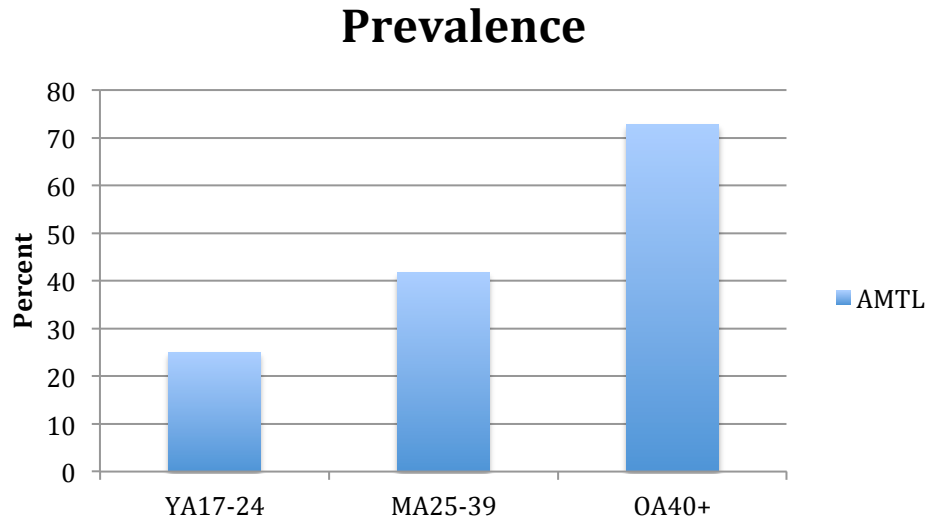
Prevalence

Figure 4-10 **Bar graph showing the prevalence of AMTL in the Tuchengzi population divided into the three age groups YA17-24, MA25-39, and OA40+. This highlights the increase in AMTL prevalence with increased age. There is a sharp increase in the OA40+ category.**

Table 4-10 illustrates the prevalence of AMTL in the Tuchengzi population. There is a trend of increased AMTL prevalence with increasing age (Fig. 4-10). Twenty five percent of young adults (17-24) (4 of 16) possessed one AMTL or more. Prevalence increases with middle-aged adults (25-39) to 41.7% (15 of 36). AMTL prevalence is highest in older aged adults (40+) with 72.7% (8 of 11). Total prevalence of AMTL at Tuchengzi is 42.9% (27 of 63) (Table 4-10; Fig. 4-10). There is a statistically significant difference between age categories when comparing the prevalence of AMTL (χ^2 = 6.112, df=2, p= 0.047; Fisher's Exact (2 sided) p= 0.017) (Table 4-10).

4.4.6. *Non-metric traits and Age: Spetal Aperture*
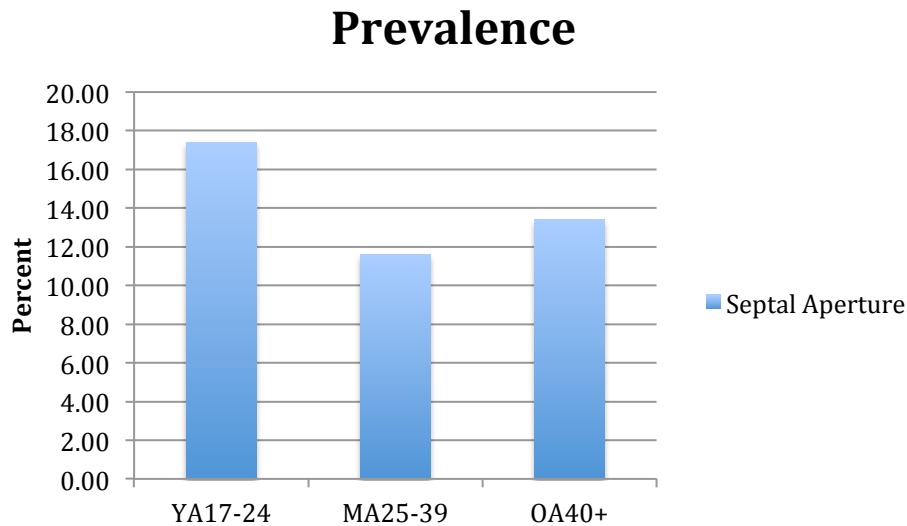
Prevalence

Figure 4-11 **Bar graph showing the prevalence of septal aperture in the Tuchengzi population divided in to the three age groups YA17-24, MA25-39, and OA40+. There is no visible trend in relation to septal aperture prevalence and age.**

Table 4-11 **Prevalence of septal aperture by age group.**

	YA n (%)	MA n (%)	OA n (%)	Total N (%)	x^2	df	p	F. Exact p
Septal Aperture	2 (17.4)	4 (11.6)	1 (13.3)	7 (13.4)	0.77	2	0.962	1.000
Total (n)	16	36	11	63				

Table 4-11 shows the prevalence of SA in the Tuchengzi population during the Warring States Period. There is no visible trend between SA prevalence and age categories (Fig. 4-11). SAs are visible in the olecranon fossa of the humerus in 17.4% of young adults (17-24) (2 of 16). Prevalence decreases in middle-aged adults (25-39) to 11.6% (4 of 36). SA prevalence in the total population at Tuchengzi population is 13.4%. (7 of 63) (Table 4-11; Fig. 4-11). Chi-square tests indicate no significant differences between these groups (χ^2 = 0.77, df-2, p=0.962; Fisher's Exact (2 sided) p=1.000)(Table 4-11).
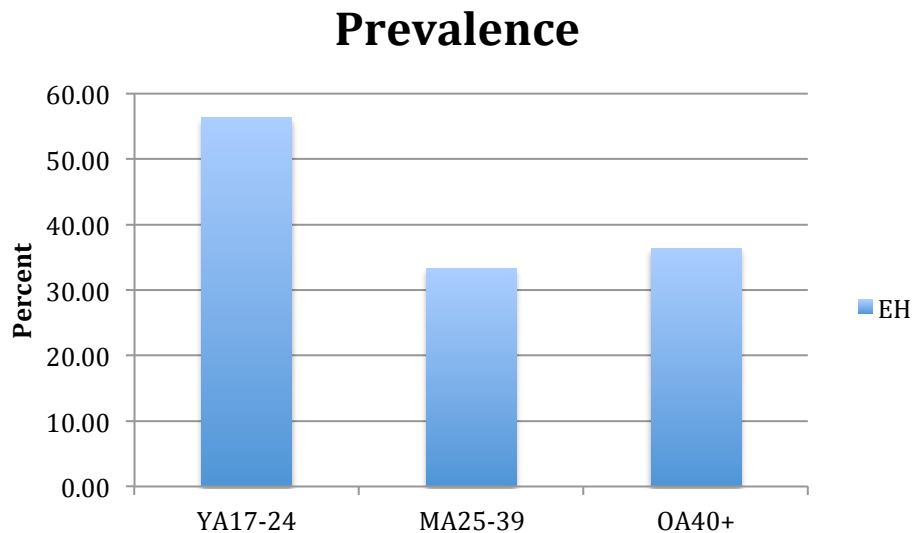
4.4.7.   *Trauma and Age*
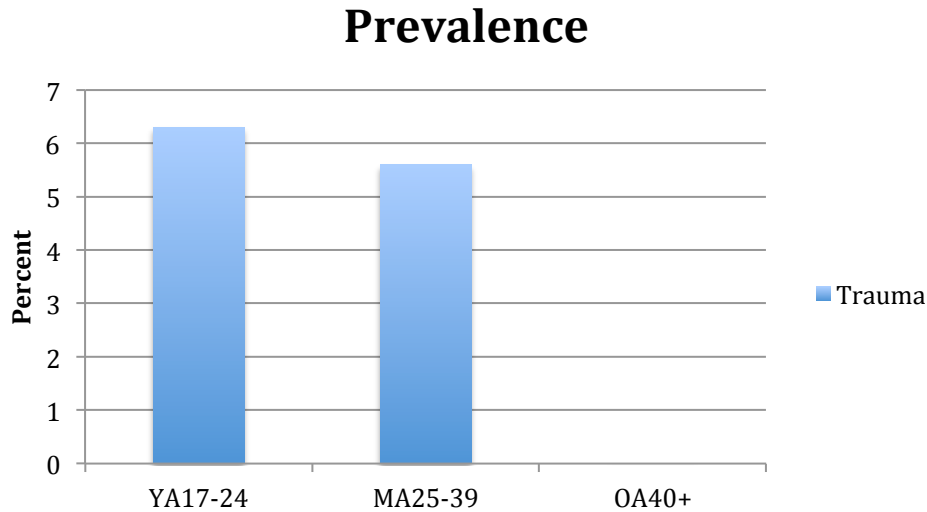
Prevalence

Figure 4-12   Bar graph showing the prevalence of trauma in the Tuchengzi population divided into the three age groups YA17-24, MA25-39, and OA40+. Trauma prevalence increases between YA and MA but decreases to zero in the OA group.

Table 4-12   Prevalence of trauma by age group.

	YA n (%)	MA n (%)	OA n (%)	Total N (%)	x^2	df	p
Trauma	1 (6.3)	2 (5.6)	0 (0.0)	3 (4.8)	0.678	2	0.712
Total (n)	16	36	11	63			

Table 4-12 illustrates the prevalence of traumatic injury (antemortem and perimortem) in the Warring States Tuchengzi population. Trauma decreases between young and middle age adults but is not present in older aged adults (Fig. 4-12). Trauma is visible in 6.3% of young adults (17-24) (1 of 16). Prevalence decreases in middle-aged adults (25-39) to 5.6% (2 of 36). No trauma is visible in older aged adults (40+), 0.0% (0 of 11) of individuals in this category. Trauma prevalence in the total Tuchengzi population is 4.8% (3 of 63) (Table 4-12; Fig. 4-12). There are no significant differences between the three age groups within this population (χ^2=0.678 df= 2 p=0.712) (Table 4-13).

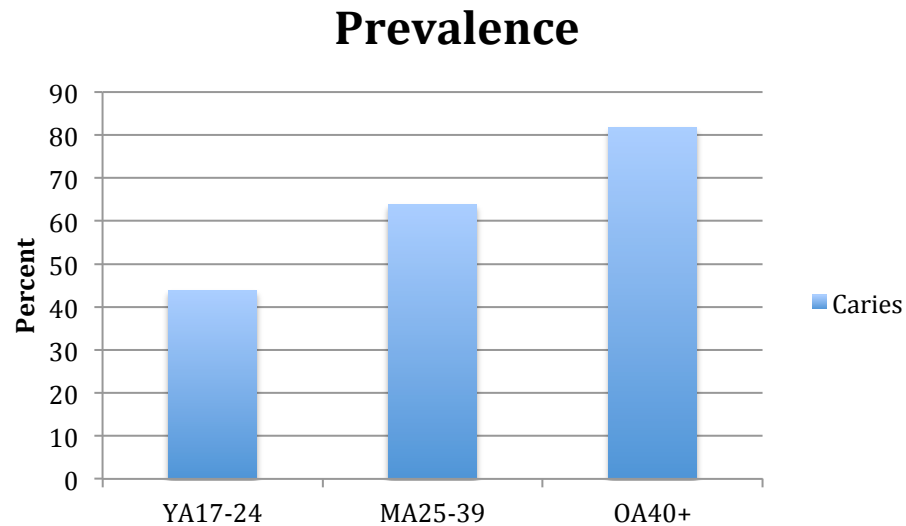### 4.4.8.   *Spinal Lesions and Age*
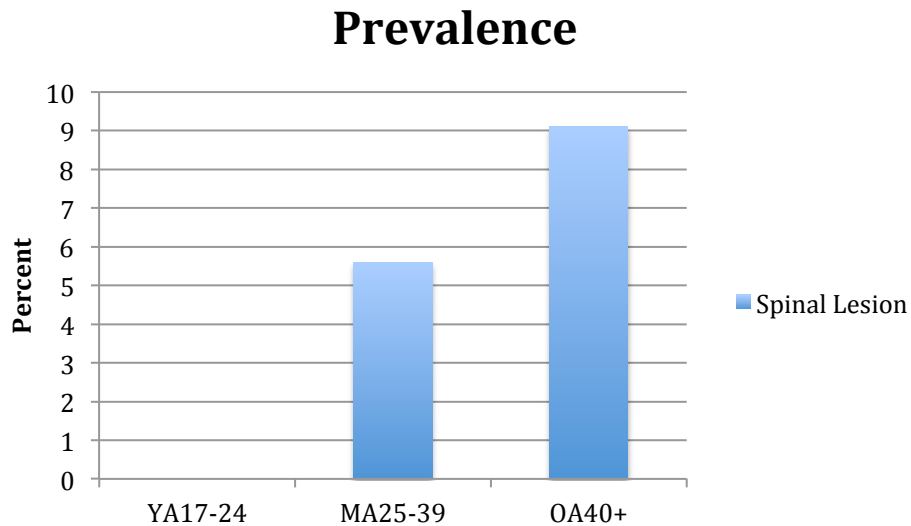
Prevalence

Figure 4-7   **Bar graph showing the prevalence of spinal lesions in the Tuchengzi population divided in to the three age groups YA17-24, MA25-39, and OA40+. This graph shows a trend towards increased spinal lesions with age.**

Table 4-13   **Prevalence of spinal lesions by age group**

	YA n (%)	MA n (%)	OA n (%)	Total N (%)	x^2	df	p	p F.Exact
Spinal Lesions	0 (0.0)	2 (5.6)	1(9.1)	3 (6.3)	1.305	2	0.521	0.263
Total (n)	16	36	11	63				

Table 4-13 shows the prevalence of spinal lesions (specifically the presence of one or more ossified zygapophyseal and intervertebral joints) in the Warring States Tuchengzi population. There is a visible trend between increased age and spinal lesion prevalence (Fig. 4-13). However, spinal lesion prevalence in the total population at Tuchengzi population is 4.8% (n=3) (Table 4-13; Fig. 4-13). There are no significant differences between these groups (χ^2 =1.305, df-2, p=0.521; Fisher's Exact (2 sided) p= 0.263) (Table 4-12).

4.5. Results by Sex

4.5.1. *Nonspecifc Indicators of Stress and Sex: Enamel Hypoplasia*
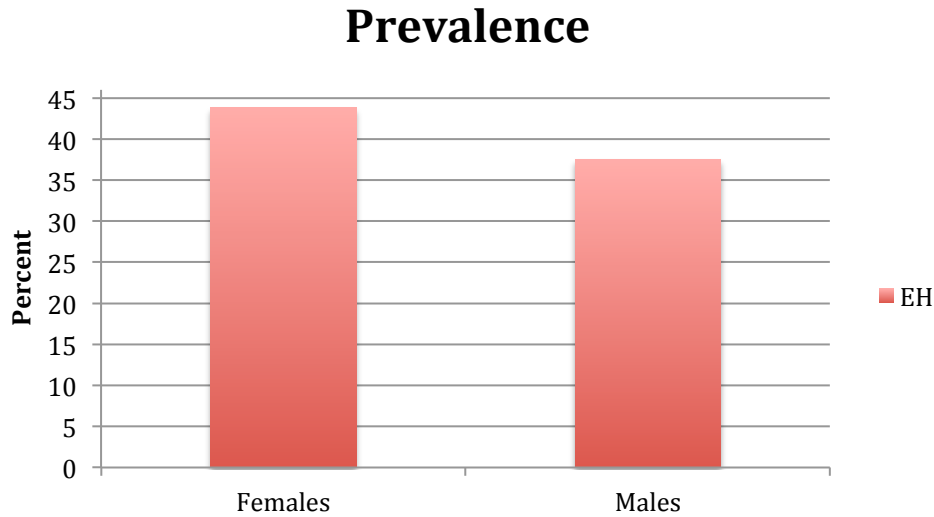
Prevalence

Figure 4-8   Bar graph showing the prevalence of EH in the Tuchengzi males and females. EH is more prevalent in females at Tuchengzi than males.

Table 4-14   Prevalence of enamel hypoplasia by sex

	F n (%)	M n (%)	x^2	df	p	p F. Exact
EH	7 (43.8)	18 (37.5)	0.197	1	0.657	0.77
Total (n)	16	48				

Table 4-14 shows the prevalence of EH in the Tuchengzi males and females. Of the nonspecific indicators of stress examined at Tuchengzi EH has the largest difference in prevalence with females being 7.4% higher than males. EH in females at Tuchengzi is 43.8% (7 of 16). Prevalence in males is lower, 37.5% (18 of 48)(Fig. 4-14). However, the difference in EH prevalence between these groups is not significant ((2 sided) p=0.770) (Table 4-14).

4.5.2. *Oral Health and Sex: Caries, Abscessing, and Antemortem Tooth Loss*

Table 4-15 **Prevalence of oral pathologies by sex**

	F n (%)	M n (%)	x^2	df	p	p F. Exact
Caries	9 (56.3)	30 (62.5)	0.197	1	0.657	0.770
Abscessing	5 (31.3)	13 (27.1)	1.030	1	0.748	0.756
AMTL	7 (43.8)	20 (41.7)	0.021	1	0.884	1.000
Total (n)	16	48				

Table 4-15 shows the prevalence of all dental pathologies (abscessing, AMTL, and caries) in Tuchengzi males and females during the Warring States period. In general the table highlights the similar prevalence of dental pathologies in male and female remains at Tuchengzi.

4.5.3.   *Caries*
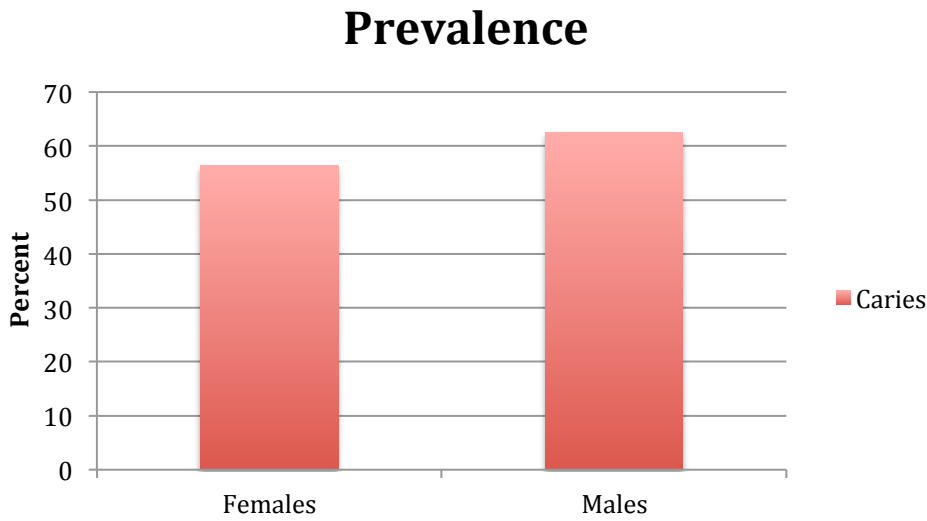
Prevalence

Figure 4-9   **Bar graph showing the prevalence of caries in the Tuchengzi males and females. Both males and females show a similar prevalence of caries.**

Table 4-15 shows the prevalence of caries (1 or more per individual) in the Tuchengzi males and females. Caries are the most prevalent dental pathology, but as with other dental pathologies the prevalence is relatively equal in both males and female. However, there is no significant difference between caries prevalence in males and females (χ^2 = 0.197, df 1, p=0.657; Fisher's Exact (2 sided) p= 0.770) (Table 4-15; Fig. 4-15).

4.5.4.   *Abscessing*
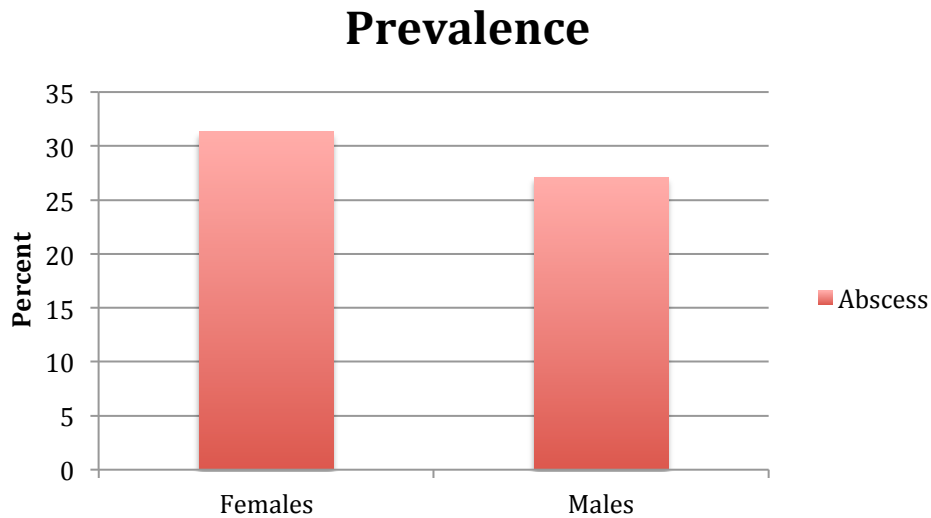
Prevalence

Figure 4-10   Bar graph showing the prevalence of abscessing in the Tuchengzi males and females. Both males and females have similar abscessing prevalence.

Table 4-15 shows the prevalence of abscessing (1 or more abscesses) in males and females in Tuchengzi population during the Warring States Period. Abscessing is visible in 31.3% of females (5 of 16). Abscess prevalence in males is slightly lower, at 27.1% (13 of 48) (Table 4-15; Fig. 4-16). Statistically there is no significant difference between abscessing in females and males (χ^2 = 1.030, df 1, p=0.748; Fisher's Exact (2 Sided) p= 0.756) (Table 4-15).

4.5.5. *Antemortem Tooth Loss*
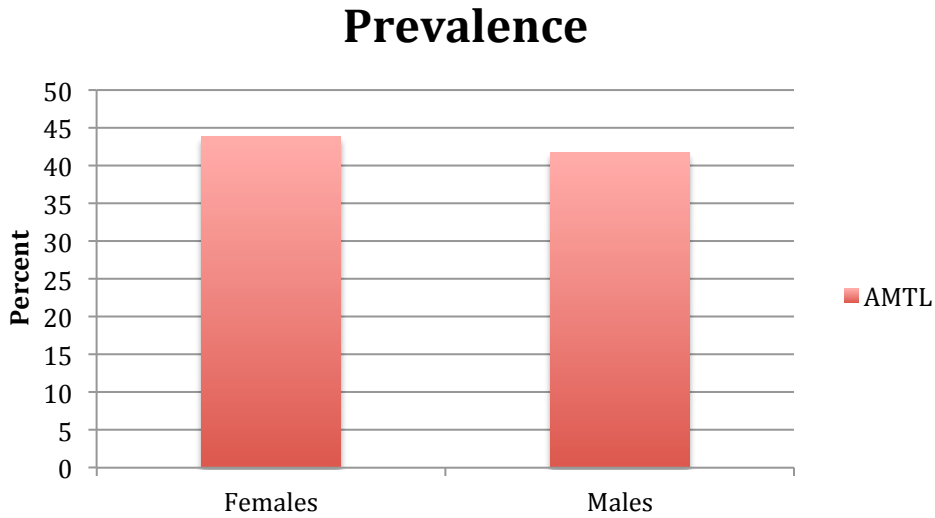
Prevalence

Figure 4-11 Bar graph showing the prevalence of AMTL in the Tuchengzi males and females. Both males and females show a similar prevalence of AMTL.

The prevalence of AMTL (1 or more per individual) in the Tuchengzi males and females is shown in Table 4-15. As with abscessing, AMTL prevalence is relatively equal in both males and female. There is no significant difference between AMTL in males and females within the Tuchengzi population (χ^2 = 0.021, df 1, p=0.884; Fisher's Exact p= 1.000) (Table 4-15; Fig. 4-17).

4.5.6. *Nonmetric Trait and Sex: Septal Aperture*
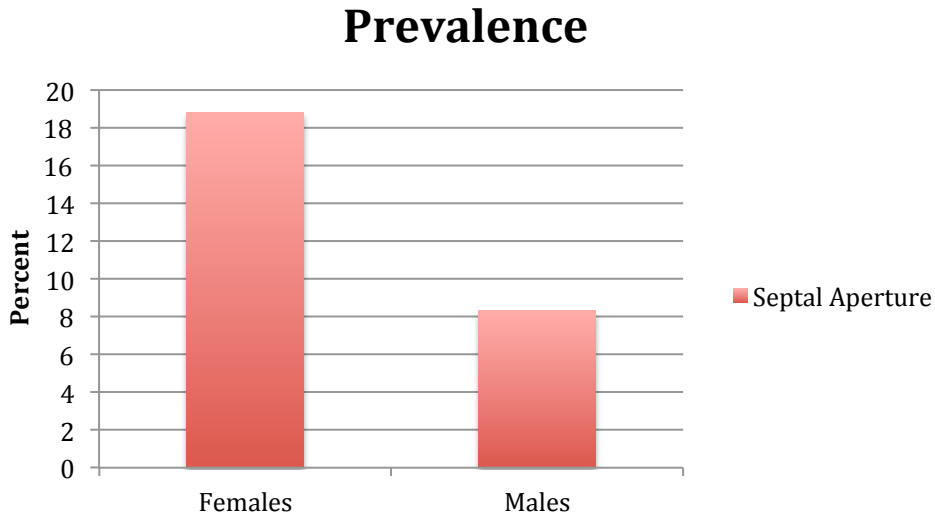
Prevalence

Figure 4-12 **Bar graph showing the prevalence of septal aperture in the Tuchengzi males and females. Septal apertures are more prevalent in females at Tuchengzi than males.**

Table 4-16 **Prevalence of septal apertures by sex.**

	F n (%)	M n (%)	x^2	df	p	p F. Exact
Septal Aperture	3 (18.8)	4 (8.3)	1.337	1	0.248	0.353
Total (n)	16	48				

Table 4-16 shows the prevalence of SA (one or more olecranon fossa of the humeri with an aperture) in the Tuchengzi males and females. SA prevalence is 5.3% higher in females than in males. SA prevalence in Tuchengzi females is 18.8% (3 of 16). Prevalence in males is lower at 8.3% (4 of 48)(Fig. 4-18). However, the difference between SA prevalence in males and females is not significant (χ^2 = 1.337, df 1, p=0.248; Fisher's Exact Test p= 0.353)(Table 4-16).

4.5.7. *Trauma and Sex*
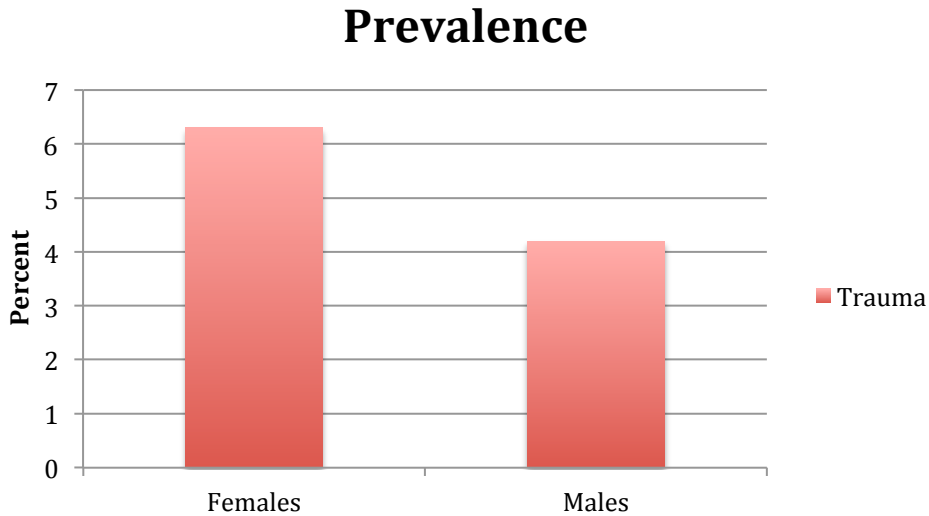
Prevalence

Figure 4-19 **Bar graph showing the prevalence of trauma in the Tuchengzi males and females. Trauma prevalence is higher in females than males.**

Table 4-17 **Prevalence of trauma by sex**

	F n (%)	M n (%)	x^2	df	p	p F. Exact
Trauma	1 (6.3)	2 (4.2)	0.117	1	0.733	1.000
Total (n)	16	48				

Table 4-18 shows the prevalence of traumatic injury (fractures, force trauma, and healed trauma) in the Warring States Tuchengzi population. Trauma is present in a higher percentage for females than males. However, statistically there is not a significant difference between the groups (χ^2 = 0.117 df-1 p=0.733; Fisher's Exact p=1.000) (Table 4-18; Fig. 4-19).

4.5.8. *Spinal Lesions*
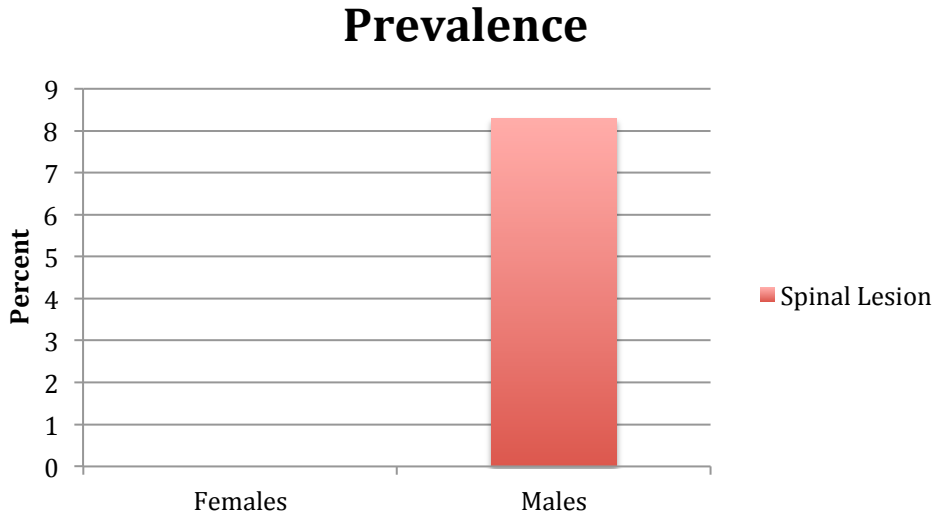
Figure 4-13   Bar graph showing the prevalence of spinal lesions in the Tuchengzi males and females. Spinal lesions are present in 6.1% of males, however there are none visible in any females at Tuchengzi.

Table 4-18   Prevalence of spinal lesions by sex.

	F n (%)	M n (%)	x^2	df	p	F. Ext. Sig
Spinal Lesions	0 (0.0)	4 (8.3)	1.422	1	0.233	0.564
Total (n)	16	48				

Table 4-17 shows the prevalence of spinal lesions (specifically the presence of one or more ossified intervertebral joints) in the Warring States Tuchengzi population. Spinal lesions do not appear in any of the females at Tuchengzi, but are present in a small percentage of the males. Zero percent of Tuchengzi females showed signs of ossified intervertebral joints (0 of 16). Spinal lesions were in present in 4 of 48 (8.3%) (Fig. 4-20). However there is no significant difference between males and females (χ^2 = 1.422, df 1, p=0.233; Fisher's Exact Test- Exact Sig (2 sided) p=0.564)(Table 4-17).

Chapter 5.   Special Case Examination

In addition to the general discussion of health of the Warring States Tuchengzi individuals (population), a more in-depth analysis is needed to further examine individual M364 (Fig. 5-1). This section examines in detail the pathological osteological elements present in the remains of individual M364. This examination begins with a general profile of age and sex, followed by an in-depth look at the all pathologies visible in the individual working from the crania to the lower limbs. The general overview is followed by a differential diagnosis in the discussion section to determine the aetiology of the unknown bilateral pathological condition visible on the distal anterior of M364's femora.

Figure 5-1   Cranium of Individual M364.

Individual M364 suffered from particularly severe manifestation of arthritis resulting in substantial osteophyte development and eburnation. In association with the arthritis lesions are indentations on the distal femora. The condition was first noticed in the research pictures of Evan Hardy, and confirmed by the pictures taken by Dr. Deborah Merrett on July 13th 2013, and an image published in Machicek and Beach's paper in Bioarchaeology of East Asia (2013).

Table 5-1   Right femur length results. Stature estimation using Trotter (1970) and Shao (1985).

Individual: M364	M364	Avg.Tuchengzi Male
Age	40+	
Femur Length	42.5cm	43.67cm
Stature Est. Trotter: (2.15(Femur)+72.57±3.80)	163.95cm±3.80	166.46cm±3.80
Stature Est. Shao: (3.66(Femur)+5±5)	160.55cm±5	164.83cm±5

Along with a description of the pathology of M364, femoral lengths were taken and stature estimations calculated. M364 was an older male falling in the OA40+ category. Individuals M364's right femur measured 42.5cm which is shorter than the mean right femur length at Tuchengzi of 43.67cm. Individual M364's stature is estimated at 163.95cm±3.80 (Trotter 1970) or 160.55cm±5 (Shao 1985), approximately 2.51cm to 4.28cm shorter than the estimated average stature at Tuchengzi (166.46cm ±3.80 (Trotter 1970) or 164.83cm±5 (Shao 1985))(Table 4-19; Table 4-2).

5.1.   Dentition and Alveolar Bone

A variety of dental pathology was visible in individual M364 including dental abscessing (5 total) and heavy occlusal wear visible in both the mandible and maxilla.

The left side of M364's maxilla includes 1 large abscess above the first molar exposing the root. The 3rd molar was lost post mortem as there is no visible sign of new bone development in the tooth socket. There is also post mortem damage to the zygomatic arch (Fig. 5-2).

Figure 5-2   Left lateral view of individual M364: This highlights one large abscess above the 1st molar (arrow), postmortem tooth loss of the 3rd molar, as well as, post-mortem damage to the zygomatic arch.

Pathology visible from the right side of the cranium includes two large abscesses exposing the roots. One located above the 1st molar, and the second directly above premolars 3 and 4. Premolar 4 also features a large caries destroying much of the crown, leaving the root below cementoenamel junction (Fig. 5-3).

Figure 5-3 Right lateral vIew of individual M364: Two large abscesses are seen, one located above the 1st molar, one above the 4th premolar (white arrows), as well as AMTL of the 3rd molar and a large caries that has destroyed the 4th premolar crown.

From the occlusal view two buccal abscesses are visible at the right and left first molar. The right 3rd molar has been lost antemortem. New bone formation has occurred and substantial alveolar healing is visible. The right 1st incisor has been lost post-mortem; no new bone formation is visible in the alveolar bone. Heavy occlusal wear is visible in all maxillary teeth (Fig. 5-4).

Figure 5-4   Occlusal view of teeth of individual M364: This highlights two large lingual abscesses, located at the right and left 1st molars (arrows), postmortem loss of the right 1st incisor and left 3rd molar, as well as the antemortem loss of the right 3rd molar.

As with the maxillary dentition the mandibular teeth exhibit heavy occlusal wear exposing the dentine. Both 3rd molars were lost ante-mortem and feature alveolar healing. The left 3rd molar alveolus has completely healed, and the right alveolus shows preliminary healing. Both the left incisors, and the left 3rd premolar have been lost post-mortem. The left mandibular canine features a caries (Fig. 5-5).

Figure 5-5 **Superior view of individual M364's mandible: The mandible features antemortem loss of both 3rd molars (arrows).**

5.2. Upper Limb Lesions

The humeri of individual M364 feature moderate marginal lipping on the proximal articular surface (Fig. 5-6 and Fig. 5-7). The marginal lipping exhibited on these articular facets is consistent with the articular facets of the ulna, radius, and humeri. The distal portion of the left humerus also features marginal lipping of the trochlea to a similar degree to that of the anatomical necks. The left humerus has an SA located in the coronoid fossa (Fig. 5-8). The left ulna features marginal lipping on the olecranon and coronoid processes (Fig. 5-9). The marginal lipping visible on these elements is indicative of the development of OA in individual M364.

Figure 5-6   Right humerus (proximal posterior view) of individual M364: marginal lipping is visible on the anatomical neck (arrow).

Figure 5-7   Left humerus (proximal posterior view) of individual M364: marginal lipping is visible on the anatomical neck (arrow).

Figure 5-8 **Left humerus (distal anterior view) of individual M364: Marginal lipping and new bone formation on the trochlea (white arrow), and a septal aperture located in the coronoid fossa (red arrow).**

Figure 5-9 **Right ulna (lateral proximal view) of individual M364: Marginal lipping visible on the olecranon process and coronoid process (arrows).**

5.3. Lower Limb Lesions

Individual M364 exhibits bilateral osseous proliferation, and marginal osteophytes, as well as depressions on the anterior distal surface of the femoral shafts. Indentations are visible on distal anterior surface (Fig. 5-10; Fig. 5-11). While the femora share the same pathological condition, the extent to which the right femur was affected by the condition appears more severe with more osteophyte growth and a larger indentation. Eburnation is present on both distal articular surfaces of the femora. Marginal osteophytes are present on all joint surfaces and a substantial amount of new bone formation is present on both distal articular surfaces of the femora, which has resulted in the alteration of the joint contours. Pitting is visible around the new bone formed on the articular facets.

The left distal femoral articular surfaces feature significant development of marginal osteophytes. The extent of the osteophytic development is visible both from the anterior and medial views (Fig. 5-10; Fig. 5-11). Osteophytes have grown to overhang the joints. From the anterior view osteophytes have visibly extended past the patellar lip, and the patellar surface on both the medial and lateral side (Fig. 5-10). Patellar contact on the left femur also resulted in subtle eburnation of the lateral anterior portion of the articular surface (Fig. 5-10). A small depression is located on the cortical bone directly above the patellar lip. The depression is approximately 1.5 cm^2. The centre of the depression is porous, and has darker, brownish hue compared to the surrounding bone. The proximal edge of the depression is more linear, where the distal edge is rounded, and has a curvature to it. The depression itself appears similar to the depressed groove made in woodworking by a gouge, or curved chisel (Fig. 5-10).

Figure 5-10   Left femur (distal anterior view) of individual M364: Marginal osteophyte growth (white arrow) is visible on the patellar surface. Wear is visible in areas of new bone growth it also porous in nature. Subtle eburnation (red arrow) is visible on the lateral side of the patellar surface. A small depression is located on the cortical bone above the patellar lip (black arrow).

From the medial view the cap-like appearance of the osteophyte proliferation is visible, as well as post-mortem damage (Fig. 5-11). Joint contact has resulted in wear that is porous in appearance. This is particularly visible from the posterior view on the medial and lateral condyles (Fig. 5-12).

Figure 5-11   Distal end of left femur (medial view): The significant level of new bone growth on the distal end of individual M364's femur is seen (arrow).

Figure 5-12   Left femur (posterior medial view): significant wear from contact between the femur and tibia is evident (white arrow) and marginal osteophyte development (black arrows).

The right femur features osteophytic development that is similar to the left femur however the development appears more severe (Fig. 5-12; Fig. 5-13). Osteophytic development has extended further above the patellar lip, and extends directly below the depression in the cortical bone (Fig. 5-14). Marginal osteophyte development is extensive and extends towards the medial epicondyle. As with the left femur, wear is visible on the facets that articulate with the patella and tibia (Fig. 5-14). The depression located directly above the patellar lip on the cortical bone is also larger and more severe

on the right femur. It measures approximately 1.5cm (height) by 2cm (width) and is located at the distal epiphysis. Like the depression on the left femur the proximal edge of the depression is more flat, but the edge is rougher and appears similar to the groove made by a chisel that is abruptly stopped. The rest of the depression is smooth and slightly darker in colour than the surrounding bone. The depression itself is angled slightly towards the medial side of the femur (Fig. 5-12).

Figure 5-13 **Right femur (distal medial view): Marginal osteophyte growth is visible on the patellar surface. Vertical striations are also present on the patellar surface. Severe eburnation is visible on the lateral to central portion of the patellar surface (white arrow). A rectangular depression is located on the cortical bone directly above the patellar lip (red arrow).**

Severe eburnation is visible on the patellar surface extending between the proximal end of the patellar lip and the distal side of the patellar surface. Eburnation is more extensive, grooving is pronounced, and grooving occurs in the direction of movement (Fig 5-14). This level of eburnation on the right femur is much more distinct than the eburnation visible on the left femur (Fig. 5-12; Fig. 5-14). Unfortunately the patellae were not available for analysis.
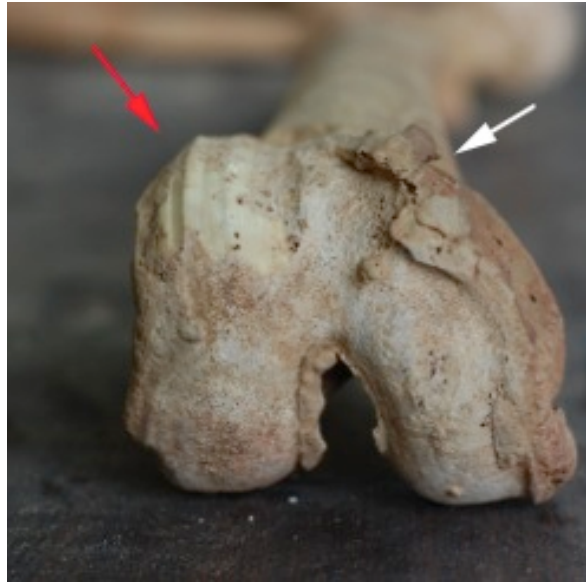
Figure 5-14   Right femur (distal inferior view): Marginal osteophyte growth (white arrow) is visible on and between the lateral and medial condyles, as well as on the patellar surface. Vertical striations (red arrow) are visible on the lateral to center portion of the patellar surface. Severe eburnation is in this area.

Bone proliferation is also visible on the tibia. Osteophytes are also visible on the attachment sites of anterior cruciate ligaments on the proximal articular surface and the extensor sulcus of both tibiae (Fig. 5-15; Fig. 5-16). The new bone appears globular and porous (Fig. 5-15).

Figure 5-15   Left tibia (anterior proximal view): Marginal osteophyte growth appears globular and porous (white arrows).

Figure 5-16   Left tibia (posterior proximal view): Marginal osteophyte growth is visible on the articular surface (white arrow) and attachment sites of anterior cruciate ligaments on the proximal articular surface (red arrow).

Individual M364 features numerous pathological conditions (Table 5-2). These include dental pathologies, an SA, and joint disease. These conditions can be used to understand the lifeways of both this individual and the population as a whole.

Table 5-2   Summary of Pathology Visible in Individual M364.

M364	Pathological Description
Abscessing	5
Caries	2
AMTL	2
SA	Left humerus
Marginal Lipping	All available articular surfaces
Severe Arthritic Development	Visible in both knees including: eburnation and the presence of small depressions directly above the patellar surface of the femora.

5.4.   Differential Diagnosis of Unknown Pathology: M364

In order to fully understand the aetiology of the pathological condition present in M364, it is necessary to parse individual pathological elements and evaluate the mechanics involved in their development. While the presence of arthritis is apparent with marginal lipping and new bone formation visible in both upper and lower limb regions (Fig. 5-4 through Fig. 5-14), the presence of a small depression on the distal anterior cortical regions of both femora is the most unusual (Fig. 5-8; Fig. 5-11). This could be the result of malalignment of the joint resulting from the significant amount of new bone growth present on the femoral condyles. Since the patella were unavailable for analysis it is difficult to evaluate this hypothesis using conventional macroscopic analysis. However, if the depressions are the result of abnormal contact between the patellae and femora, what lead to bone resorption, not proliferation (Ruff et al. 2006)? Investigation through bioarchaeological and palaeopathological literature provided an example of erosion of the patellar surface of the femur. Similarly the erosion visible in Mann et al.

(1991) was the result of the abnormal contact between the patella and femur, however it did not involve the anterior distal metaphysis as seen in individual M364, but resulted in the patella eroding through the articular surface of the distal femora (Mann et al. 1991). Examination of clinical research literature however, proved to be more fruitful.

5.4.1. *Clinical Studies*

In living individuals suffering from arthritis, soft tissue obscures morphological changes to the bone that occurs during the development of the condition. Clinical researchers rely on radiography to examine pathological changes in bone and anomalous osteological symptoms present in living individuals. These in turn are integral to palaeopathological diagnosis of anomalous skeletal conditions (Kaufman *et al.* 1997).

Rheumatological research from the 1970s and 1980s provides information regarding the aetiology of the depressions visible on the distal anterior femora of individual M364. The specific pathology is called pressure erosion resulting from abnormal contact between two skeletal elements, which results in the erosion of the cortical surface (Monsees *et al.* 1985; Lagier 1974). This seems to be consistent with the suggestion that the patellae and the femora of M364 were possibly in abnormal contact as in the clinical study (Fig. 5-17) unfortunately the patellae were not available for detailed analysis.

Figure 5-17   **Lateral view of the patellofemoral joint highlighting cartilage loss and pressure erosion on the anterior distal femur (arrows) resulting from contact between the patella and distal femur during full extension of the knee (Monsees and Murphy 1985: 821).**

Pressure erosion is most commonly associated with long-standing rheumatoid arthritis (RA), but can also occur in individuals suffering from osteoarthritis (OA) (Monsees *et al.* 1985; Lagier 1974). Since this condition is associated with both rheumatoid and OA, a differential diagnosis is needed to determine from which form of arthritis individual M364 suffered. Fortunately RA and OA affect skeletal morphology in very distinct ways. This is of great importance since RA is exceptionally rare in Old World archaeological remains (including China) prior to 1785 CE (Mackenzie and Dawson 2005). RA's rarity in the Old World could be related to its aetiology, however there is currently no consensus as to why RA does not appear in greater numbers prior to contact with the New World. Given the time period and location of Tuchengzi, if individual M364 suffered from both RA and anterior distal femora pressure erosion it would make it a truly significant archaeological find. This would then pre-date Old World examples of RA by at least several hundred years and perhaps a thousand years (Mackenzie and Dawson 2005; Waldron 2008: 47).

5.4.2. *Rheumatoid Arthritis and Pressure Erosion*

In individuals suffering from RA 4 varieties of erosions can occur: marginal erosion, compression erosions, superficial surface resorption, and pseudocyst formation

(Monsees and Murphy 1985). Compression or pressure erosions differ from the marginal erosions in both location and appearance. They are generally biomechanical in nature, and are visible as bone resorption, not destruction (Waldron 2008: 51; Monsees and Murphy 1985). This pathology is frequently associated with osteopenia, malalignment, muscle atrophy, and loss of cartilage (Monsees and Murphy 1985). Ligament laxity, and subsequent malalignment contribute increased pressure in affected joints by facilitating decreased joint stability and increased bone contact. Osteopenia appears to play a significant role in the pathophysiology of pressure erosions, as osteopenia is a reduction of bone mass. Factors commonly associated with increased severity in RA are aging, decreased physical activity, and changes in calcium homeostasis which all contribute to the development of pressure erosion. Decreased bone mass and structural integrity result in the bone's inability to respond to pressure by forming new bone. This results in erosion, as the bone resorption exceeds new bone formation (Monsees *et al.* 1985).

The pathology visually matches the appearance described by Monsees and Murphy (1985: 820) as "smooth, shallow, well defined cortical bone defects which underlie an opposing bony surface" as a result of abnormal contact between bones. Pressure erosion has been documented in hands, wrists, feet, ribs, shoulders, knees, and hips, and are most common in weight bearing regions such as hip joints and frequently used areas such as the hands and wrists (Monsees *et al*. 1985). When occurring in the knee, it is generally the result of "focal erosion of the anterior distal femoral shaft underlying a sharp edge of an adjacent patella" (Monsees *et al.* 1985: 54). However these factors are not exclusive to RA and have been documented in individuals suffering from OA" (Monsees *et al.* 1985).

5.4.3.   *Osteoarthritis and Pressure Erosion*

In individuals suffering from OA, pressure erosion is generally associated with patellofemoral arthritis and occurs as a result of contact between the patella and the distal anterior femoral shaft (Alexander 1960 cited in Lagier 1974; Monsees *et al.* 1985; Lagier 1974). The pathophysiological aetiology is likely the same as seen in RA. However these contingent factors have not been outlined by researchers, with the possible exception of osteopenia since OA is generally associated bone proliferation, not bone destruction. The individual generally suffers from osteopenia, and thus the bone

does not respond with new bone development but with erosion of the cortical cone (Monsees *et al.* 1985; Lagier 1974).

5.4.4. *Differential Diagnosis of Arthritic Lesions*

M364 exhibits a developed case of bilateral arthritis, with a substantial amount of new bone formation on the articular condyles, with marginal lipping and with subchondral cyst formation. Eburnation is present on both femora, but is more pronounced on the left. In addition to the well-defined arthritis, a heretofore-unobserved pathological condition in the Tuchengzi population is present in both femora. The unknown pathological condition appears morphologically similar to severe arthritis with significant osteological proliferation, eburnation, with the addition of depressions present directly above the femoral patellar surface. Individual M364 has been examined in two other studies however neither has reported on the pathological condition visible in this individual (Machicek and Beach 2013; Gu 2012). M364 features complete upper limbs, both femora, and a right tibia. The left humerus features a SA, which are present in 13.4% of the Tuchengzi Warring State population. Marginal osteophytes are visible on all articular surfaces of the available remains from the upper and lower limbs.

Many of the skeletal elements necessary for diagnosis of RA were not available for analysis. However those available do not match the necessary criteria. Individual M364 does not exhibit any apparent bone erosion within the joint capsules. In fact the opposite is observed, both joints feature a substantial amount of new bone formation. Alternatively M364 fits all the criteria for OA (Table 5-3). In association with the OA individual M364 suffers from pressure erosion of both distal anterior femora, however this presence does not indicate definitively the aetiology of the pressure erosions. Given the condition of skeletal remains and radiographic comparison, a very strong argument can be made for the pressure erosion being the result of abnormal contact between the patellae and femora. Bone proliferation in femoral joint would result in malalignment of the joint. The malalignment and trajectory of the patella is visible in the osteophytes and eburnation (Fig. 5-10; Fig 5-13).

Table 5-3   Differential Diagnosis based on Waldron's criteria for diagnosis of arthritic conditions (2009: 34-52) in comparison to morphology of M364.

Criteria for Rheumatoid Arthritis	M364	Criteria for Osteoarthritis	M364
Symmetrical marginal erosion of small joints of hands and/or feet	NA	Presence of Eburnation	Present
Or		Or at least two of the following	
Sparing of sacroiliac joints	NA	Marginal osteophytes	Present
Minimal new bone formation	Absent	New bone formation of joints	Present
Absence of spinal fusion	NA	Pitting on the joint surface	Present
Erosion of other joints	Absent	Alternation in joint contour	Present
Osteoporosis may be found around affected joints	NA		

Mann *et al.* (1991) provide an archaeological example of pressure erosion, however the condition presented in Mann et al. appears morphologically very different from that visible in individual M364. Both examples provided by Mann *et al.* (1991) are manifestations of contact between the patella and the patellar surface of the femur resulting in eburnation. In one example the wear appears as subtle grooving on the patellar surface and the other appears much more extreme with wear through the patellar surface being parallel with the metaphysis (Mann *et al.* 1991). This makes the condition visible in the individual M364 unique in archaeological remains, as it appears morphologically similar to the condition described in the clinical literature (Monsees and

Murphy 1985). The condition visible in individual M364 represents an example of pressure erosion previously unseen in an archaeological population, an osteological condition that has not been well examined by the bioarchaeological community.

Further research is needed to more fully understand the severe joint disease observed in individual M364. The extreme progression of the condition provides information regarding activity and lifeways at the site. The individual lived in a community that could facilitate this possibly debilitating condition. If the Tuchengzi was primarily military in nature, how did an individual suffering from a debilitating condition manage to survive long enough for the condition to progress as far as it did? If the individual was removed from active duty why was he permitted to remain at the site? While the possibility exists this individual was a member of the elite or a military higher-up, it is not possible given the available evidence to determine the social status of M364.

Chapter 6.   Discussion

The remains of 64 individuals from Tuchengzi have provided many lines of evidence for the study of this particular Tuntian population. The data will be utilized in comparison with published data from both Chinese and other archaeological sites to characterize the population of individuals living at Tuchengzi.

6.1.   Demography

Age at death profiles at Tuchengzi appear quite different for males and females. Female age at death frequency is equal in both the young adult and middle adult categories and decreases during the older adult category (Fig 4-1). Male age at death prevalence peaks during middle adulthood and is relatively equal during both the younger and older adult categories (Fig 4-1). Demographic analysis done by Gu (2012) for his PhD dissertation indicates a ratio of 2.9:1 males to females. It is unclear however if this is the product of selective excavation or curation, or if it is the result of the military nature of the settlement. There also appear to be relatively few subadults (<14 years) (1.1% MNI=3) and older adults greater than 56 years (2.3% MNI=6) (Gu 2012).

Factors contributing to this demographic profile are possibly related to roles that males and females played during this time, as well as a biased product of the categories themselves. Or could be the product of selective excavation, or actual demography. The division of age in this manner naturally increases the age at death, as the middle age category is a larger age range than the young adult category. In females death during young and middle adulthood may also be associated with childbirth. The increased prevalence of death in the male middle adult category is possibly the result of adoption of new roles within the community Eshed et al. 2004). The possibility also remains that these individuals died as the result of combat or conflict and suffered from fatal soft

tissue wounds or were injured in the body area which few skeletal elements were available for analysis.

6.2. Stature

At Tuchengzi, the estimated male statures are found to increase from 163.99 cm in the Warring States period to 166.11 cm in Han Dynasty although a similar comparison for females could not be made due to the low numbers of females from Han Dynasty. The increase is inconsistent with the pattern observed from comparison with other Neolithic and Bronze Age sites in China (see Table 4-5).

The study reveals a trend of increasing stature between the Warring States period and the Han Dynasty (Fig. 4-2; Fig. 4-3). A 2012 pilot study found a 1.03cm increase in female stature, and a 6.16cm increase in male stature between the two periods (Hardy 2012), and while this study employs part of the same samples, its use of a primary-sourced sample lends further credence to the pilot study. While the trend in this study is visible in both males and females, the increase in femur length is only statistically significant in Han Dynasty males in the larger Chinese (excluding Tuchengzi) sample (Table 4-5; Table 4-7; Table 4-8). This trend towards increased stature during the Han Dynasty is not visible in Pechenkina *et al.* (2007), and this may in part be due to sample size differences, as this study employs a much larger sample size than that of Pechenkina *et al.* (2007).

Bioarchaeologists generally relate the start of intensive agriculture with a decrease in stature and decline in overall health (Cohen and Armelagos 1984; Eshed *et al.* 2010; Larsen 1995 Ozer *et al.* 2011; Pechenkina *et al.* 2002); however the possibility exists that the observed increase in male and female stature could be the result of improved living conditions driven by the technological developments of China's Iron Age. Similar trends of increase in stature corresponding with the onset of Bronze Age have been observed in Thailand (Domett and Tayles 2007), in British sites (Roberts and Cox 2007) and in Latvia (Gerhard 2005). It is possible that the advent of a new tool package or mode of tool production in these regions has provided economical and nutritional benefits that outweigh the negative factors that accompany a complex agricultural

lifestyle. Bronze technology was developed in China as early as 3100 BCE. It was a supra-regional development that spanned between Xinjiang in the west, Inner Mongolia, and the Central Plain. Bronze tools were commonly available in the Erlitou period and available for household items by approximately 1750 BCE (Linduff and Mei 2008). Metallurgy provided a great advantage over stone tools, the development of iron technology provided even further benefits. Bronze casting techniques were developed in the Spring and Autumn period and expanded to encompass metal mould techniques that facilitated more industrialized production of iron tools and coinage. These technique were particularly useful for production of agricultural necessities, specifically the development and mass production of the iron tipped plough, mouldboard plough, seed drill, and chariot parts which were widely used in Northern China (Derui and Haiping 2011; Lin 1995; Wagner 1995). The scale at which early archaeological metallurgical remains, specifically large blast furnaces, appear implies the development of wide-spread large-scale production occurred quickly and was in full effect by the Han Dynasty, techniques of metallurgy that persisted until the 1900s (Wagner 1995). These technological developments had the potential to greatly improve agricultural production, and increase nutritional intake and overall population health by insuring greater and more efficient agricultural production. The original goal of this study was to examine the effects of political and social change during a period military conflict on the health of the people, but since stature begins to increase during the this period, a period of intense warfare, it appears that technological development that began during the end of the Warring States period may have contributed to an overall increase in population health. An in-depth analysis of this phenomenon is unfortunately outside the scope of this thesis.

The estimated male stature at Tuchengzi (163.99 cm) is similar though smaller than those recovered from Spring and Autumn sites as shown in Table 4.5. The same conclusion is also made in Gu (2012)'s research, which is based on a slight different set of the same sample and includes more comparative skeletal populations.

The stature results indicate that individuals represented by the skeletal remains were not specially recruited for their physical strength and height; instead, they may just represent normal individuals of the time. However Gu (2012)'s indicates that these

individuals at Tuchengzi were more robust than those at other contemporary sites, a factor that may be the result of training for active combat. As with the all variables at the Tuchengzi, the stature data point to a site that was more likely a normal farming village, than a strictly military settlement with regular army or troops.

6.3.   Enamel Hypoplasia

EH is a physical manifestation of periods of metabolic stress, whether nutritional, illness-related or psychological (Hillson 1996). It is the result of incomplete enamel development visible as either lines or pits of thinner enamel. This pathological trait can affect both deciduous and permanent dentition (Skinner 1996). EH, as with stature, can be used for comparative purposes as one of many indicators of exposure to stress and overall population health. A visible decrease in EH is present in older age categories. EH prevalence is lower in older individuals (YA17-24= 9 (56.3%), MA25-39= 12 (33.3%), OA40+=4 (36.4%) Total= 25(39.7%)) (Table 4-9; Fig. 4-7). This could be the result of two possible scenarios: a) individuals with higher prevalence of EH die much earlier or b) dental attrition and AMTL obscure actual EH prevalence in older individuals. Due to the limited amount of data available in this population, it is quite difficult to parse out the extent of each scenario, but it is possible that both are at play here. This means that EH is likely underrepresented in the population, in particular in older individuals. However cross-cultural comparison is still necessary to generate a rough assessment of insults to growth during the Warring States period Tuchengzi. EH appears in 39.7% of individuals at Tuchengzi. EH prevalence appears to be highly variable in the past. EH prevalence is quite low at Arab Bronze Age (Umm an Nar period) ranging between 1.8% and 3.8% (Blau 2007). New World sites have drastically different ranges; it can be as low as 13% in the middle woodland, and 8.5% in the woodland North Carolina (Hutchinson *et al.* 2007). EH prevalence in East Asian sites appears to be both higher on average and more consistent. EH prevalence in the Thai Bronze Age is higher than the overall percentage (39.7%) at Tuchengzi, a bit lower than the individuals in the youngest age category at Tuchengzi (56.3%), with 40.5% at Bronze Age site Ban Lum Khao EH and 53.8% at Iron Age site Noen U-Locke 53.8% (Domett and Tayles 2007). EH prevalence at the Inner Mongolian site from the Mongol period 13th century CE is similar at 35% of individuals featuring EH (Machicek and Beach 2013).

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The Han Dynasty site of Kangjia appears to be much higher at 80% of individuals suffering from EH (Pechenkina et al. 2007a). The high prevalence of EH at Kangjia versus at Tuchengzi could explain why this trend of increased stature during the Han Dynasty is not visible in Pechenkina et al.'s previous temporal stature study (2007a). Since stature and EH are both non-specific indicators of stress they leave observable indicators of populations responses to poor socio-environmental conditions. It is unlikely that improvement in health during the Han Dynasty was universally positive and equal at all sites. Similarly, in modern populations, a positive increase in a country's quality of life or health care system does not necessarily universally benefit all individuals or all communities equally (Frisancho *et al.* 1970; Young *et al.* 2008). To best understand the relationship between stature at Kangjia, and at Tuchengzi a comparison of Han Dynasty EH prevalence would be necessary. This however is unfortunately outside of the scope of this, but is an excellent and viable direction for future research.

In general, the EH prevalence (up to 56.3%) indicates that the Tuchengzi population had suffered systemic stress. If Tuchengzi was a highly fluid settlement many of the remains could be from individuals who spent their growth and development years elsewhere. Although it is difficult to assess the differences in exposure to stressors between Tuchengzi and other surrounding populations, 56.3% is certainly not a small portion of the population. Regardless of where these individuals experienced developmental stressors, this population was certainly exposed to periods of stress during growth and development.

6.4. Caries

Caries development is a complex process that involves plaque (a bacterial film), fermentable carbohydrate presence, and acid by-products of their consumption by the bacteria. The acid produced by the bacteria can alter the pH resulting in demineralization of dental tissue; this process is contingent on oral pH levels and can be altered by oral mineral levels. Caries are the most common dental pathology. Caries appear in a continuous manner from white spots to enamel destruction/decay, the prevalence of which accumulates and persists with age, and can ultimately result in dental abscessing and AMTL (Waldron 2008: 236-237).

Caries are quite common in the Tuchengzi population (61.9% of individuals), which is to be expected of an agricultural population with millet as its primary agricultural crop (Hadjimarkos 1962; Larsen 1995). The majority of individuals in the population have caries, with significant increase in the prevalence of caries with increasing age (Fishers Exact p= 0.048). The highest presence in a group is the old age category (81.8%)(Table 4-10; Fig. 4-8). The similar prevalence of caries in males and females suggest similar access to resources and similar diet (Table 4-15; Fig. 4-15).

When comparing caries prevalence at Tuchengzi to other populations it appears Tuchengzi generally has a higher frequency than other agricultural or Bronze Age sites. Caries prevalence in pre-agricultural Georgia and Florida are quite low ranging between 0.8% and 1.2%, following the adoption of agriculture both the Georgian and Florida caries prevalence at sites range between 7.4% and 9.6%. It isn't until the Florida Late Mission period that we see any considerable presence of caries (24.4%)(Larsen *et al.* 2007). In contrast, in North Carolina caries prevalence is much higher in the horticultural period the Middle Woodland period (1-500 CE) at 40% followed by an increase to 50% of individuals featuring caries with the adoption of maize agriculture in the Late Woodland period (500-100CE) (Hutchinson *et al.* 2007). Caries prevalence at the complex maize agricultural site Ville Salvador (2200-1900 BP) is also lower than Tuchengzi at 19% of individuals featuring caries (26.8% of females and 13.4% of males). Though maize is cariogenic and a staple in South American agricultural site, Ville Salvador's coast location and likely access to marine resources may offset their reliance on maize, thus decreasing the caries rate (Pechenkina *et al.* 2007b). Caries prevalence at British Bronze Age sites are similar at 15.1% of individuals with Bronze and Iron Age peoples relying heavily on wheat, barley, oats, and flax crops as their sources of carbohydrates (Roberts and Cox 2007). Tuchengzi appears to have higher caries prevalence than agricultural sites in both the New and Old World sites. While caries prevalence in Southeast Asian agricultural sites is closer to those present at Tuchengzi, Tuchengzi caries prevalence ranges between 10 to 20 percent higher. Thai sites also feature high caries prevalence Bronze Age site Ban Lum Khao with 45.2% and Iron Age site Noen u-Locke with 42.6% (Domett and Tayles 2007). Qin sites, the period directly after the Warring States, around the Yellow River have an average of 54.55% of individuals featuring one or more caries (Miao *et al.* 2013). However in comparison the

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population at the more a western site of Taojiazhai, located in the Qinghai province, features far fewer caries at 19.6% (Jinglei 2013). This is due to the different cariogenic affects of rice- and millet-based diets. In general, rice-based diets are not associated with an increased prevalence of caries even following the adoption of an intensified agricultural lifestyle (Oxenham *et al.* 2006; Tayles *et al.* 2000; Temple and Larsen 2007). Northern Asian archaeological sites where the inhabitants practiced millet agriculture have more similar levels of caries to those of Tuchengzi.

The Han Dynasty site of Kangjia located in Shaanxi north of the Wei River showcases a site with similarly high prevalence of caries to that of Tuchengzi (61.9% of individuals). Posterior dentition caries are present in 62% of individuals, and anterior dentition caries are present in 30% of individuals. The high level of anterior dentition caries at the site has been attributed to poor mineralization of the dentition as seen by the high levels of linear EH visible in the population (Pechenkina *et al.* 2007a). The high levels of caries present at Tuchengzi are similar to other sites in the region and general time period. Sites in Northern China (Yellow River sites and Kangjia) between the Qin (54.55%) and Han Dynasty (62%) (Pechenkina *et al.* 2007a), the periods directly following the Warring States period, have within plus or minus 4% of caries prevalence at Tuchengzi (61.9%). This is most likely due to the similar diet and lifestyles shared by peoples of Northern China during the late Bronze Age/Iron Age, specifically the reliance on a millet-based diet, which is highly cariogenic. Foxtail millet has a similar sucrose level (0.9-1.1%) to maize (0.9-1.9%), although Broomcorn millet is slightly less than both (0.5-0.9%)(Larsen 1995; Shelton and Lee 2000). Millet also contains high levels of selenium (Hadjimarkos 1962). In laboratory experiments, rats with diets high in selenium show increased prevalence of caries when consumed during dental development and adulthood (Hadjimarkos 1962). This is trend was also visible in teenage humans in high seleniferous areas (Tank and Strovick 1960). Diets that are both high in sucrose and selenium increase the likelihood of carious lesion development (Hicks *et al.* 2004). These factors are compounded by the manner in which millet is often consumed. The porridge-like consistency of boiled cereals results in increased growth of bacteria in dental fissures or grooves of teeth that are difficult to clean and increases the likelihood of caries development (Larsen 1995). During these periods there is also a visible proliferation of agricultural production technologies, most certainly resulting in increased

cereal production and dietary reliance. Given the circumstances a high level of dental caries is the result of a shift to an intensive agricultural diet based on a cariogenic cereal.

High caries prevalence at Tuchengzi is likely result of the diet and the consumption of millet. Millet is cariogenic due to the manner in which it is frequently consumed (gruel) and the presence of selenium in the grain itself. The high prevalence of caries also contributes to the levels of AMTL and abscessing in the Tuchengzi population. These levels of dental pathology are the result both of lifestyle, as subsistence farmers, and of environmental factors, such as types of food available to the population.

6.5. Abscessing

Dental abscesses are localized infections in either the mandible or maxillary bone as a result of osteocyte disintegration or resorption. They often appear as areas of bone resorption in alveolar bone (White *et al.* 2012: pg. 435). As with other dental pathologies visible in the Tuchengzi population dental abscessing prevalence increases significantly (Fishers Exact p=0.031) with age (YA17-24= 2 (12.5%), MA24-39=10 (27.8%), OA40+=6 (54.5%) Total= 18 (28.6%)) (Table 4-10; Fig. 4-9). Abscesses develop as a result of dental degradation, exposure of the pulp chamber to bacteria present in the oral cavity, caries, and dental trauma. Therefore as an individual ages the likelihood of abscess development increases. There is no visible difference in abscess prevalence between males and females (F=31.3%, M=27.1%). This trend is visible in all dental health variables and points to similarities in diet and use of dentition by sex at Tuchengzi during the Warring States period (Table 4-8; Fig. 4-16). If diet or behaviour was significantly gendered a visible difference between dental wear, caries, or in this case dental abscessing would be expected. For example at the Swedish Neolithic site Ajvide abscessing prevalence differs significantly between males and females, with 47% in males and 18% females. This is likely due to difference in the use of the dentition, possibly as a part of the cultural tool kit or difference in diet (Molnar 2008). The overall population rate of 30.5% at Tuchengzi is similar to other Chinese sites; for example the Han dynasty site Kangjia, (2200-1800 BP) in Shaanxi province features an abscessing

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rate of 31% (Pechenkina et al. 2007a). Similarly, Mongol period (13th Century CE) sites in Inner Mongolia are exactly the same at 31% (Machicek and Beach 2013).

As an oral health indicator, the abscessing prevalence at Tuchengzi shows no significant difference between males and females, with prevalence increasing significantly with age. This fits a subsistence pattern with relatively little to no differential access to resources between genders. The rate of abscessing does not appear different from other Chinese sites before or after the Tuchengzi Warring States occupation, indicating similar dietary conditions. Tuchengzi appears to fit into what is to be expected for abscessing prevalence for the region and time period.

6.6. Antemortem Tooth Loss

AMTL is the end result of periodontal disease, caries, abscessing, or a combination of all three (Roberts and Manchester 2007: 74). There is a significant increase in the prevalence of AMTL with age (Fisher's Exact p= 0.017)(YA17-24= 4 (25.0%), MA24-39=15 (41.7%), OA40+=8 (72.7%), Total= 27 (42.9%))(Table 4-10). The increase in AMTL with age is logical as dental pathology increases over one's life. This trend is visible in both abscessing and caries in the Tuchengzi population. Cross-cultural differences in abscessing, caries, and AMTL prevalence represent differences in diet, oral hygiene practices and dentistry, stress, occupation, behaviour, subsistence economy, as well as biology and genetics (Boraas *et al.* 1988; Roberts and Manchester 2007: 63; Shuler 2001). AMTL is present in 42.9% of individuals from the Tuchengzi Warring States period (Table 4-10; Fig. 4-10). Dentition loss can be the result of multiple factors: periodontal disease, trauma or disease. Appearance increases with age, and results in pain, difficultly with mastication and the possibility of decreased nutritional intake as a result. Osteological healing indicates whether teeth were lost ante- or post-mortem, however when teeth were lost antemortem, aetiology can be difficult to determine, with the exception of extreme periodontal disease or obvious trauma (Waldron 2008: 238-239). A comparison of AMTL in males and females shows very little difference between prevalence (X^2=0.884 Fishers Exact p=1.000) (Table 4-10; Fig. 4-17) again indicating there was likely very little difference in diet and masticatory behaviour between males and females in the Tuchengzi population. Differential access to food, or

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a gendered division of labour, or cultural practice present at the site could manifest in a significant difference or visible trend of increased AMTL in one subset of the population, a trend not observed at Tuchengzi.

AMTL prevalence (42.9% of individuals) appears to be similar to other Asian populations, but higher comparatively than other regions: ATML prevalence at archaeological sites in the U.K. seems to range between 6% and 23.4% (Neolithic 6.1%, Bronze age 13.2%, Iron Age 3.1%, Roman 14.1%, Early Medieval 8%, Late Medieval 14.4%, Post Medieval period 23.4%)(Roberts and Manchester 2007). However, when compared with other Asian agricultural sites from the time period Tuchengzi falls within a varied range (Domett and Tayles 2007; Jinglei 2013; Machicek and Beach 2013; Miao et al. 2013; Pechenkina et al. 2007a).

At Thai sites AMTL is slightly lower during the Bronze Age with 31% at Ban Lum Khao but increases to 40.7% during the Iron Age at Noen U-Locke (Domett and Tayles 2007). At the Han Dynasty site Kangjia 77% of individuals feature AMTL (Pechenkina et al. 2007a); however at the western Qin Dynasty site of Taojiazhai 48% (47.8% males 48.4% females) of individuals feature AMTL (Jinglei 2013). However during the earlier Western Zhou period predating Tuchengzi AMTL prevalence was much lower, at 17% of individuals (Pechenkina et al. 2007a). Qin site Xishan in the Gansu province features 31.82% of individuals with AMTL (Miao et al. 2013). Sites from Inner Mongolia during the later Mongol period (13th century AD) show 54% of individuals featuring AMTL (Machicek and Beach 2013). While there are a variety of factors that can contribute to AMTL in a population, it is difficult to separate issues such as the demographic make-up of each site for adequate comparisons. Similar amounts of AMTL are visible at Asian agricultural sites. This similarity is visible in caries prevalence and it is likely the result of both similar environmental and dietary conditions.

The prevalence of AMTL is similar to that of both caries and abscessing at Tuchengzi. These patterns reflect the diet and lifeways at the site. In comparison to other sites AMTL at Tuchengzi fits in the middle of the range visible at other sites (17% to 77%), however since age breakdown at the other sites are not available, direct comparison of AMTL accumulation and age cannot be performed. Antemortem tooth

loss prevalence at Tuchengzi match the pattern visible in the other dental health variables, so it can be assumed that AMTL fits this dental pathology pattern at Tuchengzi.

6.7. Septal Aperture

SA is considered an idiopathic pathology and a nonmetric trait (Mann and Hunt 2005 2126; Mays 2008) that occurs when the thin lamina of bone between the olecranon and coronoid fossa becomes perforated (Papaloucas *et al.* 2011; Paraskevas *et al.* 2012). Johann Friedrich Meckel identified first SAs in 1816 (cited in Papaloucas *et al.* 2011: 178). They can be found in both humans and other mammals; while they can be bilateral they occur most frequently in females on the left side. This trend is consistent with the findings at Tuchengzi, with SAs present in 18.8% of females and 8.3% of males (Table 4-16; Fig. 4-18). Septal apertures generally form during adolescence into early adulthood when ossification is incomplete this is due to intralamellar space enlargement and gradual septum resorption (Papaloucas *et al.* 2011; Paraskevas *et al.* 2012). There are two competing theories as to its origins, congenital or developmental (May 2008). Glanville (1967) suggested that activity and range of movement results in SA development. Alternatively, Benfer and Tappen (1968) observed that non-human primates with more protruding olecranon processes smaller humeral and ulnar midshafts have higher prevalence of SA prevalence (Benfer and Tappen 1968). In a more recent study by Mays (2008) re-examined these competing positions using archaeological remains with no conclusive results. If the condition was developmental, we might be able to see a trend visible when separated for age, however this is not the case (Fig. 4-11). Clinical literature indicates that SA can increase the individuals' predispositions to fractures of the distal humerus (Sahaipal and Pichora 2008), however no such injury is visible in the Tuchengzi population. SA prevalence in populations varies significantly. In modern Greek samples Papaloucas *et al.* observed that SAs occurred in males: 0.0% and females 0.6% despite a large sample size of 656 pair humeri (304 male and 352 female) ranging between 22 and 92 years of age (2011). However Macalister (1990 cited in Papaloucas *et al.* 2011) observed SA in 57.2% in ancient Libyan remains. Trotter (1934 found SAs appeared three times more frequently in Americans of African descent than those of European descent (Trotter 1934). In studies on Asian populations,

specifically ancient Japanese, Ainu, and Korean populations, Eizo (1934) found prevalence similar to that found at Tuchengzi.

A study conducted on modern Chinese remains from a teaching collection at Peiping Union Medical College during 1930s (Ming-Tizu 1935) illustrates a similar pattern to that which is visible at Tuchengzi. Prevalence is higher in modern Chinese females than in it is males (Table 6-1). Japanese archaeological remains may also provide an appropriate comparative sample for the Tuchengzi, given similar lifestyle and temporal similarities. Genetic research into the origins of modern Japanese peoples highlights the close genetic relationship between Yixi people from Han Dynasty sites on North China's Shandong Peninsula, the Han Chinese, Mongolians, mainland Japanese and Korean peoples. This relationship is less genetically close with indigenous Japanese Ainu peoples (Oota *et al.* 1999). The people that now represent the modern Japanese likely emigrated from the Shandong peninsula during the Bronze and Iron Ages and would have lived a similar lifestyle to the peoples of northern China. Unfortunately the sites in Eizo's study predate modern dating methods so direct comparison cannot be made Never-the-less Japanese archaeological remains provide a more analogous sample to Tuchengzi than a medical reference sample of unknown provenance from the early twentieth century.

Table 6-1   Septal aperture prevalence in Asia.

Location	SA:Freq.-Male (N)	SA-Freq.-Female (N)	Citation (cited in Eizo 1934 unless otherwise specified)
Tokyo	6.1% (82)	21.9% (64)	Koganei 1916
Kyoto	12.7% (300)	30.1% (136)	Akabori (n.d. cited in Eizo 1934)
Kanazawa	2.5% (80)	28.0% (50)	Saito 1931
Kyusyu	13.5% (N/A)	20.6% (N/A)	Yosinaga
Ainu (Hokkaido)	2.8% (72)	14.8% (54)	Koganei 1916
Ainu (Saghalein)	36.1% (36)	30% (20)	Seki 1930
Korean	6.9% (233)	15.0% (20)	Sibata and Takahasi 1930
Modern Chinese	7.9% (242)	27.9% (22)	Ming-Tizu 1935 (not cited in in Eizo 1934)
Tuchengzi	12.1%	18.8%	

SA prevalence in Japanese archaeological remains range between 2.5% and 13.5% in males and 14.8% and 30.1% in females. Prevalence in Ainu remains range

between 2.8% and 36.1% in males and 14.8% and 30% in females. Tuchengzi most closes matches the prevalence at Kyusyu (males 13.5%, females 20.6%), which is an early Yayoi Japanese Bronze Age site dating to 400 BCE (Suzuki and Inoue 2007). The provenance of other sites used could not be determined. The possibility exists that genetic and lifestyle similarities at Tuchengzi and the Yayoi site lead to similar prevalence of SA within both populations. However the relationship cannot be tested statistical without access to the original raw data. Testing SA prevalence at Tuchengzi in comparison to other Asian archaeological sites is viable direction for future research.

SAs are a poorly understood phenomenon. The origin of the high prevalence of SAs at Tuchengzi cannot be determined and requires further investigation that are outside of the scope of this thesis. The pattern of prevalence does match other studies with increased prevalence in females, however whether the causal factors were genetic, lifestyle, or otherwise cannot be determined. Further research at Tuchengzi, other archaeological sites, and in a clinical setting are required to more fully understand the phenomenon and its prevalence at the site.

6.8. Trauma

Skeletal trauma's potential to inform bioarchaeologists about behaviour in past cultures makes trauma of particular interest in the case of Tuchengzi. The site originated in a period of both intensive political instability and warfare, and was located at the border of Central Plain and northern steppe. Immigrants from the central plains region of the Zhao State established Tuchengzi as a fortified site. However sources have provided different classifications in English as to the primary function of the site. Tuchengzi has been described as both a military outpost (Gu 2012) and as an agricultural settlement (Machicek and Beach 2013). Was Tuchengzi primarily a military outpost, a subsistence agricultural community, or both? To facilitate more effective research, in this study, the term "Tuntian" will be used to describe Tuchengzi as a mixture of military settlement and farming community. Different types of activities and behaviours result in different patterns of traumatic injury, and thus there is the potential to determine the possible amount interpersonal versus accidental violence and injury within a sample (Walker 2001).

Agriculture is considered one the three most dangerous professions in industrialized nations resulting in a surprising amount of accidental trauma, a pattern also mirrored in past populations (Judd and Roberts 1999). In subsistence agriculture communities, agriculture is less a profession and more so a way of life that incorporates the whole family. This exposes men, women and children to the risk of potential traumatic injury. Agriculture-related trauma is generally associated with falls, domestic animals, and equipment (Judd and Roberts 1999). Using Amish peoples as an analog for injury in a non-industrialized agricultural population, injuries include: throws from buggy or saddle 18.3%, horse kicks 5%, falls 28.3%, and being hit by horse drawn equipment 6.7% (Jones 1990). Given the metal horse-drawn agricultural technology and the relative lack of mechanized agricultural equipment used by the Amish people, this provides a relatively good analog for the type of injuries to which one would expect Iron Age Chinese agriculturists to be exposed. Trauma patterns from Medieval British farming villages suggest that male injuries are frequently the result of direct blows from farming equipment or falls effecting lower limbs and clavicles. In contrast injuries for females and older individuals frequently result from indirect trauma, and short falls (Judd and Roberts 1999).

Conflict and interpersonal violence similarly result in specific osteological patterns. Both males and females are the perpetrators and victims of physical violence, though interpersonal violence most frequently involves young males. Injuries resulting from interpersonal conflict are most frequently located in the craniofacial region (Judd 2004). However, many of these injuries fit into both intentional and non-intentional (accidental) spectra (Judd 2004). This pattern is visible in Xiongnu nomadic peoples from Warring States and Han Dynasty, Xinjiang province, China. These sites provide a comparative population for Tuchengzi, as they are geographically, temporally and culturally similar. Weapon use and warfare are cultural phenomena, and therefore it is beneficial to use sites that are temporally and regionally related to form the best possible comparison (Walker 2001).

Evidence of trauma appears in 3 individuals at Tuchengzi (4.8%) and affect a higher proportion of females than males, with trauma being observed in 1/16 of females (6.3%) and 2/48 males (4.2%) though they are not significantly different (χ^2=0.117 df=1

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p=0.733). Prevalence of trauma decreases between young adults 1/16 (6.3%) and middle-aged adults 2/36 (5.6%), although it is absent in the older aged individuals. These differences are not statistically significant (χ^2 = 0.673 df= 2 p=0.712). Two of the Tuchengzi examples of trauma are located in the occipital region (see section 4.3.1). Warring States and Han Dynasty remains from Yanghai, Shanshan county (N=45) featured 1 nearly healed long bone fracture of the ulna (middle aged adult female). Six (4 male, 2 female) individuals with traumatic craniofacial region injuries were recorded. Of these individuals, 3 were males featuring multiple perimortem blunt and sharp force cranial trauma. The others exhibit healed individual traumatic episodes to parietal or nasal bones (Eng and Zhang 2013). The second site, Nileke, (N=48) also dates to the Warring States period in Xinjiang. No long bone trauma is present in the remains. However, cranial trauma was present in 4 individuals, 1 with a perimortem projectile injury and others with healed craniofacial trauma (one with multiple injuries). Both sites featured sharp force trauma from projectile points and/or blade weapons (Eng and Zhang 2013). Both sites have smaller sample sizes and higher prevalence of traumatic injury, especially those suggesting the possibility that they resulted from interpersonal conflict.

When Tuchengzi is examined in the context of external populations involved in warfare, the relative lack of trauma at the site becomes apparent. In the Mid-Cumberland region of Tennessee during the Mississippian period (1000-1450 BCE) of pre-contact North America we see a distinctly different pattern of warfare related trauma than that visible at Tuchengzi (Warne *et al.* 2012). The sample consists of 870 individuals from 12 sites. While the total population prevalence of trauma is only slightly higher with 5.4% of individuals featuring trauma, when this is divided by sex a much different pattern of trauma is visible. Four point six percent of female's feature trauma as opposed to 13.1% of males, many of the individuals feature multiple healed fractures (Warne *et al. 2012*). These results are opposite to those visible at Tuchengzi, where trauma prevalence in females is higher than males, each featuring a single incident of trauma in each individual. In Mayan populations we similar pattern of trauma but with an over all higher prevalence in the population. Between the pre-classical period (starting in 1000 BCE) and the post-classical period (ending in 1519 CE) trauma prevalence in the Yucatan peninsula reflects the political and social climate at the time (Tieslar and Cucina 2012).

In the pre-classical period trauma levels are low, although still higher than at Tuchengzi, trauma is visible in 5.4% of males, 18.75% in females and a total of 13.3% of the population (Tieslar and Cucina 2012). In the post-contact, post-classical period during a period of colonial warfare waged by the Spanish trauma is visible in 25% of males, 12% of females and a total of 25% of the total population (Tieslar and Cucina 2012). This population is similar to Tuchengzi in the sense that the populations involved in colonial warfare. This highlights the relative lack of trauma at Tuchengzi and the fact that Tuchengzi does not represent a typical military population.

With the exception of individual M357 there is no evidence to suggest whether the examples of trauma at Tuchengzi are the result of interpersonal conflict or accidental injury. Individual M357's perimortem arrow wound indicates at least the potential for interpersonal conflict at the Tuchengzi site however; it cannot be determined whether that conflict occurred with an outside population or within the community. These results lead to the question why trauma prevalence is lower at Tuchengzi than at other contemporaneous sites?

6.8.1.   *Socio-Cultural Factors and their effect on Trauma Prevalence*

If Tuchengzi was in fact a military outpost, the question remains, why is trauma prevalence so low? More specifically, why are examples of multiple perimortem blunt force, sharp force or projectile trauma not visible in the remains? There are four possible scenarios, or combinations of scenarios, that could explain the relatively low prevalence of trauma present at Tuchengzi:

1) Trauma occurred and is visible in remains that were not excavated, lost due to poor preservation, were buried in another location or not available for analysis.

2) Violence occurred but was limited primarily to soft tissue injury

3) Trauma prevalence is low because the inhabitants of Warring States Tuchengzi were not subjected to the same degree of conflict as other sites or regions due to its location.

We are likely seeing a combination of the first and third scenarios. Trauma is likely under-represented but was likely not as common as in individuals in the Southern region. Tuchengzi was established as an outpost for the Zhao State to protect its northern border. The northern expansion of the Zhao State brought the people of the central plains to secure their border. The relationship between the Xiongnu and the central plains immigrants at Tuchengzi during this time is not well documented, but theoretically, there should be some peaceful co-existence and/or confrontation. Cultural remains such as large defensive walls indicate at the very least the existence of a perceived threat of conflict. Major conflict between the Chinese state and the Xiongnu peoples of the northern steppe did not occur until the Han Dynasty when the unified states increased expansion efforts (Di Cosmo 1999).

During the Warring States period the Zhao State's greatest military threat was from the Qin state. While the Qin state did eventually absorb the Zhao State, for the majority of the Warring Sates period Tuchengzi was geographically separated from both the Qin, and the other Warring States (Di Cosmo 1999). The site was located far from the frontlines of the perpetual warfare that plagued the period, making the third scenario above plausible. Tuchengzi was likely established as mixed military/agricultural site or tuntian in region with minimal contact with their major military foes, and as a result there was minimal conflict during this period. However this was likely not the case for the inhabitants of Han Dynasty Tuchengzi.

Conflict drastically increased in this region following the Warring States period as Han Dynasty colonial expansion pushed into the northern steppe brought more conflict to the region (Di Cosmo 1999). The Han successfully conquered the regions to the west and north of the central plains region taking the region of Inner Mongolia in which Tuchengzi was located, as well as Gansu province and the Gobi desert in the 120s BCE. With warfare and increased conflict, and with the Xiongnu jockeying for territory in the region it would be expect that increased prevalence of trauma may be visible in Han Dynasty remains from Tuchengzi.

Trauma prevalence at Tuchengzi illustrates the complex nature of the Tuchengzi settlement. If trauma prevalence is low, why is it assumed that the site was established

as a military outpost? Given the location of the site it is likely that Tuchengzi experienced only sporadic conflict with Xiongnu during the Warring States period. Given the prevalence of trauma, and other indicators such as stature, it does not appear that Tuchengzi operated as a designated military outpost, and suggests the possibility of something similar to a proto-tuntian site.

6.9.   Joint Disease Differential Diagnosis

Joint disease encompasses a variety of different diseases effecting joints. Aetiologies range from genetic, bacterial, to non-specific. Two types of joint disease are visible at Tuchengzi, those specifically affecting the vertebral column, and more generalized condition affecting multiple joints in a given individual. In order to understand the conditions and how they affected lifeways at Tuchengzi it is necessary to perform a differential diagnosis of the spinal lesions to determine the aetiology. Spondyloarthropathies considered are AS and Diffuse Idiopathic Skeletal Hyperostosis (DISH). AS is the most common spondyloarthropathies (Waldron 2008: 57). It is often confused with D.I.S.H., though they possess appear different patterns of pathology.

AS generally begins to develop during an individual's late 20s or early 30s, and affects men two to three times more frequently (Waldron 2008: 58). The gene HLA B27 gene, the gene associated with AS, is present in 90% of modern individuals suffering from AS. One third of individuals experience peripheral arthritic lesions in knees, hips, and shoulders (Horst-Bruinsma *et al.* 2009). It is also results in lower back pain, limited chest expansion during breathing, decreased mobility, weight loss, and fever (Roberts and Manchester 2007: 158).

DISH rarely develops in individuals under 40 (Kiss *et al.* 2002) and occurs more frequently in males (4%) than females (2.5%)(Mata *et al.* 1997). It is associated with obesity and type II diabetes (Julkunen *et al.* 1971). Through detailed comparison of a differential diagnosis it may be possible to determine whether the spinal lesions present at Tuchengzi are DISH or ankylosing spondylitis.

Table 6-2   Operational diagnosis DISH and ankylosing spondylitis (Waldron 2008: 58).

Operational diagnosis of A.S.	M364	Operational definition for DISH	M364
Symmetrical fusion of both sacroiliac joints	Present	Ossification and fusion of four contiguous vertebrae, confined to the right side of the vertebral bodies in the thoracic region	Absent
Or			
Spinal fusion with no skip lesions	Present	AND	
Bamboo spine	Present	Ossification into extra-spinal entheses and ligaments	Absent
		Early DISH may be diagnosed if fewer than four vertebrae	Absent

Using Waldron's (2008) operational diagnoses for DISH and AS to diagnose the conditions present at Tuchengzi it becomes apparent which of the conditions the individuals with spinal lesions were suffering (Waldron 2008: 58)(Table 6-2). All individuals suffering from spinal lesions presented either symmetrical fusion of both sacroiliac joints, spinal fusion with no skip lesions, "bamboo spine" or a combination of all three. The only instances when symmetrical fusion of both sacroiliac joints was not visible were in cases where the sacroiliac region was not available for analysis. Alternatively, none of the 3 criteria for the diagnosis of DISH are visible in individuals at Tuchengzi. Ossification of the vertebrae was never limited to solely the right side, nor was there presence of extra-spinal entheses and ligament ossification (Waldron 2008: 58).

AS appears in 6.3% (3 of 63) of the individuals at Tuchengzi (Table 4-12; Table 4-17; Fig. 4-13; Fig. 4-20). This is likely an under-representation of AS at the site since not all vertebrae were available for all individuals. The prevalence of ankylosing spondylitis at Tuchengzi is similar to that of the Haida population of British Columbia (4.5%) and comparatively higher than at ancient British sites: Bronze Age 1.4%, Iron Age 0.7%, Roman 0.9%, and Early Medieval 1.3% (Olivieri *et al.* 1998; Roberts and Cox 2007). AS does not appear to be a subject that has been well examined in ancient

China. The book Bioarchaeology of East Asia: Movement, Contact, Health (Pechenkina and Oxenham 2013) only features one example of AS, Eng and Zhang (2013) identified a possible case of AS, but based on the morphology could be DISH.

The presence of AS in a population is heavily influenced by genetics. Prevalence varies from as low as 1% in Europeans populations (Waldron 2008: 58) to 4.5% in the indigenous peoples of Haida Gwai, British Columbia (Olivieri et al. 1998). However AS is very rare in both Japanese and African populations occurring in only 0.1% of the population (Roberts and Manchester 2007: 158). Certain variations of the HLA-B27 antigen appear to be quite common in modern Asian populations, The HLA-B*2705 antigen is present 84% of the Siberian population, HLA-B*2704 is present in 65.8% of Chinese populations and 87.3% of Thai populations (Garcia-Fernandez et al. 2001). The prevalence of HLA-B27 antigen is higher than those of the Haida population at 50% where modern AS is visible in 4.5% of the population (Oliveri et al. 1998). The presence of the Chinese B*2704 variation of the HLA-B27 is most likely responsible for the high appearance of AS at Tuchengzi and is consistent with the high presence of the HLA-B27 antigen in modern Asian populations.

AS's high prevalence at the site is likely influenced by genetic factors in the population, however if Tuchengzi were strictly a military outpost, would the individuals suffering from severe AS in older age remain or be returned to their village of origin? While this cannot be confirmed based on available evidence, it points to the possibility Tuchengzi operated predominately as an agricultural site, and not strictly as a military settlement. The presence of individuals suffering from possibly debilitating conditions such as severe arthritis and AS does not point to a community involved in or expecting frequent conflict.

6.10. Tuchengzi as a Tuntian

The results illustrate a very different pattern from what would be expected for a specialized military base or a strictly agricultural site. The site features an interesting demographic ratio, with 1.6 females to every 4.7 men, a ratio that is similar to Gu's (2012) findings at the site. While this does not appear to a strictly military population, it

does not appear to be what we would expect from a general agriculturalist settlement with a more equal distribution of the sexes. It appears to be something in between. Tuchengzi also features a number of older individuals (11 total) and the presence of a children's cemetery dating to the Warring States period (China Post 2006), neither of which should be associated with a specialized military site.

There is a low prevalence of trauma, especially when compared to other populations engaged in active warfare (Tieslar and Cucina 2012; Warne *et al.* 2012). This is important because it points to population not involved in heavy combat, however, even if the population were to feature a high prevalence of trauma, it would not discount the argument that Tuchengzi is a proto-tuntian. It merely illustrates Tuchengzi was likely not a specialized military settlement involved in frequent combat.

A number of individuals within the sample feature conditions such as ankylosing spondylitis, and sever joint disease that would limit mobility. If the Tuchengzi represented a military base, it would likely have been a satellite site for the Zhao state. Indicating that, as individuals could no longer contribute to the army whether due to age or health they could return home, but Tuchengzi features both older individuals and ones in poor health.

Given the osteological evidence and the historic record (Machicek and Beach 2013) it appears Tuchengzi represents a particularly unique type of settlement, something that exists between a military settlement and an agricultural settlement. A site comprised of general agriculturists and military personnel established in relatively unoccupied areas by the state to provide a self-sufficient line of defense in regions with low population density for the Zhao state. This matches the system developed in the Han Dynasty extremely closely and indicates that the use of this technique by Chinese states predates the Han Dynasty by over a century.

6.11. Limitations

The initial intention of this research was to examine and assess temporal changes in population health at the site of Tuchengzi. Although it was not intentional, data collection was carried out in a way similar to a double blind test in the sense that

age, sex, and time period of individuals was not known until data were collected and cross referenced with information provided by Xiaoming Xiao of the Research Centre for Chinese Frontier Archaeology, JLU. Overall this has proven to be scientifically beneficial as my data and those data collected before by others are comparable.

Due to time constraints during data collection, methods such as X-Rays could not be carried out. Other constraints include the inability to use more accurate techniques for sex and age estimation as most frequently, only long bones and cranial bones were available.

Due to the sample size from Han Dynasty being too small, temporal health change patterns at Tuchengzi cannot be adequately assessed, with the exception of stature. Tuchengzi stature was therefore added to a larger database compiled by the author for his honours undergraduate research to conduct a comparative temporal study with other sites from China.

The incomplete skeletons available for this study have proven to be another limitation. Though postcranial bones with dramatic pathologies or traumas have been collected and made available for this study, the lack of postcranial bones for other skeletal individuals affect our ability to full assess other pathological markers for those less dramatic lesions which can provide a fuller picture on the adaptation of the populations to a variety of stresses.

Chapter 7.   Conclusion

This study has conducted an osteological examination of Warring States period skeletal remains from Tuchengzi. The sample consisted of osteological data from 64 individuals. The results of this study have revealed very important information and insights into lifeways at a colonial Warring States archaeological site.

7.1.   Life at Tuchengzi: The nature of the people and settlement

The trauma pattern observed in this study does not seem to match what would be expected at a military settlement during a period of conflict. Few incidents of trauma were identified in the remains at Tuchengzi, and the prevalence was not significantly higher than other regular agricultural or nomadic populations in ancient China. No specific types of trauma indicate systematic combat injures, although one individual features a projectile point embedded in their cranium. However, interpersonal violence within the community cannot be excluded as a possible cause for this incident.

The average adult stature at Tuchengzi fails to match the estimation of overall higher stature of military personnel, which would be expected normally. No significant difference in stature was observed in the Tuchengzi population when compared with other archaeological sites in ancient China, including both the Neolithic and imperial periods.

The examination of non-specific indicators of stress, oral health, non-metric traits and pathology yield no unique patterns indicative military selectivity at the settlement. Instead, visible patterns do not differ from what is to be expected from individuals participating in subsistence agricultural when comparative data are available. For example, overall, dental health at Tuchengzi appears to fit within the spectrum of dental health at ancient Chinese archaeological sites, and does not appear to differ significantly. Differences in dental pathology prevalence at Chinese archaeological sites,

are likely result of regional and temporal differences in diet and activity patterns, and do not appear to be the result of a military specific lifeway.

Other aspects of the osteological examination in this study indicate some distinctive features. Few subadults, few female adults and few older individuals were found in the remains, indicating a possible non-standard demographic composition of the population. However demographic interpretations prove difficult for a variety of reasons, such as the presence of a sub-adult burial ground, nevertheless, the population visible in the available sample is consistent with what might expected of a military settlement.

With archaeological and historic context suggesting that Tuchengzi was established as a military settlement, and some osteological evidence supporting at the very least a difference in demographic composition of the skeletal population, it is safe to argue that Tuchengzi represents a proto-tuntian site. This is both consistent with the mixed tuntian settlements that existed in ancient China, and what would be expected in a colonial settlement in a period of military and geographic expansion.

Tuchengzi was situated on the border between agricultural and nomadic subsistence systems, a military settlement would be needed to defend the both the border and the land acquired through colonial expansion. Defensive walls were constructed for this purpose, which were ultimately precursors to the future Great Wall of China. As with any border regions, there would have certainly been periods of war and peace between the nomadic peoples to the north and inhabitants of Tuchengzi, and other settlements of the Zhao State. It is likely that during times of peace Tuchengzi operated primarily as an agricultural settlement, however during periods of conflict they were able to mobilize military forces for combat if needed.

The palaeopathology visible at Tuchengzi, including the low prevalence of traumatic injury, average stature and general overall health pattern of the individuals suggests the possibility that the settlement was not involved in frequent or heavy combat. Demographic observations such as few subadults, female and older individuals point to the possible military component of this population, and reflect its readiness for military actions. Since Tuchengzi existed as a precursor of the future defensive sites located on the Great Wall the possibility exists that both the sites contemporary to

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Tuchengzi, and the later defensive settlements would feature both similar demographic compositions and similar patterns of population health. With the possible exception of increased trauma prevalence in later settlements as warfare between the unified Chinese states and north nomads increased drastically following the Warring States period the data from the skeletal remains are consistent with the suggestion that Tuchengzi was a proto-tuntian.

7.2. Implications and Contribution to the Field of Human Bioarchaeology

While this study demonstrates the usefulness of osteological analysis in reconstructing the nature and lifeways of an ancient settlement, it has also reminds us of the uniqueness of each archaeological site. This study has revealed some unexpected results such as low trauma prevalence, which can be effectively interpreted within social, cultural and archaeological contexts to yield powerful information about the lives of the people that inhabited this unusual archaeological site.

This study also revealed certain pathological conditions that warrant further and more in depth analysis, specifically the high prevalence of AS and the presence of pressure erosion on both femora of individual M364. Based on a limited comparison with published data the prevalence of AS is very similar to that of modern inhabitants of Haida Gwai. This phenomenon deserves a more detailed comparison and analysis to understand the possible factors leading to the similarly high prevalence in both populations. The presence of pressure erosion found on the femora of individual M364 also warrants further analysis as it is an extremely rare pathology with one other case represented in bioarchaeological literature and no other cases effecting the femora above the distal joint capsule in the same manner.

7.3. Implications to Archaeology of China

This study has highlighted the importance of integrating social, cultural and archaeological context with osteological data to understand the lives of individuals inhabiting a particular archaeological site. This has proven to be a viable and powerful research tool when applied to Chinese archaeological sites and more exciting studies

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can be expect to be undertaken using the same methods. Without knowledge of the Tuntian system in ancient China, it would be very difficult to interpret the data from the analysis of the skeletal remains at Tuchengzi.

There is a wealth of Chinese human skeletal remains and archaeological sites that have yet to be examined, or could be re-examined with increased cultural and historic contexts. This type of study can provide increased knowledge of the lifeways of average peoples that might be missing from early historic records and texts.

This research not only provides osteological evidence suggesting that the site was something much more interesting than strictly a military outpost, but a possible early precursor to a tuntian settlement. It was a fully operational agricultural settlement, as shown by the presence of woman and children, and was inhabited by people who were prepared for military duty. This is logical given the colonial expansion of the Zhao State. If a state were to expand into a new region, they would need to establish not only military control but also production of food, resource extraction, and specialized labour; in short they would need to establish a self-sufficient community. Tuchengzi is an excellent example of this, part military base, and part agricultural village. The osteological evidence at Tuchengzi also points to a lower level of conflict in this region during the Warring States period as suggested by the historic record.

Chapter 8.   Future Research

This study is a preliminary investigation to create a general profile of health at Tuchengzi. There are many avenues of research that are possible using this data set. Some of these are possible given the information that is currently available; others would require a published site report.

Firstly, individual M364 needs to be examined in further detail. While preliminary data was collected, and the extremity of the arthritic lesions present was documented, the specific nature of the individual's pathology was not deciphered without more detailed radiographic examination in the future. This would facilitate further comparison with clinical research on pressure erosion (Monsees *et al.* 1985; Lagier, 1974). Further metrics could be taken and other steps to evaluate mobility and possible circumstances leading to the individual's condition.

Since this is a relatively preliminary overview of health at the Tuchengzi site, each variable could likely be investigated in more depth. Other techniques, such as microscopy could be employed to further investigate dental pathology. The technique of casting and SEM used by Dr. Deborah Merrett and Hua Zhang to examine EH at Houtaomuga could be employed to expand the regional understanding of dental development and health in Northern China (Merrett *et al*., 2015).

If possible, sample size should be expanded and absolute dating should be carried out, which would allow for a higher resolution exploration of health at Tuchengzi. Absolute dating would facilitate more accurate regional and temporal comparison. This would allow for the sample to be reduced into smaller temporal blocks, and more accurately compared to published or collected data. Data were collected based on the samples made available, it does not appear that more samples could be used without the use of DNA sex identification, which is most likely not feasible. Furthermore, the observed stature trend could be examined using more variables such as isotopic

analysis to determine if an improved diet could be related to technological development seen in the Iron Age. This could then be situated in a cross-cultural context to further explore the impact of the Bronze and Iron Age lifeways and how phenomena such as the Silk Road and cross-cultural trade affected overall health in the region.

Finally, if a site report were to become available, it would allow for better situation of samples in both regional and culture context. A site report would allow for the inclusion of variables including grave goods, body position, grave type, and/or location in the overall cemetery. This would increase our understanding of social status, health and gender at Tuchengzi, and Northern China in general. It would also allow for further exploration of more anthropological lines inquiry, which could be further compared to other sites and lifeways in the area. Given the lack of site report and the site's destruction it appears likely that any future bioarchaeological research on the Tuchengzi will need to be conducted on the currently available remains.

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